BLUE MISSION BANOS

Supporting the Mission Ocean Lighthouse in the Baltic and North Sea Basins

Deliverable 5.1 Sustainable climate-friendly; circular Blue Economy in the BANOS Area: Current Status and Assessment and Monitoring Approaches

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Author(s)	Anda Ikauniece (LIAE); Aurelija Armoskaite (LIAE); Eero Asmala (GTK); Karoliina Koho (GTK); Liisi Lees (UT); Maciej Zdanowicz (NCBR); Merli Rätsep (UT)
Project Officer	Daniele De Bernardi
Editor(s)	Chantal Martens (VLIZ); Joanna Przedrzymirska-Ziółkowska (IO PAN)
Approved by	Angela Schultz-Zehden (SUB)
Abstract	This report presents three comprehensive desktop studies focused on the sustainable blue economy in the Baltic and North Sea area. These studies included research and national surveys to: 1) provide an overview of sustainable blue economy sectors, identifying regional priorities and industry challenges in achieving carbon neutrality and circularity; 2) analyse assessment practices related to the sustainable blue economy, including policy evaluation practices and indicators at both national and EU level; and 3) assess current industry approaches, strategies, and frameworks for achieving and measuring carbon neutrality and circularity.
Keywords	BlueMissionBANOS, Mission Ocean, monitoring, indicator, KPIs, sustainable, blue economy, Baltic Sea, North Sea

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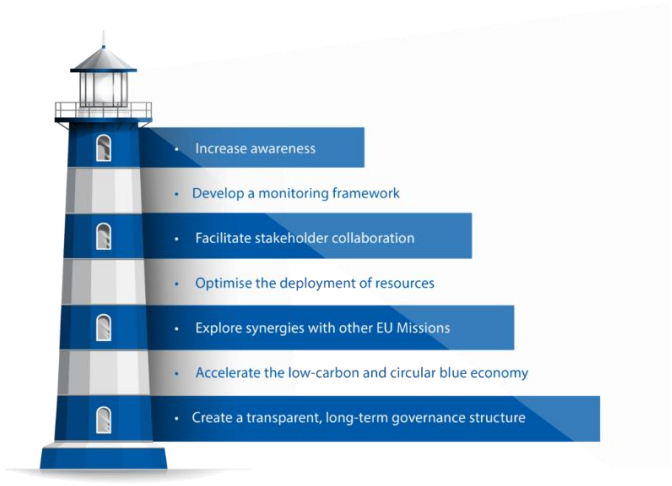
BLUEMISSIONBANOS PROJECT

BlueMissionBANOS (BMB), as a Coordination and Support Action (CSA) for the Baltic and North Sea (BANOS) Mission Ocean Lighthouse, inspires, engages, and supports stakeholders across the BANOS region in taking positive action to reach the Mission Ocean objectives. In particular, we facilitate the uptake of a sustainable, carbon-neutral, and circular blue economy by connecting national, regional, and transnational actors from politics, industry, and science, thereby creating a governance model that is conducive to innovation.

While fostering the transition towards the blue economy, BlueMissionBANOS supports the prevention and elimination of water pollution and the protection and restoration of biodiversity and marine and freshwater ecosystems. The project focus is on work reducing governance fragmentation, facilitating evidence-based decision-making and foster citizen engagement across the BANOS area. These supporting actions raise awareness, showcase opportunities, and inspire stakeholders to actively contribute to the transition and the preservation of oceans, seas and waters to 2030 and beyond.

To accelerate the transition towards an innovative and circular blue economy, in line with regions' strategic priorities, as defined by their Smart Specialisation Strategies (S3), BlueMissionBANOS organises regional pilot demonstration arenas (Mission Arena) involving innovators, business support and training organisations, local stakeholders and any interested parties to accelerate the uptake of innovative solutions in support of Mission Ocean. Furthermore, BlueMissionBANOS develops a consistent monitoring framework to assess progress in achieving carbon neutrality and circularity.

Finally, BlueMissionBANOS facilitates synergies and matchmaking between actors working towards achieving the Mission Ocean objectives in the BANOS area, by providing a catalogue of services, technical expertise and projects that can foster progress, collaboration, and knowledge sharing. The BlueMissionBANOS project is funded under the call HORIZON-MISS-2021-OCEAN-04 by the European Union under Grant Agreement ID 101093845 and runs from December 2022 until November 2025.



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BLUE MISSION BANOS

TABLE OF CONTENT

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BLUE MISSION BANOS

LIST OF FIGURES

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BLUE MISSION BANOS

LIST OF TABLES

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ACRONYMS

ASC	Aquaculture Stewardship Council
AIS	Automatic Identification System
BMB	BlueMissionBANOS - Supporting the Mission Ocean Lighthouse in the Baltic and North Sea Basin
BSAP	Baltic Sea Action Plan
BE	Blue Economy
CCUS	Carbon capture, utilization, and storage
CII	Carbon Intensity Indicator
CEAP	Circular Economy Action Plan
CFP	Common Fisheries Policy
CTV	Crew transfer vessel
DCS	Data collection system
EAF	Electric arc furnace
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing Ship Index
EPI	Environmental Port Index
ESI	Environmental Ship Index
EU ETS	EU Emissions Trading System
EUSBSR	EU Strategy for the Baltic Sea Region
ECL	European Climate Law
EEA	European Environment Agency
EMSA	European maritime safety agency
ESPO	European Sea Ports Organisation
ETIP	European Technology and Innovation Platform
EU	European Union

