

NORDIC OCEANS 2050

Future scenarios for the Nordic
ocean economy

Contributing partners



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Driven by its purpose, to safeguard life, property, and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today and is a trusted voice for many of the world's most successful and forward-thinking companies.

About DTU

DTU is a research-based, business-oriented and internationally oriented polytechnic university. Based on technical and natural sciences, DTU works to create sustainable value and welfare in society through education, research, research-based advice and innovation.

About SLU

The Swedish University of Agricultural Sciences (SLU) promotes sustainable living through science and education. It is a leading university in research on aquatic resources and ecology as well as environmental sciences, agriculture, forestry and veterinary medicine. By emphasising the interaction between humans, animals, ecosystems, and the responsible use of natural resources, SLU supports sustainable social development and enhanced living conditions on our planet.

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Foreword

**"There is a tide in the affairs of men,
Which, taken at the flood, leads on to fortune."**

– Shakespeare, *Julius Caesar*

For anyone interested in the ocean, these are heady days. As the UN's ocean decade reaches its halfway point, there is significant progress to celebrate. The Kunming-Montreal Framework dramatically expands marine protected areas, offshore renewables are becoming cheaper than fossil alternatives, and new technologies make the ocean economy more efficient and sustainable. Yet other developments are more disheartening. Overfishing remains a significant collective action problem, marine ecosystems are flashing warning lights, and geopolitical tensions are increasing at sea as on land.

In this context, this report on future scenarios for the Nordic ocean economy is timely. It takes stock of where we are now and where we are headed in the years to come. As the ocean economy will be shaped by developments in nature conservation, the energy transition, and rising concerns about competitiveness, this report serves as a basis for informed decisions that increase the chances for growth to be sustainable. It also pinpoints particular strengths, problems, and opportunities that can be addressed through Nordic cooperation.

For Nordic Innovation, the report marks the beginning of a new phase in our efforts to make the Nordic region home to the world's most sustainable ocean economy. Since 2021, we have supported practical solutions related to ocean biomass, marine multi-use, and testbed initiatives. Now, we are broadening our scope by seeking to enable rapid commercialisation of new solutions, technology-driven systemic change, and increased investments in the ocean economy. *Nordic Oceans 2050* gives vital input to that work through a data-driven and multi-sectoral analysis that includes all parts of the Nordic region.

We are grateful to DNV, the Swedish University of Agricultural Sciences, and the Technical University of Denmark for all their hard work. Our hope is that this report will be read and discussed by policymakers, businesses, investors, researchers and the general public alike – indeed, by anyone interested in understanding the tides of the ocean economy, and taking those tides at the flood, in our part of the world.



Sindre Stemshaug Bornstein
Managing Director, Nordic Innovation
Oslo, November 2025

Key messages

1. **The Nordic region's ocean economy thrives on its diversity, and can improve its resilience through cross-border collaboration**
 - **Strengths in the Nordic ocean economy** include Norway's clusters in offshore energy, shipping, and seafood; Denmark's leadership in offshore wind; Greenland, Iceland and the Faroe Islands in fisheries; Finland in Arctic technology; and Sweden in innovation.
 - **Norway has the biggest ocean economy in the Nordics by value added** and employment, due mainly to its advantages in offshore energy and seafood, but risks falling behind Denmark, Finland, and Sweden on research, development, and innovation in the economy at large.
 - Enhanced Nordic collaboration in the ocean economy can **strengthen the region's strategic position for European resilience** in energy, food, and mineral supply chains, and in the maritime industry.
2. **The Nordic ocean economy must develop future-proof strategies that are robust to uncertainties related to environmental sustainability, energy transition, national security, competitiveness, and economic growth**
 - **Aquaculture:** Development of novel feeds can reduce reliance on imported ingredients, thereby minimizing the sector's environmental footprint and reducing dependency on vulnerable global supply chains.
 - **Offshore energy:** New developments can enhance European energy security, with expansion of offshore wind directly contributing to reduced consumption of fossil fuels, and continued exports of offshore gas providing energy with a lower carbon footprint than gas imports.
 - **Shipbuilding** is essential for the functioning of the **Nordic maritime clusters** needed to retain competitiveness in knowledge-intensive service delivery in the maritime industry, and that will drive digital and low-carbon shipping.

3. **Future development of the Nordic ocean economy requires reconciling ecological integrity and economic ambition**
 - **Nordic collaboration** is needed to account for cross-border cumulative impacts on marine ecosystems when developing new ocean activities and managing existing ones.
 - **Coastal communities are particularly at risk** due to the importance of the seafood and tourism sectors in providing local livelihoods, and because of their dependency on ecosystem services.
 - **Valuing ecosystem services:** Stakeholders in the Nordic economy need to conceptualize the valuation of ecosystem services for these to be included in strategic economic development.
4. **The Nordics are ready to lead in ocean innovation, leveraging digitalization, circularity, and cross-sector knowledge transfers**
 - **Development of digital solutions** is needed to realize the full productivity growth potential and strengthen the competitiveness of the seafood, maritime, offshore, and tourism sectors.
 - **Growth in the economic productivity** of the Nordic ocean economy will be critical to tackle the dual challenge of an aging population and deliver on the transition to low-carbon solutions in the ocean sectors.
 - **The energy transition** requires reducing offshore oil and gas, among the biggest contributors to economic value added from the Nordic ocean economy, hinting at the huge challenge of transitioning to offshore renewables.
 - **Knowledge transfers** from offshore oil and gas are essential to drive forth new initiatives in the ocean economy, such as offshore wind, low-carbon offshore technologies, and aquaculture.

1. Introduction

The Nordics is a closely integrated region encompassing Denmark, the Faroe Islands, Finland, Greenland, Iceland, Norway, Sweden, and Åland. The region consists of dynamic economies that trigger and drive transformational change in the ocean economy. Denmark has taken a lead in offshore wind and is a major hub for shipping. Finland has a strong maritime sector, with particular attention on technologies for Arctic shipping. As an island nation, Iceland's seafood-related activities constitute almost 10% of gross domestic product (GDP) and are a cornerstone for the economy (Sepponen *et al.*, 2021). Norway hosts leading clusters for fisheries and aquaculture, the offshore and maritime industries, and leads European production of offshore energy – a sector with technologies and operational practices that can be transferred to other activities at sea. Sweden ranks second on the Global Innovation Index (WIPO, 2025) and hosts a dynamic start-up scene that can generate competitive advantages across the regional ocean economy and beyond. The Faroe Islands, Greenland, and Åland are highly dependent on seafood for export revenue and livelihoods, and maritime transport for trade, and their coastlines and marine environments are increasingly attracting tourists.

The Nordic Vision to 2030 is to become “the most sustainable and integrated region in the world” (Nordic Council of Ministers, 2020). This is to be achieved by 1) prioritizing the **green** transition towards carbon neutrality and circularity, 2) leveraging innovation and digitalization for **competitiveness**, and 3) promoting **social sustainability** through shared values (Nordic Council of Ministers, 2020). Since the 2020 publication of the Nordic Vision to 2030, geopolitical issues have come to the forefront after the COVID-19 pandemic and the Russo-Ukrainian war, and societal priorities are increasingly leaning towards security interests and concerns about European competitiveness (European Commission, 2024c).

The Nordic countries are small in terms of population, with open economies dependent on collaboration and integration with regional and world markets. Hence, it is essential to understand how the Nordic ocean economy can contribute to safeguarding and strengthening Nordic and European competitiveness. Successfully delivering on the green transition requires that the region meets targets related to renewable energy, more sustainable food systems, and the need to protect and restore marine ecosystems. To grow a sustainable ocean economy, it is imperative that the impact on nature and ecosystems is limited. Hence, an ecosystem-based approach is critical to understand the interdependencies between the sectors of the Nordic ocean economy.

This report is developed by **DNV**, the **Technical University of Denmark (DTU)**, and the **Swedish University of Agricultural Sciences (SLU)**, supported by **Nordic Innovation's Sustainable Ocean Economy** programme. The overall aim of the report is to provide decision-makers with relevant knowledge and insight for the development of a resilient ocean economy in line with the Nordic Vision to 2030 and beyond. The main objectives of this report are to:

1. Explore future developments in the industrial sectors of the Nordic ocean economy by creating plausible future scenarios for 2050.
2. Identify potential opportunities and barriers to the adoption of strategies for blue growth and novel value chains in the Nordic ocean economy, and for taking new scientific knowledge into account in marine policymaking.

To meet these objectives, the report builds on ocean economy data for the Nordics, as well as a series of interviews with stakeholders linked to the Nordic ocean economy. For foresight on well-established and emerging ocean economy sectors, DNV's previous forecasting efforts in the *Ocean's Future to 2050* (DNV, 2021; 2023; 2025d) and the *Energy Transition Outlook* (DNV, 2024a; 2025a-c) are important sources. Findings from previous research by DTU and SLU have been particularly important in developing the report's approach within the ecosystem, fisheries, and tourism domains.

1.1 Ocean economy in the Nordic countries – at a glance

In this section, we provide a short summary of the ocean economy in each Nordic country, and Figure 1-1 highlights some key features.

Denmark is a major hub for shipping and offshore wind, with leading clusters shaping global ocean value chains. Among OECD (Organization for Economic Cooperation and Development) countries, Denmark ranked within the top five ocean economies as a share of GDP between 1995 and 2020 (OECD, 2025). The Danish ocean economy has shifted significantly since 2010, following a commitment to phase out oil and gas, while taking a Nordic leadership role in offshore wind, with 2.6 GW installed, nearly 90% of the region's offshore wind capacity (WindEurope, 2025). Maritime transport remains central, with Denmark ranking 17th globally in fleet size by deadweight tonnage and 15th by commercial value (UNCTAD, 2024). Fisheries production has declined since 2000. Mussel farming, now the country's largest aquaculture sector at around 9,000 tonnes production in 2023 (Statistics Denmark, 2025a), is increasingly recognized as a nature-based solution to coastal eutrophication. Tourism plays a big role, accounting for more than 50% of Denmark's ocean economy employment in 2020 (EU Blue Economy Observatory, 2025).

The Faroe Islands is an archipelago of 18 islands (17 inhabited) in the Northeast Atlantic with a land area of 1,399 km² and an extensive exclusive economic zone (EEZ) of 274,000 km². In recent years, the Faroe Islands have significantly reduced their economic dependency on block grants from Denmark (Hendriksen and Hoffman, 2025). Strategically positioned between Iceland, Norway, and Scotland, the islands rely on fisheries and aquaculture, making seafood central to both the economy and exports. The Faroe Islands are among the world's largest per capita producers of seafood, with exports accounting for more than 90% of national export revenue (Statistics Faroe Islands, 2023; Hendriksen and Hoffmann, 2025). Aquaculture, dominated by Atlantic salmon farmed in fjords and exposed coastal areas, contributes approximately 8% of GDP, employs around 5% of the workforce, and generates 40% to 45% of total export value, positioning the Faroe Islands as the second-largest aquaculture producer in the region after Norway (ICES, 2023).

Finland's entire coastline borders the Baltic Sea. The unique brackish Baltic Sea is challenged by environmental pressures and supports a lower biodiversity compared to fully marine conditions. Hence, herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) constitute around 90% of Finland's fisheries (Pauly *et al.*, 2020), and the nation has taken a leading interest in efforts to improve the state of the Baltic Sea (HELCOM, 2023). Shipping is particularly important for Finland, as it serves as the primary channel for transporting goods, partly due to the country's limited alternatives for road transport as it is situated far from continental Europe. Finland holds a key role in maritime technology, particularly related to Arctic shipping and construction of icebreakers (OECD, 2018). Offshore wind has yet to emerge in Finland, but there are plans for development. Coastal tourism is well-developed, with large opportunities for recreational boating and fishing activities (Pokki *et al.*, 2021), and large numbers of coastal summer houses (Adamiak *et al.*, 2015).

Greenland is the world's largest island, and one of the world's smallest countries by population (56,000 people). It is a self-governing country within the Danish Realm and remains economically dependent on Denmark through annual block grants. The block grant constituted 30% of the island's GDP in 2003 but this was reduced to 19% of GDP by 2021 (Nordic Insight, 2025). Greenland has a unique geography among the Nordic countries, with the population clustered in a few towns and small coastal communities with limited transportation and power infrastructure. Its geography gives rise to challenges similar to other small island nations, which makes it escape easy comparison with other Nordic countries (Hendriksen and Hoffmann, 2025). Greenland has actively pursued greater autonomy or full independence. Efforts to expand utilization of natural resources like minerals and exploration of offshore oil and gas have been central to this strategy, although a moratorium on oil and gas was introduced in 2021 (Reuters, 2021). Fisheries are a key export industry, and the island has recently experienced a notable increase in cruise tourism.

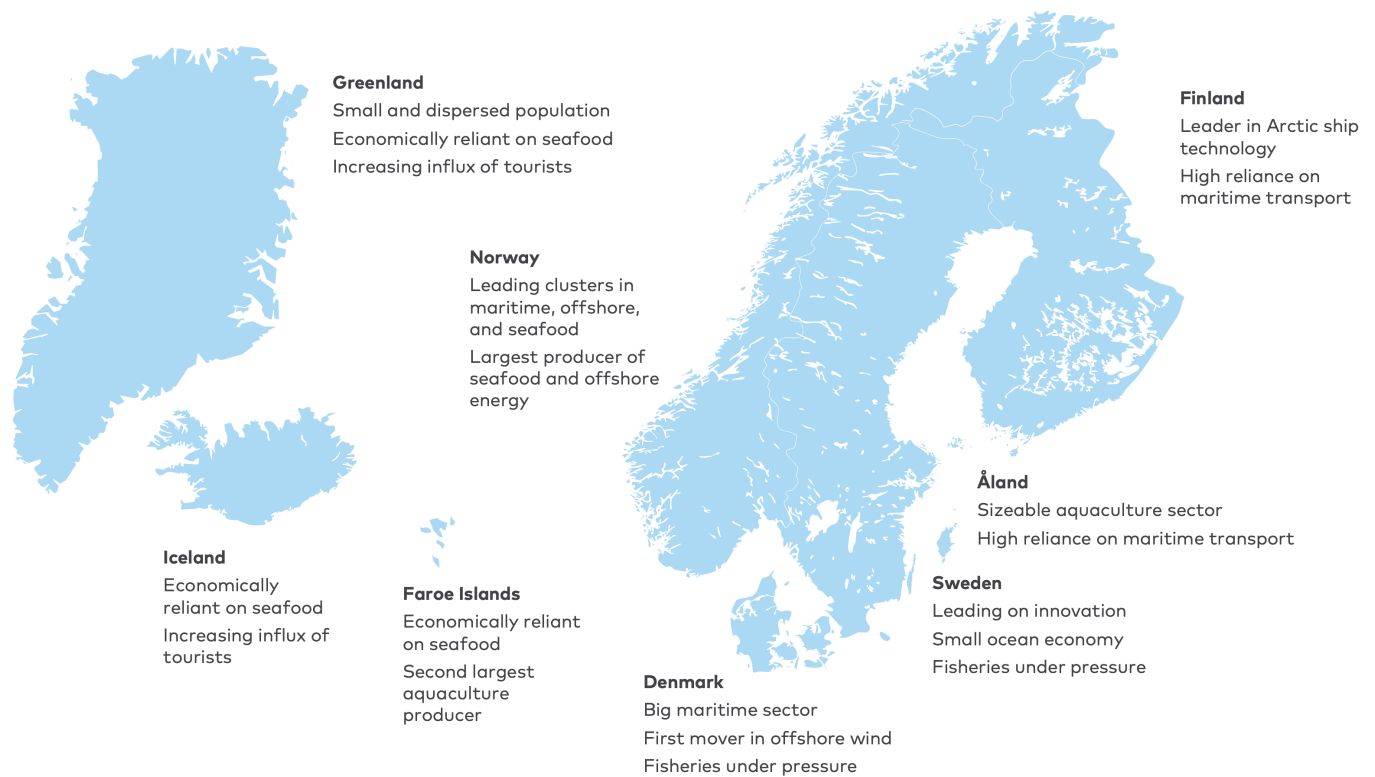


Figure 1-1 The Nordic countries with some highlighted features for the ocean economy (Greenland not to scale)

Iceland, known for its dramatic volcanic landscape and geothermal activity, has a relatively small population of around 380,000 people, concentrated in the capital region. Iceland's economy is heavily reliant on fisheries, tourism, and renewable energy, and aquaculture is considered an important growth industry for the national economy. The fisheries sector historically constitutes a vital part of the Icelandic economy and has undergone significant development over the past decades, marked by key advancements in fisheries management (Knútsson *et al.*, 2016). Most of Iceland's fish products are exported, contributing more than 40% of its export revenue (Hendriksen and Hoffmann, 2025). Due to its scale and economic relevance, the sector has evolved beyond mere resource extraction into a broader industrial activity. Fishing is a base industry, supporting a wide range of businesses developed around it, including processing, logistics, technology, and vessel maintenance. This integrated network has led to the characterization of the Icelandic fishing sector as an industry cluster (Sigfusson *et al.*, 2013).

Norway is located on the western part of the Scandinavian Peninsula, and is distinguished by its long and rugged coastline, scenic fjords, and mountainous terrain. Norway has the biggest ocean economy among OECD countries when measured as a proportion of all economic activity (OECD, 2025), and the importance of ocean industries has been remarkably consistent going back to the 1800s (Grytten and Koilo, 2025). Offshore oil and gas, fisheries, aquaculture, maritime transport, and marine technology play key roles in many sparsely populated regions and in the bigger cities, giving rise to ocean industry clusters spanning most of these value chains (Osman *et al.*, 2022; Menon Economics and DNV, 2024). Facing a likely decline in oil and gas activity in the years to come, the offshore industries are already transitioning to servicing the fast-growing European offshore wind industry (Menon Economics, 2025). The Norwegian owned fleet is the 5th biggest by value globally, and the 6th biggest by tonnage (UNCTAD, 2024). Aquaculture is the second largest export industry and often highlighted as a future growth industry, while the fisheries have been able to retain high catch volumes (Norwegian Seafood Council, 2025a).

Sweden has a long coastline and is home to the region's busiest container port, located on the west coast in Gothenburg. Compared with its western neighbours Norway and Denmark, Sweden's dependence on the ocean economy is relatively limited. The role of fisheries is small, despite its strong importance in the past, with several stocks having been over-exhausted (Swedish Agency for Marine and Water Management, 2025). Like Finland, the country plays a leading role in advancing ecosystem-based management internationally (HELCOM, 2023), and within national boundaries (Swedish Agency for Marine and Water Management, 2025). Offshore wind is progressing slowly, due to political and financial uncertainty, a laborious permitting system (Malafry and Öhman, 2022), and a recent setback due to defence-related restrictions in the southeastern Baltic Sea (Swedish Government, 2024). Currently, Sweden's economic strength lies mainly in other sectors and contributes to diversification of the Nordic economies. For instance, Sweden retains a robust manufacturing base and has developed the Nordic region's most dynamic innovation landscape (The Economist, 2024).

Åland consists of 6,500 islands, and the country is intrinsically tied to the blue economy and livelihoods. Its seafood industry may appear modest in numbers, yet fisheries and aquaculture play significant roles in the local economy despite challenges (Paisley *et al.*, 2010; Raitaniemi and Leskelä, 2024). Tourism has been a key driver of Åland's economy for decades (Rundberg and Kinnunen, 2014). Closely linked to tourism, shipping plays a vital role contributing around one fifth of the country's GDP. Continuous ferry traffic between Sweden and Finland, as well as Estonia, passing through Åland, is of particular importance (Kinnunen, 2016). A distinctive factor is the availability of tax-free sales of alcohol, tobacco, and cosmetics on these sea routes (Lindström and Palmer, 2011).

1.2 Global policy trends can drive innovation in the Nordic ocean economy

The ocean economy of the Nordic region is tightly integrated with global markets through shipping, seafood exports, energy exports, and international tourism. It will be subject to many of the trends and forces that drive the rest of the world. The Nordic countries play important roles in several of the most economically important ocean industries, and as such can have a significant impact on how the world develops its ocean economy. Among the OECD countries, Norway has the largest ocean economy, measured as a proportion of its overall economy in the period between 1995 and 2020, with Iceland and Denmark also in the top five (OECD, 2025).

A range of global initiatives, rooted in civil society, government, and business, highlight the growing importance of a sustainable ocean economy which can shape the opportunity space for the Nordics. Examples are the *High Level Panel for a Sustainable Ocean Economy* (the 'Ocean Panel'), the World Economic Forum's 'Friends of Ocean Action', and the UN Global Compact's 'Ocean Stewardship Coalition'. Additionally, the *UN Decade for Ocean Science for Sustainable Development* runs from 2021 to 2030, emphasizing "transformative ocean science solutions for sustainable development, connecting people and the ocean" (UNESCO-IOC, 2021).

As an example, the 'Ocean Panel', backed by 18 countries and first initiated by Norway, aims to spearhead efforts to bridge and balance solutions for ocean wealth and ocean health. A special report published by the 'Ocean Panel' assesses the role of the ocean as a solution to the climate crisis (Hoegh-Guldberg *et al.*, 2023). It evaluates the maturity of ocean-based climate mitigation options, including *increased efforts* in marine conservation and restoration, *upscaling* of offshore renewables, *emission reduction* across shipping, aquaculture, and marine tourism (e.g. cruise), *reducing* ecological impacts of fisheries and feed production, *demand-led reductions* and *stop in expansion* of offshore oil and gas, and *upscaling* of low-carbon seafood, marine carbon removal, and carbon capture and storage.

The above solutions represent key opportunities for the Nordics to take a leading position. In a report on *Mapping of Nordic Strongholds*, written for Nordic Innovation, Sepponen *et al.* (2021) concluded that innovation opportunities in the Nordic ocean economy lie primarily within sustainable aquaculture, maritime technologies, and advanced offshore solutions. Within these three areas, the report highlighted cross-cutting opportunities in new applications for technology, use of the Nordic region as a test bed, and digitalization.

Though many new, innovative solutions for a sustainable ocean economy exist, their uptake is highly dependent on overall socioeconomic developments, reflecting the balance between ocean health and long-term sustainability, competitiveness, growth and profitability. Next, we introduce a scenario approach that will be used throughout the report to capture the key uncertainties in global and regional drivers impacting the Nordic ocean economy.

1.3 Future scenarios for the Nordic ocean economy

To facilitate strategic positioning of the Nordic ocean economy against potential risks and opportunities, we outline four scenarios based on the Shared Socioeconomic Pathways (SSPs). SSPs are scenarios commonly applied in climate change and energy systems research that define plausible narratives for future socioeconomic development (Riahi *et al.*, 2017), and with several earlier applications in the ocean economy, like Baltic Sea ecosystem dynamics (Bauer *et al.*, 2019; Zandersen *et al.*, 2019), Finland's nascent offshore wind sector (Jenkins *et al.*, 2022), and global fisheries and aquaculture (Blanchard *et al.*, 2024; Pinnegar *et al.*, 2021). Table 1-1 describes an overarching state of the world and the Nordics in each scenario.^[1]

1. We do not represent climate change scenarios (Representative Concentration Pathways – RCPs) explicitly. We assume that 'Nature First' (SSP1), 'Constant Compromise' (SSP2) and 'Regional Rivalry' (SSP3) follow a 'middle-of-the-road' climate pathway (RCP4.5). 'Growth First' (SSP5) follows RCP8.5, which is a world that does not cut carbon emissions. Scenario names are borrowed from Zandersen *et al.* (2019), except 'Regional Rivalry', which is the title for SSP3 in Riahi *et al.* (2017).

Table 1-1 Four future socioeconomic scenarios (inspired by Riahi *et al.*, 2017 and Zandersen *et al.*, 2019)

<p>Nature First</p>	<p>Global: A return to international cooperation focused on achieving global sustainability goals, and pursuit of sustainable development within planetary boundaries. Ocean ecosystem protection and restoration prioritized before growth in the ocean economy. Nordics: Takes a leading role in scaling environmental technologies within the ocean economy.</p>
<p>Constant Compromise</p>	<p>Global: A return to pre-COVID-19 state with moderate international cooperation and economic growth, and with few shifts from historical patterns in social, economic, and technological trends. Progress towards global goals in the ocean moves forward, but slower than needed to meet ambitions on offshore renewables and environmental protection. Nordics: Pursues a leading role in scaling sustainable technologies for the ocean economy. Efforts to meet regional ambitions for environmental protection and offshore renewables are prioritized but prove difficult to meet due to regulatory delays and supply chain barriers.</p>
<p>Regional Rivalry</p>	<p>Global: National priorities take precedence over international collaboration, with concerns about competitiveness and security (including cybersecurity) gaining attention. Increasing barriers to global collaboration and international trade, including both goods and services (e.g. tourism), cause trade patterns to realign according to economic blocs. Trade barriers raise costs, reduce the pace of sustainability-driven technology developments, and limit economic growth. Nordics: Nordic collaboration is strengthened, while the need for resilient and secure supply chains in the EU shifts attention to Nordic sources of energy, food, and minerals. Energy security takes precedence over decarbonization. Efforts towards realizing deep-sea mining are intensified to increase resilience in mineral supply chains.</p>
<p>Growth First</p>	<p>Global: Economic growth is in focus, with continued increase in demand for fossil fuels. The economy experiences productivity improvements from the adoption of new technology and from an open trade system. Environmental concerns receive little attention, resulting in high climate-change impacts and degradation of marine ecosystems, at the expense of fisheries and aquaculture in vulnerable regions.</p>

Besides providing plausible future pathways for the Nordic ocean economy, the scenarios allow decision-makers across the Nordics to start exploring the trade-offs that emerge among different priorities. What is the consequence for ocean health of primarily seeing the ocean as a source of economic prosperity and a contributor to Europe's competitiveness? How should conflicts that emerge between objectives related to seafood production, offshore energy production, and transportation be resolved? How do we value the benefits that the marine ecosystems provide? By comprehensively exploring plausible futures and the related trade-offs, policymakers, investors, industrialists, and environmentalists can begin to identify win-win solutions and exploit synergies so that several objectives can be pursued through common solutions. Table 1-2 provides some highlights from the scenarios of each chapter.

Table 1-2 Main trends in future development of the Nordic ocean industries in the scenarios

	Ecosystems (Chapter 3)	Fisheries (Chapter 4)	Aquaculture (Chapter 5)
Nature First	Ambitions for nature protection are met.	Strong international fisheries management in the Nordics.	Novel fish feed scaled up to reduce environmental footprint. Low-trophic aquaculture prioritized
Constant Compromise	Current trends in environmental pressures.	Long-term stock declines due to fishing pressure.	Increasing demand , slow environmental adaptation.
Regional Rivalry	Lack of international commitments. Local impacts prioritized, cross-border impacts ignored.	Breakdown of international quota agreements in Nordic sea areas.	Trade barriers hurt demand for Nordic seafood and reduce access to feed supplies.
Growth First	Collapse in some regions (e.g. Baltic) and large changes in Arctic ecosystems due to warming.	Exploitation of new stocks in the Arctic and collapse of Baltic fisheries.	Climate change challenges output consistency. Focus on new technologies for salmon production.
	Offshore energy (Chapter 6)	Maritime (Chapter 7)	Tourism (Chapter 8)
Nature First	Ambitions for offshore renewables nearly met.	Large investments in low-carbon shipping , and new biodiversity targets.	Shift towards domestic tourism and activities with less degradation potential.
Constant Compromise	Significant shortfall from North Sea and Baltic Sea offshore wind ambitions.	Gradual shipping decarbonization and limited demand growth.	Continued increase in international tourism.
Regional Rivalry	No decline in North Sea oil and gas. Less offshore wind development due to maritime security concerns.	Trade barriers drive down demand, increased focus on domestic maritime cluster capacity building.	Reduction in international tourism, shift to domestic tourism.
Growth First	Increase in oil and gas with expansion in Arctic regions.	Arctic sea routes open, continued growth in tanker and gas carrier trades.	Increase in international tourism to the Nordics, due to 'coolcation' trend, both coastal and cruise.

2. The Nordic ocean economy and societal drivers

This chapter offers an overview of the entire Nordic ocean economy and the relative importance of its key sectors. It also introduces some key trends in the underlying socioeconomic driving forces.

2.1 Socioeconomic driving forces

The key driving forces behind economic activity in the ocean are population growth and economic development. As living standards grow, people tend to consume more goods and services, including those produced from the ocean. Innovation and market access are essential to drive productivity improvements, and we review how the Nordics fare in these dimensions.

2.1.1 Population development

The population of the Nordic region is around 28 million, as of 2025. More than a third of the Nordic population lives in Sweden, which has surpassed 10 million. Denmark and Finland earlier had similar population sizes, but Denmark has grown faster and reached 6 million. Finland and Norway each have around 5.5 million, and Iceland around 380,000. The Faroe Islands and Greenland each have slightly more than 50,000 people, and Åland around 30,000. In total, the population of the Nordics is around 6% of the 450 million in the EU in 2025 (EUROSTAT, 2025d).

Aging populations: Like most European and industrialized countries, the Nordics experience sub-replacement fertility rates. Most population forecasts still indicate some growth due to immigration, with relatively high wages attracting talent to the region. The total working age population (20–64 years) declined 3% for the region over the period 1990–2025, with big variations between countries (Nordic Statistics, 2025b). For the 2023–2040 period, Norlén *et al.* (2024) estimates a marginal 1.9% increase in working-age populations in the Nordics, as opposed to a 6.5% decline in the EU. The risk of declining working-age populations will likely drive capital investment in technologies such as automation, to improve productivity and support economic growth (Acemoglu and Restrepo, 2022).

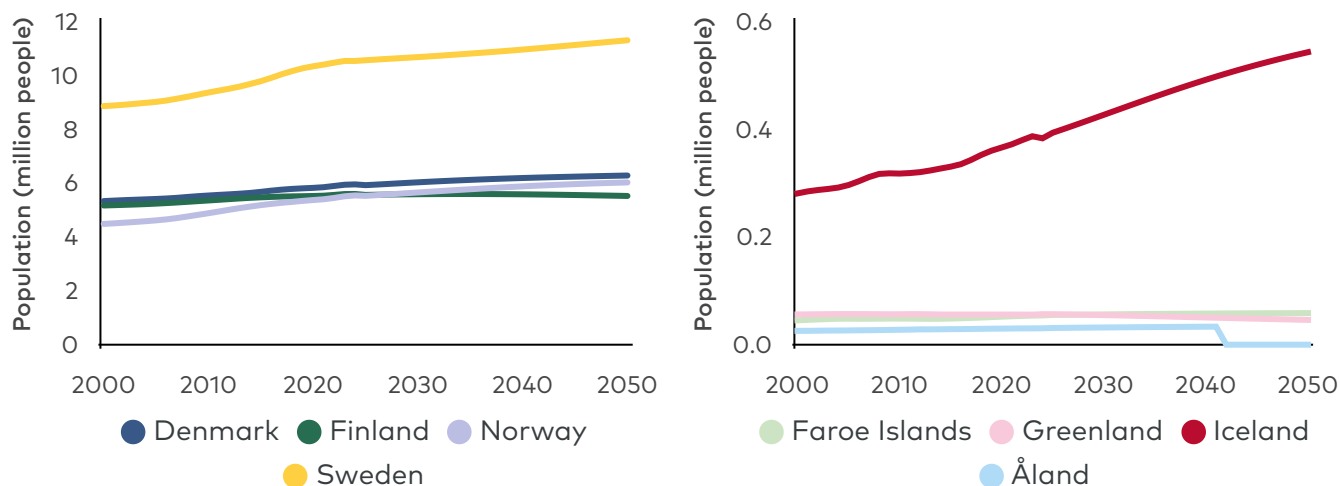


Figure 2-1 Population forecast to 2050, with left pane showing countries with population above 1 million people and right pane showing those with population below 1 million

Source Nordic Statistics (2025a): forecast for Åland available only up to 2040

Urbanization: All Nordic countries see shifts in the spatial distributions of their populations towards the major cities (Norlén *et al.*, 2024). In Finland, Norway, and Sweden, the major cities in the south have increased their shares of the populations over time, but the shift is historically most pronounced in Sweden. The same trend is clear in Denmark and Iceland, with Copenhagen and Reykjavík seeing their shares of national population soar. Urban population centres are not necessarily hubs for core activities in the ocean economy but often provide a range of related services.

2.1.2 Living standards

Gross domestic product (GDP) is the most used indicator for the economic output of countries, calculated as the gross value added (GVA) less the value of production inputs (production approach), or the sum of government expenditures, investments, and consumption, plus net exports (expenditure approach), with both approaches yielding the same result. Hence, GDP per capita both measures living standards and the productivity of the economy overall.

The Nordic countries all rank high in GDP per capita terms globally and by European standards but still see substantial variation, ranging from Finland at little more than EUR 50,000 to Norway above EUR 70,000.^[2] In the 'Constant

2. Measured in constant 2024 EUR, and at purchasing power parities from 2017 international USD. IIASA (2025) states values in constant 2017 USD. These numbers are therefore not directly comparable with others in the report.

Compromise' scenario to 2050, Iceland nearly catches up with Norway as the former's growing population drives economic activity. Denmark and Sweden follow similar pathways, and Finland will still have the lowest GDP per capita in 2050 (see Figure 2-2). Figure 2-2 excludes Åland, the Faroe Islands, and Greenland. Both the Faroe Islands and Greenland receive annual block grants from Denmark to improve their economies and reduce the difference in living standards with Denmark, though these are being reduced to increase financial independence.

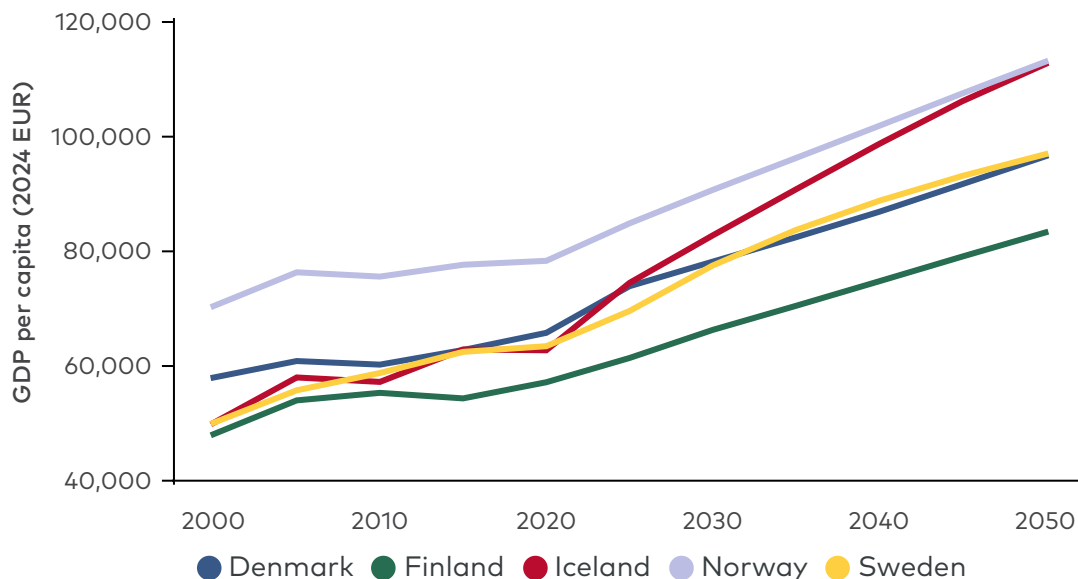


Figure 2-2 GDP per capita forecast to 2050, under SSP2 – ‘Constant Compromise’, excluding Åland, the Faroe Islands, and Greenland

Source IIASA, 2024

2.1.3 What the scenarios say about population and living standards

Tables 2-1 and 2-2 show population and GDP per capita under the four scenarios for 2050. The scenarios consistently show the slowest increases in population and living standards when there is ‘Regional Rivalry’, and the fastest (for all countries) under ‘Growth First’. ‘Nature First’ and ‘Constant Compromise’ lead to identical populations in 2050, but ‘Nature First’ delivers higher living standards than ‘Constant Compromise’. Table 2-1 also contrasts the scenarios with Nordic Statistics (2025a) population prognosis referred to in Figure 2-1. The data in Figure 2-2 corresponds to the ‘Constant Compromise’ scenario.