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GMF	Global Maritime Forum
GES	Good Environmental Status
GHG	Greenhouse Gas Emissions
GDP	Gross domestic product
HELCOM	Helsinki Commission (Baltic Marine Environment Protection Commission
ICT	Information and communications technology
IMP	Integrated Maritime Policy
IMS	Integrated Maritime Services
IOC	Intergovernmental Oceanographic Commission
IAPH	International Association of Ports & Harbors
ICS	International Chamber of Shipping
IMO	International Maritime Organization
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LTA	Low-trophic aquaculture
MPAs	Marine Protected Areas
MSFD	Marine Strategy Framework Directive
MSP	Maritime Spatial Planning
MSPD	Maritime Spatial Planning Directive
MAPs	Multiannual Plans
NZIA	Net Zero Industry Act
NEAES	North-East Atlantic Environment Strategy
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo-Paris Convention (for the Protection of the Marine Environment of the North-East Atlantic)

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PA	Policy areas
PINE	Policy Instruments for the Environment
PP	Project Partners
SOV	Service operation vessel
SEEMP	Ship Energy Efficiency Management Plan
SRIA	Strategic Research and Innovation Agenda
SBE	Sustainable Blue Economy
TWh	Terawatt-hours
BESF	The Blue Economy Sustainability Framework
EUMOFA	The European Market Observatory for fisheries and aquaculture
UNECE	The United Nations Economic Commission for Europe
UNESCO	The United Nations Educational, Scientific and Cultural Organization
URL	Uniform Resource Locator
UN	United Nations
VASAB	Vision and Strategies Around the Baltic Sea
WFD	Water Framework Directive
WP	Work package

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BLUE MISSION BANOS

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BLUE MISSION BANOS

EXECUTIVE SUMMARY

This report, part of the BlueMissionBANOS project deliverable 5.1, presents an in-depth study of the Mission Ocean relevant blue economy sectors in the Baltic and North Sea (BANOS) region. The study includes a series of national surveys, desk research and expert consultations to identify regional priorities, challenges, and gaps in achieving sustainability, carbon neutrality and circularity in these sectors.

The report examines current assessment practices and indicators used at national and EU level. It assesses existing methodologies and highlights existing indicators relevant to sustainable blue economy initiatives.

The results of the analysis underline the diversity of approaches in different countries within the BANOS area, reflecting different levels of progress and focus. The report also highlights the need for greater coordination and integration of strategies across the region to effectively harness the potential of the blue economy.

The report provides key insights for policy makers, industry stakeholders and researchers, and serves as a fundamental resource for guiding future policies and practices in the sustainable blue economy sectors of the BANOS region.

The report also provides an important steppingstone for developing key performance indicators (KPIs) for sustainable blue economy in the BANOS area, BlueMissionBANOS project deliverable 5.2 KPIs for a carbon-neutral, circular blue economy.

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INTRODUCTION

A sustainable blue economy promotes economic growth, social inclusion and improved livelihoods while ensuring the environmental sustainability of the natural capital of the oceans and seas (European Commission 2021a). The blue economy includes marine-based or marine-related activities (European Commission 2022). In the broad sense, it includes all industries and sectors related to the ocean, seas and coasts, whether they are based in the marine environment (e.g. shipping, fisheries, energy generation from tides, waves or wind), or on land (e.g. ports, shipyards, land-based aquaculture, coastal tourism) (European Commission 2023).

In 2021 the EU Commission launched 5 so-called 'EU Missions' as a new type of programme. Of these, the EU Mission "Restore our Ocean and Waters" aims to protect and restore the health of our ocean and waters through research and innovation, citizen engagement and investments. To carry out the mission, Europe was divided into four Lighthouse Areas: The Baltic Sea and the North Sea; the Atlantic and Arctic Coasts, the Mediterranean Sea and the Danube Basin. The mission is planned in two phases: pilot and implementation. In the pilot phase, innovative solutions are developed, with each basin focusing on finding solutions for a specific goal:

- Danube Basin: protection and restoration of ecosystems and biodiversity (freshwater),
- Atlantic and Arctic coasts: protection and restoration of ecosystems and biodiversity (marine),
- Mediterranean Sea: pollution prevention and elimination,
- Baltic and North Sea basin: making the blue economy carbon neutral and circular.

The blue economy is widely recognized as playing a significant role in the global economy and has been subject of extensive discussion at both national and international levels. However, a consensus on how to measure its impact remains elusive, largely due to varying accounting methodologies used in different studies, which often lead to divergent results (Kwiatkowski and Zaucha, 2023).

The aim of this report is to study current practices and datasets in the Baltic and North Sea (BANOS) area to map the situation and create a baseline for a Monitoring Framework for Sustainable, Carbon-Neutral and Circular Blue Economy, that is necessary to study the progress towards the three specific objectives of the Baltic and North Sea Lighthouse: (i) Net Zero Emissions to the Sea, (ii) Zero Carbon Aquaculture and (iii) Low-Emission and Comprehensive Use of Marine Space. Based on the baseline study by Technopolis, the following sectors have been analysed in the BlueMissionBANOS project with focus on their carbon neutrality and circularity:

1. **Waterborne transport** includes freight (goods, vehicles, etc) and passenger movement using both maritime and inland waterways. This involves different types of watercrafts, such as ships, cargo and passenger ferries, cargo and fishing vessels and cruise ships. The definition is based on Debah 2010, UNCTAD 2018, Grosso et al. 2021, Waterborne Technology Platform 2021.

2. **Ports and associated facilities** include the infrastructure necessary for transport operations within the port area. Ports are places purposely built for the loading, unloading, storage, and handling of cargo, as well as the boarding and disembarking of passengers from ships and boats. These locations are crucial hubs in the transportation network, acting as important links between land-based and water-based transport systems. Associated facilities include basic port infrastructure that

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comprise berths, cargo handling gear, storage spaces, passenger terminals, customs, and security structures, fuelling and maintenance spots, administrative buildings, and more. (European Commission 2013, 2017, Sekimizu 2012, UNECE 2022)

3. **Renewable 'blue' energy production and storage facilities** refer to infrastructure and technology that capture and store renewable energy from marine and aquatic sources, such as the ocean, seas, rivers, and lakes. This approach focuses on utilizing kinetic energy, thermal gradients, and other natural phenomena associated with water bodies to generate electricity and other forms of energy. It includes multipurpose platforms, wind farms, wave & tidal, hydropower, power-to-x. It is a way to produce power while reducing greenhouse gas emissions. The definition is based on European Commission 2020, Directive EU 2018/2001.

4. **Low trophic aquaculture** refers to a relatively sustainable and environmentally friendly approach to cultivate low-trophic species such as algae, filter-feeding shellfish (e.g., mussels, oysters), herbivorous fish, and invertebrates (European Commission, 2021b). Such species do not require extra feed, but live and grow from the nutrients in the water. They are therefore environmentally and climate positive in various ways: they filter and remove nutrients from ambient water and offer an alternative to land-based agriculture. It includes circularity aspects as well as challenges and opportunities in processing in view of achieving an overall positive 'Mission' related impact.

In addition to 4 sectors, this report explores the Mission relevant concept of **multi-use** in marine spaces, which refers to the combined use of resources in close geographical proximity, either by a single or multiple users. This approach spans a diverse array of combined activities in marine environments, indicating a transition from the traditional model of exclusive resource rights to a more collective approach of resource and space sharing (Schupp et al., 2019). The activities in question, such as aquaculture, renewable energy generation, shipping, and tourism, are combined to enhance both efficiency and sustainability.

To analyse the above sectors, methods such as desk research, data analyses using various open databases, case studies, workshops and questionnaires were used.

This report has been prepared under the Monitoring Work Package (WP5). It combines the results of three desktop studies focusing on the sustainable blue economy in the Baltic and North Sea regions. These studies, consisting of desk research and national questionnaires, have three main objectives:

1) to provide a comprehensive overview of the sustainable blue economy sectors, identifying regional priorities and industry challenges in achieving carbon neutrality and circularity;

2) to examine the practices used to assess the sustainable blue economy, including the evaluation of policies and indicators at national and EU level; and

3) to assess the current approaches, strategies and frameworks used by industry to achieve and measure carbon neutrality and circularity.

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The findings of this report will feed into Task 5.2 of the BlueMissionBANOS project, in particular Deliverable 5.2 to identify best practices, frameworks and approaches to formulate preliminary Key Performance Indicators for a sustainable, carbon neutral and circular economy.

We would like to acknowledge all project partners who contributed to this report. We express our gratitude to the following individuals, listed alphabetically: Eero Asmala (GTK), Aurelija Armoskaite (LIAE), Karoliina Koho (GTK), Kinnie De Beule (Blauwe Cluster), Emily Cowan (SINTEF), Anda Ikauniece (LIAE), Careen Krüger (PTJ), Liisi Lees (UT), Chantal Martens (VLIZ), H. Cecilie Petersen (SDU), Joanna Przedrzymirska-Ziółkowska (IO PAN), Maciej Zdanowicz (NCBR), Merli Rätsep (UT), Martin Sjöberg (IVL), Angela Schultz-Zehden (SUB), and Alberto Terenzi (SUB). Each of these individuals made significant contributions to this report, and we appreciate their collaborative efforts.

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1. NATIONAL OUTLOOK FOR SUSTAINABLE BLUE ECONOMY SECTORS IN THE BANOS AREA

Authors of this chapter are Aurelija Armoskaite (LIAE) and Maciej Zdanowicz (NCBR), who received national input from Eero Asmala (GTK), Kinnie De Beule (Blauwe Cluster), Emily Cowan (SINTEF), Anda Ikauniece (LIAE), Karoliina Koho (GTK), Careen Krüger (PTJ), Liisi Lees (UT), Chantal Martens (VLIZ), H. Cecilie Petersen (SDU), Joanna Przedrzymirska-Ziółkowska (IO PAN), Merli Rätsep (UT), Martin Sjöberg (IVL), and Floor ten Hoopen (DTU). Their contributions greatly enhanced the content of this chapter.

This overview focuses on the national and macroregional priorities within the BANOS area, specifically targeting the reduction of emissions from waterborne transport, ports, and associated facilities (the 'greening' of these existing maritime activities). Additionally, the overview addresses the emergence and expansion of renewable blue energy production and low-trophic aquaculture sectors. These newer maritime activities are gaining attention as low-carbon alternatives, contributing to the region's overall environmental sustainability goals.

1.1. METHODS

To acquire a national perspective, a survey was circulated among the BlueMissionBANOS project partners. This questionnaire requested participants to outline their national priorities and to pinpoint key documents (refer to Appendix 1). The responses from this survey laid the groundwork for further analysis. This was complemented by a detailed document review, which facilitated the development of a concise overview for each country involved. The report is structured in two segments: initially, it presents an in-depth, country-by-country breakdown of the findings. Subsequently, it offers a synthesized overview, highlighting key takeaway messages to the two macro-regions and the BANOS area as a whole.