The Nordic population grows in all scenarios, and this is also observed on the country level, except for Finland. Finland only sees population growth in the 'Growth First' scenario. Icelandic population growth in all SSPs is lower than the 2050 forecast by Nordic Statistics (2025a). The difference between the lowest and highest population scenarios for 2050 is between 7% and 12% for all countries. GDP per capita grows the fastest in Iceland in all scenarios, but only in 'Growth First' does the estimate for Iceland bypass that of Norway. The difference between the highest and lowest GDP per capita scenarios for 2050 is between 22% (Norway and Sweden) and 27% (Iceland).

One caveat of the SSP framework is that it does not address the recent boom in artificial intelligence (AI) (Carlsen *et al.*, 2024), and these analyses therefore do not fully consider the potential economic impact of AI on productivity and employment. This effect is highly uncertain, and DNV (2025a) assumes a modest addition to GDP per capita to account for this effect, for a 'most likely scenario' assumed to lie between 'Constant Compromise' and 'Regional Rivalry'.

Table 2-1 Population forecast (million people) and range of scenario estimates

Source Nordic Statistics (2025a); Wittgenstein Centre for Demography and Global Human Capital (2023)

	2050 scenarios					2050 forecast (Fig 2-1)
	2025	Nature First	Constant Compromise	Regional Rivalry	Growth First	Nordic Statistics
Denmark	5.9	6.2	6.2	6.1	6.5	6.3
Finland	5.6	5.5	5.5	5.4	5.8	5.5
Iceland	0.4	0.4	0.4	0.4	0.4	0.5
Norway	5.6	6.1	6.1	6.0	6.6	6
Sweden	10.6	11.7	11.7	11.4	12.7	11.3

Table 2-2 GDP per capita forecast and range of scenario estimates (2024 EUR, 2017 PPP)

Source IIASA, 2024

2050 scenarios					
	2025	Nature First	Constant Compromise	Regional Rivalry	Growth First
Denmark	74 000	101 000	97 000	85 000	111 000
Finland	61 000	88 000	83 000	74 000	97 000
Iceland	74 000	119 000	113 000	97 000	133 000
Norway	85 000	120 000	113 000	101 000	129 000
Sweden	70 000	103 000	97 000	86 000	111 000

2.1.4 The role of innovation

The last few years have seen rising concerns over European competitiveness relative to China and the US, especially following rising geopolitical tensions and years of ambitious regulatory efforts related to climate, energy, and environmental sustainability that have made compliance more complex and driven up costs (European Commission, 2024c). Still, the Nordics perform well on technology development and innovation, with the region's listed companies reporting higher annual returns than in other European countries (The Economist, 2024). Particularly in the digital sphere – where development globally is currently led by the US – the Nordics are ahead of Europe as a whole. Explanations of this include high uptake of digital technology in society (e.g. early digitalization in banking, insurance, public services), attractive cost-to-skill ratio in engineering, large industrial players (e.g. Equinor and Maersk) that invest heavily in technology, and generous education and social welfare systems (Bjørndalen *et al.*, 2024).

Figure 2-3 shows that private and public research and development (R&D) spending in most of the Nordic countries exceed the EU average when measured as a share of GDP. Sweden spent approximately the same share of GDP on R&D efforts as the US, while both Denmark and Finland spent slightly less than 3%. Only Norway spent a lower share of GDP on R&D than the EU average. Sweden currently (as of 2024) also attracts the most early-stage venture capital among the Nordic countries (NVCA, 2025) and ranks second on the Global Innovation Index (WIPO, 2025), often explained by good framework conditions both in a

Nordic and a global context. A good example of Nordic collaboration in R&D is the Nordic Five Tech alliance^[3] which promotes mobility among graduate students and researchers.

2.1.5 The Nordics as small, open economies

Figure 2-4 shows the value of trade (exports plus imports) as a share of GDP. This is a commonly applied measure of economic openness, often referred to as the 'trade openness index'. The openness of the Danish and Faroese economies exceeds that of the EU average, whereas Iceland and Norway are relatively less dependent on trade. Neither Iceland nor Norway are member states of the EU but have access to the EU internal market through the EEA (European Economic Area). Compared to the US, all Nordic countries are highly exposed to trade through their tight integration with European markets. The ocean economy is especially export-driven, with seafood production exceeding consumption in Norway, Iceland, and the Faroe Islands as examples.

Foreign trade is a source of significant revenue but also creates vulnerabilities in the Nordic ocean economy. For instance, the Faroese and Greenlandic economies are particularly exposed to trade disruptions affecting seafood, as seafood contributes more than 90% of their exports (Hendriksen and Hoffmann, 2025). For Denmark, exports of goods (e.g. equipment) and services (e.g. international shipping) constitute more than 80% of the output of the maritime industry (COWI, 2024).

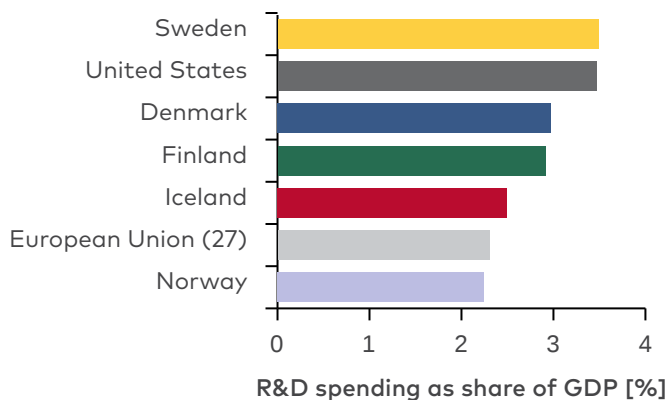


Figure 2-3 Research and development expenditure as a share of GDP in 2020

Source UNESCO Institute of Statistics (2025) – processed by Our World in Data

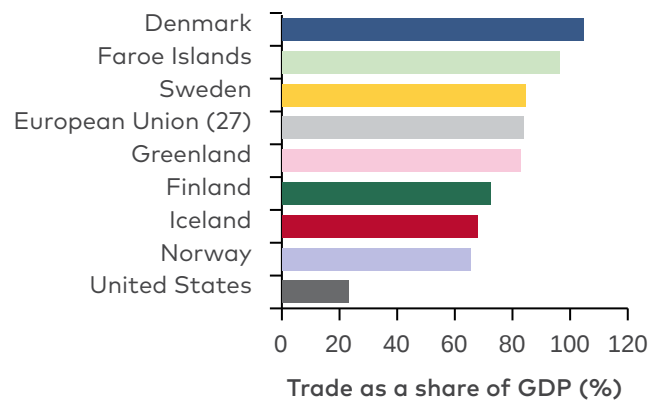


Figure 2-4 Trade (exports plus imports) as a share of GDP in 2020

Source World Bank and OECD (2025) – processed by Our World in Data

3. Aalto University in Finland, Chalmers University of Technology and KTH Royal Institute of Technology in Sweden, DTU in Denmark, and the Norwegian University of Science and Technology (Nordic Five Tech, 2020).

2.2 How economically important are the ocean sectors?

There are big disparities between the ocean economies of the Nordic countries. For the Faroe Islands, Greenland, and Iceland, the seafood industry is of utmost importance for the national economy. Aquaculture alone contributes 8% of the Faroese GDP (ICES, 2023), and 2% to 3% in Åland (ÅSUB, 2024). In Norway, the ocean sectors have contributed at least 10% of GDP since the 1800s, first with seafood, then with increasing emphasis on shipping, and lately (last 40–50 years) on offshore energy (Grytten and Koilo, 2025). Similarly, Denmark has historically played a large role in seafood and shipping. This contrasts with Sweden and Finland which in recent years host much smaller ocean economies.

Figure 2-5 shows the direct economic contributions, measured in GVA (see text box) of the ocean sectors of Denmark, the Faroe Islands, Finland, Greenland, Iceland, Norway, and Sweden. This does not include oil and gas, and coastal and marine tourism. These sectors are excluded due to the disproportionately big GVA contribution by fossil fuels (20% of Norway's GVA and 75% of its ocean economy (Randen *et al.*, 2022)), and due to methodological differences between the EU and Norway in including tourism in ocean accounts. Without oil and gas and tourism, the value added of Norway's and Denmark's ocean economies were approximately of equal size in 2020. The Danish ocean economy has undergone a dramatic shift away from fossil-fuel dependency since 2010, with offshore wind GVA tripling between 2010 and 2020 from a very low starting point. Still, Danish maritime transport GVA has increased even more in absolute terms. In Norway, growth in seafood was insufficient to offset declining activity in the shipbuilding and maritime transport sectors, and the GVA of the ocean economy (excluding fossil fuels) was slightly lower in 2020 than in 2010, after peaking in the interim years.

Figure 2-6 shows the breakdown of the Nordic ocean economy by sector (excluding oil and gas and coastal and marine tourism). In this view, maritime transport and associated maritime activities such as ports and shipbuilding contribute more than the seafood industries and the nascent offshore wind industry. Figure 2-6 focuses on direct contributions, but it is important to acknowledge that the forecasted rapid growth in offshore wind will drive activity in other sectors that are part of the offshore wind *supply chain*, such as ports, shipbuilding, and maritime transport. Besides this, these statistics could underplay the role of services in the ocean value chains, as these often fall outside the classification schemes used to quantify the size of the ocean economy.

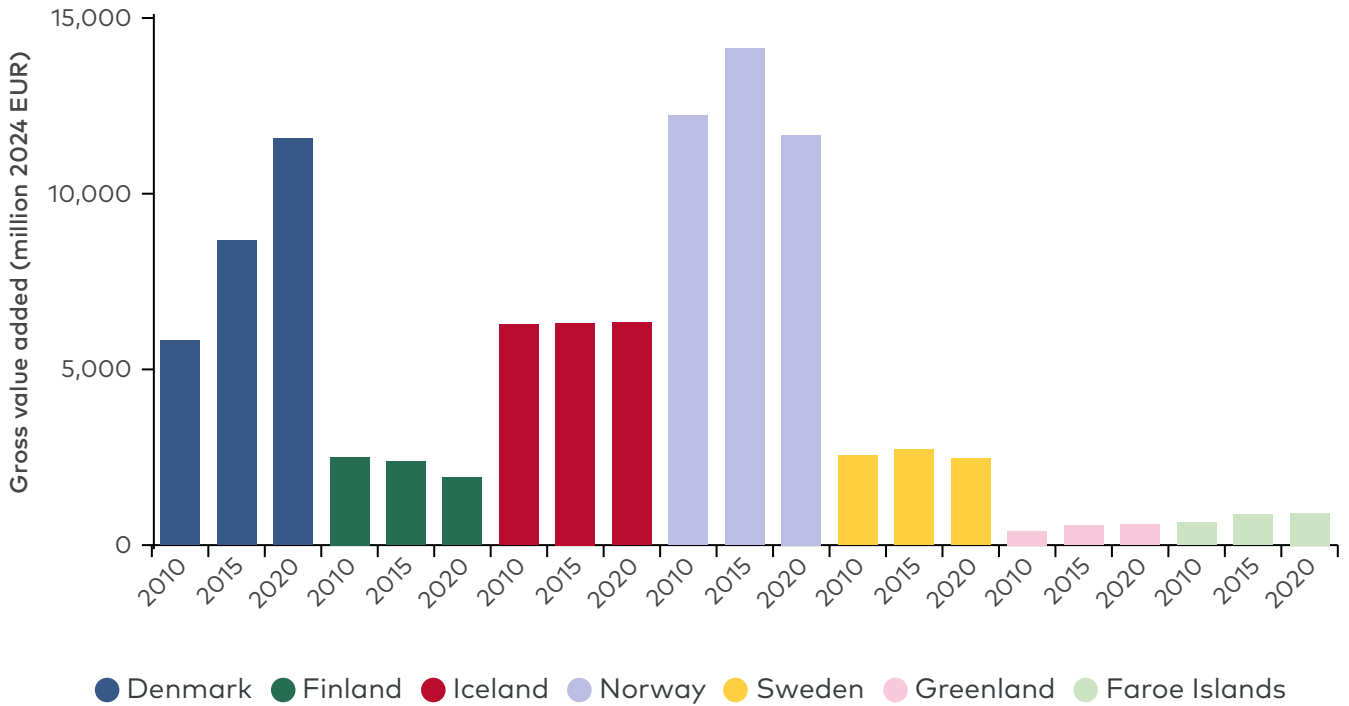


Figure 2-5 Gross value added of ocean industries by country, except oil and gas, and coastal and marine tourism

Source EU Blue Economy Observatory (2025); Statistics Faroe Islands (2025c); Statistics Greenland (2025c); Statistics Iceland (2025c); and Statistics Norway (2025a)

Gross value added

To measure direct economic impact, we use gross value added (GVA). This measures the value of the gross output of a production process minus the value of the inputs that are transformed by use of capital and labour in the production process. GVA only captures the direct value creation in the sector, and hence does not consider the sector's supply chain, thereby avoiding double counting. There are no directly comparable datasets for GVA that cover the ocean economy for all Nordic countries, so some sectors are not accounted for here. For the three EU member states – Denmark, Finland, and Sweden – the EU Blue Economy Observatory (2025) provides a comprehensive satellite account for sectors and subsectors, most recently updated with 2021 data. For Norway, Iceland, the Faroe Islands, and Greenland, we make direct use of national accounts data. A known issue with relying on national accounts for estimating the size of the ocean economy is that the categorization is often broad and not developed with the intent of separating out marine and maritime activities. Separate ocean accounting approaches have been developed by the national statistical bureaus in Norway (Randen *et al.*, 2022) and Sweden (Vanacore *et al.*, 2024).

Although coastal and marine tourism is a big GVA contributor, it is intentionally left out in Figure 2-5 and 2-6 as it is often difficult to categorize: In 2019, the last pre-COVID year, coastal and marine tourism contributed 63% of Sweden's ocean economy GVA, 42% of Finland's, and 24% of Denmark's. In contrast, the Norwegian ocean accounts (Statistics Norway, 2024) estimate that only 5% of Norway's GVA from the ocean economy came from coastal and marine tourism (after excluding oil and gas and related services), indicating methodological differences from the EU approach. Åland is also excluded, since the categorization is inadequate, despite significant contributions from ocean sectors to Åland's economy.

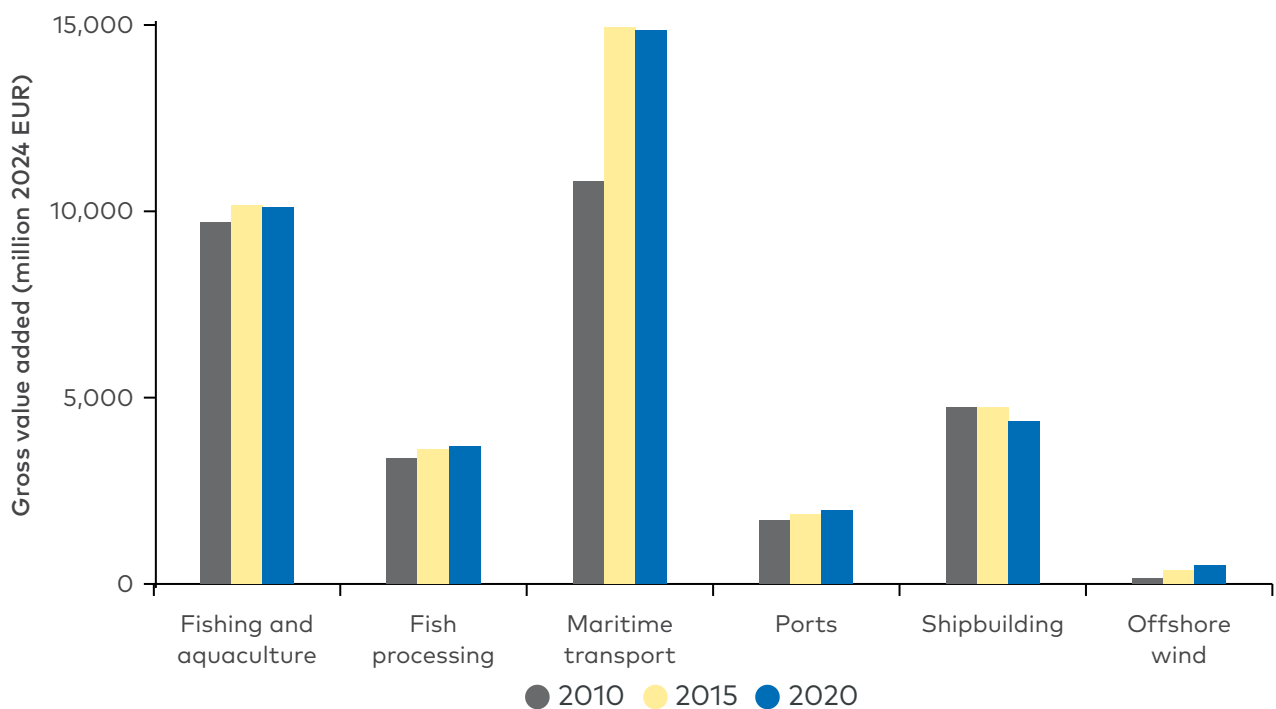


Figure 2-6 Gross value added of ocean industries, except oil and gas^[4] and coastal and marine tourism

Source EU Blue Economy Observatory (2025); Statistics Faroe Islands (2025c); Statistics Greenland (2025c); Statistics Iceland (2025c); and Statistics Norway (2025a)

4. Shipbuilding data series is called 'Building of ships, oil platforms and modules and other transport equipment'.

2.3 Employment in the Nordic ocean economy

The Nordics have an inclusive labour market, with high labour participation by European standards. Within the EU, only the Netherlands has a higher employment rate than Sweden and Denmark as of 2022 among those in the age bracket 20–64 years (Norlén *et al.*, 2024). From high employment rates, many regions and sectors of the economy are at risk of labour shortages as the working-age population stagnates, but the changes in working-age populations vary greatly between regions. Rural areas are especially at risk as young people move to urban areas (Norlén *et al.*, 2024), and much of the ocean economy operates from coastal communities with low populations. Aquaculture is one key example, employing 13,000 people across the Nordics, with around 10,000 in Norway (Statistics Norway, 2024), and most of the remainder in the Faroe Islands and Iceland (Statistics Faroe Islands, 2025b; Statistics Iceland, 2025a). In Norwegian aquaculture, almost 60% of the employees live in municipalities classified as 'least' or 'second-least' central (Statistics Norway, 2025c), and only around 20% of employees at the farms are female (Norwegian Directorate of Fisheries, 2025a). Hence, improving the gender balance in aquaculture could increase the resilience of rural, coastal communities across the Nordic region.

Table 2-3 compares employment estimates for 2015 and 2020 as provided in the EU Blue Economy Observatory (2025) (for Denmark, Finland, and Sweden) and the Norwegian ocean satellite accounts (Statistics Norway, 2024). In the EU accounts, tourism (e.g., accommodation, transport, activities) is by far the biggest employer in the ocean economy. Even in 2020, during the COVID-19 pandemic, tourism accounted for 65% of Swedish ocean economy employment, and more than 50% in Denmark. The sizeable employment footprint of the shipbuilding and offshore oil and gas sectors in Norway should be noted. Much of the offshore construction and equipment sector is included in the shipbuilding category, and this sector is increasingly serving the fast-growing offshore wind industry in the Nordics and beyond. Only Denmark had direct employment in offshore wind (electricity production, transmission, and distribution) as of 2020, according to the EU Blue Economy Observatory (2025). In contrast, Ørsted – the biggest offshore wind farm operator – employed 2,000 people in Denmark in 2020 (Ørsted, 2020). Ørsted's global staff totalled 6,000, of which half worked in the offshore wind area (Ørsted, 2020). Ørsted's staff grew another 25% to 8,000 people in 2024 (Ørsted, 2024).

As mentioned in Section 2.2., the Norwegian ocean economy estimates for tourism are not directly comparable with those of the EU member states due to differences in methodology. Similarly, the direct employment estimates in Table 2-3 are not directly comparable with estimates in industry-specific reports, which often include

indirect employment effects. For instance, both Danish (COWI, 2024) and Norwegian (Menon Economics, 2025) estimates for the maritime industry include subsectors that cross into the tourism (e.g. cruise), aquaculture (e.g. wellboats), and offshore industries (e.g. offshore ships).

Table 2-3 Direct employment (full-time equivalents) in Denmark^a, Finland^a, Norway^b, and Sweden^a, by ocean industry in 2015 and 2020.

^aSource EU Blue Economy Observatory (2025); ^bSource Statistics Norway (2024)^[5]

	2015				2020			
	Denmark	Finland	Norway	Sweden	Denmark	Finland	Norway	Sweden
Fisheries	1 700	1 700	9 000	1 800	1 800	1 600	9 400	1 900
Marine aquaculture	100	200	7 000	100	100	200	9 800	100
Fish processing	4 300	1 200	12 600	2 200	3 100	1 300	14 100	2 300
Maritime transport	34 200	10 700	30 400	17 300	22 900	9 700	28 400	14 800
Ports	5 700	7 600	N/A	3 700	5 600	5 800	N/A	4 000
Shipbuilding	3 600	8 300	32 000	7 000	3 500	8 700	31 900	7 600
Offshore oil and gas	2 700	N/A	26 100	N/A	2 600	N/A	24 700	N/A
Offshore oil and gas services	N/A	N/A	51 400	N/A	N/A	N/A	56 100	N/A
Offshore wind	900	N/A	N/A	N/A	1 100	N/A	N/A	N/A
Coastal and marine tourism	61 200	21 900	1 400	57 000	48 100	18 000	13 700	63 300

5. Shipbuilding includes 'Building of oil platforms and modules' and 'Equipment and repair'. 'Ports' not available for Norway.

2.4 Productivity in the Nordic ocean economy

With rising concerns about European competitiveness (European Commission, 2024c), the Nordic ocean economy needs to contribute to both future economic growth and ocean sustainability. Macrotrends such as aging populations and increasing urbanization also indicate that it is essential to raise labour productivity in the ocean economy in the years ahead. The OECD (2025) states that ocean industries do not yet take full advantage of new digital technologies that could improve productivity, and this is likely true for the Nordic ocean economy as well.

Figure 2-7 illustrates the relative labour productivity of selected sectors^[6] in the Norwegian ocean economy for 2018, 2020, and 2022, shown on a logarithmic scale. All numbers are scaled relative to the labour productivity of coastal and marine tourism in 2020, which is set equal to 1. Figure 2-7 shows that the main driver for labour productivity in the Norwegian ocean economy is still offshore oil and gas, which far exceeds the other sectors when measuring the GVA per full-time equivalent. This is true also in years with known disruptions, such as 2020 (COVID impacts on tourism) and 2022 (Russo-Ukrainian war impacts on gas prices). Aquaculture and fisheries rank as the second and third most productive ocean sectors.

A common trait for the sectors that see the highest labour productivity is the focus on production of commodities (seafood and fossil fuels) for export, rather than services (e.g. tourism) or manufactured products (e.g. ships and marine equipment). Although tourism is a labour-intensive sector with relatively low productivity compared to other sectors in the ocean economy, tourism plays a vital role in sustaining coastal communities.

Besides labour, it is also necessary to understand the role other input factors play in the production process. Figure 2-8 shows the relative importance of intermediate consumption, capital, and labour in generating the gross output of Norwegian ocean economy sectors. Offshore oil and gas are by far the most capital-intensive of these industries, whereas the fisheries and coastal and marine tourism stand out as most heavily reliant on labour for value creation. Rapidly evolving sectors such as offshore wind rely on large investments in physical infrastructure, with relatively light personnel needs, and hence will likely have a structure similar to oil and gas. In marine aquaculture's move to more technology-intensive operations, a drive to larger investment has already been observed (Misund, 2022).

6. Categories that are included in the Norwegian ocean accounts but excluded here are: 'Services incidental to oil and gas extraction', 'Building of oil platforms and modules', 'Equipment and repair', 'Domestic shipping', 'Services incidental to sea transport', 'Supply operations', 'Research and development', and 'Other service production'.

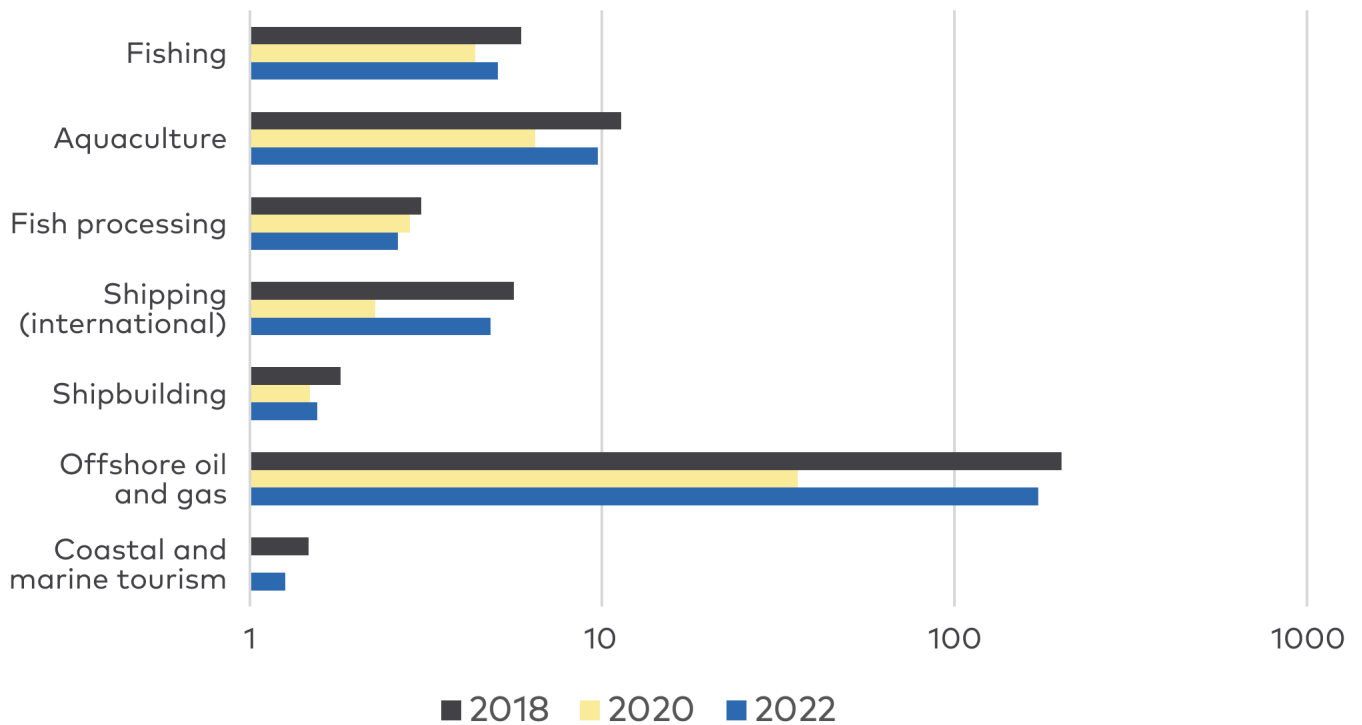


Figure 2-7 Relative labour productivity of selected ocean industries in Norway. All sectors scaled relative to tourism, which is set equal to 1 in 2020.

Source Statistics Norway, 2024

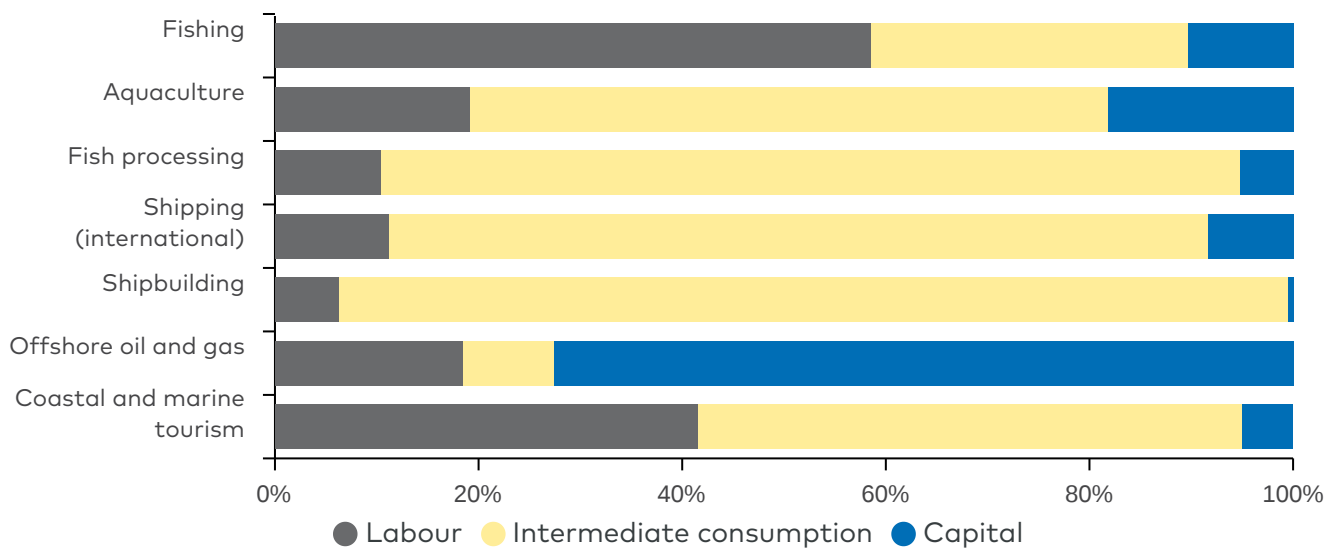


Figure 2-8 The share of intermediate consumption of goods and services, capital, and labour in gross output of selected Norwegian ocean industries in 2018

Source Statistics Norway, 2024

3. Nordic ocean ecosystems

The marine environment of the Nordics spans several sea areas, or large marine ecosystems (LMEs), including the Canadian East Arctic (west Greenland), Canadian High Arctic (north Greenland), Greenland Sea, Barents Sea, Norwegian Sea, North Sea, Baltic Sea, Faroe Plateau, and Icelandic waters (Figure 3-1). In addition, the Arctic Ocean and broader North Atlantic are of close relevance to the Nordic economy. Together, these vast sea areas host a wide diversity of species and habitats that provide opportunities for marine activities and resource use. But the systems are also under stress from human pressures and climate change, which may limit the prospects for development of some marine sectors. Together, these aspects raise the need to include sustainability considerations in the future development of all marine sectors in the Nordic region. This chapter offers an overview of the marine ecosystems of the Nordics, with a focus on the ecosystem services, pressures, and trends as well as prospects of conservation.

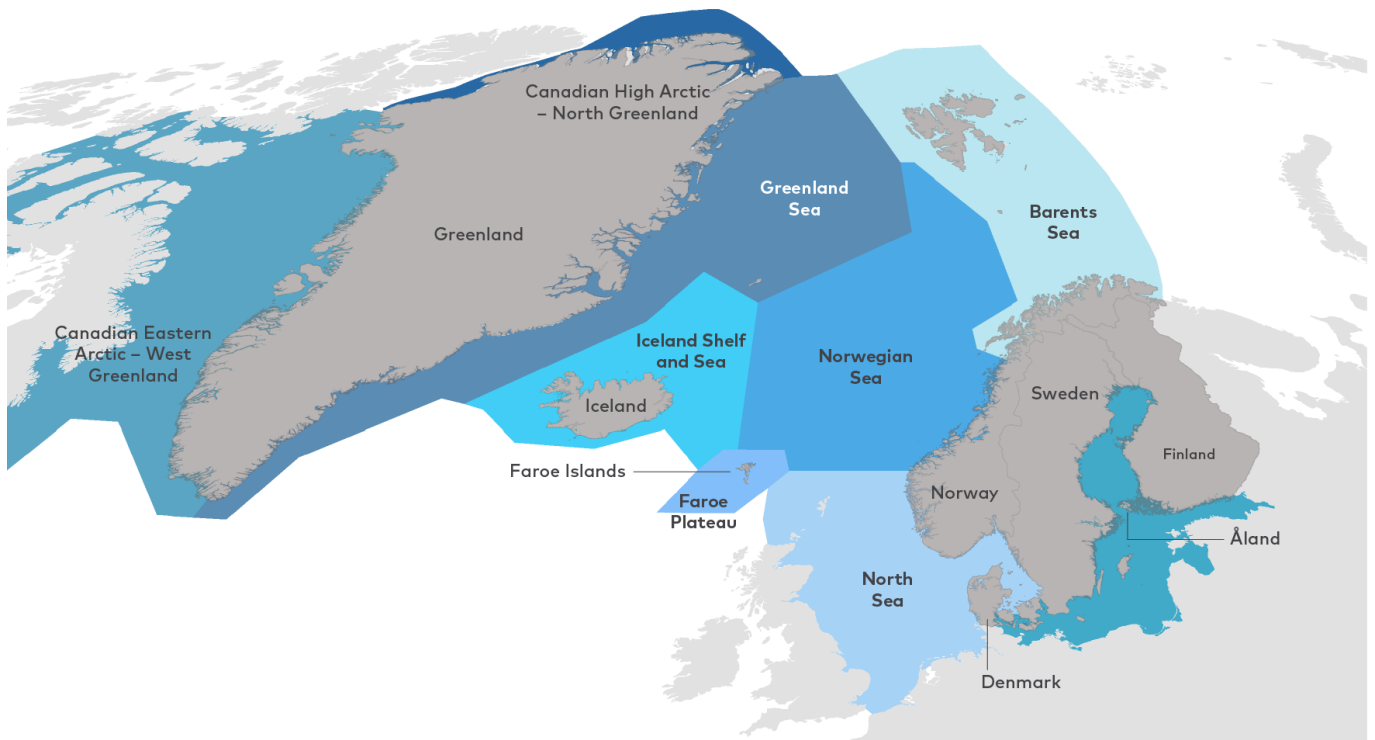


Figure 3-1 Large marine ecosystems of the Nordic region

3.1 Economic dependency on the marine ecosystem and its services

Several ocean sectors in the Nordics, like others worldwide, are strongly dependent on the marine environment and the services it provides. Marine ecosystem services can be grouped into **provisioning** (e.g. seafood), **supporting** (e.g. nutrient cycling, habitat provision), **regulating** (e.g. coastal protection, carbon sequestration), and **cultural services** (e.g. recreation, tourism) (Ahtiainen and Öhman, 2014). The interactions between marine sectors and these services are complex: some activities negatively affect marine species that underpin key services, while others depend directly on them. Figure 3-2 illustrates these dynamics across existing marine protected areas in the Baltic Sea, the North Sea, and the Northeast Atlantic, highlighting how both land-based and marine activities depend on marine species groups or affect these (Lusseau et al., 2025). Fisheries and tourism are the sectors that depend most clearly on the presence and health of certain species groups or natural habitats, as illustrated by the green links in the figure. Red links indicate the impacts from economic activities on species groups. Next, we review specific human-induced environmental pressures that drive ecosystem impacts in the Nordics.