1.2. NATIONAL OVERVIEWS

This section provides an overview of the prospects for each of the four sustainable blue economy sectors, analysed country-by-country. National-level goals, objectives and monitoring approaches are identified and described, based on document analysis and questionnaire responses. Special attention is given to documents of national significance, such as maritime spatial plans, sectoral strategic level plans, or climate adaptation strategies. These documents outline national positions and pathways towards greening existing sectors, like shipping and ports, or supporting new, low-carbon emission activities, including the production and storage of renewable energy and low-trophic aquaculture.

1.2.1. Belgium

1. **Waterborne transport**

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The Federal Public Service Mobility and Transport of Belgium represents the International Maritime Organization (IMO) in Belgium and ensures compliance with international maritime standards (Maes et al., 2022). For example, MARPOL Annex VI controls – such as fuel sampling and analysis – are carried out on board vessels in Belgian ports. Additionally, the Management Unit of the North Sea Mathematical Models (MUMM), a department of the Royal Belgian Institute of Natural Sciences, has been measuring vessel sulphur emissions since 2015 and nitrogen emissions since 2021. This is done using sniffer sensors, with results communicated to the Federal Public Service Mobility and Transport. These measures support targeted actions during port inspections and assist in the implementation of the Bonn Agreement. MUMM's work includes developing and utilizing mathematical models for studying and managing the ecosystems of the North Sea.

Strengthening the waterborne transport sector is a central focus of the North Sea Policy Statement of 2020 (Van Quickenborne, 2020). This statement indicates Belgium's intention to maintain a pioneering role in environmental regulations concerning waterborne transport in the North Sea. Specifically, Belgium plans to initiate controls on soot (black carbon) emissions starting in 2021. The results of these tests are intended to lay the groundwork for new international regulations on black carbon emissions.

2. Ports and associated facilities

In 2018, the direct added value to the Flemish economy from the maritime sector was 17.2 billion euros, with an indirect added value of up to 29.1 billion euros, accounting for 10.8% of the Flemish GDP. Belgian seaports rank among the busiest in the world (Maes et al., 2022). The Flemish government and port authorities are focused on reducing local shipping emissions at ports. One strategy involves expanding shore-based power infrastructure, enabling vessels to turn off their engines while docked (The Flemish Port Strategy 2020; Maes et al., 2022). Additionally, the Flemish ports are addressing emissions fraud and promoting the use of more efficient and low-emission trucks (Roadmap for Reducing Climate and Air Emissions from Freight Transport, 2019). Preparations are also in progress at all Flemish seaports to support the supply of liquefied natural gas (LNG) and to introduce cleaner, more environmentally friendly fuel options for ships (Maes et al., 2022).

The Environmental Ship Index (ESI) is a voluntary international scheme that evaluates the environmental performance of ships, scoring them from 0 to 100, with 100 representing the best-performing vessels. In Flanders, port companies use ESI scores to offer reductions in port dues (The Flemish Port Strategy 2020). Furthermore, vessels operating on environmentally friendly fuel are eligible to submit a dossier to the Flemish authorities for reduced fees (Maes et al., 2022).

3. Renewable ‘blue’ energy production and storage facilities

Belgium's first fully developed offshore wind zone has a capacity of 2.2 GW (The Belgian Offshore Platform 2023). An additional area of 281 km², the 'Princess Elisabeth Zone', has been designated for offshore renewable energy production in the Long-Term Vision for Marine Spatial Planning (MSP) 2020-2026. The development of more offshore wind farms in the 'Princess Elisabeth Zone' aims to contribute to the 4 GW target set in the National Energy and Climate Plan by 2030 and support the overall European target of achieving 27% renewable energy in the total energy consumption of a Member State by 2030.

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The North Sea Policy Statement of 2020 further emphasizes the commitment to increase offshore wind energy production in the Belgian part of the North Sea. This includes the development of innovative energy storage solutions both on land and at sea, such as batteries or the conversion of energy into hydrogen. The policy also advocates combining wind energy with other alternative sources like wave energy, tidal energy, and solar panels.

4. Low trophic aquaculture

Two hundred nine tonnes of oysters, including both flat and hollow varieties, were produced in the Belgian coastal zone in 2020, valued at 1.4 million euros (Belgian Strategic Plan Aquaculture 2021-2030). The North Sea Policy Statement of 2020 also mentions the potential for cultivating macroalgae for biofuel as a source of renewable energy.

Table 1. Belgium: key national documents to developing the national priorities for waterborne transport (1), port and associated facilities (2), blue energy (3) and low-trophic aquaculture (4).

Key document	BE Sector priorities			
	1	2	3	4
North Sea Policy Statement 2020 ('Exposé d'orientation politique Mer du Nord' in French; 'Beleidsverklaringen Noordzee' in Dutch), is a document which outlines the Belgian government's policy objectives, strategies, and plans concerning the North Sea. It covers environmental protection, emissions and pollution, economic development, energy and navigation.	X		X	X
The Flemish Port strategy. Concept note (2020) (In Dutch: Vlaamse havenstrategie. Conceptnota) outlines the development and goals for the Flemish ports.		X		
Roadmap for reducing climate and air emissions from freight transport 2019) (in Dutch: Roadmap voor vermindering van klimaat- en luchtemissies van vrachtvervoer. Bijlage. Departement Mobiliteit en Openbare Werken). Describes the most cost-efficient, logical and feasible way to achieve the climate ambitions in a timely manner.		X		
Long-Term Vision for MSP 2020-2026 (2019) is a strategic level plan for using Belgium's maritime space to achieve ecological, economic, and social objectives. Sets the ambitions that by 2050 multi-use is the norm for all use of space within the Belgian North Sea to resolve competition for space. It is legally binding planning document by Royal Decree.			X	
Belgian National Strategic Plan for Aquaculture 2021 – 2030 (2022) (In Dutch: Belgisch Strategisch Plan Aquacultuur 2021 – 2030) is an overview of the Belgian aquaculture sector, with an analysis of strengths, weaknesses, opportunities and threats and the strategic objectives for the period 2021 – 2030 and an environmentally and economically sustainable aquaculture sector, both on land and at sea.				X
The National Energy and Climate Plan by 2030 outlines national offshore targets, including wind energy production.			X	
Belgian Vision for the North Sea 2050 (2017) (In Dutch: Langetermijnvisie Noordzee 2050) by the Think Tank for the North Sea and the State Secretary for the North Sea builds on and guides future Belgian maritime spatial plans and sets a long-term vision describing the development process and principles for the Belgian North Sea. Key topics explored include nature, blue economy, innovation and multi-use.			X	X

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In addition to Table 1 (key national documents), the "Knowledge Guide Coast and Sea 2022 - Compendium for Coast and Sea" serves as a comprehensive reference on the socio-economic, environmental, and institutional facets of the coast and sea in Flanders and Belgium. It includes Chapter 2, which details the present state and future trends in maritime transport, shipping, and port development; Chapter 5 discusses the current and future trajectory of offshore energy development, including aspects related to cables and pipes. Chapter 7 delves into marine aquaculture, providing insights into its status and growth potential, with a focus on seaweed, molluscs, and crustaceans.

1.2.2. Denmark

1. Waterborne transport

The Blue Denmark is one of 14 different Climate Partnerships representing the various sectors of the Danish economy formed to support the reduction of greenhouse gas emissions in Denmark by 70% by 2030. The Blue Denmark provides 21 recommendations on energy efficiency, ports, shipping, green fuels, and climate diplomacy. Because shipping is a global industry, enormously competitive and sensitive to regulation, the general position in Denmark is that the regulation should go through the IMO (DK2030 2022; Klimapartnerskab for Det Blå Danmark 2021). At the same time, Blue Denmark aims to reach climate neutrality by 2050 without relying on carbon offsetting and have the first ocean-going zero-emission vessel commercially operational by 2030. In the *Klimapartnerskab for Det Blå Danmark Sektorkøreplan* (2021) (In English: Climate partnership for the Blue Denmark Sector Roadmap), Blue Denmark emphasises that shipping companies do not produce fuels, they depend on being integrated into a green energy system, therefore renewable 'blue' energy production and storage facilities are a prerequisite for decarbonising the shipping sector.

The international public-private partnership, 'Zero-Emission Shipping Mission', is led by the Danish Maritime Authority. This global public-private partnership published an Industry Roadmap for Zero-emission shipping by 2030 (Zero-emission Shipping Mission 2022), which identifies innovation gaps and introduces goals for vessels that operate on zero-emission fuels, as well as goals for scaling up production of zero-emission fuels (ammonia, methanol, advanced biofuels, and hydrogen) and developing a global port infrastructure to support zero-emission vessels. It also developed six Key Performance Indicators for tracking the progress of alternative fuel use in the shipping industry (Zero-emission Shipping Mission 2023), among other incentives.

2. Ports and associated facilities

The Blue Denmark Partnerships emphasises the role of the industry in reducing waiting time in ports and the role of government in supporting the development of new energy infrastructure for ports, green highways and green ferry tenders and services (The Danish Government's Climate Partnership 2021). It also highlights that the energy infrastructure on land and in ports must be upgraded to enable it to handle new types of fuels (*Klimapartnerskab for Det Blå Danmark Sektorkøreplan* 2021). Danish ports and the Danish government are in dialogue, and the ports plan to phase out all fossil strain fuels in the ports' machines by 2025 and base all Danish ports' energy consumption on renewable energy by 2030 at the latest.

3. Renewable 'blue' energy production and storage facilities

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The Climate Partnership for Energy and Utilities indicates that there is potential for offshore energy to produce 40 GW of energy. Of this, 15 GW would contribute to achieving carbon neutrality in Denmark, defined as reducing emissions by more than 95% since the 1990s. Additionally, 25 GW could be exported (The Danish Government's Climate Partnership 2021).

4. Low trophic aquaculture

Mussel and oyster farming in Denmark takes place within zones defined in the Danish Maritime Spatial Plan. However, due to issues such as the high concentration of organic matter and concerns about privatizing sea space and seascapes, the Minister of Food halted new applications for mussel farming licenses in 2021. The Ministry of Food, Agriculture and Fisheries is currently developing a proposal for a new approach to shellfish farming. Additionally, in several Danish waters, seaweed (primarily sugar kelp) is commercially cultivated both as food and as a way to mitigate pressures on marine ecosystems from other activities.

Table 1 Denmark: key national documents to developing the national priorities for waterborne transport (1), port and associated facilities (2), blue energy (3) and low-trophic aquaculture (4).