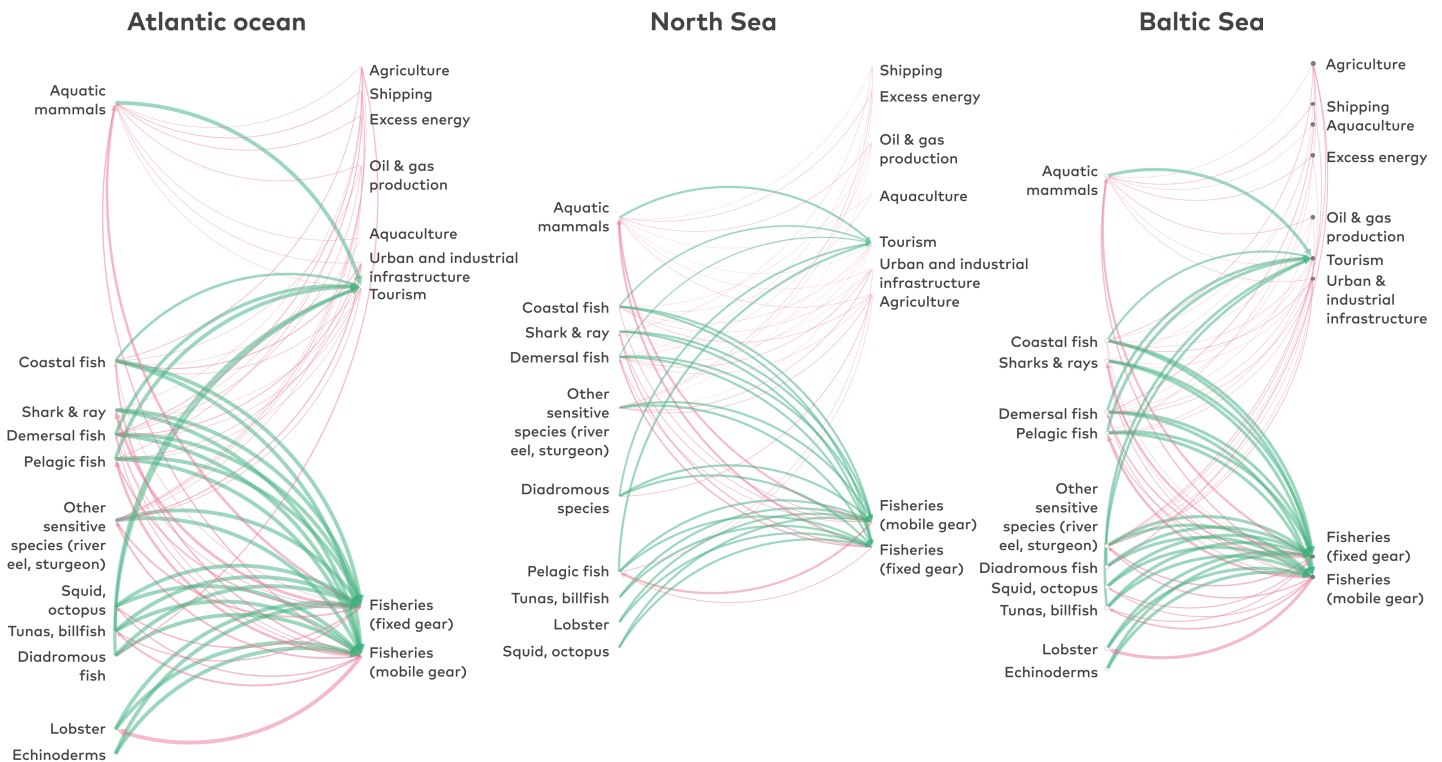


Figure 3-2 Positive (green) and negative (red) interlinkages between key marine species and industrial and human activities at sea and on land in marine protected areas in the North Atlantic, the North Sea, and the Baltic Sea (Lusseau et al., 2025)

3.2 Environmental pressures

This section presents environmental pressures on Nordic sea areas, roughly in order of their significance of impact according to the International Council for the Exploration of the Sea (ICES) ecosystem overviews (ICES, 2025a), which provide syntheses for broader North-Atlantic ecoregions.

3.2.1 Selective extraction of species

Selective extraction of species is predominantly driven by commercial fisheries in the form of targeted extraction and/or incidental bycatch (ICES, 2025a). Fishing a species has a variety of impacts on the marine ecosystem. It can lead to changes in biological communities and food web interactions, which could reduce biodiversity and influence other fisheries. Long term overfishing influences the sector itself by reducing yields, triggering fisheries collapse, and may lead to negative impacts on the broader ecosystem. As seen in some Nordic stocks, actions for sustainable fisheries management can remediate and mitigate negative effects and contribute to the future development of the fisheries sector. However, several stocks and food webs in Nordic sea areas remain vulnerable.

3.2.2 Physical seabed disturbance

Seabed disturbance consists of substrate abrasion, resuspension, removal, or smothering (ICES, 2025a). Bottom-contacting fishing gear like bottom trawls, bottom seines, dredges, and beam trawls is a major source of seabed disturbance. Other activities that contribute to this pressure include cable laying activities and physical seafloor installations in connection with the establishment of marine infrastructure, navigational and capital dredging to support navigation, and coastal development. Seabed disturbance contributes to habitat loss and reduced biodiversity, with indirect but significant impacts on ecosystem composition and dynamics. Physical seabed disturbance can be addressed through regulations, habitat restoration activities, and the general enforcement of marine policies (e.g. marine protected areas), and in some cases be mitigated via nature-inclusive designs.

3.2.3 Marine litter

Marine litter consists of manufactured materials that are discarded, disposed of or abandoned in the marine and coastal environment. It is introduced into marine ecosystems through local human activities such as fisheries, maritime transport, wastewater, military, and tourism, as well as litter transported from elsewhere by currents. Ghost gear represents a considerable challenge, as it can continue to trap

and entangle fish, birds and marine mammals for years after being lost (Tschernij and Larsson, 2003). In the Nordics as well as globally, plastics are a key contributor to marine litter, this being the most persistent material (ICES, 2025a). Impacts include habitat disturbance, entanglement, and ingestion. The latter is of particular concern since plastics have been found in the guts of a variety of organisms, including zooplankton, fish, birds, and humans (Adamovsky *et al.*, 2021; Savoca *et al.*, 2021).

Despite negotiations, UN member countries were recently unsuccessful in establishing a Global Plastics Treaty (Stallard and Poynting, 2025). However, with a growing array of strategies, sustainable alternatives, and innovative technologies to help manage plastics from production to disposal, there are numerous opportunities for Nordic countries to invest in impactful solutions across the entire plastic value chain.

3.2.4 Contaminants

Contaminants (e.g. persistent organic pollutants, polycyclic aromatic hydrocarbons, and heavy metals) are introduced into marine ecosystems through a variety of activities, such as shipping, oil and gas extraction, and fisheries, as well as through wastewater discharges and deposition from land-based industries. Among the sea-based activities, shipping is a major source for the Baltic Sea and North Sea (ICES, 2024a-b), as are fisheries for the Faroe Plateau (ICES, 2023). In the Norwegian Sea, polycyclic aromatic hydrocarbons are linked to local petroleum activities while persistent organic pollutants are linked to activities outside of the ecoregion (ICES, 2022). Long-range transport of contaminants from outside the ecoregion is a significant concern for most Nordic marine ecosystems, but the reverse impact of the Nordics on other ecoregions can also be an issue. Effects on marine life can be both acute and chronic, leading to reduced productivity, developmental deformities, and impaired physiological function. On an ecosystem level, impacts on habitats and biota can be widespread, long-lasting, and cumulative. Collaboration among Nordic authorities in contaminants' sectors has contributed to shaping European and global regulations, promoting safer and more sustainable chemical management (Nordic Council of Ministers, 2024), however there remains a great need to deepen our understanding of the occurrence and effects of both currently known and more recently introduced contaminants (OSPAR, 2023).

3.2.5 Underwater noise

Underwater noise emanates through impulsive noise and continuous noise. Impulsive noise is typically short-lasting and occurs with high intensity in connection to, for example, pile driving, seismic surveys, and military activities. Continuous noises have more stable sound profiles, originating from activities such as shipping, fishing, oil and gas extraction, and offshore wind energy generation. The North Sea

basin is subject to some of the highest levels of impulsive noise in the region, due to extensive exploration activity where seismic surveys are a dominant source (OSPAR, 2023). Pile driving, such as for the installation of bottom-fixed offshore wind turbines, also contributes to impulsive noises. In the southern parts of the North Sea, along major shipping routes, low-frequency noise exceeds the natural level of 20 decibels more than half of the time (OSPAR, 2023).

Consequences of such noise pollution include stress, behavioural disturbances, and effects on the communication and foraging activities of animals, while high intensity noise even can lead physical injury. Cetaceans are especially vulnerable to both impulsive and continuous noise (OSPAR, 2023).

3.2.6 Introduction of non-indigenous species

The introduction of non-indigenous species is of concern for the North Sea, the Baltic Sea, and the Arctic Ocean. The annual discovery of non-indigenous species in the North Sea has steadily increased since the 1990s (ICES, 2024b). Non-indigenous species in the marine ecosystems are carried primarily through the maritime sector via ballast water and hull fouling. Observed ecological impacts includes outcompeting native species, changing chemical compositions of habitats, and fouling on aquaculture equipment and fishing gears. A clear example is the round goby (*Neogobius melanostomus*) in the Baltic Sea, which has been shown to negatively affect several native species (Thor *et al.*, 2023).

Since 2017, the International Maritime Organization (IMO) has enforced legislation to reduce the spread of non-indigenous species through ballast water (DNV, 2021). The spreading of species through biofouling is still an issue. In Norway, new regulations are under consideration to require hull cleaning before entering Norwegian waters (Erlandsen, 2025). By setting requirements for proactive hull cleaning, the Nordics may develop early experience with these technologies, allowing future potential exports to other markets that may later adopt similar regulations. Uptake of novel technologies to reduce biofouling could also reduce ship resistance, and hence contribute to energy efficiency.

In some cases, non-indigenous species are being valorised as new fisheries resources. Two examples are the aforementioned round goby in the Baltic Sea and the king crab in the Barents Sea, which have been taken up as regulated fisheries resources in some countries.

3.2.7 Nutrient and organic enrichment

Eutrophication refers to the enrichment of marine environments through the excess presence of nitrogen, phosphorus, and silica compounds. Nutrient enrichment arises from multiple sources, including domestic waste, industrial activities, sewage, and agriculture (Andersen *et al.*, 2017). Nutrients from aquaculture production is also an

issue but regarded as fairly small relative to other aquaculture impacts, despite disturbances in some fjord systems (Grefsrud *et al.*, 2025). Eutrophication occurs in several areas of the Nordic seas. Eutrophication disrupts ecosystems by intensifying algal blooms, increasing water turbidity, altering benthic communities, and reducing oxygen availability (Dorgham, 2013). Long-term oxygen depletion makes marine habitats unsuitable for fish and other marine organisms.

In the Baltic Sea, nutrient enrichment has had a big impact on the marine environment, although other factors also influence ecosystem change (Östman *et al.*, 2016; Reckermann *et al.*, 2022). Signs of eutrophication were first observed in the 1950s and a peak of nutrient loading in the 1970s and 1980s (Andersen *et al.*, 2017). The main driver is wastewater and run-off from the Baltic Sea's extensive catchment area, which supports a population of more than 82 million people (Svendsen *et al.*, 2021). Substantial river inflow combined with long retention time for water within the basin contributes to this effect, which is amplified by the Baltic Sea hydrography (Andersen *et al.*, 2017). The Baltic Sea water column is stratified, with layers of distinct salinity levels that limit vertical water exchange. Hence, eutrophication is a strong driver of oxygen deficiency in the deep water of the Baltic Sea, where an area equivalent to approximately 1.4 times the size of Denmark is now anoxic (Carstensen and Conley, 2019; Hansson and Viktorsson, 2024).

In comparison, fewer problems due to eutrophication have been identified in the North Sea. However, the Oslofjord is an example of an area with hydrographic similarities to the Baltic Sea, which is also threatened by eutrophication. Additionally, the southern North Sea receives nutrient rich discharges from major European rivers, making it a hotspot for nutrient enrichment (Skogen *et al.*, 2014).

3.2.8 Climate change

Rising air temperatures across the Nordic region influence a range of physical factors, including water temperature, hydrodynamics, salinity, acidity, oxygen concentrations and ice cover. These shifts have far-reaching consequences for biological processes, shaping the structure and functioning of marine ecosystems. Changes in precipitation patterns can also affect the levels of run-off from land, and hence the amounts of organic matter and nutrients that are carried into the marine system (HELCOM, 2024).

In coastal areas, climate effects may be more tangible than in open seas, with impacts on habitats across the Nordic seas including rocky shores, soft-bottom habitats, and seagrass beds, consequently also affecting the associated algal and animal communities (Short and Neckles 1999; Singer *et al.*, 2017). Coastal habitats play a crucial role in maintaining biodiversity, as they support a wide variety of species. They also serve as important spawning sites and nursery grounds for many species that migrate further offshore as adults (Seitz *et al.*, 2014).

Species may also be directly affected by rising temperatures, with corresponding

changes in distribution ranges, physiology, or population structure. One example is the commercially important cod (*Gadus morhua*) which is not expected to be favoured by climate change in Nordic waters, and which is already subject to overfishing and stock depletion, so that the sensitivity of populations may become even more severe (Kjesbu *et al.*, 2022). Several fish stocks are observed to shift their distribution in response to changing conditions, including for instance North Sea mackerel (*Scomber scombrus*) (Jansen and Gislason, 2011), (see Chapter 4), with potential implications for fisheries and the regulation of fishing rights. Similar effects are also seen in other species groups, where the effects will vary among species and likely lead to shifts in local species abundances (Hiddink *et al.*, 2015; Weinert *et al.*, 2016).

Marine mammals in Nordic waters are also expected to be affected by climate change due to habitat alteration and food availability (Meier *et al.*, 2004; Kovacs and Lydersen, 2008). A major factor influencing several species is the reduction of sea ice coverage, which serves both as a refuge and as a platform for reproduction. Rising temperatures are also expected to alter the distribution of prey species. Furthermore, warming waters may drive temperate species northward, potentially increasing competition with native species, as they move into new areas.

3.3 New nature policies shaping the future of Nordic marine ecosystems

In 2022, all the Nordic countries signed the Kunming-Montreal Global Biodiversity Framework (GBF), commonly called the Nature Agreement. It includes goals for nature conservation and restoration, calling for effectively conserving a minimum of 30% and restoring 30% of degraded nature areas on land and sea (Convention on Biological Diversity, 2022). The EU Nature Restoration Law in force since 2024 mandates the restoration of at least 20% of the EU's degraded land and sea areas by 2030, and all ecosystems in need of restoration by 2050 (Regulation 2024/1991/EU).

3.3.1 Nature conservation

New global policies for nature conservation, driven by climate change and the need for ensuring sustainable marine resources, present an opportunity for the Nordic countries to adopt a holistic thinking to the preservation of vital marine ecosystems of the region. Collective approaches to the design and designation of a cohesive network of marine protected areas and zonation across the Nordic Seas can serve countries in developing national growth policies that are consistent with the overarching goals of the nature agreement.

The GBF calls for protection of at least 30% by 2030, of which 10% of the total should be strictly protected. Figure 3-3 shows the proportion of protected sea area based on the World Database on Protected Areas (WDPA), indicating that vast Nordic ocean areas still need to be protected to meet the goal of 30%. All countries are far from the target, but particularly Greenland and Norway have large ocean areas and current low rates of protection compared to Denmark, Finland, and Sweden. The smaller island countries Åland, the Faroes Islands, and Iceland currently protect close to none of their marine areas according to the WDPA, although Åland and Iceland have marine protected areas with status not reported to the WDPA.

As countries are developing conservation strategies, the implications for future coexistence with existing and new ocean industries remain unresolved. Understanding the combined effects from all human activities across sea basins remains a challenge, and Nordic collaborative research in this field will be imperative to guide holistic planning and integrated ocean management.

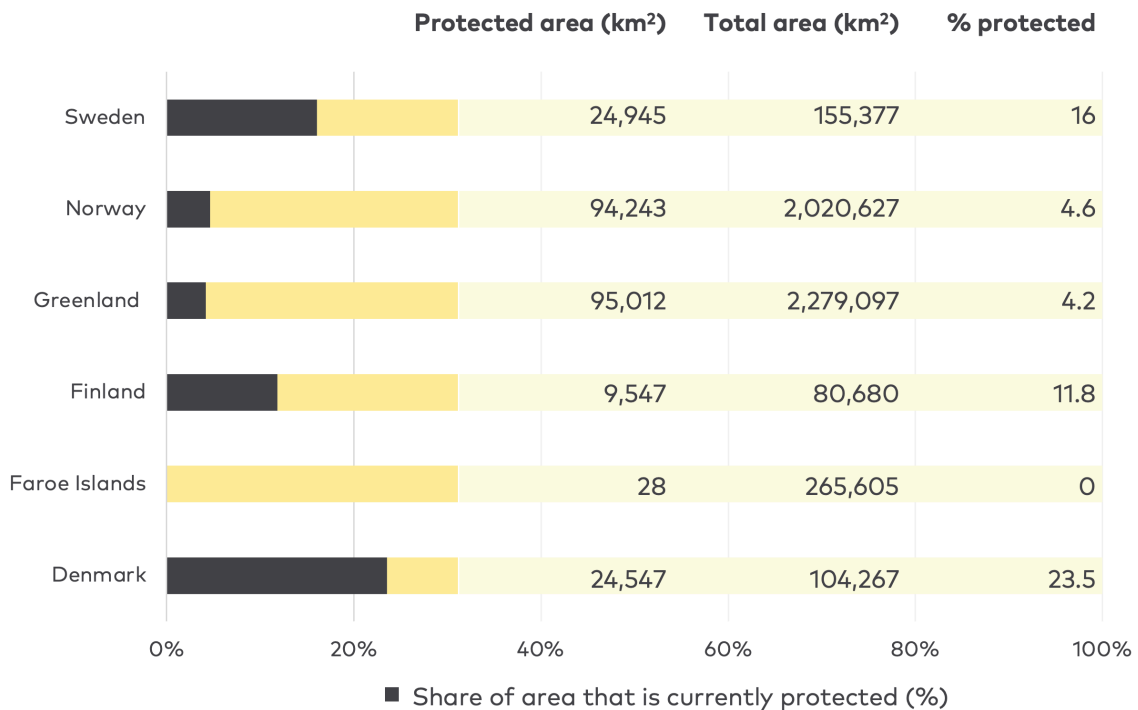


Figure 3-3 Degree of marine conservation in the Nordic countries by actual area and percentage of area, shown in relation to the 30% goal of the Kunming-Montreal Framework: note that Åland and Iceland has marine protected areas not reported to the WDPA and are not included

Source UNEP-WCMC and IUCN, 2025

3.3.2 Nature restoration

Vast areas of degraded marine coastal ecosystems in the Nordics call for large-scale restoration efforts to reach pledged restoration goals. This is both a major challenge and an opportunity. So far, restoration efforts have been fragmented, small-scale, and mainly performed by researchers or volunteers with varying success and monitoring of results over time. There is a clear need for innovation to identify the most efficient and scalable restoration techniques for the respective ecosystem types. Competence, logistics and resources from other ocean industries such as local fisheries may prove particularly valuable to establish large-scale marine restoration efforts.

Coastal ecosystems are particularly impacted by climate change and intensifying human activity. As these ecosystems generally are some of the most productive and biologically diverse, there is reason to include coastal habitats as the primary focus of restoration efforts. Several ocean habitats, including blue forest ecosystems such as kelp forests and seagrass beds, also contribute to ecosystem services that could bring co-benefits that mitigate environmental pressure, such as carbon sequestration and nutrient retention.

'Forests' of kelp and other brown algae are widespread coastal ecosystems across large parts in the Nordics, covering most of the rocky shores of Greenland, Iceland, Norway and the Faroe Islands (Frigstad *et al.*, 2021). Rockweeds and seagrasses are more common in the brackish Baltic Sea. Soft substrates, which are particularly typical of Denmark, for example, are suitable for seagrass meadows. However, several seagrass meadows have declined sharply in the Nordic region over the past decades. For instance, de los Santos *et al.* (2019) estimated a historical loss of 67% of seagrass meadows in the Baltic Sea, the main reasons being water quality decline and disease. Losses are also seen in other habitats. For instance, Norway hosts the largest known kelp forests in Europe, currently covering 7,400 km² (Frigstad *et al.*, 2021), while an area of 5,000 km² of what was previously kelp forest habitat is barren, lost to sea urchin grazing (Verbeek *et al.*, 2021). For context, restoring 30% of the degraded Norwegian kelp forest by 2030 in line with the Kunming-Montreal Framework would mean restoring 1,500 km² (an area equivalent to 140,000 football fields) over a five-year period.

Along with recovering lost ecosystem services and benefits, restoration efforts can also unlock novel value chains. The targeted restoration activities will in themselves require a range of support services, including materials, logistics, and operational expertise. Involving local communities in restoration efforts could help contribute to coastal livelihoods, counteracting for example effects of the ongoing decline in small-scale fishing vessels (see Chapter 4). Such win-win solutions not only support ecological recovery but also generate economic opportunities for local coastal communities. Under Ytan in Åland is a company looking to combine restoration and offshore wind with low-trophic aquaculture as a business model (OX2, 2023).

3.4 Scenarios of future marine ecosystems

Nature First	<p>Goals for conservation, restoration, and nutrient pollution are largely met, including by implementation of national policies to support compliance with the Nature Agreement. This gradually improves the health of ecosystems and fish stocks. Climate-change effects are still acting on species distribution, but the worst effects are largely curbed due to strong international efforts on decarbonization. Fish stocks are conservatively managed and seek to improve ecosystem functionality, with good international collaboration.</p> <p>Offshore wind farms increasingly support conservation and restoration targets by incorporating nature-inclusive design and acting as sensor platforms supporting ocean observation. Shipping and tourism industries are managed with a focus on reducing impacts on nature (e.g. invasive species and noise).</p>
Constant Compromise	<p>Pressures on the marine ecosystem continue along current trends. This leads to some improvements in international collaboration, but with large residual difficulties in other Nordic sea areas. The Baltic Sea faces slight recovery due to collaborative efforts to handle nutrient discharge from agricultural run-offs.</p> <p>Fisheries management follows trends similar to today, with a focus on managing stocks with little consideration for ecosystem functionality. Offshore wind farms create de facto marine reserves that could drive recovery and spillover of specific fish species to nearby areas.</p>
Regional Rivalry	<p>International collaboration weakens, causing difficulties in meeting targets such as the Nature Agreement. Goals for conservation, restoration, and nutrient pollution are largely ignored if they require international cooperation. Local and national efforts are prioritized, but not if they come into conflict with interests such as national security or competitiveness.</p> <p>Cross-border impacts are increasingly ignored in environmental management. Higher nutrient loads persist in the Baltic Sea, due to reduced effectiveness of the HELCOM^[7] collaboration. Lacking agreement on fisheries management (e.g. Atlantic cod in the Norwegian Sea and Barents Sea) causes overextraction of transnational fish stocks. The amount of ocean data increases due to collection for surveillance purposes, but little of this is shared openly with researchers for security reasons, limiting its use.</p>
Growth First	<p>Strong focus on economic growth drives ecosystem impacts across Nordic sea areas. Climate change causes large-scale ecosystem shifts, with northward migration of many species contributing to altered predator-prey dynamics that disrupt sensitive Arctic ecosystems. In the Baltic Sea, eutrophication intensifies due to growth in agricultural production, and reduced efforts to address this. Elsewhere in Nordic ocean areas, fisheries management will not be enforced, and when threatened with collapse in specific stocks, new opportunities will be sought in lower-trophic species or in new areas such as the Arctic.</p>

7. HELCOM – The Baltic Marine Environment Protection Commission – also known as the Helsinki Commission (HELCOM).

4. The future of Nordic fisheries

Commercial capture fisheries play a central role in the Nordic blue economy (Sepponen *et al.*, 2021; ICES, 2025a). The region ranks among Europe's leading seafood producers, with capture fisheries providing essential contributions to food, culture and trade. By mid-century, fisheries in the Nordics will likely experience large changes, as the ecosystems respond to cumulative environmental changes caused by climate change and a variety of human activities at sea (see Chapter 3). This chapter presents an outlook for the Nordic fisheries, outlining key trends, opportunities, and barriers.

Figure 4-1 maps fisheries activity in the Nordic sea areas in 2024, excluding Greenland, based on AIS (automatic identification system) data. Key fishing hot spots include the waters offshore Iceland; on the Faroe Plateau; in the heavily trawled Kattegat and Skagerak areas between Denmark, Norway, and Sweden; in North Sea fishing grounds in Danish and Norwegian waters, including along the Norwegian trench; and along the coast of central and northern Norway and into the Barents Sea.

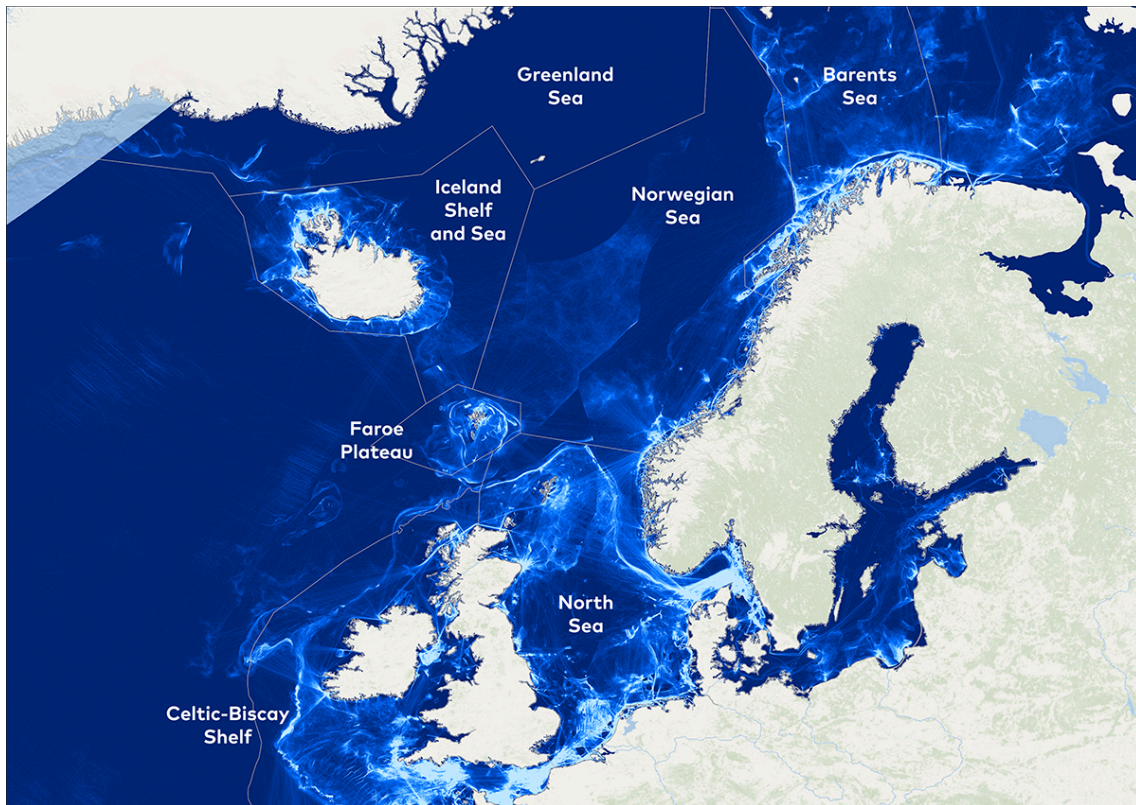


Figure 4-1 Overview of 2024 fishing activity in the Northern European and Nordic large marine ecosystems, excluding Greenland

4.1 Fisheries in the Nordic countries

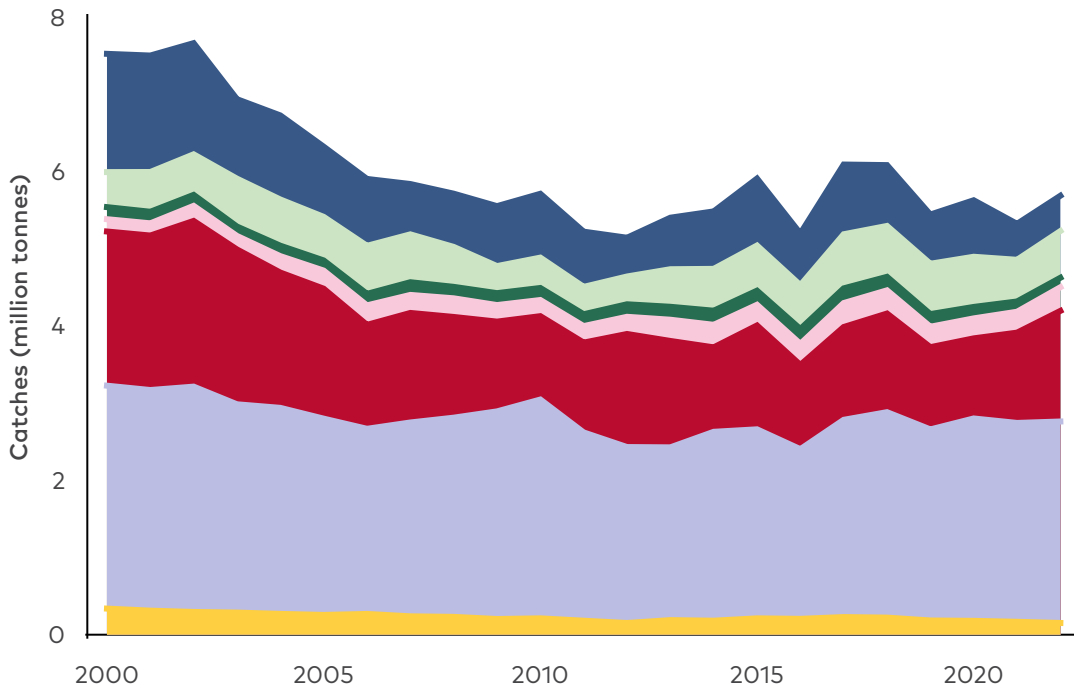
4.1.1 Trends in production

In 2022, the Nordic region produced nearly 5.7 million tonnes of seafood through fisheries (FAO, 2025c). All Nordic countries contribute to fisheries production, but the leading producers by weight and landed value are Norway and Iceland (Figure 4-2). Nordic production by weight has gradually decreased in recent years but the trend varies by country. Since 2000, production by weight has generally decreased in Denmark, Iceland, and Sweden, and increased in the Faroe Islands, Greenland, and Åland (FAO, 2025c; ÅSUB, 2025). In contrast, production by value has generally increased for all Nordic countries except Denmark (Pauly *et al.*, 2020).

Between 2019 and 2024, the catch value of Icelandic fisheries increased 12.45% (Statistics Iceland, 2025b). During this period, the value of Norwegian fisheries exports increased 45.8% (Norwegian Seafood Council, 2020, 2025a). This trend suggests that Nordic fisheries are generating more economic value per unit of catch, despite overall volume reductions. It is also a signal that fish supplies generally do not keep up with increases in seafood demand, leading to higher sales prices, and providing excellent conditions for aquaculture to meet unmet demand for fish (see Chapter 5).

Nordic fisheries production is closely tied to the species being caught. According to the UN Food and Agriculture Organization's (FAO) capture fisheries data collection for Nordic countries, over 300 distinct common names are recorded, highlighting the diversity of landings in the region (FAO, 2025c). These species span categories including pelagic fish, demersal fish, crustaceans, and seaweed. Despite this diversity, Nordic fisheries production is dominated by several main species, many of them pelagic (Figure 4-3). Some of the pelagic species driving production by weight include Atlantic herring, blue whiting (*Micromesistius poutassou*), capelin (*Mallotus villosus*), and Atlantic mackerel. The demersal species Atlantic cod also makes significant contributions to the overall production by weight. Some of the main species driving production by value include Atlantic cod, Atlantic herring, Northern prawn (*Pandalus borealis*), Atlantic mackerel, and Saithe (*Pollachius virens*).

Nordic fisheries production by weight



Nordic fisheries production by value

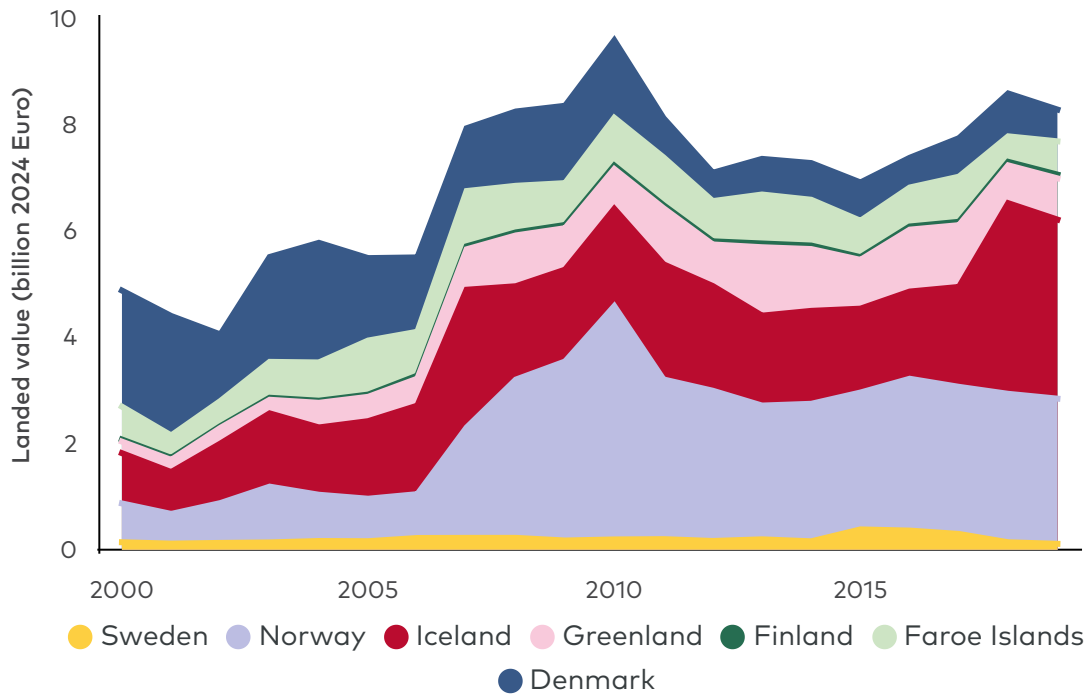


Figure 4-2 Production of Nordic capture fisheries by weight, 2000–2023 (FAO, 2025b), and value, 2000–2018 (Pauly et al., 2020)

Source FAO (2025b); Pauly et al. (2020)

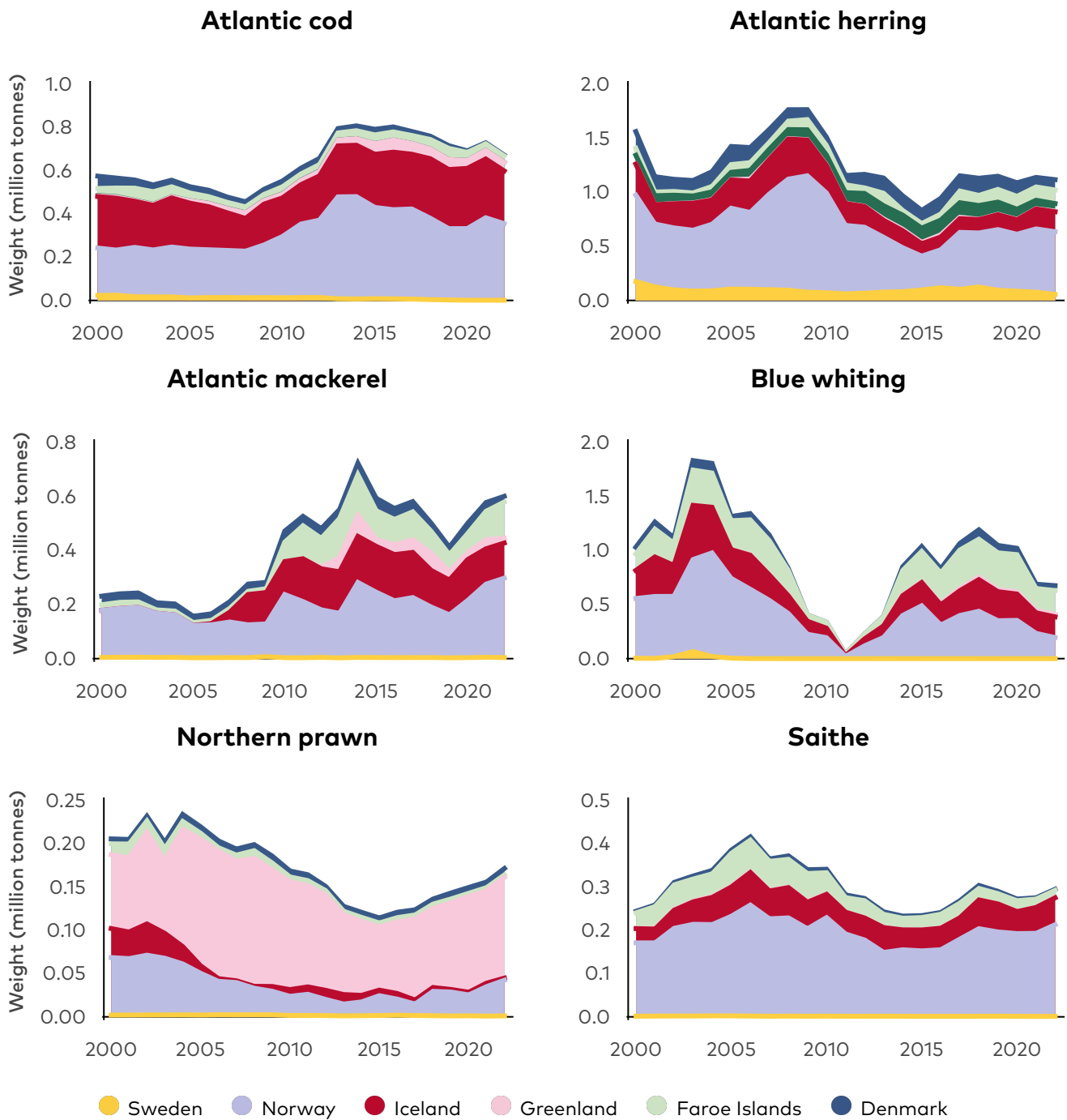


Figure 4-3 Production of Nordic capture fisheries by weight (million tonnes) since 2000 for a selection of key species (FAO, 2025c), by weight (FAO, 2025c) or value (Pauly et al., 2020)

Source FAO (2025c); Pauly et al. (2020)

Trends in Nordic fisheries production are shaped by factors such as stock dynamics, fisheries management practices, and socioeconomic and technological changes. The following examples illustrate how some of these elements have influenced catch trends across different Nordic regions and species.