Key document	BE Sector priorities			
	1	2	3	4
Climate partnership for the Blue Denmark Sector Roadmap (2021) (In Danish: Klimapartnerskab for Det Blå Danmark Sektorkøreplan) by the Danish Government's Climate Partnership Blue Denmark.	X	X	X	
DK2030 Greener, Safer and Stronger Denmark 2030 (In Danish: DK2030 Et grønnere, sikrere og stærkere Danmark 2030) is the government's economic policy pathway to 2030.	X			
Danish national strategy for aquaculture 2021-2027 (in Danish: Strategi for en bæredygtig Akvakultursektor 2021-2027) is focused on environmental solutions to reduce the environmental impacts of aquaculture. The strategy has six action areas: (1) Land-based fish farming, (2) Low trophic aquaculture, (3) Organic aquaculture, (4) Research, development and innovation, (5) Product development, marketing and consumer information, (6) Education and qualified labour.				X
Climate Partnerships for a Greener Future (2021) by the Danish Government's Climate Partnerships describes the approach to public-private action and aims of the 14 climate partnerships, their goals and recommendations.	X	X		
The Danish Maritime Spatial Plan Explanatory Notes (2021) stresses the significance of multi-use and designation of space for multiple purposes as competition for space increases. The Danish Maritime Spatial Plan designates areas for aquaculture (including mussel and oyster cultivation), offshore wind farms and most direct shipping and transport routes to reduce emissions.	X		X	X

1.2.3. Estonia

1. Waterborne transport

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The Estonian Transport and Mobility Development Plan 2021–2035 (2021) and the Estonian Maritime Strategy White Paper 2022-2035 (Majandus- ja Kommunikatsiooniministeerium, 2022) emphasize the need for energy-efficient modern technologies (such as automatic mooring systems, alternative fuels for ships, and creating a bunkering market) to support circular economy practices in the maritime sector and facilitate a move towards climate neutrality. In line with European Union targets, the Estonian government has set goals to reduce the greenhouse gas emissions of the transport sector by 30% relative to 2018 levels (Majandus- ja Kommunikatsiooniministeerium, 2023).

Estonia's 2030 National Energy and Climate Plan (2019) envisions the electrification of ferries between the mainland and the islands of Saaremaa (100% of the connection). This electrification is expected to result in a reduction from 2023 on the Saaremaa line by 8072 t CO2/year and on the Hiiumaa line by 4120 t CO2/year, potentially reducing emissions by up to 110,000 tonnes of CO2 by 2030.

2. Ports and associated facilities

The Estonian Maritime Strategy White Paper 2022-2035 highlights the role of ports in achieving climate neutrality, specifically the need for onshore power supply to limit emissions at ports. The white paper also suggests the use of port charges as a way to award environmentally well-performing vessels.

3. Renewable 'blue' energy production and storage facilities

Estonia's 2030 National Energy and Climate Plan (2019) and the Low Carbon Strategy 2050 (2017) state that the national target is to reduce greenhouse gas emission levels by approximately 70% compared to 1990 by 2030, 72% in 2040 and 80% by 2050. Additionally, at least 42% of total final energy consumption is sourced from renewable energy by 2030. To increase the share of renewable energy and meet targets, the Estonia Government currently runs reverse auctions. It plans to invest in research and development programmes under Estonia's 2030 National Energy and Climate Plan, conduct wind farm feasibility studies to attract developers and cross-border projects in the Gulf of Riga and analyse the impacts, risks, and benefits of renewable energy projects on local communities (Estonia's 2030 National Energy and Climate Plan 2019). The Estonian Maritime Spatial Plan (2021) states that marine space must be used to produce renewable energy. The current focus is on developing the wind energy sector, and the plan presents areas suitable for wind energy development. The estimated offshore wind potential by 2030 is 7000 MW (The Estonian Maritime Spatial Plan 2021).

The Estonian Maritime Spatial Plan (2021) also states that the coastal sea areas adjacent to densely populated areas may, in the future, also be used for other types of renewable energy production (e.g., cooling, and thermal energy, hydrogen production and in exceptional cases floating solar plants and wave energy solutions). In the longer term, the development of distributed energy could also be considered to enable coastal communities to develop energy solutions to meet their needs. Additionally, the Low Carbon Strategy until 2050 emphasises that Estonia needs to facilitate renewable energy production technologies and knowledge-based, ecological, and sustainable upcycling of biomass and other renewable energy resources for producing electricity, heat and fuel for transport.

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4. Low trophic aquaculture

The Agriculture and Fisheries Strategy 2030 (Ministry of Rural Affairs of Estonia, 2021) highlights the development of algae, shellfish, and multitrophic (algae, shellfish, and fish) farming, upskilling of the current workforce, and implementing international cooperation as key action points. These steps aim to achieve an environmentally conscious, sustainable, and competitive fisheries sector.

Table 2 Estonia: key national documents to developing the national priorities for waterborne transport (1), port and associated facilities (2), blue energy (3) and low-trophic aquaculture (4).

Key document	BE Sector priorities			
	1	2	3	4
The Estonian Maritime Spatial Plan (2021) was officially adopted in 2022 and is legally binding (based on the Planning Act – in force since July 2015). Chapter 5.4 covers the future development of the waterborne transport sector with a sub-chapter on the development of ports but does not mention decarbonisation. Chapter 5.6 covers renewable energy production. Chapter 5.3 covers aquaculture; however, low-trophic aquaculture is not mentioned.	X	X	X	
Estonia's 2030 National Energy and Climate Plan (2019) sets the national targets to achieve the energy and climate policy targets agreed upon in the European Union. Describes ongoing measures and actions to be taken by the government to reach the targets.	X		X	
Transport and Mobility Development Plan 2021–2035 (2021) (In Estonian: Transpordi ja liikuvuse arengukava 2021-2035) aims to secure comfortable, safe, fast, sustainable, energy-efficient transport and mobility in Estonia and reduce the environmental footprint of transportation.	X			
Estonian Maritime Strategy White Paper 2022-2035 (2021) (In Estonian: Meremajanduse valge raamat 2022-2035) was published alongside the Transport and Mobility Development Plan 2021–2035. The white paper describes a vision of the Estonian maritime economy, government goals, and objectives.	X			
Agriculture and Fisheries Strategy 2030 (Ministry of Rural Affairs of Estonia, 2021) identifies eight directions and specific objectives to be achieved to boost competitiveness across agriculture, fisheries, aquaculture, and the food industry, sustainable rural and coastal development and protect the environment and biodiversity.				X