Blue whiting catch decline and sustainability setbacks: Across the Nordics, blue whiting production by weight declined significantly between 2003 and 2011, primarily due to poor recruitment and high catches (Figure 4-3; Payne *et al.* 2012). Although catch volumes later rebounded following improved recruitment, persistent overfishing beyond scientific advice, driven by quota disagreements, led to the loss of Marine Stewardship Council (MSC) certification (Marine Stewardship Council, 2024).

Shifting targets in Åland fisheries: During the early 2010s, Åland commercial fisheries underwent a notable shift in focus, moving predominantly away from cod and toward herring and sprat (ÅSUB, 2025). This transition reflects a broader trend across the Baltic Sea, driven by a decline in the cod stock and a parallel regime shift towards increased predominance of small pelagic species like herring and sprat (see Chapter 3).

Blue mussel fishery reform in Denmark: Denmark, the heart of the Nordic blue mussel (*Mytilus edulis*) fishery, experienced a 77% reduction in mussel catches between 2001 and 2010. This transition reflects a series of actions undertaken by the fishery to achieve MSC certification, which occurred in 2010 and has since been maintained (Marine Stewardship Council, 2025).

4.1.2 Fleet structure and gear use

The structure of the fisheries sector has undergone significant changes over the previous decades, marked by substantial reductions in the size of the European fishing fleet. Between 2008 and 2023, vessel numbers fell 27% in Sweden, 27% in Finland, and 36% in Denmark (European Commission, 2024d). In Norway, the number of registered vessels declined by around 19.3% during the same period (Norwegian Directorate of Fisheries, 2025c), except for industrial fishing vessels, whose number increased more than 20%. In Iceland, the number of fishermen has decreased approximately 30% since 2000 (Statistics Iceland, 2025a), while in Norway, the decline is closer to 50% (Norwegian Directorate of Fisheries, 2025d).

The changes in the structure of the fisheries industry are also observed in the use of fishing technology. Due to the geographical and ecological differences as well as culturally specific techniques, fishing practices vary widely across the Nordic region in terms of techniques used and species targeted. Figure 4-4 shows the development in catch from 2004 to 2019 for the three most common gear types; bottom trawling, pelagic trawl, and purse seine.

While producing protein with a low-carbon footprint relative to other food sources, the fisheries are also under increasing pressure to decarbonize, including calls for renewing the fleet with vessels operating on alternative fuels (see also Chapter 7). In the EU, fishing vessels are exempt from the Emissions Trading System (ETS), which applies to most cargo vessels (DNV, 2025c). In Norway, the planned

introduction of a carbon dioxide (CO₂) tax for fisheries was recently delayed following protests from the fisheries organizations. The Norwegian fisheries organizations argue that the tax would risk putting the industry at a competitive disadvantage relative to EU fishermen (Fiskebåt, 2023).

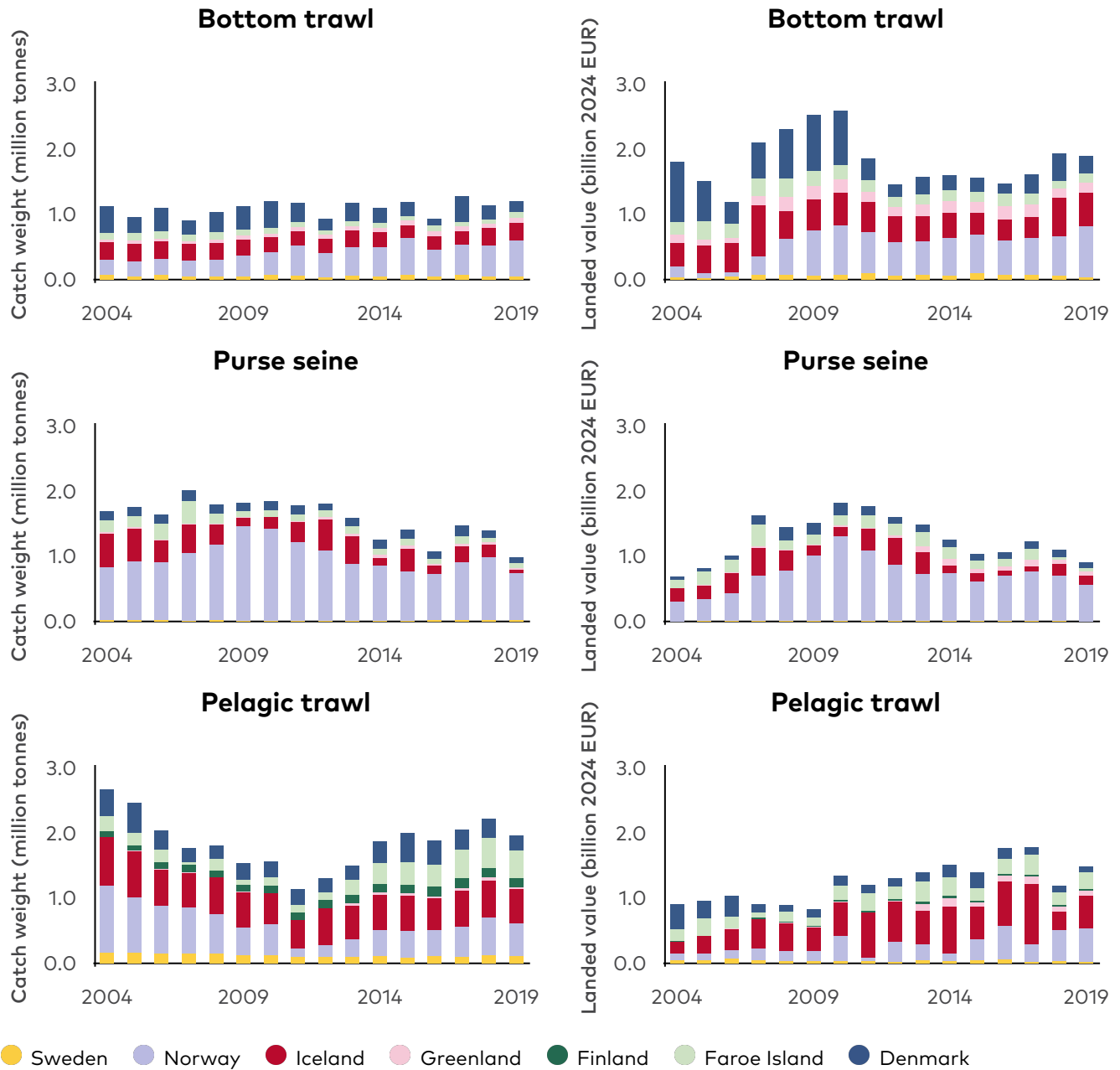


Figure 4-4 Production of Nordic capture fisheries for main gear types by weight (million tonnes) and value (billion 2024 euros) from 2004 to 2019

Source Pauly *et al.*, 2020^[8]

8. We make two corrections for outliers in this data set: 1) Icelandic pelagic trawl landed values are presented without outliers for 'high seas' catches in 2018 and 2019; 2) Norwegian blue whiting catches are corrected by being reassigned from bottom trawl to pelagic trawl after 2010, which is the gear specified before 2010.

4.2 Trade patterns for Nordic fisheries products

Nordic capture fisheries are a huge source of export revenue for the economies of Greenland, the Faroe Islands, and Iceland, and are a considerable contributor to Norwegian exports. For Greenland, wild-caught fish alone account for more than 90% of national exports by value, a large share being unpeeled shrimp, indicating a large economic dependency on fisheries, and low maturity in the processing sector (Hendriksen and Hoffmann, 2025). The Faroe Islands has been able to reduce its dependency on wild-caught fish through scaling of aquaculture and fish processing, but seafood overall still contributes more than 90% of Faroese exports by value (Statistics Faroe Islands, 2023; Hendriksen and Hoffmann, 2025).

Figure 4-5 shows the trade flows of seafood from the Nordic region to the 15 biggest importer markets in 2023 (the rest of the world is also included as a separate entry). Figure 4-5 intentionally excludes seafood products from salmon and trout aquaculture but includes fish feed ingredients like fish oil and meal, and fish waste products. Norway, Denmark, Iceland, and the Faroe Islands were the biggest exporters in absolute terms, with Denmark and Norway as the largest destinations. Denmark is a net importer but plays a key role in fish processing and production of marine ingredients for fish feed used in aquaculture (see trade flow from Denmark to Norway). Besides trades internally in the Nordic region, the largest trading partners are China and a variety of European countries.

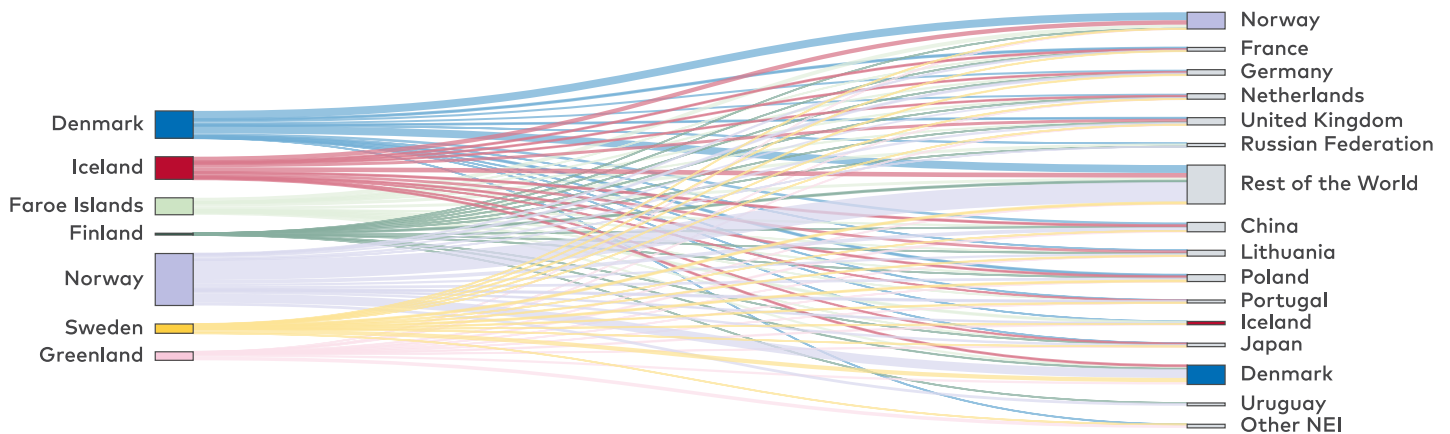


Figure 4-5 Most important export destinations (right) for wild caught fish from the Nordic countries (left) in 2023, measured by weight, including exports to unknown destinations 'Other NEI' ('not elsewhere included')

Source FAO, 2025b

4.3 Opportunities and barriers

4.3.1 Growth opportunities for Nordic fisheries

Globally, wild-capture fisheries have plateaued since the 1980s, with most increases in aquatic food supply coming from aquaculture (FAO, 2024). The Nordic region reflects this trend: while capture fisheries remain economically and culturally important, future growth in seafood supply will largely originate from aquaculture expansion.

Sustainability, marine conservation and restoration: For capture fisheries, adequate management of fish stocks generally represents the most reliable avenue for growth and resilience (FAO, 2024; Costello *et al.*, 2016; 2020). Marine protected areas (MPAs) and seasonal closures can provide additional benefits, where the clearest effects are seen for local or more sedentary species (Halpern and Warner, 2002). Spatial closures are less effective for highly mobile stocks unless vast areas are covered. This is shown by the limited outcomes of the 'plaice box' and 'Norway pout box' in the North Sea, two spatial closures designed to reduce bycatch and protect juvenile fish (Pastoors *et al.*, 2000; ICES, 2017).

Diversification into new species: Novel resources such as mesopelagic fish and Antarctic krill are currently explored as potential 'new' fisheries resources (Fjeld *et al.*, 2023; Grimaldo *et al.*, 2020). The Northeast Atlantic mesopelagic biomass is estimated to be large (Hidalgo and Browman, 2019; St. John *et al.*, 2016), and exploratory surveys have identified species with commercial potential. However, their ecological roles in marine food webs are poorly understood, and any development would require precautionary, ecosystem-based approaches to their management and new harvesting technologies (Olson *et al.*, 2016).

Climate-change driven redistribution Climate change is already reshaping Nordic fisheries by driving poleward shifts in commercially important species (Pinsky *et al.*, 2020). This has created both opportunities and governance challenges, exemplified by the Northeast Atlantic mackerel dispute, where shifts in stock distribution led to contested quota allocations (Spijkers and Boonstra, 2017; Østhagen *et al.*, 2022). Anticipatory and flexible governance, including adaptive harvest control rules, transboundary cooperation, and dynamic spatial management, will be essential to ensure redistributions can be harnessed rather than destabilizing fisheries. If stocks expand northward, catches could increase in Arctic waters. The potential for growth in fishing activity in new Arctic areas needs to be approached with extreme caution due to limited knowledge about the ecosystem impacts. International agreements take a precautionary approach to fisheries in the Central Arctic (currently covered by sea ice); *The International Agreement to Prevent Unregulated Fishing in the High Seas of the Central Arctic Ocean* prevents commercial fishing in

this area until 2037 by the signatory states, including Denmark, Iceland, Norway, and the EU (Arctic Council, 2021).

Technological innovations: Advances in selective gear designs, vessel monitoring systems, AI-driven catch forecasting, and improved hydroacoustic methods are making fisheries more efficient and selective (Jenkins *et al.*, 2023; Dunn *et al.*, 2016). These technological innovations can reduce bycatch, reduce ecosystem impacts, and increase the economic return per unit of effort, raising the efficiency of fisheries. If managed sustainably, this might also reduce operational costs of fisheries and increase efficiency.

Value-chain and market innovations: Eco-labelling, traceability, and branding (e.g. MSC, Nordic sustainable seafood initiatives) can increase product value, while investments in onshore processing, cold-chain logistics, and product diversification (e.g. omega-3 concentrates from novel species) strengthen competitiveness (Kaiser and Edwards-Jones, 2006). Such approaches generate higher value per tonne landed, even when total catches remain stable. Novel value-added products from fisheries are also discussed in Chapter 9.

4.3.2 Barriers to fisheries growth

Ecosystem conditions: Several human-induced pressures (see Section 3.2) can act as barriers to developing the fisheries sector through effects on the abundance and quality of captured fish. Natural determinants of fish abundance and distribution include aspects like depth, temperature, proximity to the coast, hydrodynamics, habitat structure, predation and food availability. Overfishing is among the most impactful disturbances in most Nordic ecosystems (see Chapter 3) and can also be a long-term barrier to developing the fisheries sector.

Bycatch: Unintentional catching of protected species remains a concern in Nordic waters, particularly affecting marine mammals, such as harbour porpoise and seals, and fish-eating seabirds (ICES, 2024c). Bycatch is most associated with gillnet fisheries in coastal areas, and some trawl fisheries (ICES, 2024c). Although monitoring and reporting have improved in recent years, data gaps remain, hampering robust assessments of bycatch mortality. Measures to improve the conditions and support the development of effective mitigation strategies include expanded observer coverage, adoption of electronic monitoring, and more comprehensive sampling across different fisheries to ensure reliable bycatch estimates (ICES, 2024c). Mitigation approaches such as acoustic deterrent devices ('pingers'), gear modifications, and spatial-temporal fishing restrictions are under development for some Nordic fisheries, though their potential effectiveness varies across fisheries (ICES, 2024c).

Lack of cooperation in fisheries management: Many stocks are harvested by multiple Nordic countries (Figure 4.2), as well as by other countries, which makes internationally coordinated fisheries management essential. If stock distributions shift across national boundaries, prevailing quota agreements may come under pressure. For example, mackerel catches were driven by the UK, EU, and Norway until the early 2000s. Since then, mackerel stocks have migrated northwestward, increasing fishing opportunities for Iceland and the Faroe Islands (Figure 4.2). Without a comprehensive quota-sharing agreement between all parties, total mackerel catch has consistently exceeded tolerable limits for the stock. Consequently, the Atlantic mackerel fishery lost its MSC certification in 2019 (Østhagen *et al.*, 2022). Progress was made in 2024 with a tripartite deal between the UK, Norway, and the Faroe Islands. However, this deal was criticized by the EU and Iceland (Welling and Sandvik, 2024), highlighting ongoing tensions and the need for broader cooperation, and how a lack of cooperation can operate as a barrier to sustainable growth.

Spatial competition with new ocean activity: The rapid expansion of offshore wind drives growing spatial competition with commercial fisheries. For the fisheries, an immediate consequence is exclusion from areas where safety zones and operational restrictions prevent either access or the use of specific types of fishing gear. Fishing with mobile or bottom-contacting gear types is typically excluded, while passive fishing methods such as pots and gillnets can in some cases be operational. In Denmark's Kriegers Flak wind farm, static gears are permitted under regulated conditions, while trawling remains prohibited. At Horns Rev 3, small-scale gillnetting is technically allowed, but in practice it has been limited due to safety concerns and changing catch opportunities. In addition to the loss or reduction of profits from catches from some traditional fishing grounds, fleets can be affected by offshore wind development through costs related to additional steaming time, fuel costs, and crowding in remaining fishing grounds, which can erode margins and create new types of conflicts (van Hoey *et al.*, 2021; ICES, 2025b). Hence, with reduced access to fishing areas comes the risk of income instability for fishers and challenges in ensuring fair and transparent compensation for losses.

Offshore wind farms alter local habitats through reef effects from turbine foundations and scour protection, attracting benthic and demersal species, while also introducing noise, electromagnetic fields, and sediment disturbance that may stress sensitive species (van Hoey *et al.*, 2021). See Section 6.2. for an overview of coexistence-related issues for fisheries and ecosystems, relating to offshore wind.

4.4 Scenarios for the Nordic fisheries sector

Nature First

Strong international fisheries management guided by sustainable exploitation and precautionary approaches. Quota agreements are generally respected, and no species are fished above their sustainable yields. Fisheries are **displaced in large areas** in the North Sea and the Baltic Sea by offshore wind build-out and marine conservation, but the general increase in ecosystem productivity balances fisheries yield. Fishers are being increasingly included in marine restoration efforts. Byproducts from fish processing are increasingly utilized for value-added products.

Carbon emissions are largely curbed, but **residual effects of climate change** are felt in the fishing sector, particularly through shifting species distributions. Improvements in ocean monitoring and **efficient data sharing drives dynamic management** that takes this into account.

Constant Compromise

Fisheries management and pressures on the marine ecosystems continue along the **same trends as today**. This leads to some improvements where international cooperation succeeds in some instances, with remaining difficulties in others. For instance, large ecosystem challenges such as **high nutrient loads** in the Baltic Sea continue to impact local fisheries.

Pressures on the fishing fleet to decarbonize lead to a continued but **slow consolidation** of fishing efforts among larger vessels. Fisheries displacement by offshore wind continues in the North Sea, exacerbating the difficult situation for small-scale and coastal fisheries.

Regional Rivalry

Little coordination of fisheries management of transnational fish stocks, potentially leading to **overexploitation as nations set their own quotas**. Demand for seafood declines due to increased prices in the short term and weakening of international trade, eventually causing prices for seafood exports to drop. National security, including **food security**, prioritized over marine protection and conservation.

The seafood industry maintains its level of activity through **active government subsidies** in the sector, and an increased focus on **building fish processing locally** (e.g. in Northern Norway and Greenland).

Growth First

Fisheries are optimized for profit, leading to exploitation for short-term gains to supply demand for **both human consumption and aquaculture feed**. The fishing fleet moves towards fewer, larger and more efficient vessels, strongly focused on improving economic productivity. Regulations are enforced only when stocks are close to collapsing and when threatened, fisheries move to lower trophic levels (e.g. meso-pelagics).

Fisheries impacted by ecosystem collapse due to weak environmental management and high nutrient loads in densely populated areas such as the Baltic Sea and North Sea. Fisheries increasingly exploit **opportunities in Arctic waters**, where warming waters see an influx of species from waters further south, driving rapid economic development in areas like Greenland.

5. Marine aquaculture in the Nordics

Balancing challenges in capture-based fisheries requires harvesting fish sustainably, and we expect future growth in aquaculture to meet increasing global demand for seafood. In this chapter, we look at how aquaculture is positioned for resilience and future development, and how future global market demand will impact this export-driven industry.

5.1 Aquaculture in the Nordic countries

The aquaculture industry is of particular importance for Åland, the Faroe Islands, Iceland and Norway, where the industry is a solid contributor to each of their local economies. In 2022, aquaculture generated 1.53% of Norway's mainland GDP (Statistics Norway, 2024). In recent years, the industry contributed around 8% of Faroese national GDP (ICES, 2023), and in Åland, 2% to 3% of GDP (ÅSUB, 2024). In Iceland, a government report on aquaculture concluded it could generate value amounting to as much as 6% of GDP by 2032 (Björnsson *et al.*, 2023). In Denmark, Finland, and Sweden, aquaculture is currently less of an economic focus than in the aforementioned countries, while Greenland has no aquaculture industry of note.

Figure 5-1 shows the forecast for marine aquaculture production in Norway (DNV, 2025d), by far the biggest Nordic producer (see Figure 5-2). Production in Norway is likely to grow to around 2.4 million tonnes by 2050, up from 1.6 million tonnes today, much slower than the tripling in global finfish production that DNV forecasts by then (DNV, 2023). Most of the growth will come from new production systems, such as capacity-expansions in exposed or offshore locations, in land-based facilities, or in closed-containment systems near shore. Fish farming is dependent on suitable aquatic conditions and remaining ecosystem carrying capacity, limiting the potential for growth (see Section 5.3).

5.1.1 Atlantic salmon and rainbow trout

The Nordic region is a powerhouse in salmon aquaculture, producing more than half of the world's salmonids. Salmonids contribute more than 98% of the region's aquaculture production as of 2022, when measured both by value and weight. These large-scale operations have reshaped seafood supply chains across Europe.

Norway is the main producer, but significant and increasing quantities are also farmed in the Faroe Islands and Iceland. What began as a small-scale industry has evolved into a major global enterprise, perhaps particularly after being popularized as a fish well suited for sushi (Norwegian Seafood Council, 2025b). Besides Norway, Denmark is the largest producer of rainbow trout (*Oncorhynchus mykiss*), followed by Finland, Åland, and Sweden. The relative importance of the sector is high in Åland, which by volume produces around the same amount from sea-based aquaculture as Finland, despite a considerably smaller population.

Figure 5-2 shows production of salmon and trout in whole weight for all Nordic countries for the period 2017–2023, with Norway on the secondary axis. Where Norway produces around 1.6 million tonnes, the other Nordic countries combined contribute less than 200,000 tonnes.

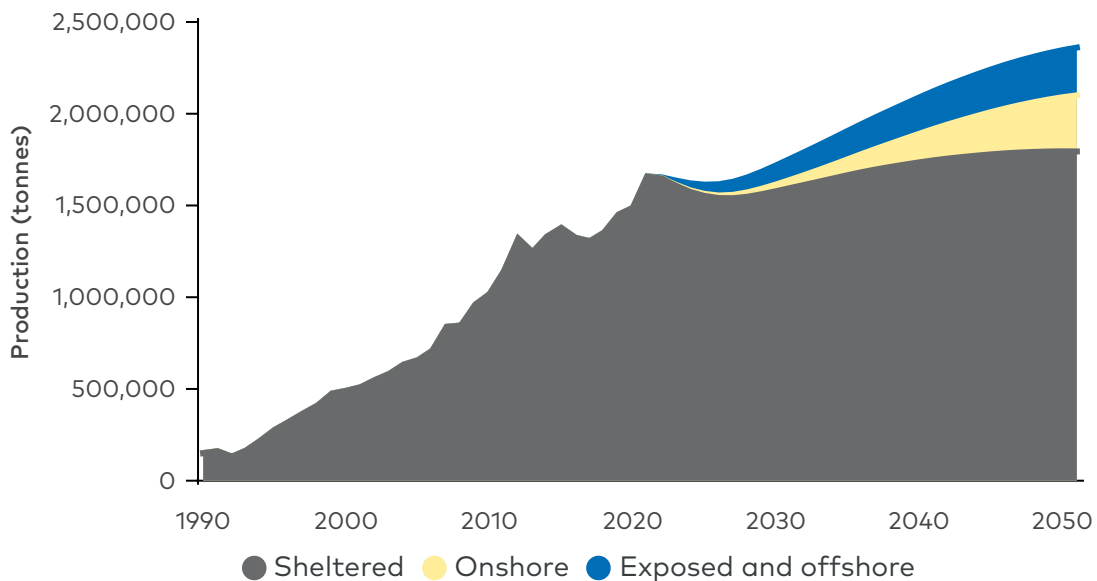


Figure 5-1 Forecast of marine finfish aquaculture production for Norway

Source DNV, 2025d

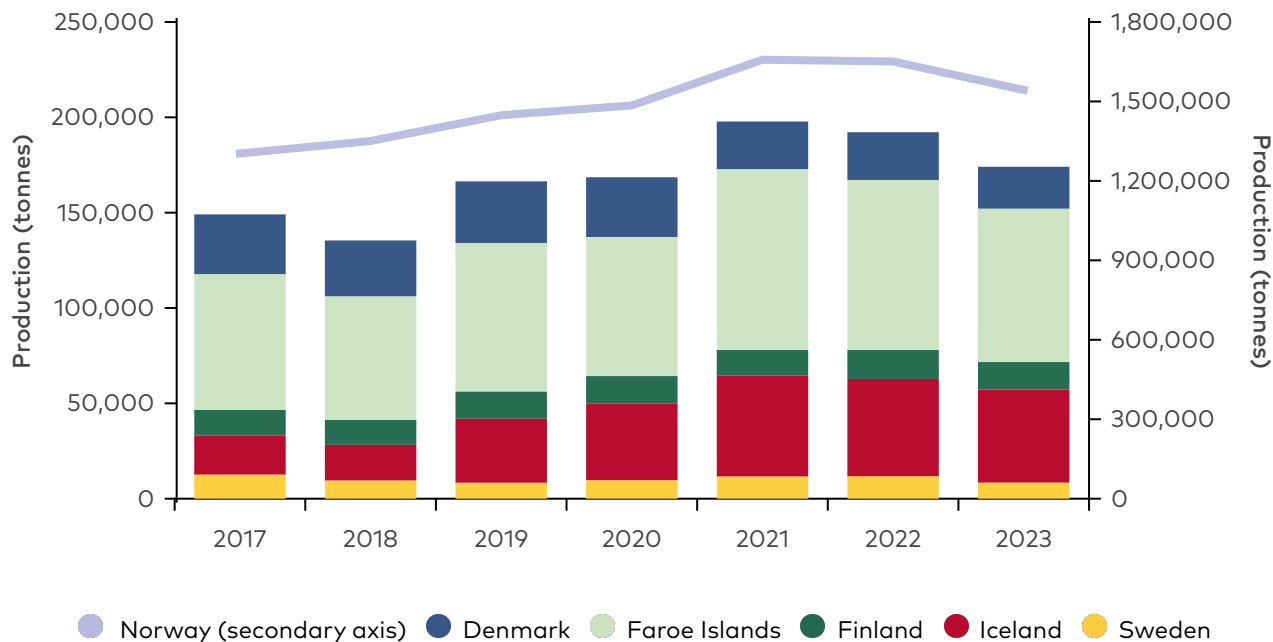


Figure 5-2 Production of salmonids in the Nordic countries, in whole weight

Source EUROSTAT (2025e); Luke (2025); Statistics Faroe Islands (2025d)

5.1.2 Other finfish species

Besides Atlantic salmon and rainbow trout, species such as Atlantic halibut (*Hippoglossus hippoglossus*), Atlantic cod, Arctic char (*Salvelinus alpinus*), and yellowtail kingfish (*Seriola lalandi*) are produced in small, but growing quantities. The life cycles and farming strategies of these species differ from Atlantic salmon, as reflected in their value chains. Some finfish species are 'R-selected', meaning they lay more eggs, and invest less energy and nutrition in each egg. They are usually less developed than Atlantic salmon at the time of hatching, resulting in a dependency on live feed, rather than dry feed pellets right after the egg-yolk stage. This increases the complexity of the production at the hatcheries. Fish species like Atlantic cod can also spawn in the pen if they mature prior to harvest, and the maturation process can be harder to spot than for Atlantic salmon, where changes in the jaws and skin colour are observed. Maturation is important for cod farmers to control, as it has ecological and regulatory consequences, as well as economic impacts for the farmer. Despite the biological hurdles, species like cod attract commercial interest as a potential aquaculture growth segment, due to the limited growth opportunities in the cod fisheries.

The salmon farming value chain

Broodstock: The salmon life cycle in aquaculture starts with collection and fertilization of eggs. The breeding and broodstock stages of the value chain have received increased attention due to the potential of genetic technologies, the development of advanced methods for selection, and the handling of both egg and sperm cells. Over time, the availability of salmon roe has become less seasonal, with supplies available year-round. Together with post-smolt strategies, this has contributed to increased stability in production output as reported stocking of fish in the sea is also less seasonal (Norwegian Directorate of Fisheries, 2025b). However, access to roe in Norway is challenged as biosecurity concerns and capacity limits hamper supply, while demand is increasing.

Freshwater phase: Following hatching at land-based facilities, the salmon are reared in freshwater through their early life stages until smoltified. Smoltification is a process that enables them to survive and live in saltwater. The smoltification process must be controlled to ensure the fish groups being put into the sea are robust and ready. Before sea transfer, all fish are vaccinated to protect against impactful diseases. The transfer of smolts or post-smolts to the sea-based facilities is achieved mainly by using wellboats. However, road transport is preferred in some areas in the Faroe Islands due to low access to wellboats and is made possible at farms close to roads.

Post-smolt describes smolt produced to sizes larger than traditional smolts. Post-smolts are reared in land-based facilities or closed containment systems in the sea. Use of post-smolts reduces production time in the open sea, improving utilization of production capacity and reducing the need for treatments. This strategy is impactful when fish farms are regulated on the basis of maximum allowable biomass – currently the case in Norway – and in areas with limited access to new capacity or in locations such as in the Faroe Islands. Increased use of post-smolts drives investment in land-based facilities.

Grow-out is mostly done in open-net pens, with a feeding barge supplying feed and power to the pens. Production in open nets provides the fish with fresh and oxygenated water, ideal for growth. This also exposes the fish to risk factors such as sea lice, disease pathogens, harmful algae, jellyfish, and uncontrolled changes in water parameters like oxygen and temperature. It also means that uneaten feed pellets, faeces and dissolved nutrients will be introduced to the environment. If the farm is equipped with sludge-collecting equipment, this can be reduced. Discharge of sea lice larvae, following sea lice infestations, and shedding of viruses or bacteria, are also concerns that farmers face in the open-net pens, as well as the risk of escaping fish (see Section 5.3). The production strategy is highly dependent on vessels such as wellboats, service vessels, feed transport vessels, ensilage vessels, and process boats.

Processing and distribution: At harvest, the fish is either transported to a slaughter facility and held in cages until slaughter, or is processed using a process boat which then transports the products to onshore facilities for further processing. In the Nordic countries, the refinement stage is often located outside the production country. The transportation mode varies depending on the country of origin and target destination, and both airfreight, trailers, and seafreight are used. In the Faroe Islands, the company Hiddenfjord has stopped airfreight, opting instead for seafreight in an initiative to reduce carbon emissions, a strategy supported by developments in freezing and thawing technologies making it possible to maintain the quality of frozen products. Under Norwegian regulations, 'production-quality' fish (e.g. fish with damage and wounds) can only be exported if the reason for the damage or wound has been remediated in Norway (Forskrift om kvalitet på fisk og fiskevarer, 2013). One vessel, the 'Norwegian Gannet', has a dispensation from this regulation and transports fish directly from Norwegian fish farms to Danish processing facilities.

5.1.3 Low-trophic species

Low-trophic aquaculture refers to production of species that extract nutrients from the seawater rather than relying on feed. Low-trophic aquaculture in the Nordic region is mainly bivalve production, at very small quantities compared to finfish. Norway and Sweden have produced around 2,000 tonnes of blue mussels annually for the last decade, while Denmark has increased its production to 9,000 tonnes in 2023 (FAO, 2025a). Blue mussel is currently Denmark's largest aquaculture species by volume. In addition to its consumption value, mussel production is increasingly being considered as a nature-based solution for removal of excess nutrients from run-off in coastal waters affected by eutrophication.

In Europe, **seaweed** production is still in its early beginning but getting increased attention, as an activity with a variety of potential end-uses like food, methane-reducing feed additives, alternative proteins, biostimulants, bioplastics, fabrics, nutraceuticals, pharmaceuticals, and construction materials (World Bank, 2023). Additionally, seaweed farming can have positive effects such as carbon sequestration and nutrient sequestration (DNV, 2024b). In the Nordics, the industry is currently driven by many small start-up companies with relatively low profits. Norway still has the most seaweed companies in Europe (Araujo and Peteiro, 2021), and production reached 600 tonnes in 2023 (FAO, 2025a). The Faroe Islands has been producing around 100 tonnes on average in recent years, and Denmark has some production. Most seaweed produced is sugar kelp (*Saccharina latissima*) and winged kelp/dabberlocks (*Alaria esculenta*) for food and feed. There have been challenges in identifying end-uses for farmed seaweed in Europe. Many start-up companies initially focused broadly on the entire value chain of seaweed production to sales, but the industry trends towards specialization for specific value-chain elements – such as seedling production, farm design, harvesting, or product development.

5.2 The aquaculture sector is highly reliant on trade

Export of seafood from aquaculture is a large source of export revenue for Norway, the Faroe Islands, and Iceland, as the region produces much more than what is consumed within it. At the same time, finfish aquaculture, such as salmon production, is highly dependent on imports of feed ingredients from outside the Nordic region (Aas *et al.*, 2022). Hence, both upstream and downstream, the salmon value chain is vulnerable to disruptions. In Norway, though fisheries still export bigger volumes, the export value of farmed salmon far exceeds that of wild-caught fish (Norwegian Seafood Council, 2025a).

Figure 5-3 shows that the main destination countries for Nordic aquaculture products are within the EU, with leading importers such as Poland, France, Denmark, and the Netherlands. In many cases, value-added (secondary) processing in the EU is favourable due to high costs and custom duties for value-added products processed in Norway (Olafsdottir *et al.*, 2019). The value-added products are then distributed further within the EU. The other main destinations for exports are the US and East Asian countries like China, Japan, and Korea. In the case of Iceland, export of fertilized salmon roe for farming contributes significantly to the total export value of aquaculture products, with Norway, the UK, and the Faroe Islands as the main markets (Radarinn, 2025).

5.2.1 Trends in Nordic aquaculture exports

The aquaculture industry is highly skilled at marketing, going back to the 1980s when high-quality raw salmon was first introduced to Japanese sushi (Norwegian Seafood Council, 2025b). Since then, geopolitical events have led to sudden disruptions in established seafood supply chains. Following sanctions imposed on Russia after the 2014 annexation of Crimea, Russia introduced a ban on seafood imports from Norway and other Western countries. At the time, Russia was among the largest markets for Norwegian salmon outside the EU. Following the import ban, several European countries increased their imports of Norwegian seafood, while Turkish production of rainbow trout increased to fill the gap in the Russian market (Knudsen, 2025). With the worldwide reach of salmonid products and proven proficiency in adapting to changing market conditions, the industry is expected to be resilient to sudden and disruptive changes in the global market.

Interregional trade of aquaculture products is projected to increase towards 2050 (DNV, 2023), despite current geopolitical uncertainty. **North America** is currently the single most important export market for Atlantic salmon outside Europe for Nordic salmon producers. The demand for farmed finfish in the region is projected to gradually increase by 38% by 2050 from current levels and thereafter decrease

somewhat in correlation with the expected population decline (DNV, 2023). New trade barriers (e.g. tariffs) and emphasis on growing the domestic aquaculture industry in the US based on offshore or land-based production could shift the outlook for exports to North America.

The Middle East and North Africa are forecast to become an increasingly important market for Atlantic salmon from the Nordics. The demand for Atlantic salmon varies greatly among countries, but an increase is predicted in several countries that will see a steep increase in both GDP per capita and population towards 2050. Current leading importers in the region are high-income countries like Israel, the United Arab Emirates, and Saudi Arabia (Statistics Norway, 2025b). From Europe as a whole, farmed finfish imports to the region are forecast to reach almost 700,000 tonnes in 2050 (DNV, 2023).

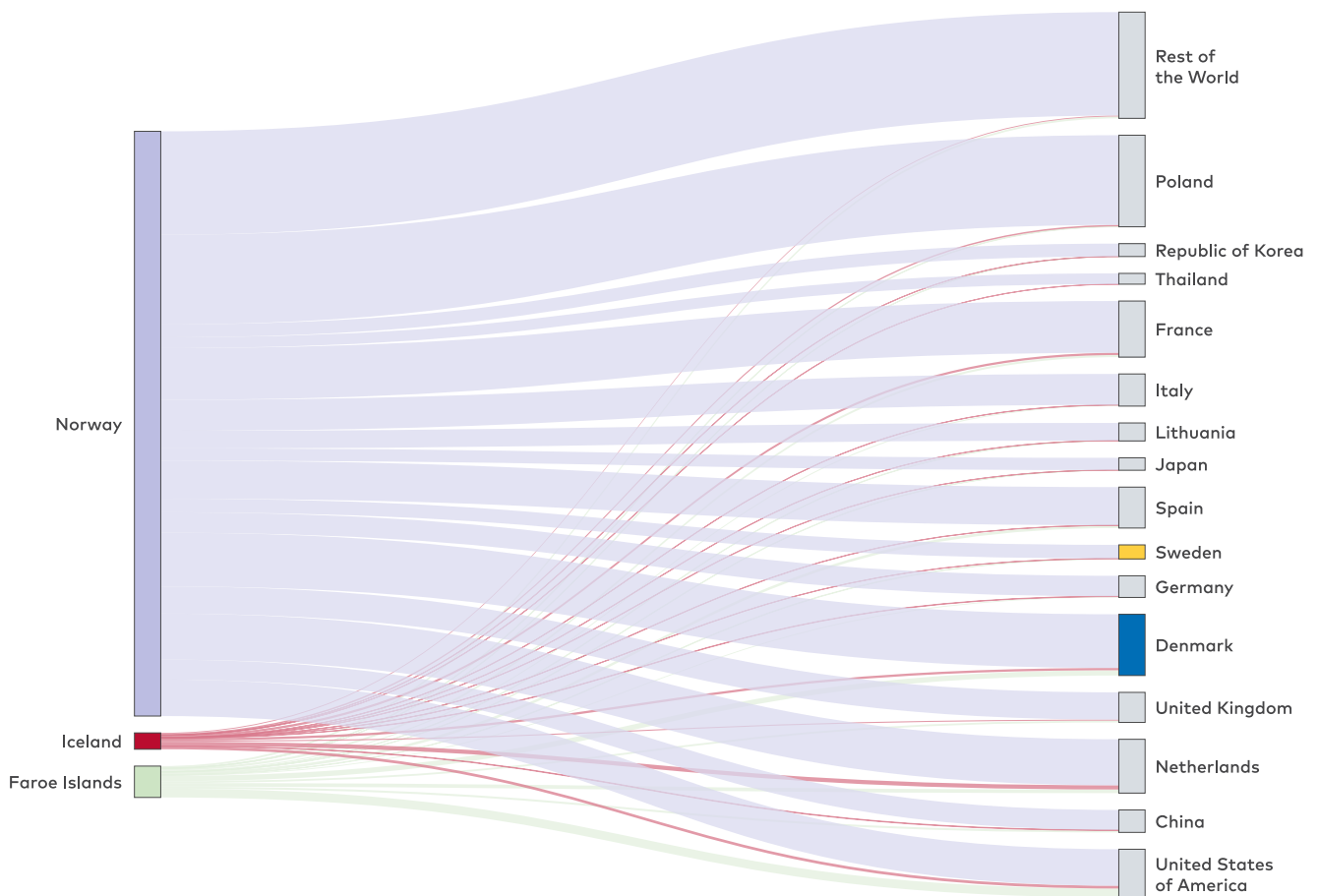


Figure 5-3 Most important export destinations (right) for salmonid aquaculture from the Nordic countries (left) in 2023, measured by weight

Source: FAO, 2025b

5.2.2 Reducing the dependency on import of feed ingredients

Most of the species farmed in the Nordics are reliant on imported feed ingredients. Due to innovations in the fish feed industry, most ingredients originate from plants (wheat, soy, canola, legumes), in addition to fish meal and fish oil sourced from marine ingredients, and supplements such as vitamins (DNV, 2023). Feed is the most important contributor to carbon emissions from aquaculture due to feed production, manufacturing, and transport (DNV, 2023), and feed costs make up around half of the production costs for Atlantic salmon (Misund, 2022). The vast majority (92%) of around two million tonnes of feed ingredients used for Atlantic salmon farming in Norway in 2020 were imported (Aas *et al.*, 2022), rendering the industry susceptible to disruptions and price changes in global fisheries and agricultural supply chains. Increase in feed prices contributed to the doubling of the production cost per kg, as reported by the Norwegian Directorate of Fisheries (2025b), between 2018 and 2023. The Nordic countries provide much of the marine ingredients from fisheries, supplemented by fisheries in South America (Peru and Chile), and Africa (Morocco and Mauritania).

With rising geopolitical tensions, further regionalization of feed sourcing can be a strategy to reduce vulnerability to global supply disruptions (Krause *et al.*, 2025). In line with this, to improve supply chain resilience and the environmental footprint of salmon production, the Norwegian government has launched a mission to encourage the development of new feed ingredients (Norwegian Government, 2024). However, large and steady volumes will be needed to replace the vast amount of such ingredients imported annually. By 2050, DNV (2023) forecasts a tripling of feed demand globally for marine aquaculture, driven by the growth in seafood demand and consequent production expansion. In mid-century, novel ingredients will have a 30% share in the feed ingredients used globally as production of algal oil, single-cell proteins and insect meal scales up (DNV, 2023). As production of these takes off, novel feed ingredient production costs are expected to reduce, making it affordable to reduce reliance on feed imports. Several novel ingredient types lend themselves well to circular business models (see Chapter 9). Examples include the use of insects or fungi that transform by-products from the food industry into high-value feed ingredients, for instance by the start-up Norwegian Mycelium (Garcia, 2025).

5.3 Opportunities and barriers

5.3.1 Growth opportunities for Nordic aquaculture

Improved management strategies to resolve fish health issues: The geographical distribution of aquaculture activity within Norway is suboptimal, with potential to improve biosecurity through changes in locality structure alone (Huserbråten *et al.*, 2020). The Faroe Islands have less issues with mortality and sea lice. This is partly due to natural conditions and more coordinated farm management practices with a 'one fjord, one farmer' approach in which a single fjord can have only one commercial actor. Historically, the country has experienced significant impacts from Infectious Salmon Anemia (ISA), which led to the 'one fjord, one farmer' approach. This makes planning and implementing biosecurity measures and strategies easier than in Norway, where several actors operate in the same fjord system. The Faroe Islands were also early in utilizing post-smolt strategies that reduce the seawater phase. As Icelandic aquaculture grows, it can draw on learnings from Norway and the Faroe Islands.

Technological advances: Strategies and equipment are being developed to limit exposure to pathogens and reduce infestation success. Measures include sea lice traps, electrical fences, physical barriers, submerged pens, closed containment systems, breeding, and laser nodes. Novel pen technologies are also increasingly used in operation to mitigate these issues. **Closed containment systems** provide growth opportunities in sheltered areas, as this technology reduces environmental impact. However, maturation and investment incentives are needed to counter the added costs compared to open-net pens. The Norwegian government is planning to allow volume growth in areas where capacity has previously been reduced, if farmers opt for closed containment systems (Norwegian Government, 2025a).

Submersible pens, which lower the fish to depths below most of the sea lice, have also been gaining traction. Lerøy Seafood, one of Norway's largest salmon farmers, has already implemented submersible and semi-closed systems for more than 30% of its production (Lerøy Seafood Group, 2025).

Offshore aquaculture and co-location: Norway is now allocating area and design regulations to start **offshore aquaculture** in three areas (Norwegian Government, 2025b), potentially greatly increasing access to space for industry growth. Venturing into offshore fish farming involves uncertainties. For example, what would be a realistic timeframe to establish regulation? There are also concerns regarding investment costs, supply chains, spatial competition, and environmental impacts. **Co-location** with industries such as offshore wind is being investigated for aquaculture, including salmonids in submerged pens (Freja Offshore *et al.*, 2025). As offshore wind is spatially extensive, co-location with aquaculture is an

interesting test case for combined use of the sea (see Section 6.2). China already combines offshore wind and low-trophic aquaculture at scale in several provinces (DNV, 2024b). Europe hosts several research projects on co-locating low-trophic aquaculture and offshore wind, with several pilots such as the Danish Krieger's Flak wind farm (Vattenfall, 2024). Co-locating seaweed and salmon farming has also been tested in Norway as a bioremediation measure termed 'integrated multi-trophic aquaculture' (SINTEF, 2023).

Land-based farms: These are starting up and scaling up production across the Nordics, especially in Iceland and Norway. Land-based facilities are a part of the supply chain in traditional salmonid aquaculture, related to life stages in freshwater. The technology has been developed to rear fish up to normal harvest sizes. Land-based farms require more energy and access to high quality water than traditional farms. The availability of geothermal energy and clean water give Iceland a natural advantage in land-based marine aquaculture. In Þorlákshöfn, an area called 'Salmon Row' is being developed, with five companies building farms, each aiming for an annual capacity of around 20,000 tonnes (Wilcox, 2022; Arellano, 2024). If successfully established, they will give a large boost to Iceland's production volume, currently around 50,000 tonnes.

Innovative end-uses for seaweed: There are many potential end-uses for seaweed: food, methane-reducing feed additives, alternative proteins, biostimulants, bioplastics, fabrics, nutraceuticals, pharmaceuticals, and construction materials. The World Bank (2023) recently evaluated the viability of these applications, judging the most promising short-term uses to be biostimulants, animal feed, pet food and, potentially, methane-reducing additives. In the medium term, nutraceuticals, and possibly alternative proteins, are expected to become established applications (DNV, 2024b). In addition, ecosystem services from seaweed cultivation, such as carbon sequestration, nutrient sequestration and biodiversity gains can be monetized if crediting schemes are developed along with the required monitoring, reporting and verification approaches.

5.3.2 Barriers to aquaculture growth

Biological challenges like sea lice and diseases are shaping salmon farming and their associated costs are massive (Misund, 2022). These issues compromise the welfare of farmed fish and pose a serious threat to wild salmonid populations. Sea lice represent the single greatest challenge, as their prevalence directly limits the industry's potential for growth. Continued efforts are being made to mitigate spread of disease from one area to another, as some may be endemic in one area but non-existent in another. The industry frequently experiences periods of intense biological pressure, amplified by high production intensity. During such times, biosecurity concerns may be deprioritized, thus increasing vulnerability to disease outbreaks and operational disruptions. One example is wellboats travelling

between areas that should remain biologically isolated. External issues like harmful algal blooms and jellyfish are also causes for concern, as effective mitigation measures are limited. Escaped salmon remain a major concern due to their **genetic impacts on wild stocks**. Additionally, **benthic impacts from discharge** of biological waste and use of anti-fouling compounds like tralopyril and copper raise environmental alarms.

Fish welfare is under pressure as from thermal and mechanical treatments used to combat sea lice infestations. Sea lice management is mandated by regulations and often comes at the expense of animal welfare. Fish mortality rates have seen an increasing trend over the past decade in Norway, reaching a peak of 17% in 2023 (Moldal *et al.*, 2025), much higher than the stated governmental goal of a 5% maximum. This highlights the complex trade-offs in sustainable aquaculture management. Use of cleanerfish that eat sea lice as a mitigating measure is decreasing due to animal welfare concerns for the cleanerfish (Norwegian Directorate of Fisheries, 2025e). Freshwater and medicine-based treatment methods are also used to reduce the impact on the farmed fish.

Changes in the marine environment are an emerging concern. Sea lice development and infestation pressure are closely linked to sea temperatures, with warmer periods often triggering rapid increases in sea lice populations. With climate change and continued ocean warming, there is growing risk associated with both intensified sea lice outbreaks and more harmful algal and jellyfish outbreaks. Similarly, the strength and frequency of marine heatwaves are likely to increase (Grefsrud *et al.*, 2025). This underscores the increasing importance of effective management strategies and innovative solutions to biological and non-biological challenges alike.

Regulatory instabilities and inefficiencies are at times seen as a barrier to growth. For example, Iceland has experienced incidents with outbreaks of sea lice and disease, highlighting the need to modernize regulation. Regulatory updates are currently ongoing in Iceland, inspired by Norwegian and Faroese regulations. The Norwegian regulatory system is also subject to change, following a broad political settlement regarding regulatory strategy. Along with the introduction of a ground rent tax, the uncertainties surrounding regulatory strategy have hampered and delayed new investments.

Identifying scalable market applications is a challenge for growth in seaweed production. Seaweed farming in Europe differs from other types of aquacultural practices, as the motivation behind production is not necessarily driven by product demand. In fact, it has so far been challenging to find market applications for seaweed farmed in Europe, despite its various potential uses. One of the main motivations behind establishing a seaweed cultivation industry is the potential to produce biomass with low environmental impact, which is reflected in several EU initiatives (DNV, 2024b).

5.4 Scenarios for the Nordic aquaculture sector

Nature First

Novel technologies are being widely adopted to reduce environmental impact from open-net finfish farming, based on regulatory requirements and consumer demand. Collection and **circular use of sludge** to reduce the nutrient load from the industry is scaled further. Technologies for closed systems will reduce the effects from pathogens, harmful algae and jellyfish, **benefitting fish health and welfare** as well as **reducing production costs**. **Scaling** the production of novel fish feed ingredients reduces the carbon footprint of the aquaculture industry, despite short-term increases in feed costs.

Scaled production of seaweed and other types of low-trophic aquaculture, with end-uses that are beneficial for the environment. Examples include purpose-built seaweed initiatives developed for restoration, nutrient and carbon sequestration, and in seaweed production in combination with offshore wind or as part of integrated multi-trophic aquaculture systems with salmon.

Constant Compromise

Aquaculture regulations continue as they are now, often **failing to prevent and reduce** environmental impact. This leads to consistent and relatively high pressure of pathogens and **biological risk**. Higher production costs and issues related to compromised animal welfare will increase gradually, but **not sufficiently to offset increasing global demand** for salmon produced in the Nordics. Harmful algal and jellyfish blooms will continue to affect the industry with increasing frequency and severity.

Low-trophic aquaculture will increase in some regions, but slowly. Only the companies with long-term financial backing will be able to survive.

Regional Rivalry

The salmon industry faces increasing issues with sourcing input materials such as feed, particularly from sustainable sources. **Feed prices increase**, and subsequently production costs too, potentially **hurting demand**. Production development is highly uncertain, due both to high costs and increasing trade barriers for Nordic aquaculture trade with regions beyond Europe. **Little incentive to develop new land-based and offshore** aquaculture systems in the Nordic region, but developments in these technologies continue in other regions to grow local supplies.

Novel feed ingredients are developed, driven primarily by the need for improvements in sourcing rather than for their sustainability credentials. High costs of other feed ingredients offset the price of novel alternatives, making them relatively cheaper. Likewise, processing is also increasingly conducted in the Nordic region rather than in other countries.

Growth First

Production of the most **valuable finfish species** is intensified, with strong **profit-driven motives to reduce fish mortality** and introduce new technologies. Total production increases, compromising local coastal environments. **Intensification coupled with climate change** increases the frequency in mass mortality events in some regions. Such crashes can lead to production being moved to new areas such as Iceland and Greenland, to land-based facilities, or further **offshore**. Meanwhile, global sourcing of feed continues with reduced focus on the sustainability of feed sources. Low-trophic species such as seaweed and mussels receive little consideration.

6. The energy transition in Nordic oceans

The Nordics offshore energy sector has begun its transformation, aligned with Europe's broader shift toward renewable energy. Denmark stands out as a Nordic leader in this transition. DNV forecasts that offshore wind will deliver 25% of Europe's electricity in 2060 (DNV, 2025a), with most capacity in the North Sea, followed by the Baltic Sea (DNV, 2025d).

6.1 Offshore wind contribution to electrification – will targets be reached?

Offshore wind in the Nordics will contribute to a more integrated electricity system in Europe, a region focused on decarbonizing its energy mix. Europe will be the world region with the highest share of offshore wind in its energy mix in 2050. The region has ample wind resources, and large areas suitable for bottom-fixed (jackets, gravity-based or monopile structures) and floating (semi-submersible, tension leg platforms, or spar-buoys) offshore wind structures, particularly in the North Sea (DNV, 2025d). The long-run trend of adding offshore wind to the energy mix will continue as costs are reduced due to efficiency gains from learning and increased standardization. The cost-learning effect suggests that costs fall at a given rate each time cumulative installed capacity doubles (DNV, 2025a). In the short term, the sector faces headwinds due to supply chain disruptions and high costs, especially related to price developments in input materials such as steel.

The Nordics currently contribute around 8% of the current offshore wind capacity in Europe. Denmark dominates the Nordic offshore wind sector today, with 2.6 GW installed, almost 90% of the Nordic capacity. The rest of the Nordics countries, Sweden (192 MW), Norway (101 MW), and Finland (71 MW) only make up around 1% of the total European capacity. In a European setting, the UK is by far the most important country for offshore wind at 16 GW (44%), followed by Germany (25%), and the Netherlands (13%). In terms of yearly capacity additions, the leaders in 2024 were the UK, Germany, and France, which together added more than 2 GW in 2024.

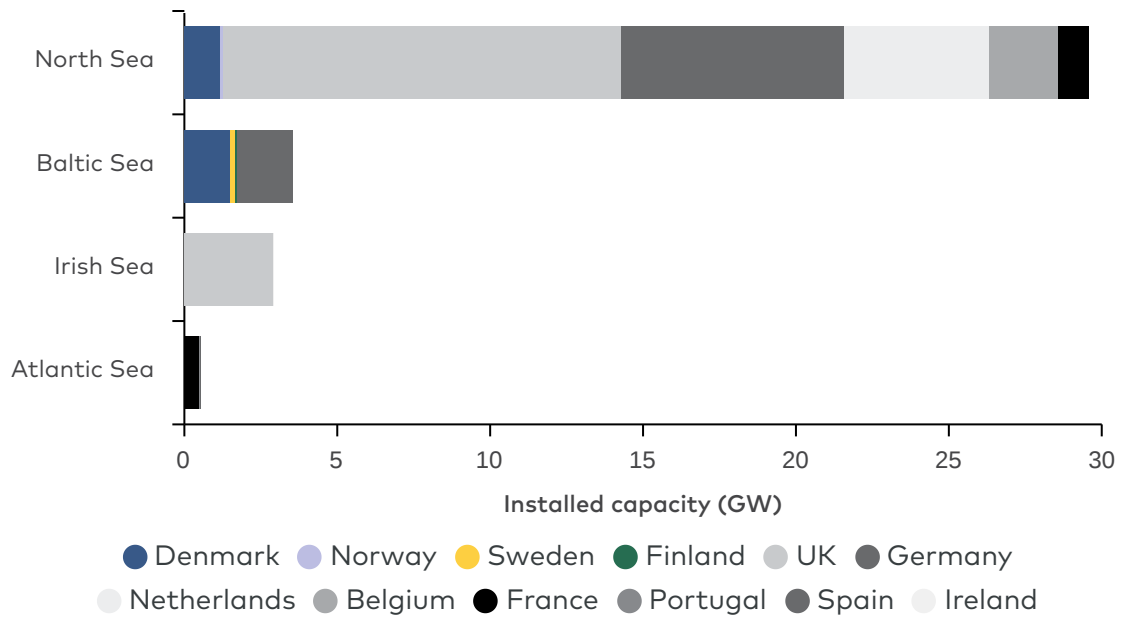


Figure 6-1 Installed capacity by country and sea basin as of spring 2025

Source WindEurope, 2025

Figure 6-1 breaks down offshore wind capacity by sea basin and country. The North Sea hosts almost 30 GW, approximately 80%, of European capacity today, followed by the Baltic Sea and the Irish Sea. Denmark’s capacity is roughly evenly split between the Baltic (56%) and the North Sea, while 80% of Germany’s capacity is in the North Sea. Though most of the installed capacity so far is using bottom-fixed turbines, Norway and the UK plan to build large volumes of floating offshore wind in waters deeper than 100 metres. Some of the first large-scale offshore wind farms are intended to electrify offshore oil and gas operations. Examples are Hywind Tampen, already in operation (Equinor, 2023), and GoliatVIND, commissioning planned in 2028–2029 (Ocean 24, 2024).

Ambitious plans for growth in offshore wind exist in most Nordic countries, aligned with the broader European prioritization of renewable energy. The need to accelerate the energy transition is driven by many factors, but primarily the need to reduce greenhouse gas emissions from power production. The ongoing war in Ukraine has disrupted energy supplies, leading to increased energy prices and rising concerns about availability, highlighting Europe’s dependence on energy imports.

EU targets for offshore wind were revised in November 2024, considering integration of European offshore grids in all sea basins (European Commission 2024a-b), and following the *Renewable Energy Directive* targets of 281–354 GW by 2050 (European Commission, 2023). Adding to the EU targets, the *Ostend Declaration* was also signed by Norway and the UK, putting the overall capacity

target for the 'North Seas'^[9] at 120 GW in 2030, and 300 GW in 2050 (NSEC, 2023). Also embedded in the *Ostend Declaration* are agreements on cooperation and knowledge exchange between Denmark and the UK on offshore infrastructure, and between Denmark, Belgium, Germany, and the Netherlands on development of energy islands (NSEC, 2023). Among the Nordic EU members, Denmark and Finland provide specific targets (non-binding goals) as of the November 2024 revisions, whereas Sweden does not specify targets but refers to its 2022 Maritime Spatial Plan (MSP) for allocation of area (European Commission, 2024a). For 2050, Denmark aims for 35 GW in its North Sea sector and 7.2 GW in its Baltic Sea sector, and Finland targets 12 GW (European Commission, 2024a-b). Norway aims to allocate area for 30 GW by 2040 under the *Ostend Declaration* (NSEC, 2023).

Figure 6-2 compares the expected 2030 capacity and 2030 pledges made by European countries, including the Nordics, according to an assessment by WindEurope (2024b). Note that this overview includes a previous Swedish target for 2030. Among European countries, France and Poland are most likely to achieve these ambitions. The Nordics will fall short of reaching the goals, and by a large margin. Denmark is expected to come closest, at 53% of the 2030 goal. Norway's first large-scale bottom-fixed offshore wind project at Sørlige Nordsjø II, with 1.5 GW capacity, is expected to be completed in 2031, meaning the 2030 estimates in Figure 6-2 are already on the optimistic side. Large-scale floating offshore wind projects are taking longer to realize, due to high costs, high technological risks, and slow permitting processes. DNV (2025d) estimated a shortfall of approximately 15% from the 2050 ambitions for the North Sea basin.

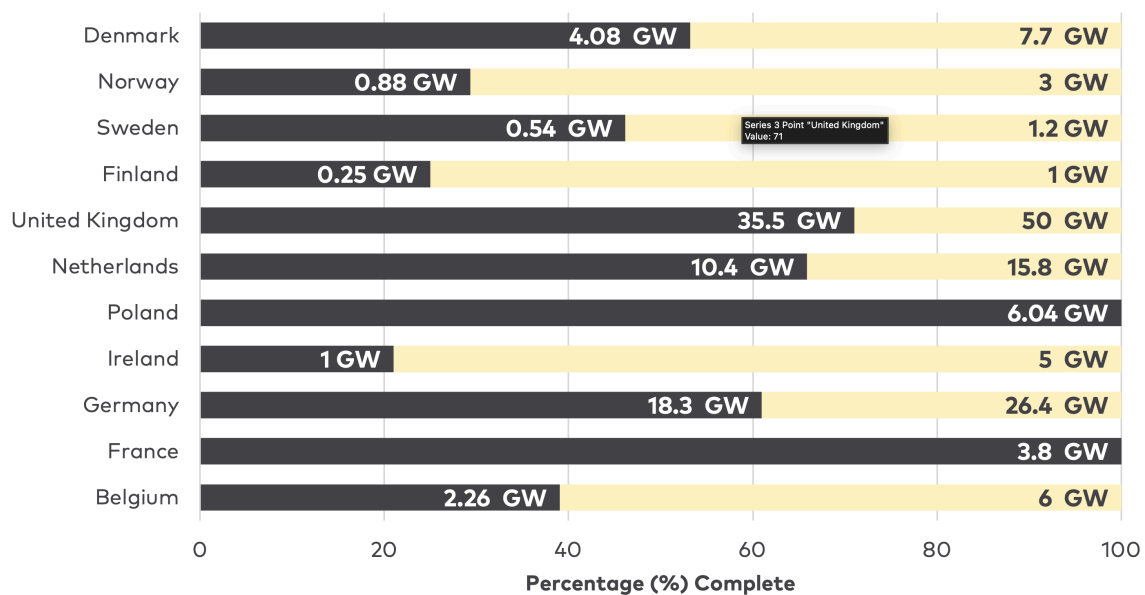


Figure 6-2 Expected and pledged 2030 offshore wind capacity

Source WindEurope, 2024b

9. Note that this is not one-to-one with the North Sea. 'North Seas' is taken to include all North Atlantic waters (all sea basins) of the signatory states, including areas in the Bay of Biscay (France), the Irish and Celtic Seas (Ireland and the UK), and the Norwegian and Barents Seas (Norway) (DNV, 2025d).

6.2 Challenges for coexistence with other uses

Offshore wind's space use, and its potential environmental and visual impacts, are key concerns that drive attention on coexistence between offshore wind, other human activities, and marine ecosystems. In the North Sea basin (including parts of Denmark's, Norway's, and Sweden's EEZs), space use by offshore wind can increase up to six-fold, occupying 60,000 km² or around 9% of the sea basin (DNV, 2025d). Previous Nordic initiatives have provided recommendations on inclusion of coexistence in tendering requirements for offshore wind (Nordic Energy Research, 2023).

Nature and ecosystem: Ecosystem impacts of offshore wind differ by foundation type and by lifecycle phase; construction, operation, and decommissioning (Bergström *et al.*, 2022). During installation, underwater noise due to pile-driving (for monopiles and jackets) can induce physical damage and stress in fish and marine mammals (Bergström *et al.*, 2022; Öhman, 2023). Noise-reduction techniques like bubble curtains are used to reduce these impacts (Tsouvalas and Metrikine, 2016). Installation operations can also cause the formation of sediment plumes that may impact marine life. Impacts during the operational phase include underwater noise from the structure, and electromagnetic fields from cables. Through the operational phase, the foundations may act as artificial reefs, attracting fish and other marine organisms that colonize the structures (Andersson and Öhman, 2010; Bergström *et al.*, 2013). Less is known about the environmental impact of decommissioning. The effects could be similar to those in construction phase, though other managerial considerations may arise (Hall *et al.*, 2022).

Fisheries: The possibility for coexistence with fisheries is a matter of ecosystem preconditions and impacts, as well as access to area. The fisheries are concerned that allocating space for offshore wind reduces what is available for fishing and navigation. See also Sections 4.4 and 6.5.

Aquaculture: Possibilities for co-location with low-trophic and salmon aquaculture are being considered. Low-trophic aquaculture is likely easier to combine with offshore wind, as the operations are simpler and there is less navigational risk. For instance, low-trophic aquaculture needs neither transport of feed, nor fish handling operations. Combining low-trophic aquaculture and offshore wind has progressed in demonstrating viability (e.g. at Krieger's Flak in Denmark), but recent innovation projects also find that salmon farming combined with floating offshore wind can be technically feasible, despite regulatory and operational hurdles (Freja Offshore *et al.*, 2025), see Section 5.3.

Tourism: The visual impacts of wind turbines and large energy plants are key concerns in the coastal tourism sector (and coastal communities in general). An example is the planned energy island on Bornholm, where there are additional concerns about the land connection points for the offshore grid located close to popular beaches, and the additional influx of construction workers that will compete with potential tourists for space at hotels and summer house rentals (Hansen, 2024).

Shipping: For shipping, a key concern is increased navigational risk in fairways close to wind farms, which is also the case for other ship types, such as fishing vessels. However, potential synergies include offshore charging infrastructure near wind farms to increase the range for battery-powered ships (see also Chapter 7).

Low-carbon technologies: Carbon capture and storage (CCS) and offshore wind have the potential to conflict spatially, due to the need for vessel-based monitoring of active carbon storage sites, as exemplified by a dispute between Ørsted and BP in the UK sector (Buljan, 2023). The Danish Maritime Spatial Plan (MSP) features several locations in which offshore wind development zones overlap with carbon storage sites (Danish Maritime Authority, 2025). See Sections 6.4 and 6.5.

Defence: Military considerations have hindered developments due to conflicting strategic interests. The most prominent Nordic example is the Swedish government halting 13 wind farms in the southern Baltic Sea in 2024 (Swedish Government, 2024). The rationale for rejecting offshore wind includes concerns about navigation, radar coverage, and the risk of sabotage of turbines or electricity cables. These concerns echo the Nord Stream pipeline explosions and the cutting of several Baltic Sea subsea cables (Bueger and Edwards, 2024).

6.3 What is the future for offshore oil and gas?

The prospects for continued offshore oil and gas in the Nordic region illustrate the trilemma between energy affordability, security, and environmental sustainability. Oil and gas production is a huge contributor to the economic value of the ocean industries and has contributed 15% to 20% of the Norwegian national economy in terms of gross value added since the early 1990s (Figure 6-3). Norwegian offshore oil and gas is essential for European energy security and affordability. After the Russian invasion of Ukraine, Norwegian offshore gas transported through North Sea pipelines has been vital in reducing the EU's dependency on Russian natural gas imports, along with liquefied natural gas (LNG) imports (DNV, 2024a). Long-term power purchasing agreements (PPAs) for Norwegian gas was proposed as a measure to improve the competitiveness of the European economy by ensuring

robust access to energy and stability in prices (European Commission, 2024c). In terms of carbon footprints associated with upstream activities (production and transport), Norwegian pipeline gas emits approximately 3–4 kgCO₂ per barrel of oil equivalent, as opposed to 40–120 kg per barrel for imported American LNG. For comparison, emissions during consumption are in the range 300–400 kg per barrel (Norwegian Department of Energy, 2025).

The long-term trend will be a reduction in oil production, due to field depletion and consequent reduction in the competitiveness of these products compared to cheaper oil from elsewhere. Consequently, oil production will most likely decline faster than for gas, in line with the need for a *demand-led* downscaling of fossil fuels (Hoegh-Guldberg *et al.*, 2023). Capacity additions in oil and gas will mainly be built out as 'tiebacks', fields with subsea installations connected to existing infrastructure (Norwegian Offshore Directorate, 2024). In 2050, DNV prognoses indicate that most remaining production of oil and gas in Europe will come from fields on the Norwegian Continental Shelf (DNV, 2024a). Denmark has also been an active oil and gas producer in the North Sea but, unlike Norway, has decided to completely phase out production by 2050. Compared to Norway, the Danish offshore oil and gas sector has never played a similarly important role in the national economy, and hence it has likely been easier to reach political acceptance for phasing it out.

Figure 6-4 displays the production pathways forecasted by the Norwegian Offshore Directorate (2024), measured in standard cubic metres of oil equivalents (Sm³ o.e.). They present high, low, and base estimates. These all indicate production decline towards 2050 but differ in the degrees to which areas are explored for new resources and technology is developed to exploit reserves. The base and high scenarios are consistent with most new developments being marginal and often developed close or connected to existing infrastructure. DNV (2024a) estimates are close to the base scenario presented in Figure 6-4. About half of the remaining offshore gas production in 2050 will likely be used to scale production of 'blue' hydrogen and derivatives such as ammonia (DNV, 2024a) in pathways involving steam reforming natural gas with CCS to reduce associated carbon emissions.

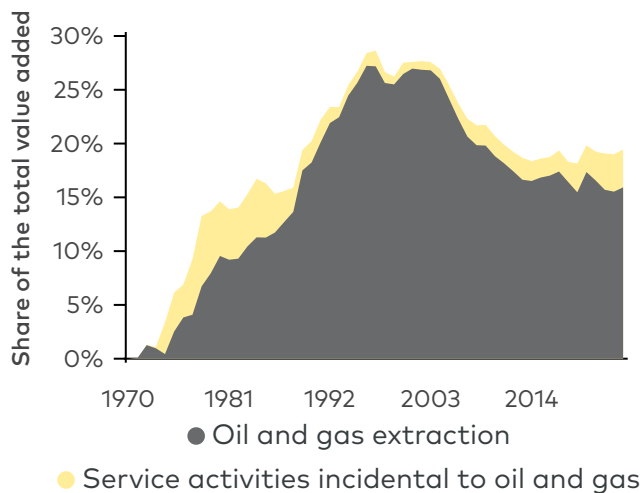


Figure 6-3 Offshore oil and gas as a share of total value added in the Norwegian economy

Source Statistics Norway, 2025a

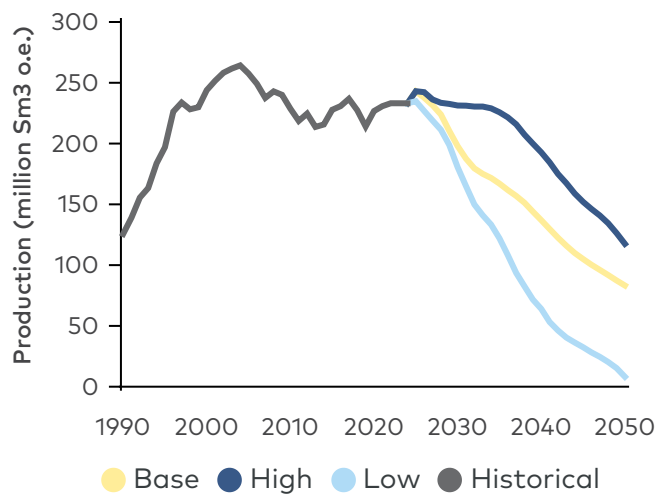


Figure 6-4 Three production pathways for fossil-fuel production on the Norwegian Continental Shelf

Source Norwegian Offshore Directorate, 2024

6.4 Low-carbon technologies in the ocean space

6.4.1 Carbon capture and storage

By 2030, the global capacity of carbon capture and storage is expected to quadruple, and CCS is expected to capture 6% of global CO₂ emissions by 2050 (DNV, 2025b). This is a large increase from today but falls significantly short of what is required to achieve net-zero emissions by 2050. CCS will primarily be applied in hard-to-abate manufacturing sectors such as steel and cement production, for gas and hydrogen production, and in combination with bioenergy use. In the maritime sector, implementation of onboard CCS is expected from 2040 onwards (DNV, 2025b), with a first commercial-scale pilot of Finnish manufacturer Wärtsilä’s onboard CCS system on the Norwegian-owned LPG tanker Clipper Eris in 2025 (Maritimt Forum, 2025).