1.2.4. Finland

1. Waterborne transport

In 2019, the maritime cluster – the maritime industry, shipping, and port operations - totalled more than EUR 14 million and employed around 50,000 people (The Maritime Policy Action Plan, 2022). It is one of the three priority areas of maritime policy as defined by the Finnish government, the other two being marine production and protection of seas. According to the Government Resolution on Finland's Maritime Policy guidelines from the Baltic Sea to the Oceans (2019), the future goal is to support digitalisation, autonomic transport and emission reduction in the maritime transport and logistics sectors while maintaining competitiveness.

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2. Ports and associated facilities

Helsinki Port Ltd. is committed to becoming carbon neutral by 2035 and reducing emissions by 32% compared to 2015 (World Port Sustainability Program, 2023). Their Carbon-Neutral Port 2035 program focuses on implementing measures within the first five years (2020-2024), with ongoing updates as new solutions emerge. The port aims to influence other stakeholders' emissions through recommendations and incentives. Targets include reducing vessel emissions by 25%, cutting heavy traffic emissions by 60%, and decreasing port machinery emissions by 60%. Strategies involve promoting alternative fuels, electric infrastructure, and renewable energy sources. The port also aims to minimise energy consumption and impact subcontractors' carbon footprint through procurement practices. Helsinki Port has agreed with Port of Tallinn to create a new green corridor between Finland and Estonia across the Gulf of Finland as they seek to lower the emissions of the two million vehicles that cross the water every year (Bovenizer, 2023).

Turku Port is part of a project that aims to develop a carbon-neutral “green corridor” between Turku and Stockholm through which cargo and passengers can travel by 2027 (Åbo Akademi University, 2022). In addition, city of Turku is since December 2023 one of 100 cities in EU that aims to be carbon neutral by 2030, and one of the concrete actions is decarbonisation Port of Turku (2023).

Pori Port, consisting of Mäntyluoto and Tahkoluoto harbours, is one of Finland's major cargo ports. It handles various products, including metal refining goods, raw materials, bulk liquids and solids, circular economy, and green energy products. The port's advantageous location and excellent transportation connections contribute to its success. Looking ahead, Pori Port aims to develop its logistic operations and industrial facilities, particularly in sustainable blue economy and carbon neutrality. The port actively seeks companies involved in circular economy and renewable energy, and significant investments are expected in these fields in the coming years, including the establishment of recycling facilities, bioconversion plants, and renewable energy projects. There is also an interest in attracting hydrogen-related initiatives to the port area.

3. Renewable ‘blue’ energy production and storage facilities

The Tahkoluoto wind farm in the Gulf of Bothnia (total output of approximately 44.3 MW) and the Ajos wind farm on artificial islands in the proximity of a port (output of about 26.4 MW) are the only two offshore wind farms in Finland (Finnish Wind Power Association, 2023). There are currently several new offshore wind power projects at different planning stages, including five projects that would increase offshore wind farm energy production capacity by around 6000 MW by 2030 (Metsähallitus, 2023).

Hydropower is an important source of renewable blue energy in Finland, currently producing 10-20% of Finnish electricity production, with production capacity of 3100 MW. Future development plans of hydropower facilities are facing challenges especially due to local environmental issues. There are opportunities to enhance the energy production of existing facilities via new innovations and digitalization (Energiateollisuus, 2024).

4. Low trophic aquaculture

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Marine production, aquaculture and species cultivation for low-carbon energy and food are some of the three priority areas of maritime policy as defined by the Finnish government (Prime Minister's Office, 2023). In recent years, a wide range of research projects on algae cultivation experiments have been conducted in Finland. The aim is to explore the use of macroalgae in recovering and recycling nutrients from wastewater to reduce water pollution. In 2019, a circular economy research environment called CircLab was established, which involved the construction of Finland's largest photobioreactor to recover nutrients from industrial by-products and various species of microalgae and conduct experiments on wastewater purification using microalgae. Industries such as fish farming, bioenergy, brewing, mining, and pulp and paper can benefit from the research environment. The cultivated algae can be used in fish feed, fertilisers, as a superfood, for dyeing textiles, and cosmetics, among other applications (e.g., Nemo Sea farms or Origin by Ocean).

Table 3 Finland: key national documents to developing the national priorities for waterborne transport (1), port and associated facilities (2), blue energy (3) and low-trophic aquaculture (4).