Carbon capture plants are planned or under commissioning in Denmark, Sweden, and Norway. The North Sea area has a strategic advantage in CCS due to existing offshore infrastructure and world-leading offshore industry clusters, making Denmark and Norway well-positioned to lead on storage of captured CO₂ in retired gas wells off the coast. CO₂ capture has also previously been applied in the oil and gas industry for EOR (enhanced oil recovery), injecting CO₂ into existing reservoirs to increase pressure and thereby increase oil production while trapping

the CO₂ underground. The subsea injection systems for Northern Lights CCS in Norway are controlled from the existing Oseberg A platform, and both the Bifrost and Greensand Future projects in Denmark will make use of offshore platforms previously used in the oil industry.

The newly opened Northern Lights in Western Norway has a current storage capacity of 1.5 million tonnes of CO₂ annually, and the project has received official approval for a phase 2 which will increase capacity to 5 million tonnes. This, the world's first full-scale supply chain for CCS, began operating in 2025. The CO₂ was first captured at the newly-built carbon capture plant at Heidelberg Materials, South of Oslo, then transported on the specially designed CO₂-carrier ship Northern Pioneer to final storage at Northern Lights. For the project's next phase, storage agreements have been signed with several partners, such as Stockholm Exergi in Sweden, Ørsted in Denmark, and Yara in the Netherlands (DNV, 2025b).

6.4.2 Blue and green hydrogen, and ammonia

DNV's Energy Transition Outlook for Norway (2024b) forecasts that production of blue hydrogen – made from natural gas coupled with CCS – will increase and peak in 2040 to supply Europe's increasing demand. Production of blue hydrogen, and hydrogen derivatives such as ammonia and e-fuels (mainly e-methanol), will drive a continued demand for Norwegian natural gas. The maritime sector will be a main demand driver for ammonia and e-fuels.

Green hydrogen production – hydrogen produced through renewables-powered electrolysis – is also expected to pick up towards 2050. Countries with an excess of renewable and affordable electricity will have an advantage; however, the EU and US both have regulatory frameworks with clear requirements for electrolysis-based hydrogen. Starting in 2028, the EU will require green hydrogen production to be powered by additional renewable electricity that would not exist in the absence of hydrogen production – for instance, electricity produced by offshore wind (DNV, 2025a). This is to ensure that hydrogen production does not conflict with renewable electricity consumption targets.

Hydrogen will need specialized infrastructure for distribution, storage, and bunkering. Most will be transported through medium-distance pipelines, of which some will be repurposed natural gas pipelines to reduce cost. Ammonia and e-methanol will also need bunkering infrastructure but can use existing distribution and storage infrastructure currently used for global ammonia trade and transport in other industries (DNV, 2025a).

6.5 Opportunities and barriers

6.5.1 Growth opportunities for Nordic offshore energy

Knowledge transfer from offshore oil and gas to low-carbon offshore technologies:

Technologies such as offshore and marine structures, including subsea technology, can be successfully repurposed for uses in offshore wind and carbon capture and storage, as well as seabed mining (see Chapter 9). Seabed and geological data gathered for purposes such as oil and gas exploration can be reused for decisions on siting several low-carbon offshore technologies, such as identification of offshore reservoirs for carbon storage. For offshore suppliers, offshore wind already represents a venue for technology transfers from offshore oil and gas to drive significant exports (COWI, 2024; Menon Economics, 2025).

Standardization of concepts for offshore wind: This a likely prerequisite for reductions in costs and project development time. Energy system forecasts commonly assume positive feedback between cost reductions and cumulative capacity to account for learning, including in offshore wind (DNV, 2025a; d). Standard solutions (e.g. set turbine sizes, foundations) create repeatability in projects and reduce uncertainty regarding technical requirements for the marine engineering and construction supply chain (e.g. construction vessel capabilities and port restrictions).

Multi-use and co-location: Co-use of space has gained a lot of research interest in areas where there are big plans for offshore wind, such as in southern North Sea countries like the Netherlands, Germany, and Denmark (Nordic Energy Research, 2023). See Section 6.2 for several concrete examples of this, including co-location of offshore wind with aquaculture and other offshore activities.

Synergies with nature protection and restoration: Offshore wind can indirectly have positive effects on conservation as certain human activities, such as fishing and shipping, may be restricted in the developed areas (see also Section 4.3). These effects have led offshore wind farms being described as de facto marine reserves, creating a win-win outcome for renewables and marine protection (Fitkov-Norris *et al.*, 2025). Wind farms in areas previously impacted by bottom trawling can reduce a major stressor and facilitate recovery of sensitive species. By providing a refuge for demersal fish species such as cod and sandeel, wind farms can deliver ecosystem benefits, including feeding, spawning, and recruitment areas. In turn, this could increase productivity in these areas. Spillover effects from such areas can positively impact surrounding areas that are still accessible to fisheries (Galparsoro *et al.*, 2022). These circumstances may require more selective fishing practices, a change in use of fishing gear, and careful attention to coexistence between offshore wind and fisheries (see also Chapter 4).

Repurposing of offshore infrastructure: This can reduce the investment cost burden for low-carbon technologies such as CCS and hydrogen, while also reducing the material footprint of new infrastructure. It can also reduce the risks of stranded assets. The costs associated with decommissioning offshore oil and gas are likely to be very high, and finding alternative uses for these structures can be beneficial both economically and environmentally (DNV, 2025d).

6.5.2 Barriers to an efficient energy transition

Area use and spatial planning: Offshore wind requires significant amounts of ocean area. Insufficient allocation of area in marine spatial plans can slow growth in offshore renewables. Inclusive marine spatial planning processes can reduce the risk of competition for space with other actors, while taking into consideration the role of ecosystems. The EU Maritime Spatial Planning Directive mandates development of spatial plans for the EEZs, and current plans in Denmark, Finland, and Sweden therefore allocate space for offshore wind while taking other sectors into account (Directive 2014/89/EU, 2014). In Norway, the ocean management plans exist but are not legally binding, and the Ministry of Energy is responsible for allocating area for offshore wind (Ehler, 2021).

Permitting: Permitting systems vary by country, with Denmark, Finland, and Norway using a centralized approach where the responsible government agency opens and auctions out area and aligns this with the development of offshore electricity grids (WindEurope, 2024a; European Commission, 2024a-b). Sweden's approach differs, with its use of a so-called 'open-door' system assigning more of the planning efforts to the developers (WindEurope, 2024a), including requirements for environmental surveys and coordination of spatial planning with the local authorities (Malafry and Öhman, 2022).

Grid connections: Expanding grids to accommodate new power production such as offshore wind also require large investment and is the responsibility of transmission system operators (TSOs) in their respective countries. Large-scale infrastructure for which TSOs are responsible includes export cables, offshore substations, and prospective energy islands planned in the Danish North Sea and on Bornholm, but which face delays due to high costs (DNV, 2025d).

Strained supply chains: Constraints on access to materials (e.g. steel), components (e.g. permanent magnets for wind turbines), and infrastructure (e.g. ports and construction vessels, see also DNV (2025d)), can constitute major bottlenecks in offshore wind. Many key port areas in Nordic cities have been redeveloped with housing or urban amenities (Donovan *et al.*, 2021), reducing the supply of potential coastal sites for industrial activity (see text box in Chapter 7). Offshore oil and gas, and offshore wind, often compete in a global market for the same construction vessels (DNV, 2025d). When high oil and gas prices boost their producers' revenues, offshore wind will often struggle to hire construction vessels, an example of capital-intensive assets being prioritized for uses related to fossil fuels.

The potential for other emerging offshore renewables

'Emerging offshore renewables' here refer to those other than offshore wind. Examples include technologies for **floating solar power**; **tidal barrage** – using the difference between high and low tides to produce energy by forcing the flow through a barrier; **tidal stream** – generators directly in the tidal stream without obstructing the flow; **ocean thermal energy conversion (OTEC)**; and **marine current power** (DNV, 2025a). DNV (2025a) argues that these are most likely to serve niche markets such as small island states, or as part of 'multi-use' solutions that couple power generation with other production systems offshore (e.g. concepts for seawater desalination or aquaculture farm power supplies). In these cases, energy imports or grid connections could be costly, thereby justifying the investment in novel types of offshore renewables.

Floating solar PV has been proposed mainly for inland bodies of water, with less saltwater intrusion, but offshore concepts have also been suggested. Floating solar is also considered in combination with offshore wind – for example, Dutch-Norwegian SolarDuck's demonstration project installed in an RWE-operated wind farm offshore Holland (SolarDuck, 2024). Furthermore, Norwegian start-up Alotta has installed floating solar power at several fish farms, reducing, but not eliminating, the need for diesel generators at fish farms in Norway and Chile (Alotta, 2025).

Tidal energy: Swedish company Minesto operates one tidal power plant in Hestfjord in the Faroe Islands. Minesto's concept is a submerged kite anchored to the seabed, with the most recently commissioned version having a 1.2 MW power rating. The company aims to scale up operations to deliver 200 MW power generation capacity to the grid, thereby contributing to the Faroese ambition of 100% renewable energy by 2030 (SEV, 2025).

6.6 Scenarios for the Nordic offshore energy sector

Nature First

The Nordics nearly close the implementation gap with **the political ambitions for offshore wind**, while emphasizing coexistence with other sustainable ocean industries and the environment. Successful development of floating offshore wind and of power-to-X solutions to produce green hydrogen. Other offshore renewables see some uptake, particularly in the Faroe Islands. Realization of **nature-inclusive design and co-use options** for aquaculture production in offshore wind farms to maximize value of output per area and reduce overall human footprint at sea.

Europe decarbonizes at a quick pace, but still with an implementation gap relative to EU net-zero targets. Norway follows the 'low' trajectory for offshore oil and gas as presented by the Norwegian Offshore Directorate (2024), see Figure 6-4. Offshore CCS initiatives are developed, with few project failures relative to planned projects.

Constant Compromise

The Nordics **do not completely overcome barriers** related to long project development cycles and supply chain bottlenecks, although offshore wind costs will come down. The region sees substantial shortfall compared to the stated political ambitions for offshore wind generation capacity. Offshore oil and gas in Norway follow the base trajectory of Figure 6-4, with blue hydrogen production laying claim to an increasing share of the natural gas output.

Regional Rivalry

The Nordics exercise **caution on energy security**, prolonging Norwegian fossil-fuel exports to the EU to reduce further the dependency on energy imports (Russian natural gas and LNG from other regions).

There will be **fewer investments in offshore wind**, particularly detrimental to development of floating offshore wind. Most new development happens in the Danish EEZ. Shallow water areas are prioritized for development, and potentially at the expense of fisheries and environmental considerations. Additionally, military concerns retain their precedence in permitting decisions, limiting the potential for new build-out in the Baltic Sea.

Offshore wind that is being built out will see stricter security requirements, including **cybersecurity and surveillance**. Ocean monitoring systems installed with focus on surveillance, including **'dual-use' equipment** for monitoring, biodiversity management, and maritime surveillance.

Growth First

Continued offshore oil and gas exploration and development of new areas (Barents Sea and Greenland), due to high social acceptance for fossil fuels and high demand in an EU focused on **energy stability**. Correspondingly, there is little appetite for floating wind projects with high initial costs. Some fixed offshore wind projects will be developed (subsidy-free), mainly in Denmark. These developments will increasingly be **standardized to realize cost reduction** benefits.

Fewer mitigation actions are taken to reduce the environmental impact of offshore energy production, including carbon emissions.

7. The Nordic maritime industry

The Nordic vision for the maritime industry is to become the “most sustainable and integrated shipping region in the world” (Slotvik *et al.*, 2024). Owing to strong maritime clusters, the Nordic countries are uniquely positioned to address this challenge, while maintaining their competitive edge in shipping. Clusters form when companies that together constitute an entire value chain exist in proximity to each other, thereby laying the groundwork for good collaboration and knowledge exchange. Several good examples exist in the maritime industry on the western coast of Norway.

According to a bi-yearly study by Menon Economics and DNV (2024), Oslo and Copenhagen are the 5th and 9th most important cities for the maritime industry globally in terms of shipping, finance and law, maritime technology, ports and logistics, and attractiveness and competitiveness. While seemingly robust, Nordic maritime clusters are facing risks related to high costs in the manufacturing sector (e.g. shipbuilding and equipment), which could threaten the completeness – and hence competitiveness – of the clusters in the long run.

7.1 The Nordic shipping sector

In global shipping, Norway ranks 10th and Denmark 17th by size of fleet, measured in deadweight tonnes. By commercial value, the Norwegian fleet ranks 6th due to its large number of complex offshore vessels, Denmark 15th, and Sweden 33rd (UNCTAD, 2024). The Nordic region’s fleet totals around 5,000 vessels. Figure 7-1 shows the development of Nordic vessel ownership from 2005 and onwards in terms of vessel number per country, and the deadweight tonnage of the whole Nordic fleet. While the number of ships has grown 25% over this period (DNV, 2025a), its deadweight tonnage has grown nearly 80%, on a par with growth in transportation work globally (see Figure 7-2).

This implies that the Nordics have retained a strong position in international shipping, relative to what would be expected given the region’s relatively modest demand for cargo. It also means that the Nordic region holds a lot of human capital and knowledge about managing and operating ships and maritime logistics systems. This phenomenon is particularly evident in the role of regional maritime clusters across the Nordics.

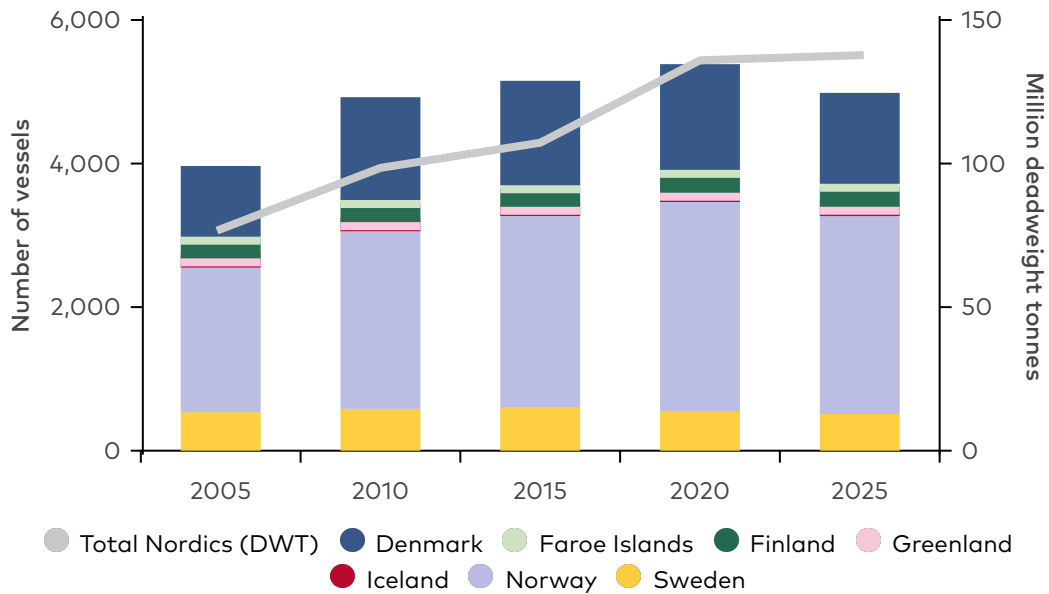


Figure 7-1 Size of the Nordic fleet per country measured in number of vessels, and whole fleet by deadweight tonnes

Source Clarksons Research, 2025b

International (deep-sea) shipping: Shipping accounts for around 80% of the global trade volume measured by weight. The world's maritime trade, measured in tonne-miles transportation work, is projected to grow only 10% to 2030, before plateauing and declining back to current levels (DNV, 2025a). Figure 7-2 shows that a modest growth will continue in container shipping and other cargo vessels. However, this is insufficient to offset declining fossil-fuel trades (oil, gas, and coal) and a potential regionalization of supply chains, though regional instabilities and supply chain disruptions can temporarily cause increased shipping distances.

Among major deep-sea shipping companies that are owned and operated from the Nordic countries are Denmark's A.P. Møller-Maersk, running the world's second biggest container fleet (UNCTAD, 2024), and Norwegian-Swedish Wallenius Wilhelmsen, operating one of the biggest fleets of roll-on/roll-off (RoRo) vessels, serving the automotive industry. In Figure 7-2, there is still mainly a positive outlook on growth in segments transporting manufactured goods. However, these segments will be heavily impacted in the short term by trade barriers such as new tariffs imposed on exports to the US (Coyne, 2025).

Short-sea shipping: Most maritime transport to and from Nordic ports is done by smaller vessels designed to operate on shorter routes. The short-sea shipping segments in the Nordic countries carry cargo between Nordic ports or from larger,

globally connected ports in Europe – such as Rotterdam, Antwerp, Bremerhaven, and Hamburg – to Nordic ports. Passenger ferries are a key feature of Nordic short-sea shipping, as these routes often serve as extensions of the road network (e.g. between Finland and Sweden), serving cargo and passenger transport. These routes see high regularity and predictability, making them key candidates for 'green corridors' where ports and shipowners can more easily partner on investment in and scaling up the availability of alternative, low-carbon fuels like ammonia and methanol (Slotvik *et al.*, 2024).

Offshore ships and other specialized segments: These are driven by trends other than transportation demand. Offshore support vessels are one segment where North Sea operations (e.g. Norway and Denmark) have long set the standard for ships operating in harsh environments. This part of the Nordic shipping ecosystem is in the midst of transitioning to renewables, serving offshore wind. Additionally, we see operational concepts using service operation vessels (SOVs) from offshore wind being introduced back into increasingly unmanned North Sea oil and gas operations (Aker BP, 2025). Other important special ship segments in the Nordics include fishing and aquaculture vessels, ferries, cruise (see Chapter 8), and in the case of Finland, icebreakers. Aquaculture support vessels have also increased in complexity with growing fish farm size and stricter biosecurity considerations (see Chapter 5).

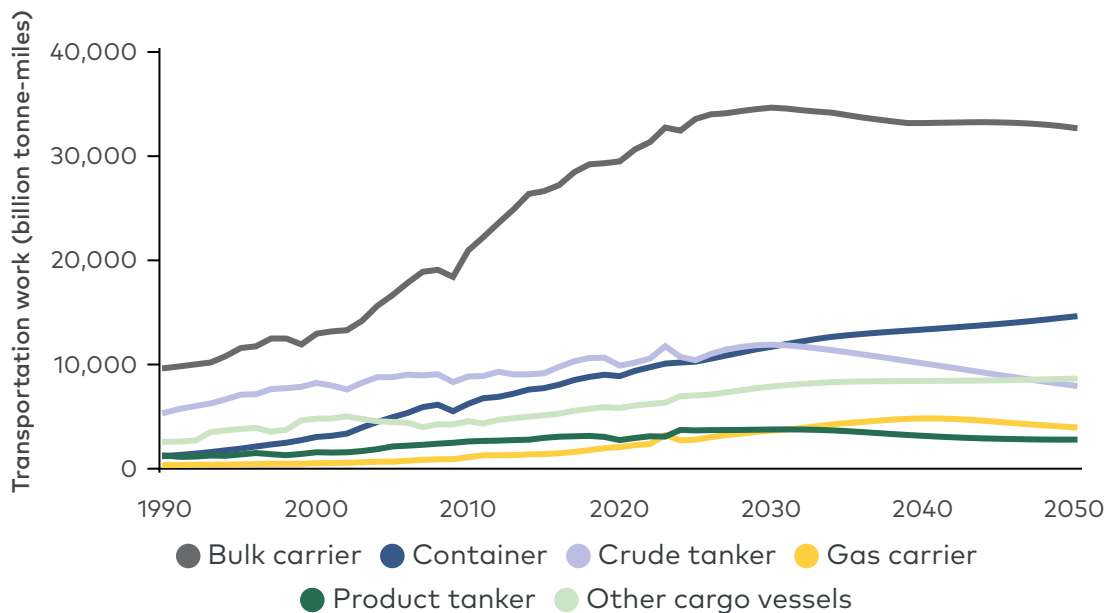


Figure 7-2 Forecast of transportation work in the global maritime sector to 2050

Source DNV, 2025a

7.2 The future of Nordic ports

Ports are vital components of the transportation system, with high strategic and commercial significance, supporting the flow of goods and maritime logistics. With the increasing societal emphasis on security, the awareness of ports as critical infrastructure is likely to rise. Over the period 2015–2023, Nordic ports handle goods (imports and exports) equivalent to roughly 17% of all goods in the ports of the EU-27, measured by weight (EUROSTAT, 2025a). In contrast, Nordic ports handle around 5% of the containers (EUROSTAT, 2025b). During this time, there have been relatively small changes in volumes. The difference between the Nordics' shares of shipping traffic in volume versus containers reflects that the Nordics play an important role in supply of commodities relative to the region's importance in manufactured goods.

Figure 7-3 shows port handling by weight of goods in 2015 and 2023. For most Nordic countries, except for Norway, volumes have declined slightly. Norway handles around 200 million tonnes per year, leading by this metric mainly due to sizeable petroleum exports from terminals in the Bergen area (66 million tonnes in 2023) (EUROSTAT, 2025c). With declining oil and gas activity, this will reduce, though new trades such as shipping of CO₂ for CCS facilities in the North Sea will add some volumes. By weight, the second biggest port of the Nordic region is Gothenburg, by far the leading container port in the region. A port featuring surprisingly high on the list of ports (4th) when ranked by weight of goods handled is Narvik (EUROSTAT, 2025c), the primary export port of Swedish iron ore miner LKAB (Luossavaara-Kiirunavaara Aktiebolag), which transports most of its ore by rail from Kiruna to Narvik, thereby avoiding the icy conditions of the Baltic Sea during winter (LKAB, 2022). LKAB produces most of Europe's iron ore, illustrating that small towns in Northern Norway and Sweden play essential roles for the resilience of European steel-supply chains.

Figure 7-4 shows the number of containers handled by Nordic ports in 2015 and 2023. In the container segment, volumes handled have grown for all Nordic countries, except Finland. Sweden handled around 1.6 million TEUs (twenty-foot equivalent units) in 2023, followed by Finland at 1.2 million, both far exceeding Denmark and Norway. Finland handles the most containers on a per capita basis, probably due to its geography, despite requiring icebreaking capacity to keep sea lanes open during the winter months (Arctia, 2024). Before the Russo-Ukrainian War, Finland used to be a transit country for Russian imports, including cars (Port of Helsinki, 2023). However, the slight reduction in activity at Finnish ports suggests the decline in Russian transit has had a minor impact on them.

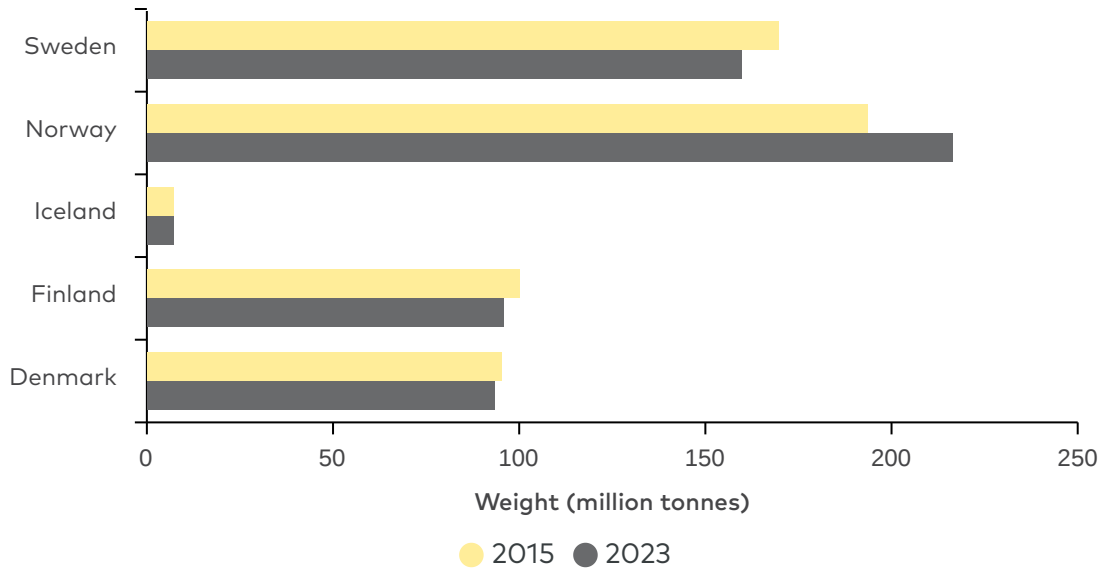


Figure 7-3 Goods handled in Nordic ports, measured in tonnes

Source EUROSTAT, 2025a

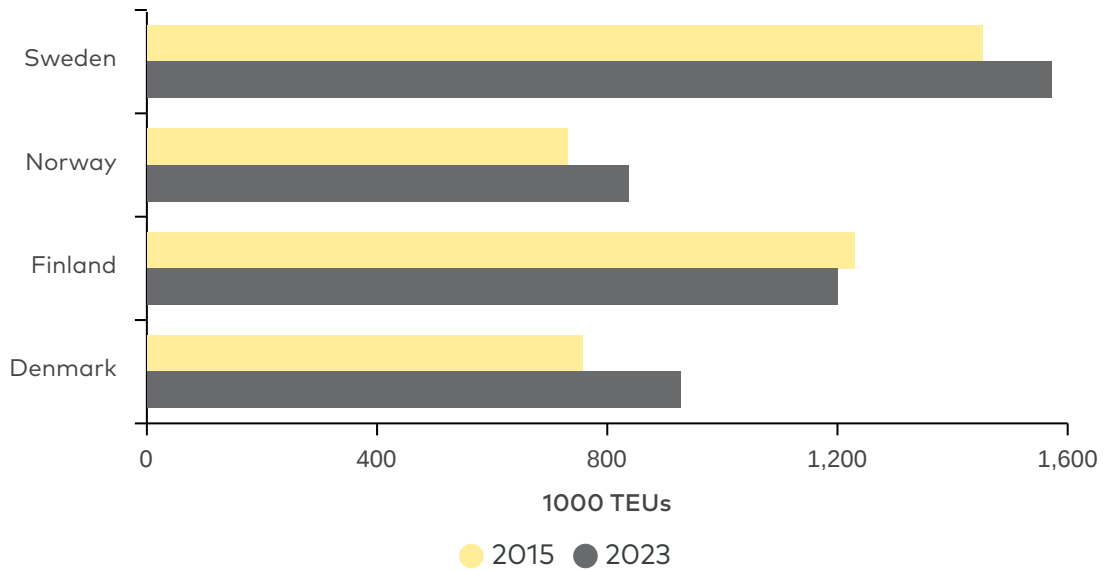


Figure 7-4 Containers handled in Nordic ports, except Iceland, measured in 1,000 TEUs

Source EUROSTAT, 2025b

7.2.1 Emerging roles for the port sector

If the Nordics follow the same trends as the rest of the world, as shown in the forecast of maritime transportation in Figure 7-2, the Nordic ports sector is likely to grow more dependent on handling containerized goods, and less on handling commodities. Additionally, new demands from the growing cruise and offshore wind sectors will impact the types of infrastructure investment needed in the port sector and could drive renewed demand for port capacity. In many cases, Nordic cities have redeveloped their old and disused port areas for residential spaces, making high-value waterfront acreage available to the public (Donovan *et al.*, 2021). However, this could come at the expense of society's ability to meet the future needs of the port sector, for instance in offshore wind (see text box).

In many cases, the ports remain tightly connected with the city, with the result that docked ships often add to air pollution. In the case of the Port of Bergen, where the cruise vessels dock downtown, three vessels can now be supplied simultaneously by onshore electricity. Cruise vessels that connect to shore power are eligible for a 20% discount, and vessels that emit more than the emission threshold are subject to penalty. Emissions are being reported through the Environmental Port Index, developed by Bergen Harbour in collaboration with the Green Shipping Programme, and the system is now widely used in Nordic cruise harbours (Green Shipping Programme, 2020). The ports also play an essential role in the scaling of alternative fuels, reflected in their participation in green corridor initiatives (see Section 7.5).

Is there enough port capacity in the Nordics to support offshore wind?

Offshore wind is a big driver for future port activity in the Nordics. At the same time, access to port infrastructure for construction and assembly, as well as operations and maintenance of wind turbines, constitutes a major bottleneck for further build-out of offshore wind (see also Section 6.5.2). Ports will need to support approximately 12 GW of yearly capacity additions across the North Sea basin in the late 2030s and early 2040s, up from less than 4 GW/year currently (DNV, 2025d). This will also be a major challenge for the offshore wind segment in a front-runner market such as Denmark. The Port of Esbjerg, the largest offshore wind port in the North Sea, aims to expand the installation capacity it can support to 4.5 GW/year by 2030 (Menon Economics, 2023). It has also partnered with several other North Sea ports across the UK, Germany, the Netherlands, France, and Belgium, to overcome capacity issues.

The *New Offshore Wind Ports in the Nordics* project mapped out the Nordic port landscape, focusing on Nordic collaboration opportunities. 50 port industry actors across the Nordics contributed, and the initiative was coordinated by industry cluster organizations (Energy Cluster Denmark, OffshoreVäst Sweden, and Norwegian Offshore Wind, 2024).

7.3 Shifts in the shipbuilding industry

The Nordic countries' shipbuilding industry has undergone massive change in the last 20 years. In the Nordics, mainly Finland and Norway still deliver newbuilds. Most Danish shipyards have transitioned to ship repairs and retrofits, and delivery of maritime equipment, but some have specialized in smaller craft and fishing vessels (OECD, 2024). The decline in shipbuilding is part of a wider European trend, where activity has moved to Asia or other low-cost countries.

Segments where the Nordics retain some competitiveness within newbuilding include, in Norway, offshore, fishing vessels, aquaculture, and ferries, and in Finland, cruise, ferries, and icebreakers. As an example, more than 50% of the global icebreaker fleet was built at Helsinki Shipyard (Davie, 2024). These vessel types are typically more complex than those intended for transportation. Figure 7-5 shows how newbuilding deliveries from Nordic yards have evolved over the last few years, with a declining number of ships delivered. The Finnish sector generally produces vessels with a higher CGT (compensated gross tonnage) than Norway, which delivers many more vessels. CGT is a measure of the work needed to build a ship, often considered a measure of ship complexity. Note that the source data excludes vessels less than 100 gross tonnes (GT), and does not cover fishing, aquaculture and naval vessels.

Figure 7-5 shows how the roles have shifted in ship production, with this trend expected to continue. When the main function of a vessel depends more on the onboard equipment than the amount of steel used, the role of the shipyard moves from primarily a manufacturing industry to more of a system integrator. The role of the Nordic yards is very often limited to outfitting, whereas the hull manufacturing is done in low-cost countries (Semini *et al.*, 2023). A system integrator role implies working with a much wider field of equipment suppliers and service providers to meet customer requirements, setting higher standards for Nordic yards (see Figure 7-6). In many cases, these suppliers are local companies that do not necessarily feature in ocean accounts (see Chapter 2) but play an essential role in local maritime clusters.

Nordic shipyards have moved into more knowledge-intensive roles, including a greater focus on ship design and engineering than before (i.e. provisioning of services) (Lagemann *et al.*, 2024). A consequence is that some design choices can be delayed well into the shipbuilding process to create flexibility for new solutions (Semini *et al.*, 2023). This capability becomes even more important for Nordic yards in the face of the uncertainty posed by the increasing adoption of automation and new fuels. Despite this potential benefit of building in Nordic yards, the ship design sector seems more robust. A recent case is SOVs for offshore wind operations, where Norwegian firms (HAV Design, Kongsberg, Salt Ship Design, Ulstein, and Vard) have *designed* more than 80% of the SOVs delivered since 2018 (Clarksons Research, 2025a).

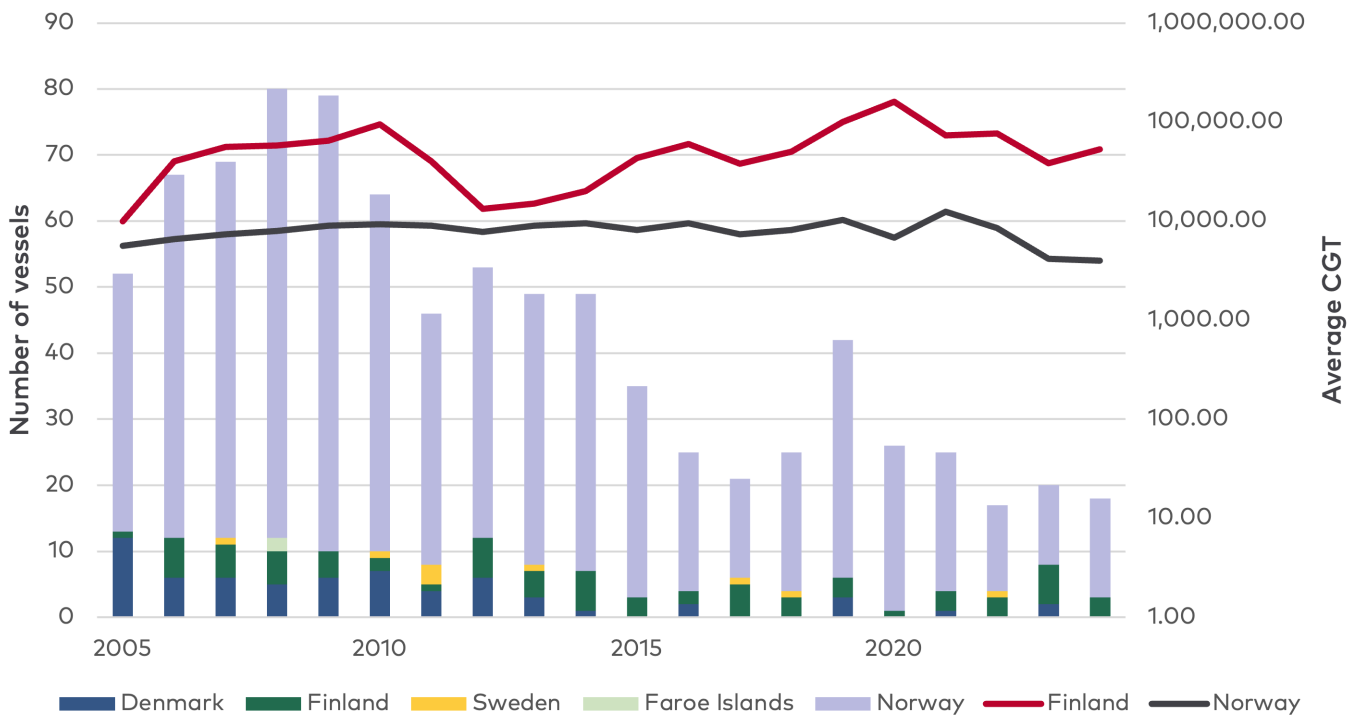


Figure 7-5 Number of ships (>100 GT) delivered from Nordic yards, and the average compensated gross tonnage (CGT) of deliveries from Norway and Finland

Source Clarksons Research, 2025b

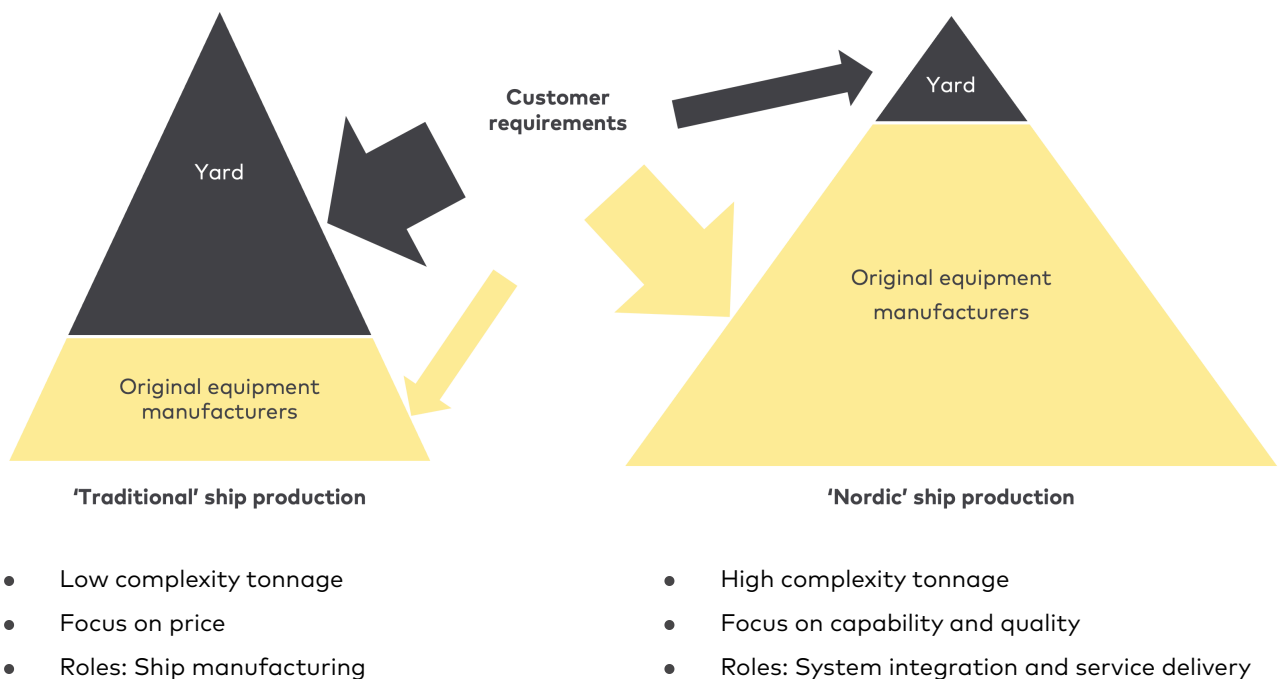


Figure 7-6 Conceptual model for the relative importance of yard versus equipment manufacturers in ship production in Nordic yards. Ship complexity increases with the width of the triangle

7.4 The Nordics as a testbed for maritime technology

For the Nordic maritime industry to remain competitive amidst increasing competition from low-cost countries, it needs to tackle the twin transitions of reducing environmental footprint and increasingly automating operations. New regulations from the EU (Fuel EU Maritime and the EU Emissions Trading System) provide strong incentives to reduce the emissions of the fleet (DNV, 2025c), trailed by the IMO's delayed Net-Zero Framework (IMO, 2025), and there is an increasing awareness about biodiversity impacts from noise and invasive species. In a rapidly digitizing world with an aging population, increasing automation is becoming a key growth area, driven by a shortage of sailors and rising crew costs.

Decarbonization: New technologies such as low-carbon shipping fuels are most easily adopted at a local scale, such as local ferries, urban mobility solutions, and workboats, before scaling to regional and global routes becomes possible. Sweden's Candela operates electric hydrofoils as part of the Stockholm public transport system (EU Urban Mobility Observatory, 2025), and Norway's Pascal Technologies is advancing air cushion technologies for electric boats, with applications extending from fast ferries to workboats in aquaculture (Butler, 2025). Among early car ferry routes to be served by electric ferries were Lavik-Oppedal on the Norwegian West Coast, and Horten-Moss in the Oslofjord (Slotvik *et al.*, 2024). MF Hydra in 2023 became the first hydrogen-powered car ferry (Norwegian Public Roads Administration, 2023).

The recent *Nordic Roadmap for Future Fuels for Shipping* supported several pilots testing new fuels, including green corridor initiatives on short-sea shipping routes in the North Sea, such as Oslo-Rotterdam (hydrogen), Esbjerg-Immingham (ammonia), and Gothenburg-Frederikshavn (methanol) (Slotvik *et al.*, 2024). The platform supply vessel Viking Energy, expected in 2026, is likely to be the first ammonia-powered offshore vessel (Skipsrevyen, 2024). For offshore ships, batteries are particularly well-suited due to their operational profiles, and the Maersk-owned Stillstrom is a likely first mover in installing offshore charging systems for SOVs (Stillstrom, 2022).

Digitalization and maritime autonomy: Like low-carbon fuels, initiatives for maritime autonomy are first tested on very short routes. Urban waterborne transport is one early use case, as seen in the first trials in 2022 of the autonomous ferry milliAmpere 2 across a short canal in Trondheim, though IMO Collision Regulations still required an onboard safety operator in case of emergency (Alsos *et al.*, 2024). This technology is currently being tested in Stockholm, and there are plans to extend its use to Åland for so-called virtual cable ferries (Zeabuz, 2025). Similar initiatives have been piloted in Denmark (DTU, 2022). Maritime autonomy is being piloted in the short-sea segments, with several initiatives in the Oslofjord (Kongsberg, 2024), and in offshore operations (MarineLink, 2025).

7.5 Opportunities and barriers

7.5.1 Growth opportunities for the maritime industry

Taking advantage of collaboration within clusters: The strong maritime clusters in Denmark, Finland, and especially Norway, can enable continued Nordic leadership in digital and environmentally friendly technologies in the maritime industry.

- **Shipping companies** can support continued efforts in technology development with decarbonization, digitalization, and in the specialized shipping segments (e.g. offshore, cruise, aquaculture). This model of **partnership between shipping and technology providers** positions the Nordic clusters to expand into new areas in the global blue economy, with new export opportunities within the sectors that do not yet take full advantage of technology. Example initiatives include Wilhelmsen and Kongsberg's autonomy joint venture 'Massterly', and Maersk's initiatives in R&D funding for decarbonization (Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping).
- **Ports in green corridors:** Through several green corridor initiatives, ports already play an important role in development of the infrastructure for green shipping. Green corridors are collaborations between ports to facilitate bunkering of alternative fuels, enabling low-carbon shipping on specific routes. Early movers are routes with high frequency and regularity, such as ferry routes between Finland and Sweden, like the collaboration between Wasaline and the ports of Vaasa and Umeå (Slotvik *et al.*, 2024).

Incentives from cargo owners: Cargo owners can play an important role in scaling new solutions in the digital and the decarbonization spaces by setting requirements during tendering, and by partnering with specific technology providers to ensure uptake of new technologies in the market. In autonomy and battery-powered ships, examples of Nordic cargo owners that have taken a proactive position in this area include Equinor (offshore), Yara (fertilizer producer), and Asko (grocery provider).

Government policy: Maritime policies and public procurement processes can play an important role in advancing new technologies in shipping. The high regulatory pace in decarbonization, for instance with the EU ETS and FuelEU Maritime, can help drive innovation in low-carbon shipping, helped by local initiatives in the Nordic regions, such as zero-emission requirements for Norway's World Heritage Fjords (Norwegian Maritime Authority, 2025). Similarly, new technologies for hull cleaning are being introduced to comply with new requirements that are set in place to avoid the introduction of invasive species from hull fouling (see Section 3.2.6.). In the car ferry segment, requirements for electric propulsion systems are an example of public procurement playing an active role in advancing new low-carbon ships.

7.5.2 Barriers to growth in the maritime sector

High costs constitute a risk to the competitiveness of the Nordic maritime industry, as seen in the shipbuilding example, in which the Nordics risk losing an important part of the value chain, with potential detrimental consequences for the region's maritime clusters. Similarly, costs related to shipping operations are generally expected to rise with uptake of alternative fuels and diversification of the fuel mix. Productivity gains through increased uptake of digital technologies are one lever for continued Nordic competitiveness in the sector.

Sourcing of alternative fuels: The key rationale behind green corridors is to reduce the uncertainty related to availability of alternative fuels such as ammonia or methanol. Despite successful partnerships between Nordic shipowners and ports, sourcing could remain an issue. Ammonia production will need to expand significantly to meet demand as a shipping fuel without cannibalizing supplies intended for fertilizer products.

New environmental regulations: With increasing awareness of environmental stressors such as biofouling and marine noise, the maritime industry in the Nordics could soon need to adapt to new regulations. In addition, new risks arise, such as the potential leakage of ammonia to the environment.

7.6 Scenarios for the Nordic maritime industry

<p>Nature First</p>	<p>The demand for trade in bulk and tanker segments declines faster due to a big reduction of coal and oil in the energy mix globally. Decarbonization in shipping is largely successful, following international collaboration on advancing GHG emission regulations at the IMO. Green fuels and increasingly autonomous solutions go hand in hand, but a more diversified fuel mix with alternative fuels cause shipping costs to rise significantly, likely reducing overall shipping demand. Productivity gains from automation partly offset the operational cost increases from new fuels.</p>
<p>Constant Compromise</p>	<p>Globally, maritime transport follows the pathway indicated in Figure 7-2. Maritime transport scales new fuels beyond green corridors, and hydrogen-based fuels (ammonia and e-fuels) gain a large share of the fuel mix (DNV, 2025a). Fuel costs increase, but not sufficiently to dampen shipping demand. First mover advantages in digital and decarbonization strengthens the region's role as a technology provider, whereas the clusters are at risk due to the lack of retention of shipbuilding capacity.</p>
<p>Regional Rivalry</p>	<p>New trade barriers dampen the demand for trade in goods significantly, driving homeshoring and refocusing trade within 'economic blocs'. Additionally, disruptions due to geopolitical tension become more likely. Disruptions on key routes, e.g. through the Strait of Hormuz and the Red Sea, reduce the efficiency of trade networks, meaning rising transportation work and higher chartering rates also for Nordic-owned ships, at least in the short run. Lower priority on decarbonization, and cybersecurity concerns, further reduce the potential for autonomous shipping.</p> <p>The Baltic Sea will see stricter maritime security measures, which could disrupt shipping activity. There will be limited activity on the OEM side and among maritime technology providers due to demand uncertainty, coupled with rising prices and delays due to supply chain issues. At the same time, local shipbuilding and maritime technology will see increasing preferential treatment through framework conditions (e.g. taxes) and public procurement processes.</p>
<p>Growth First</p>	<p>No decline in petroleum transport segments. Rising demand for fossil fuels from new regions drives maritime transport. Offshore shipping segments in Norway will mainly support oil and gas operations.</p> <p>Focus on new trade routes that shorten average transport distances (e.g., Arctic 'Northern Sea Routes') leading to higher demand for icegoing vessels and potential reduction in tonne-miles. Increased activity in the Arctic will drive investment in ports and infrastructure in the far north (Northern Norway, Greenland), and benefits the Finnish maritime cluster, which has a strong position in ice technology.</p> <p>Little attention on decarbonization of the maritime industry, as short-term cost consciousness takes precedence over making investments in new, and more expensive, fuels. Reversal and lack of enforcement of environmental regulations in shipping. Loss of current competitive advantages in the Nordics with respect to shipping decarbonization.</p>

8. Coastal and marine tourism in the Nordics

Coastal and marine tourism constitutes a large fraction of the Nordic Ocean economy and is particularly important as a source of employment. Both coastal communities and natural features in the marine environment offer a thriving array of attractions which are used for leisure activities by domestic and international visitors. The COVID-19 pandemic profoundly disrupted the tourism industry in 2020–2021, but the recovery has shown the sector's resilience and points towards future growth.

8.1 Coastal tourism in the Nordic countries

Much of international marine tourism statistics are often reduced to the cruise industry because economic reporting is more tractable and attributable to marine habitats. Even though coastal tourism is a key contributor to the ocean economy (EU Blue Economy Observatory, 2025), reporting on coastal and marine tourism (e.g. infrastructure, visitor numbers, and economic contributions) differs between countries (see Section 2.3.). The development of comparable data is a priority of the *Nordic Tourism Plan* (Nordic Council of Ministers, 2025) to improve the competitiveness of this sector.

8.1.1 Attractiveness of coastal and marine tourism relative to other tourism

Figure 8-1 shows the estimated proportion of infrastructure that should be counted as coastal and marine (A), and the relative attractiveness of coastal attractions (B) on the NUTS 3 regional level,^[10] based on an analysis of data from OpenStreetMap (OpenStreetMap contributors, 2025) and Wikipedia (Wikimedia Foundation, 2025). Hence, we use the footprint of online searches and reports of attractions and destinations to understand key attributes attracting tourists to a region. This provides additional context to national statistics and drives understanding of what features attract visitors to specific regions (Erskine *et al.*, 2021; Mancini *et al.*, 2020).

10. NUTS 3 (Nomenclature of territorial units for statistics) is the EU classification of small regions.

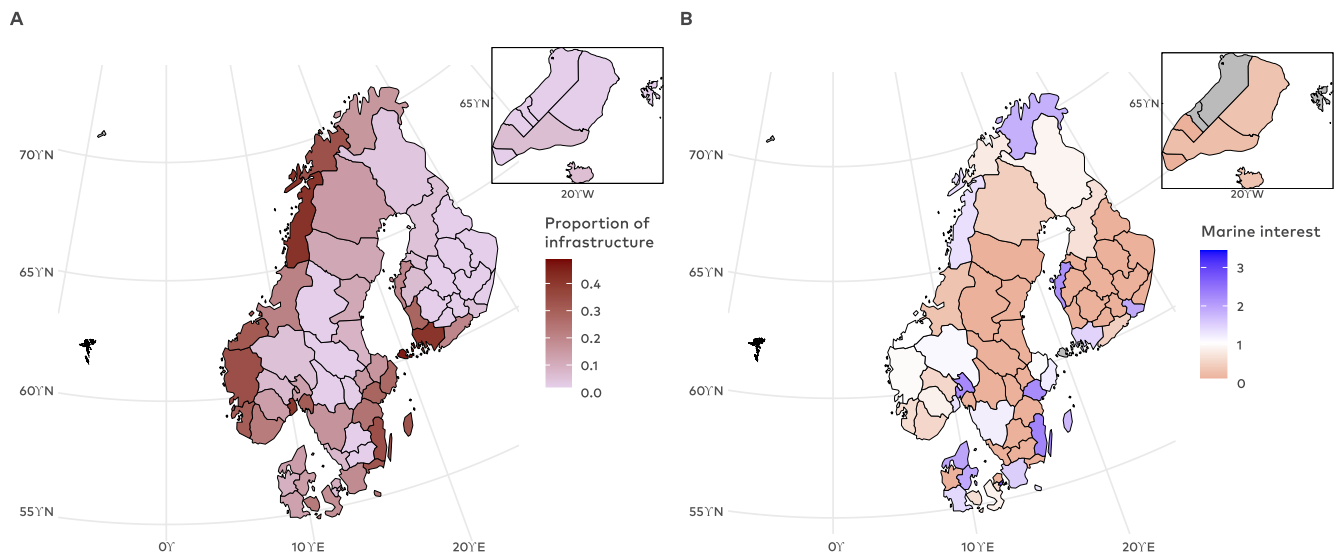


Figure 8-1 Estimate of (A) the proportion of marine and coastal tourism infrastructure and (B) the relative attractiveness of marine attractions reported on OpenStreetMap with a Wikipedia page in a region (NUTS 3)

Åland, the Faroe Islands, Nordland county in Norway, and Southwestern Finland are among the areas where the largest proportion of infrastructure (A) is assigned as a part of the coastal and marine tourism industry. From the perspective of marine interest (B), other regions rank highest – for example, Bornholm, Funen, East Jutland and North Jutland in Denmark; Ostrobothnia and Kymenlaakso (Kymmenedalen) in Finland; Kalmar (including Öland) and Södermanland in Sweden, and Akershus and Finnmark in Norway. The latter metric for ‘marine interest’ probably underrepresents qualities in the marine environment that would not necessarily be considered a specific attraction easily listed on the map, such as activities at sea, like recreational fishing or whale watching.

For Figure 8-1, part A, the number of places of accommodation is used as a proxy for tourism infrastructure. We estimate from OpenStreetMap the proportion of seafront hotels and other accommodation (within 100 metres of the shoreline) relative to the total number of accommodations in a NUTS 3 region to estimate the coastal and marine tourism contribution to employment, infrastructure use, and expenditures. For Figure 8-1, part B, we define marine and coastal tourist attractions as those within 250 metres of the shoreline, based on user-reported attractions in OpenStreetMap, and use this to quantify the proportion of marine and coastal tourism in tourism overall. We then retrieve all those attractions with a Wikipedia page and estimate the number of views per page over the past 10 years, with the potential caveat of downplaying more recently popularized destinations. From the sum of views, we estimate the attractiveness of marine

destinations compared to all destinations in a region, where the attractiveness coefficient is 1 if the proportion of the views attributable to marine destinations is equal to the proportion of marine tourist attraction Wikipedia pages. Hence, the 'marine interest' score can be above 1 if the associated Wikipedia entries are visited more often than the sites for non-marine tourist attractions.

The thresholds used to qualify marine attractions and infrastructure do not affect the between-region variability observed in the data. They are selected to conservatively denote marine attractions and infrastructure across both urban and rural landscapes. They probably underrepresent the number of marine attractions and infrastructure in a region. For instance, the registration of accommodation does not consider privately owned summer houses, which are commonly found in coastal areas in all Nordic countries.

8.1.2 COVID-19 impact and tourism sector recovery

The tourism sector was heavily affected by COVID-19 but has generally bounced back to or above previous levels. We use reported overnight stays, occupancy rates, and employment to shed light on future developments.

Overnight stays: Figure 8-2 shows overnight stays in the tourism sector since 1995 on a logarithmic scale, with the impact of COVID-19 evident in all countries. Tourism flows have resumed post-pandemic, but growth patterns differ to those seen pre-COVID (see Figure 8-3). Countries ranked by overnight stays follow population for most countries, but Denmark and Norway report more overnight stays than Finland, reflecting that their tourism sectors are slightly smaller on a per capita basis. Note that accommodation offered via collaborative economy platforms (e.g., Airbnb) is not included here, though statistics on short-stay accommodation booked via online platforms are available as 'experimental statistics' in EUROSTAT (2025f).

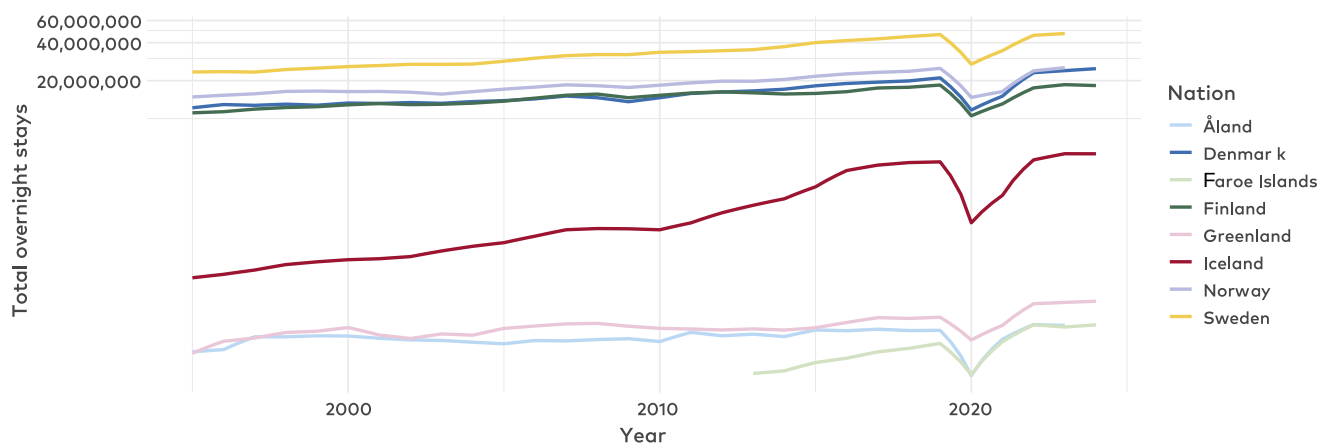


Figure 8-2 Total annual overnight stays (note the y-axis is on a log scale) 1995–2024

Source ÅSUB (2025); Statistics Denmark (2025); Statistics Faroe Islands (2025); Statistics Finland (2025); Statistics Greenland (2025); Statistics Iceland (2025); Statistics Norway (2025); Statistics Sweden (2025)

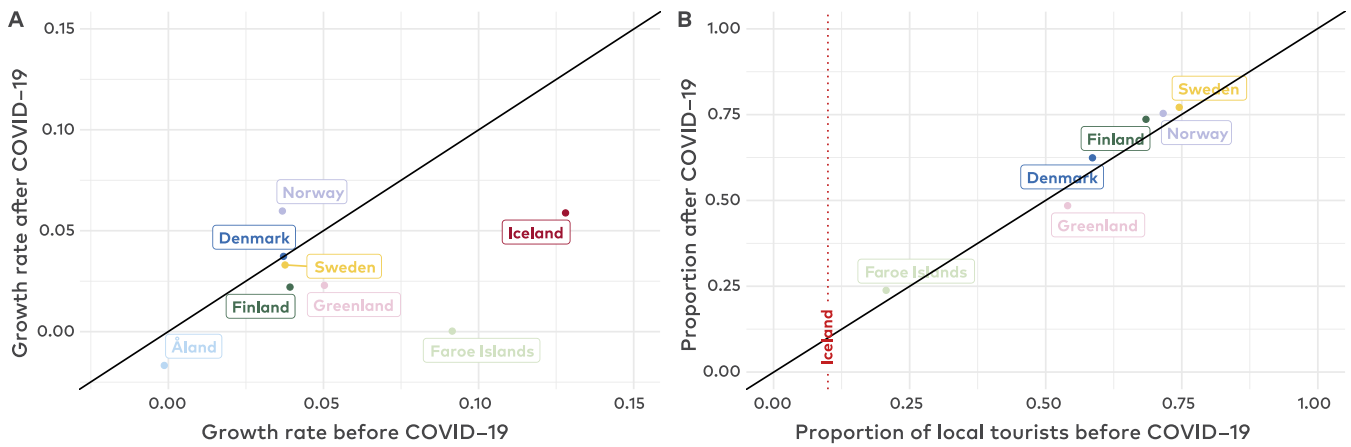


Figure 8-3 Comparison of the tourism sector before (2016–2019) and after (2022–2024) COVID-19: (A) compares annual growth rates, and (B) compares proportion of overnight stays by domestic tourists

Source ÅSUB (2025); Statistics Denmark (2025); Statistics Faroe Islands (2025); Statistics Finland (2025); Statistics Greenland (2025); Statistics Iceland (2025); Statistics Norway (2025); Statistics Sweden (2025)

Figure 8-3 compares the growth rate (A) and share of international tourists (B) in the tourism sector before (2016–2019) and after (2022–2024) COVID-19. Only Greenland and Åland see more tourists post-COVID than we would expect if COVID-19 had not happened. Tourism growth was 12% annually in Iceland before COVID-19 but is now closer to 5%, on a par with several other Nordic countries. The share of international tourists has not changed much in any of the countries (Figure 8-3, B).

Occupancy rates: Overall, occupancy rate has recovered post-COVID for all countries and continues to reflect the high degree of seasonality in the tourism industry. Occupancy rates peak during summer and wane during winter, with down to 20% utilization in low season. Figure 8-4 shows the development in occupancy rates for selected Nordic countries but does not account for bookings through collaborative economy platforms.

Employment: Jobs in the tourism sector were particularly hard hit by COVID-19, but the recovery reveals certain shifts. Figure 8-5 shows tourism employment as a share of total employment, revealing that the level of employment has largely bounced back but does not show the same growth as earlier, in line with Figure 8-3. Some service professions may also have reduced staff permanently, with the scaling of automated hotel check-ins and self-ordering in restaurants a potential factor. Such a trend would have the biggest effect on employment of women, who constitute a bigger share of the accommodation and food services workforce than men.

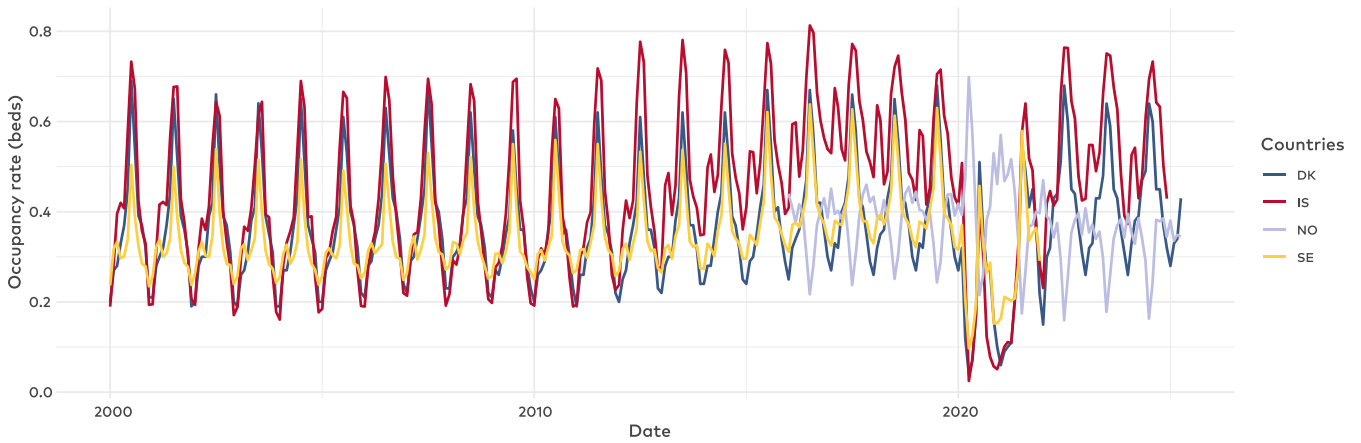


Figure 8-4 Seasonality in occupancy rates in selected Nordic countries, 2000-2024

Source Statistics Denmark (2025); Statistics Iceland (2025); Statistics Norway (2025); Statistics Sweden (2025)

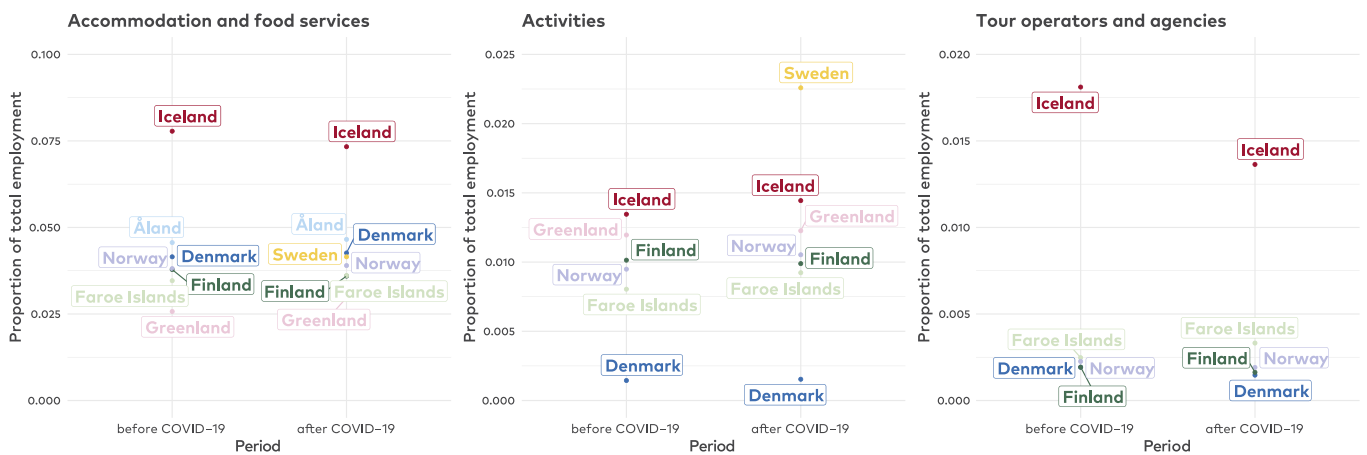


Figure 8-5 Share of total employment for three tourism subsectors reported in national statistics, with pre-COVID annual averages (2017–2019) and post-COVID annual averages (2022–2024)

Source ÅSUB (2025); Statistics Denmark (2025); Statistics Faroe Islands (2025); Statistics Finland (2025); Statistics Greenland (2025); Statistics Iceland (2025); Statistics Norway (2025); Statistics Sweden (2025)

8.1.3 Coastal and marine tourism's impact and dependency on nature

As shown in Section 3.1, tourism and marine ecosystems are closely interconnected through the provisioning of cultural services. At the same time, many coastal and marine tourism activities threaten to cause degradation of the ecosystems they depend on (Mancini *et al.*, 2020; Lusseau and Mancini, 2018). Globally, human disturbances caused by tourism and recreational activities are a conservation threat for more than 1100 marine species (IUCN, 2025). In addition, there are around 1,600 marine species threatened by tourism infrastructure globally, primarily due to the habitat modification it causes (IUCN, 2025).

Figure 8-6 shows that 68 marine and coastal species are red-listed due to tourism-related habitat modification, and 36 red-listed due to recreational activities. 16 species are red-listed due to both. Among these 88 species, some are sensitive to both threats, including endangered species like angelsharks, and species currently listed as 'of least concern', such as ringed seals. Some of these species (e.g. dolphins, whales, and seabirds) are critical assets for nature-based tourism which attracts visitors to destinations. There is potential for negative feedback from biodiversity deterioration to economic contributions from tourism.

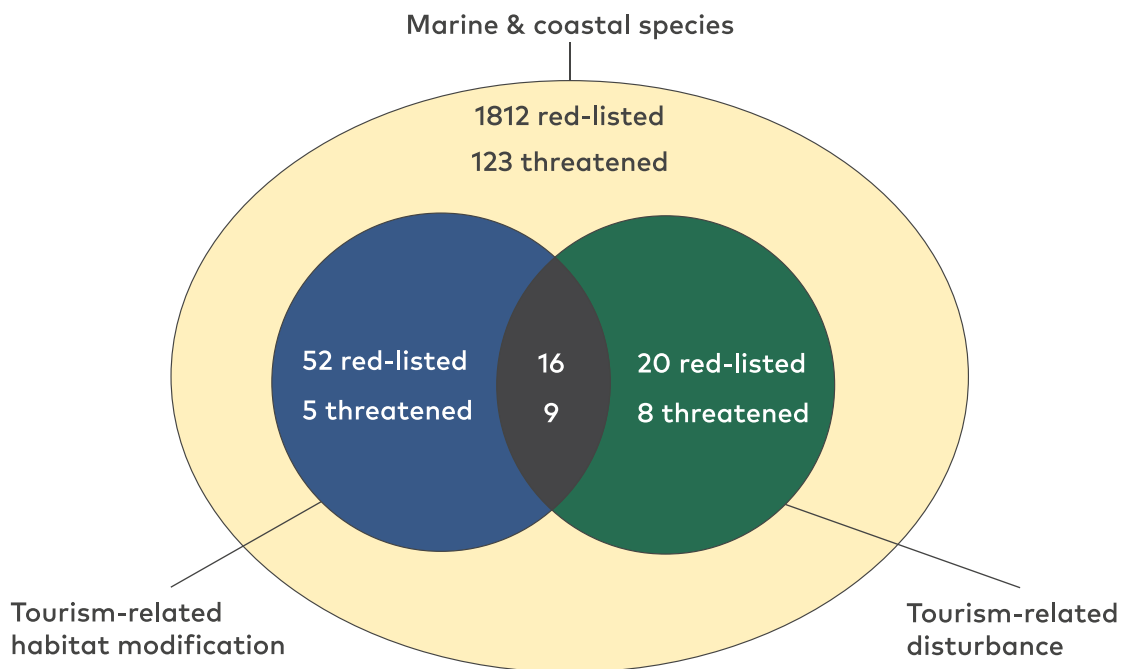


Figure 8-6 IUCN (International Union for Conservation of Nature) Red List species living in the Nordics that have been assessed and found to be threatened by tourism activities

Source IUCN, 2025

8.2 Cruise tourism in the Nordic region

Cruise tourism in the Nordics can be roughly divided into two geographical markets, Non-Mediterranean Europe and the emerging 'exploration cruise' regions (CLIA, 2025). Non-Mediterranean routes largely intersect with traffic in the North and Baltic Seas, covering destinations such as the UK, Germany and, until 2020, Russia, besides Nordic cities like Copenhagen, Gothenburg, Helsinki, Oslo, and Stockholm. The exploration cruise category, with itineraries covering Greenland, Iceland, and Northern Norway, has recently grown much faster, with a 20% increase in the number of passengers since 2023 (CLIA, 2025).

The Nordics are a relatively small cruise region, with less than 10% global market share in terms of passenger counts (CLIA, 2025). In terms of passenger arrivals, Norway leads the Nordic cruise industry with about 5.8 million arrivals in 2024, having rebounded from COVID-19 (Norwegian Coastal Administration, 2025). Germans are the biggest nationality among cruise tourists in Norway, and this used to be the case for Greenland too. However, after the COVID-19 pandemic, US visitors have skyrocketed and constituted 50% of passengers in 2024 (Statistics Greenland, 2025a). Figure 8-7 shows annual cruise passenger arrivals for all Nordic countries, except Åland, on a logarithmic scale. Despite lacking data for Åland in Figure 8-7, note that passenger ferries are crucial for Åland's tourism industry, as they carry most visitors to the archipelago.

Greenland: After the recovery of this sector in 2022, the flow of cruise passengers to Greenland ports continues to grow at a similar rate to before COVID-19. The biggest destinations are Qaqortoq and Nanortalik in the south, and the capital Nuuk on the western coast, with passenger numbers rising fastest for Nanortalik and Nuuk (see Figure 8-8 and 8-9). Due to cold winters with icy waters, the season is limited to summer and early autumn (four to six months depending on the region). It is unclear how much cruise tourism benefits the national economy of Greenland, and how much cruise's use of Greenland's ecological assets leaks economically outside the nation.

Norway: In Norway, cruises rebounded from COVID-19 with 45% growth in passenger numbers between 2022 and 2023. The top five ports over the period 2015–2024 were Bergen, Stavanger, Oslo, Ålesund, and Flåm (see Figure 8-8 and 8-10). The years since the pandemic has seen some movement in the top five, with Ålesund exceeding Bergen in terms of arrivals after the pandemic. In 2024, Stavanger also caught up with Bergen in terms of arrivals. Stricter environmental regulations are also impacting the selection of ports, with Flåm and Geiranger, both within the World Heritage Fjords, experiencing a 33% reduction in port calls between 2019 and 2022, also adjusting for the COVID-19 impact. The post-COVID period has also seen a shift in seasonality, with more arrivals in autumn compared with before the pandemic. Ports like Oslo and Tromsø are generally less impacted by seasonality than Bergen, Ålesund, and Stavanger.

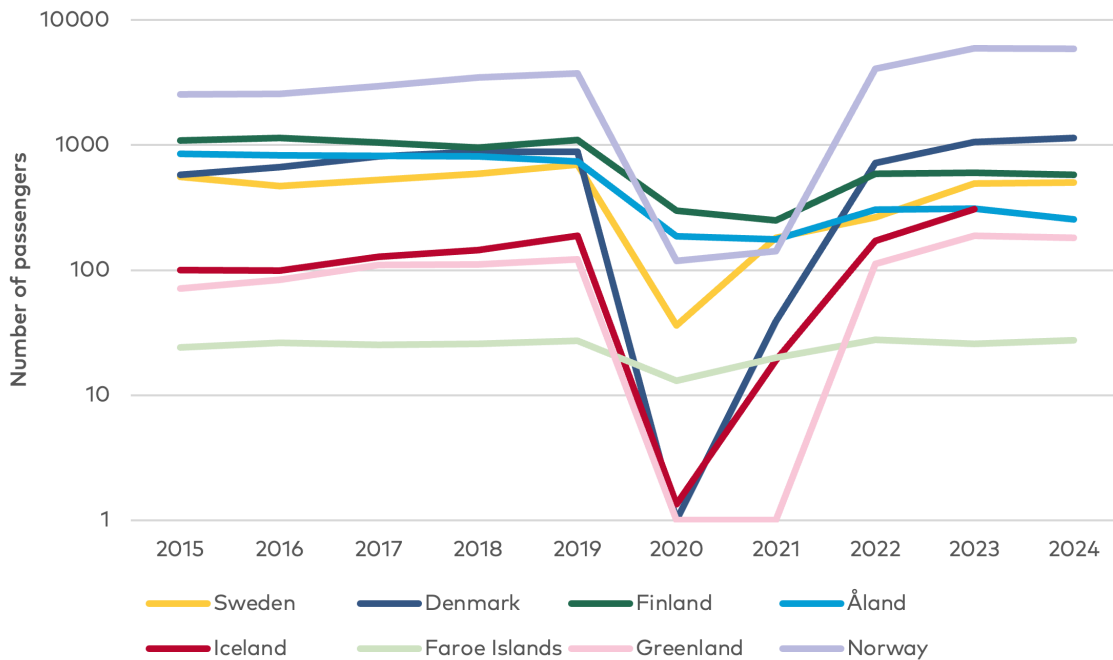


Figure 8-7 Annual cruise arrivals by country, 2015–2024

Source Norwegian Coastal Administration (2025); Statistics Denmark (2025b); Statistics Faroe Islands (2025a); Statistics Finland (2025); Statistics Greenland (2025b); Statistics Iceland (2025d); Transport Analysis (2025)

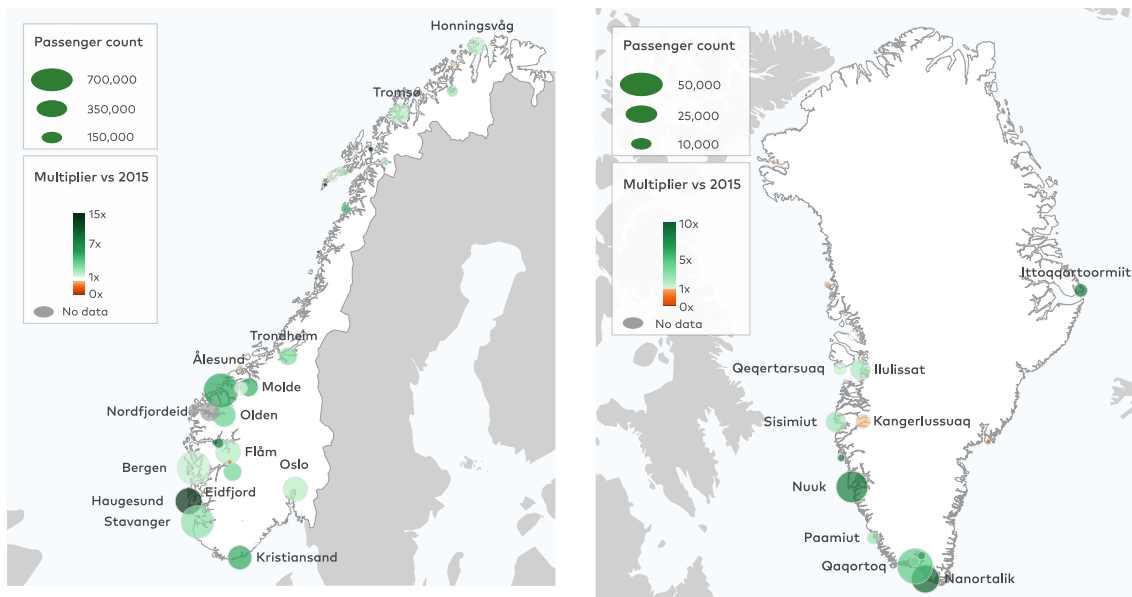


Figure 8-8 Main cruise ports in Greenland (A) and Norway (B) are shown with circles sized proportional to 2024 passenger counts and colour indicating the growth multiplier relative to 2015 (> 1 = growth, < 1 = decline); port labels with greater than 5,000 and 150,000 passengers are included for Greenland and Norway, respectively

Sources Statistics Greenland (2025b); Norwegian Coastal Administration (2025)

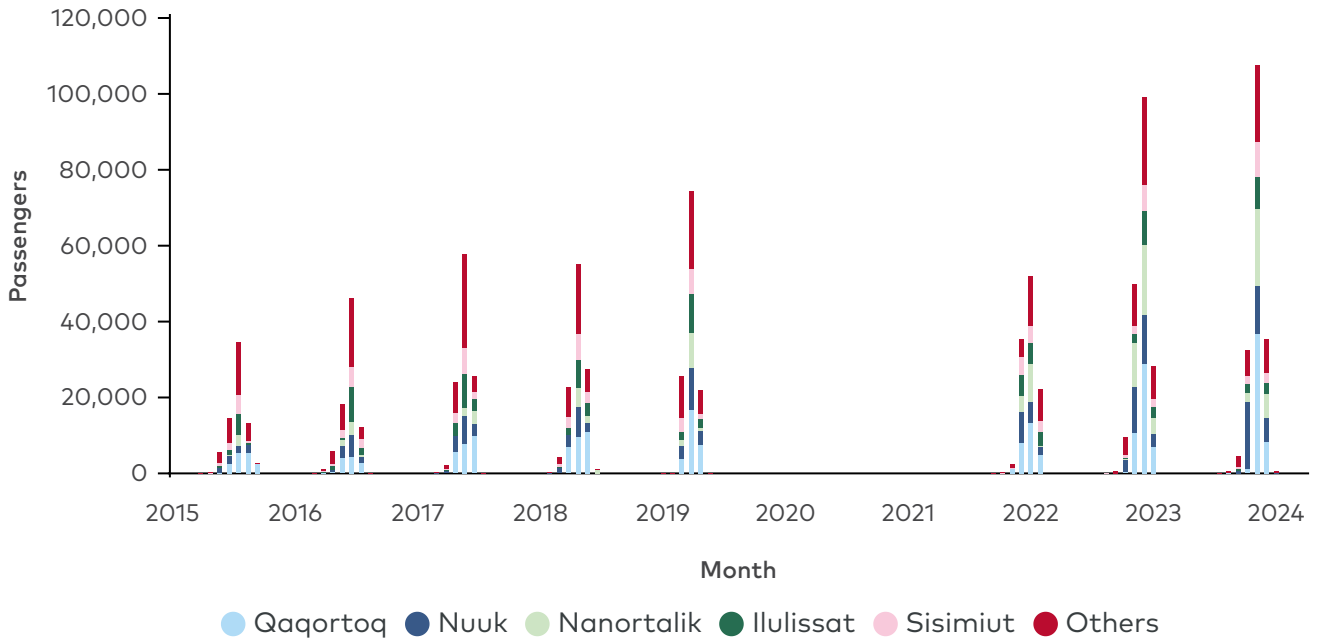


Figure 8-9 Cruise passengers in Greenlandic ports by month, 2015–2024

Source Statistics Greenland, 2025b

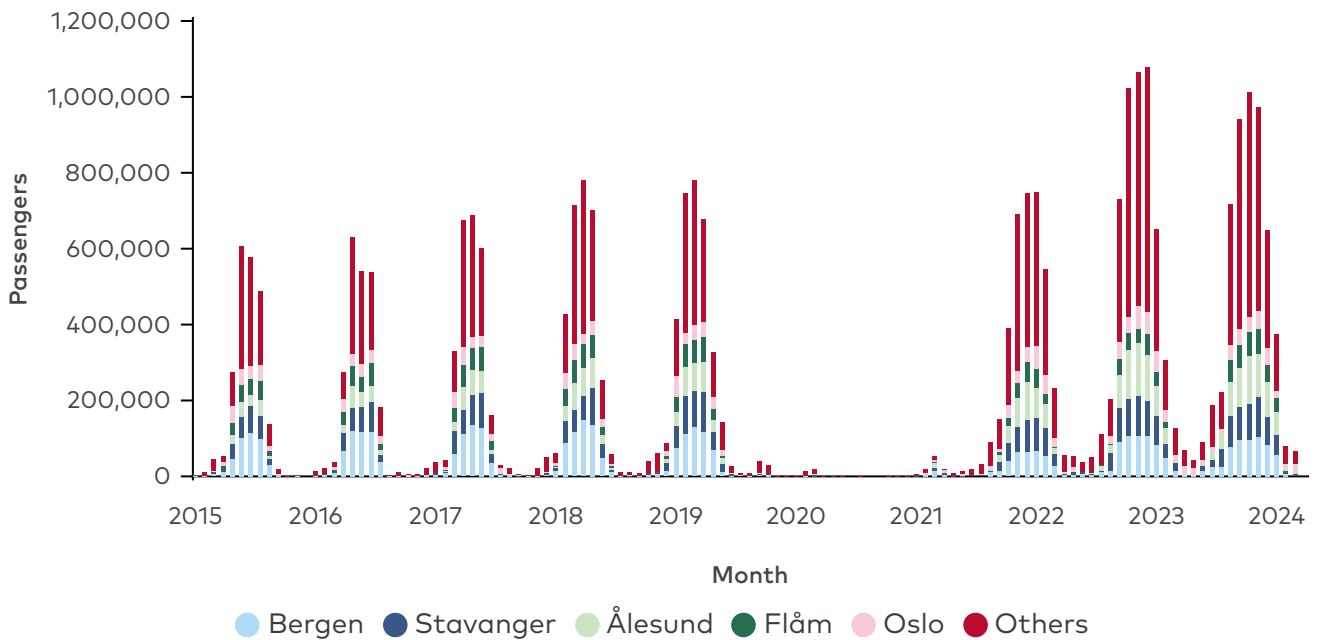


Figure 8-10 Cruise passengers in Norwegian ports by month, 2015–2024

Source Norwegian Coastal Administration, 2025

8.3 Opportunities and barriers for coastal and marine tourism

8.3.1 Opportunities for growth in tourism

Infrastructure flexibility: Occupancy remains at rates that leave space for growth and highlights that infrastructure capacity is not a constraint for tourism growth (see Figure 8-4). With collaborative economy platforms adding flexibility, the tourism sector adds substantial reserve capacity, reducing the need for development of new tourism infrastructure to meet growing demand (e.g. from 'coolcations'). It is necessary to understand potential impacts of these hybrid accommodations on the social capital of local communities (e.g. housing prices), given the backlash against tourism observed in some countries.

Advance zero-emission marine tourism: In 2026, the Norwegian Government will introduce a zero-emissions requirement for tourist ships and ferries under 10,000 GT in the World Heritage Fjords, and for larger vessels in 2032 (Norwegian Maritime Authority, 2025). The goal is to promote sustainable tourism by keeping the fjords clean and driving technological development for emission reductions, while creating opportunities to advance new business models for zero-emission and silent boats for excursions.

8.3.2 Barriers to growth in tourism

The need to curb carbon emissions: Tourism globally contributes 8% to 9% of global greenhouse gas emissions. With air transport responsible for around 50% of the tourism emissions (Sun *et al.*, 2024), growing Nordic tourism sustainability hinges on development of low-carbon aviation or a shift to tourists that can access Nordic destinations through other modes of transportation. This limits the pool of tourists to Europe, which, contrasting with much of Asia, is unlikely to grow tourism demand (DNV, 2021).

Biodiversity impacts: Environmental degradation from tourism and other human activity (see Chapter 3) reduces both the cultural services offered by ecosystems, potentially reducing the attractiveness of visited sites. On the other side of this trade-off, stricter regulations to mitigate biodiversity degradation may hinder tourism development.

Cannibalization of local tourism industry: Cruise can both compete with and supplement coastal tourism. In mature areas, cruises compete with local offerings due to its all-in-one package including travel, accommodation, and entertainment reducing local value creation and employment in coastal communities. In areas with sparse infrastructure, cruises greatly improve the availability of destinations, with Greenland and other 'exploration cruise' destinations offering prime examples.

8.4 Scenarios for coastal and marine tourism in the Nordics

<p>Nature First</p>	<p>Tourism management has a strong focus on value creation based on low-impact use of natural habitats and biodiversity assets. Focus on attracting domestic tourists and those from neighbouring countries, over those that rely on air transport. Countries such as Iceland relying on air transportation of international visitors' struggle. Visitor numbers consequently decline.</p> <p>Decreased biodiversity footprint from tourism activities, through strictly advancing sustainable practices and low-impact technologies like zero-emission silent tourist boats and pleasure craft. Overall increase in cultural ecosystem services generated, and an increase in the share of skilled labour in employment.</p>
<p>Constant Compromise</p>	<p>Economic contributions and employment continue to grow, but at a slowing pace. The sector might struggle to compete with other economic sectors to retain workforce, as working-age populations stagnate with rural, coastal communities hard hit by this trend.</p> <p>The biodiversity and carbon footprint of tourism continues to increase with this growth, but efforts to reduce harm to cultural ecosystem services are prioritized at the policy level. Recent summer growth continues to accelerate as climate conditions in traditional European summer destinations worsen.</p>
<p>Regional Rivalry</p>	<p>Slowdown of international arrivals and disruption of current visitor flows. Countries such as Sweden and Norway that rely more on domestic visitors are more sheltered from these disruptions and can continue to grow tourism with a dichotomous focus on mass tourism and high-end luxury tourism.</p> <p>Decrease in employment in the sector, driven by lower arrivals and much lower access to personnel due to stagnant working-age populations in rural, coastal areas. Continued increase in biodiversity footprint and overall decrease in cultural ecosystem services generated, also due to security priorities generally taking precedence over environmental considerations.</p>
<p>Growth First</p>	<p>Demand increases as traditional European summer destinations are less popular or even less accessible due to climate disruptions. Large influx of tourists also from other regions, such as East Asia and the Middle East. Tourism is optimized for profit, leading to divergence in the Nordics between regions specializing in luxury exclusive tourism ('coolcations' turning into 'climate refuge' service) for international flying visitors (e.g. Iceland) and regions focusing on mass tourism.</p> <p>A large increase in the popularity of exploration cruise destinations, such as Greenland and Svalbard, as Arctic infrastructure develops. Impact on cultural ecosystem services generation is not clear as new species and new areas become available to tourism.</p>

9. Emerging blue industries in the Nordics

This chapter describes some of the emerging industries that may have significant growth potential in the future Nordic ocean economy.

9.1 Increased value creation from ocean bioresources

A key lever for a more sustainable ocean economy is to increase the value creation from natural resources. Two primary pathways for emerging industries are: 1) identifying or producing new marine biomaterials for commercial use, such as identifying new species or compounds applicable for biotechnology and pharmaceuticals, or farming new species; and 2) increasing the value creation from existing marine resources, such as upcycling waste and by-products which are currently used for applications found in the lower part of the biomass value hierarchy. Figure 9-1 shows the biomass value hierarchy, from high-volume, low-value applications such as waste and energy to low-volume, high-value applications such as food, pharmaceuticals, and medical uses.

9.1.1 Blue biotechnology and pharmaceuticals

The pharmaceutical industry is well-established and highly profitable. In the biomass value hierarchy (see Figure 9-1), pharmaceuticals along with medical products and cosmetics are the uses with the highest potential value added from upcycling of marine biomass. There are long traditions for pharmaceuticals in the Nordic countries. For example, one of the world's largest pharmaceutical companies, Novo Nordisk, is Danish and was founded over a 100 years ago. Swedish-British AstraZeneca is another example with major activities in the Nordics (Sweden in particular) and is by revenue an even larger company than Novo Nordisk. Although well-established, they still represent actors that can play a growing role in the blue bioeconomy, given their potential to develop novel pharmaceutical products from the oceans, part of a wider trend to extract and utilize underused resources from the ocean to grow the blue economy in the Nordic countries.

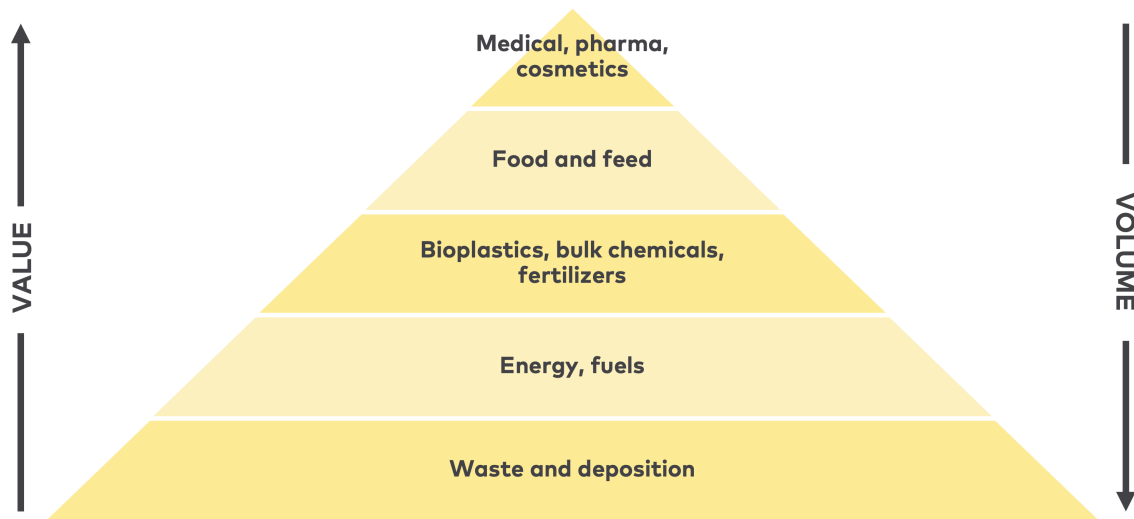


Figure 9-1 The biomass value hierarchy, inspired by Lange and Lindedam (2016)

Several initiatives in the Nordic region focus on the screening of ocean-derived organisms with potentially therapeutic applications. One, Marbio at UiT (The Arctic University of Norway), recently isolated from driftwood a new fungus species exhibiting inhibitory activity against bacteria (Maharjan *et al.*, 2025). Another recent article from Marbio found that a natural compound isolated from an Arctic marine invertebrate could potentially have applications for the development of a therapeutic agent against diabetes (Ullsten *et al.*, 2025). Other leading Nordic research communities in blue biotech are: MATIS (Iceland), VVT Technical Research Centre of Finland (Finland), RISE - Research Institutes of Sweden (Sweden), DTU Aqua (Denmark), and NORCE (Norway). Ocean Tunicell produces **biomedical** nanocellulose from the tunicate *Ciona intestinalis*. ArcticZymes Technologies produces enzymes derived from the Arctic marine environment for molecular research and diagnostics.

9.1.2 Novel marine bioproducts and value chains

Novel marine bioproducts such as bioplastics, bulk chemicals, and fertilizers, also feature as relatively high value-added in Figure 9-1. We briefly review some key trends in these emerging value chains.

9.1.2.1 Marine bioplastics reaching the market

The need to replace fossil-based polymers and increasing concerns about the effects of plastic pollution in food and ecosystems, are drivers for developing bioplastic. Seaweed contains sugars suitable for producing bioplastics with a range of uses. An example is the edible seaweed water pods provided under the 2019 London Marathon, replacing single-use plastic cups and bottles (Watts, 2024). In addition to providing alternatives to single-use plastic and food wrapping, seaweed is also being used as a novel type of fabric in clothing. For instance, the seaweed fabric Kelsun has been used by clothing brands like Stella McCartney and H&M

(Sweet, 2025). Shells of crustaceans such as shrimp, crab and crayfish contain the polymers chitin and chitosan which both hold potential for bioplastics.

9.1.2.2 Increased upcycling of fish by-products

Today, large volumes of fish by-products not used for food are either processed into pet food, aquafeed, or used for biogas production. Figure 9-1 highlights opportunities to increase the value added of these by-products by finding new and innovative ways of processing them, where key learnings can be drawn from examples in Iceland and Norway:

- A range of Nordic companies are focusing on **nutraceuticals** from the ocean. Examples are omega-3 supplements derived from fish trimmings (Möllers, Nutrimar, Hofseth Biocare) and new fisheries resources such as Antarctic krill (Aker Biomarine) and *Calanus* copepods (Zooca).
- Calcium supplements are made from fish bones (Hofseth Biocare), while fish skin rich in collagen is used to develop supplements.
- In Iceland, the company Kerecis produces fish skin for **medical purposes** such as wound care and tissue regeneration.
- Fish skin is also making its way into the **fashion** industry as the Icelandic company Nordic Fish Leather, and the Norwegian companies Norsk Fjordskinn, Norskin and STUDIO EBN, base their leather products on skin from salmon and spotted wolffish.

Utilization of existing raw material, such as nutrients sourced from Atlantic salmon (for feeding the same species), and gene editing techniques like CRISPR, are identified as possible impactful ways of improving circularity and environmental impact from the aquaculture feed industry and production, although considered somewhat controversial.

9.1.2.3 Utilization of fish sludge

The large-scale farming of salmon in the Nordics generates substantial amounts of fish sludge (feed spill and faeces). This waste is rich in nutrients, but due to the additional costs and lack of incentive, only a handful of companies are currently collecting and using it. Currently, the main use of collected sludge is in the production of biogas, as well as fertilizer. Other uses are under consideration – for example, as feed for invertebrates. Sele *et al.* (2024) investigated this use case, finding that the sludge is nutrient-rich but could also contain undesirable substances.

In closed and land-based fish farms, the farmers can collect sludge relatively efficiently, as they control the waterflow in and out of the system. In open-net pens – the most widely used fish farm systems - collection of sludge is more challenging as water is flowing freely through them. However, there has recently been a drive to implement collection systems in these systems as well, which has led to several innovative solutions. In the future, this unutilized resource can become a new source for biogas and fertilizer, to name two examples.

9.2 Seabed mining

Seabed mining, an emerging sector of the ocean economy, refers to the extraction of mineral deposits from the seafloor. Deep seabed ores of relevance typically contain copper, gold, cobalt, lithium, nickel, and rare earth elements (REE). REE are a group of minerals, such as scandium and yttrium, with catalytic and magnetic properties useful in the energy transition. REEs are seen as particularly vulnerable from an availability perspective, since China controls most of the world's supply.

Seabed mining includes existing activities such as mineral extraction (dredging) in shallow waters, as well as deep-sea mining in deeper waters (e.g. > 400 m depth). Deep-sea mining has not yet moved past the exploration and resource assessment stage, except for test activities in a few technology pilots.

The three main types of deep-sea mining resources are: 1) seafloor massive sulphides (SMS) which are found at hydrothermal vents at oceanic ridges, 2) polymetallic nodules found on sediment surfaces, and 3) ferrometallic crusts accumulated on hard-rock substrates (Solheim *et al.*, 2023). In the Nordics, seafloor massive sulphides feature in, for example, the Norwegian EEZ, between Svalbard and Jan Mayen, far offshore and in deep waters (Solheim *et al.*, 2023). The extraction of nodules has been proposed in the Bothnian Bay, with Scandinavian Ocean Minerals prospecting on two sites east of Skellefteå in Sweden, at depths between 60 and 120 metres (Deep Sea Reporter, 2024).

The energy transition and geopolitics are key drivers for seabed mining activities. The **energy transition** requires large amounts of metals for applications such as batteries, electric vehicles, and wind turbines. With rising demand, metal prices could rise sufficiently to make seabed mining profitable in the future. With the dominance of a few actors in the metals supply chain, **geopolitics** is also an argument for extracting seabed minerals. China controls a large fraction of the rare earth elements needed for the energy transition, implying high geopolitical risk. The EU *Critical Raw Materials Act* is one example of legislation at EU level that aims to secure mineral supplies through increased production in the EU.

Seabed mining offers an opportunity to increase the supply of locally sourced minerals, thereby contributing to resilience in European metals supply chains. Secondly, technology providers in the offshore sector sees this as a new market – for instance, to sell equipment to operators globally. For example, ships for diamond dredging offshore Namibia have been designed and built in Western Norway. Companies delivering subsea technologies for offshore applications in the oil and gas industry see deep-sea mining as a promising new market if activity in offshore oil and gas declines.

The barriers to seabed mining fundamentally relate to the need for a precautionary approach to its environmental impact, due to the limited understanding of ecosystem structure and functioning in the deep ocean. This is explicitly addressed at the EU level, where there is limited willingness to source minerals provided from seabed mining, thereby significantly limiting market access. The EU moratorium on deep-sea mining, which is also supported by the majority opinion in the Nordic Council, is evidence of heavy resistance (Nordic Council, 2024). Similar political disagreement and lack of public acceptance also slow the regulatory timeline in more positively inclined countries (e.g. Norway). This negatively impacts the ability of deep-sea mining firms to access capital, as seen in the recent bankruptcy of Loke Marine Minerals (Bryan, 2025).

Moreover, advances in existing metals supply chains and land-based mining can also reduce the need for new mining activities. Circular metal supply chains have the potential to reduce the need for new minerals in the market, exemplified by LKAB's plans for processing critical minerals from iron ore mining waste streams close to Gällivare in Sweden (LKAB, 2024). Land-based ores across the Nordics (e.g. in Finland, Greenland, Norway, and Sweden) are candidates for development, also reducing the need for developing a seabed mining value chain.

9.3 Technology for ocean observation, data, and analytics

Technologies for ocean observation, data, and analytics support a plethora of applications across the Nordic ocean industries. These advancements are driven by rising demand for the collection and analysis of ocean data, enhanced by artificial intelligence (AI) and machine learning. The potential for drawing benefits from these technologies is enormous – for instance, by automating remote observations and operations, understanding the human impact on the ocean, monitoring changes in the ocean environment and in infrastructure at sea, meteorological forecasting, and climate tracking. The OECD (2025) recently argued that the ocean economy has been relatively slow to take advantage of digital technologies, and this is an area where the Nordics are well-positioned. With an increasing need for maritime security – for instance, to protect critical infrastructure at sea – surveillance applications also become a big driver of demand. Key digital technologies, several of which can operate together as part of an observational pyramid, and as enablers for 'digital twins' of the ocean, include:

- **Satellite monitoring:** The growing capabilities, availability, and cost-effectiveness of satellite technology – combined with advances in AI and big data – have made satellite data increasingly more actionable. Platforms are delivering ever more accessible and consolidated information products based

on earth observation. These are increasingly fit for purpose in environmental monitoring programmes (e.g. Ocean Monitoring Indicators) (EU Copernicus Marine Service, 2025) and are becoming essential for ocean industries, such as their application in detection of algal blooms that harm fish farming (Hommedal, 2024). The Esrange Space Center in Kiruna and Andøya Spaceport are examples of how the Nordics are playing a key role in the development of European satellite launch capabilities (Ahlander, 2025).

- **Unmanned and autonomous vehicles.** These collect in-situ ocean data, in some cases on a continuous basis. Some of these vehicles are part of offshore operations, such as autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), and autonomous surface vessels (ASVs), based on innovations often anchored in offshore technology. Another example is dedicated ocean science infrastructure, like floaters following ocean currents coordinated under the Global Ocean Observing System, and its European and Arctic components (Euro Argo, 2025). This monitoring system delivers in-situ accounts of ocean conditions, enabling early detection of anomalous conditions such as marine heatwaves, contamination, and hypoxia.
- **Ship- and structure-mounted sensor systems:** These are essential for decision-support during operations in maritime, offshore energy, and seafood, but increasingly also serve additional functions ('dual use') such as military surveillance and biodiversity monitoring. One example, cameras for bird detection and tracking, are in operation at the Hywind Tampen floating offshore wind farm (Spoor, 2023). With Nordic shipowners owning and operating a large share of the world fleet, this also represents a key opportunity to utilize these assets as a resource for data collection across vast, little-explored ocean areas (Danish Ship Finance, 2025; Wallenius Wilhelmsen, 2025).
- **Marine analytics** capabilities are rapidly expanding as computational power becomes cheaper and large-scale data centres are developed. Aker, a Norway-based investment company with large interests across ocean industries, owns the major offshore Internet-of-Things actor Cognite, whose technology forms the backbone of HUB Ocean's ocean analytics platform (Cognite, 2024).
- **Computing infrastructure:** This is essential for the rapid scaling of digital technologies in the ocean economy. Data centres are believed to be one of the largest new drivers of energy demand on the global scale, and with ample access to cold seawater for cooling, the Nordics could have an edge in this sector. As an example of the integration of the nascent data centre sector and the ocean economy, Aker recently partnered with NScale and Open AI to establish a large-scale data centre in Northern Norway (Nscale, 2025). This step secures priority access to the growing Nordic AI industry, which serves many ocean-related use cases.

10. Conclusions

This report explores future development trends and identifies opportunities and barriers to strategies for blue growth and development of novel ocean value chains across the Nordic region. Based on four future scenarios based on the Shared Socioeconomic Pathways framework, we explore strategic uncertainties and divergent policy trends that impact the ocean industries to 2050. By reviewing sectoral status and outlook for the Nordic region, elaborating on scenario developments, and carefully addressing interlinkages between the major ocean industries, the report puts forward new knowledge and foresight for the development of a resilient ocean economy in line with the Nordic Vision to 2030 and beyond. This chapter concludes by synthesizing key takeaways.

To address the capacity of the Nordic ocean economy to be resilient given a variety of potential futures, we presented four scenarios. The four scenarios range from describing the Nordics in 1) 'Nature First' - a world shaped by international collaboration to fight climate change and improve environmental sustainability, to 2) 'Constant Compromise' - a world with constant compromises between priorities related to growth and environmental sustainability, to 3) 'Regional Rivalry' - a world with weakened international collaboration, increased trade barriers, and focus on national security, and 4) 'Growth First' - a world in which economic profitability always takes precedence.

Nordic collaboration is supported by a large diversity in economic activity at sea.

The study shows a large variation in the importance of the ocean economy to national economies in the Nordics, and in the role each sector plays nationally. Åland, the Faroe Islands, Greenland, and Iceland share a strong dependency on seafood, with marine and coastal tourism playing an increasing role. Among the four major Nordic countries, Norway is by far the most reliant on its ocean industries, with clusters across the energy, seafood, and shipping value chains, but also with substantially higher dependency on raw materials such as energy commodities and seafood, compared to Denmark, Finland, and Sweden. The latter three score better on innovation overall (NVCA, 2025; WIPO, 2025) and spend more on research and development (World Bank and OECD, 2025), positioning them well to take leading roles in emerging ocean sectors – with Denmark's offshore wind sector as a key example.

Nordic collaboration will be necessary to take full advantage of the **forthcoming productivity gains from digitalization**. This is becoming increasingly important as the working-age population stagnates and access to labour reduces. Across shipping and offshore activities, the advantages of digitalization are evident in increasing levels of autonomy. In the seafood sector, digitalization is driving better management through monitoring, decision support, and control, on both the policy

and business sides. Another example is tourism, where collaborative economy platforms – a technology from outside the blue economy – make available large infrastructure reserves such as summer houses, reducing the pressure to scale up accommodation capacity and personnel to realize growth.

The Nordic ocean economy can improve the resilience of European energy, food, and mineral supply chains, and Europe's maritime industry. This is particularly valid in the current geopolitical landscape, where concerns about national security and competitiveness are gaining traction across Europe, sometimes at the expense of considerations regarding environmental sustainability. Offshore energy is a key example where the Nordics will continue playing a role to support European resilience through the growing offshore wind sector and continuation of offshore gas exports to Europe, both of which will be increasingly coupled with low-carbon technologies. Another example is the critical role of the Nordics in securing European mineral supply chains, exemplified by the critical role the port of Narvik plays in safeguarding European access to Sweden's iron ore supplies. In maritime, Nordic leadership in digitalization and decarbonization can be attributed to the completeness of local value chains, and well-functioning maritime clusters. To safeguard the maritime clusters, Danish, Finnish and Norwegian shipyards and equipment providers need to drive new and innovative solutions and build on knowledge-intensive roles and service delivery to justify the cost premium relative to competitors in low-cost regions.

The Nordic ocean economy needs to balance considerations of ocean health and ocean wealth. The use of scenarios also sheds light on the trade-offs that exist, at least in the short term, between considerations related to ecological integrity and ecosystem services and economic activities at sea. All Nordic sea areas are under severe stress from a combination of pressures originating both within the ocean economy and from land-based activities, and restoration and conservation efforts are increasingly prioritized by policymakers at international, EU, and national levels. Cross-border environmental impacts are important to consider in the development of offshore wind and the management of fisheries, aquaculture, and ecosystems. As a semi-enclosed sea, the Baltic Sea offers an interesting test case for the effectiveness of measures which require cross-border coordination (e.g., through HELCOM), which can be emulated in other Nordic sea areas.

The seafood and tourism sectors are particularly dependent on well-functioning ecosystem services for their value creation. The fisheries sector is especially important in this regard, as it can only sustain itself if ecosystem services function well. The fisheries are the most important ocean industry for the Faroe Islands, Greenland, and Iceland, illustrating the role ecosystem services play in sustaining livelihoods in smaller, coastal communities across the Nordics. Tourism, also a fast-growing industry in small, coastal communities (e.g. in Greenland and Iceland), sees similar ecosystem dependencies for attracting visitors, suggesting a cautious approach is needed to prevent ecological degradation in new tourist areas.

Due to its potentially large spatial footprint, offshore wind has triggered concerns about coexistence with other industries and nature. Offshore wind developers have taken a proactive stance on coexistence, with efforts to co-locate with activities that could have a positive environmental impact, such as low-trophic aquaculture and nature-inclusive designs. Offshore wind offers an interesting **test case for how ecosystem services can be monetized** through development of nature credits or tendering criteria, explicitly rewarding initiatives that have a positive nature impact. A first-mover position on nature valuation could enable the Nordics to more effectively balance ecosystem impacts with development of new economic activity at sea, with principles that can be adopted across ocean sectors and exported elsewhere.

Innovation opportunities in the Nordic ocean economy are cross-sectoral. The fast-growing offshore wind industry shows how new offshore activities make use of knowledge transfer opportunities, particularly from the pre-existing offshore and maritime industries, where the Nordics have a clear advantage. The use of offshore technology from oil and gas in offshore wind and CCS offers clear examples, as does the continued advantage of Nordic ship designers and technology providers in special ship segments for offshore wind.

There are also several cross-sector innovations in seafood, especially in the interplay between novel ocean value chains, aquaculture, fisheries, and the land-based food system. Novel ocean value chains that aim to valorize biomass waste streams by developing new products or fish feed are examples that reduce both dependency on global supply chains and the pressure on natural resources for raw material inputs. Examples include the **circular business models** that utilize biomass waste streams to feed insects, which then are looped back into feed production as insect meal, thereby reducing the need to import feed ingredients.

The scenario approach used in this report highlights the need to identify future-proof strategies for new developments in the Nordic ocean economy. The large diversity in the Nordic countries' ocean economies suggests that the **competitive advantages for the Nordic ocean economy** lie where there are big opportunities for cross-border and cross-sector collaboration. By driving attention towards the areas where synergies and knowledge transfers can drive added value, while focusing on strategies that are resilient to disruption under a variety of future scenarios, the Nordic ocean economy can thrive – to the benefit of a Nordic region that is green, competitive, and socially sustainable.

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External consultations

A number of consultations with stakeholders within the Nordic ocean economy have been carried out in preparing this report. Most of these consultations were conducted as interviews with questions about current and future trends, scenario pathways, and the potential for Nordic collaboration in the ocean economy. The experts consulted were:

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Reviewers

Selected experts were also invited to review the final report. The following DNV colleagues contributed as reviewers of the report: Per Arild Åland, Caryl Benjamin, Ingeborg Hutcheson Fiskvik, Trude Heggstad, Eduard Romanenko and Nafiha Usman.

About this publication

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