Key document	BE Sector priorities			
	1	2	3	4
Government Resolution on Finland's Maritime Policy Guidelines: From the Baltic Sea to the Oceans (2019) is a strategic document outlining Finland's maritime policy objectives and principles. Covers topics including automation, digitalisation and data; competence, research and education; exercising influence at the EU and international level; a secure operating environment; and financing.	X	X		X
The Maritime Policy Action Plan (2022) supports Finland's maritime policy and the national implementation of the EU's maritime policy. Focus areas include - sea protection, development of the maritime cluster, and marine production for food and energy, and a total of 44 measures.	X	X		X
The Carbon Neutral Finland 2035 – national climate and energy strategy (2022) describes the measures for reaching the EU's climate commitments for 2030, achieving the targets set in the Climate Change Act for reducing greenhouse gas emissions by 60 per cent by 2030 and being carbon neutral by 2035.	X		X	

1.2.5. Germany

1. Waterborne transport

The Federal Ministry for Economic Affairs and Climate supports maritime technology research and development in Germany through a dedicated Maritime Research Program (Maritimes Forschungsprogramm, 2025). One of the four cross-cutting focus areas of the programme is MARITIME.green – Environmentally friendly maritime technologies, which focuses on green propulsion technologies and measures to reduce emissions from both seafaring and inland vessels. MARITIME.green has the following three underlying strategic goals: (1) Green transportation Zero Emission: No harmful emissions to air or water, prevention of any environmental damage and complete climate neutrality; (2) Green production: energy and resource minimal manufacturing and complete recyclability of maritime products. The programme has already funded national projects for developing solutions for

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alternative fuel use e.g., ammonia combustion engines (projects ‘Ammonia Motor’, ‘AmmoniaMot’), flexible fuel use e.g., developing concepts for multi-fuel retrofit solutions for climate-neutral e-methanol and ammonia in large maritime engines (project ‘CliNeR-Eco’), optimising ship design for increasing energy efficiency (e.g., project ‘Dynamo’) (Maritimes Forschungsprogramm 2025: Projektübersicht).

At the strategic planning level, the Maritime Agenda 2025 emphasises the role of the Federal Government in supporting the industry, ports, and local authorities in developing solutions for decarbonising the shipping sectors, including the development of fuel alternatives, infrastructure, and technologies. The National Masterplan for Maritime Technologies, which supports the Maritime Agenda 2025, highlights two of the technological priorities directly related to waterborne transport – i) Innovative special shipbuilding system integration, energy efficiency, lightweight construction, and high-performance production systems on board and ii) low-emission and climate-friendly maritime transport (Federal Ministry of Economic Affairs and Energy, 2023).

Germany has also joined as a co-lead the ‘Zero-Emission Shipping Mission’ – an international public-private partnership with a published roadmap for lower shipping emission aims by 2030 led by the Danish Maritime Authority, the United States, Norway, Global Maritime Forum and Mærsk McKinney Møller Center for Zero Carbon Shipping.

2. Ports and associated facilities

Fields of action for the National Ports Strategy (Die Nationale Hafenstrategie 2023) are: (1) Strengthen Germany's competitiveness as a port location, (2) Developing ports into sustainable hubs for the energy transition, (3) Exploiting the potential of digitalisation, automation, and innovation, (4) Shaping training and employment for the future, (5) Maintaining and expanding transport and communications infrastructure in line with demand. The Maritime Agenda 2025 also highlights that infrastructure for alternative fuels and onshore power are necessary elements of effective climate protection, and the development of new infrastructure demands the support of the Federal and Länder Governments and is a key priority.

3. Renewable ‘blue’ energy production and storage facilities

The expansion of offshore wind energy is a central component of the German energy transition. The amendment to the Offshore Wind Energy Act from summer 2022 is expected to speed up all procedures and allow offshore connection lines to be commissioned several years faster. Planning and approval procedures will be streamlined, and environmental assessments will be bundled. In addition, offshore expansion has been strengthened in decisions on weighing up other interests and will, in the future, be explicitly in the overriding public interest. In line with the changes to the EEG, the expansion targets for offshore wind energy have also been significantly increased to at least 30 GW in 2030, 40 GW in 2035 and 70 GW in 2045.

In the past, auctions for the promotion of offshore wind energy have repeatedly resulted in zero-cent bids. With a new tendering procedure, revenue can even be expected in future, which will flow into reducing the offshore grid levy and nature conservation, among other things.

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The offshore realization agreement signed in November 2022 between the federal government, the affected federal states and the transmission system operators (TSOs) sets out concrete milestones and timetables for achieving the target of at least 30 GW by 2030. It includes steps for the designation of areas at sea, environmentally friendly expansion, specific timetables and milestones, the crossing of the territorial sea and the necessary coordination and resources required to accelerate the processes. Further legal adjustments are intended to ensure improved utilization of offshore connection lines. Regulations have also been created that will make it easier to cross the territorial sea.

In summer 2023 four areas with a total volume of 7,000 MW were tendered out. Three areas for offshore wind farms, each with a capacity of 2,000 MW, are located in the North Sea and one area with a capacity of 1,000 MW is located in the Baltic Sea. 90 percent of the proceeds from the offshore tenders will go towards reducing electricity costs and five percent each towards marine nature conservation and the promotion of environmentally friendly fishing. These 670 million EUR earmarked for marine protection and fishing each must be paid to the federal budget within one year. However, these 670 million EUR for sustainable fishery have recently been diverted to be used also for agriculture – meaning that by now only 134 million EUR are left to the fishery cause. The electricity cost reduction component is to be paid over a period of 20 years in constant annual instalments to the transmission system operator responsible for the connection, starting from the completion date of the wind farm in 2030.

4. Low trophic aquaculture

The Federal Ministry of Food and Agriculture covers the topics of sustainable fisheries and aquaculture. No strategy or program exists for low-trophic aquaculture.

Table 4 Germany: key national documents to developing the national priorities for waterborne transport (1), port and associated facilities (2), blue energy (3) and low-trophic aquaculture (4).

Key document	BE Sector priorities			
	1	2	3	4
Maritime Research Program 2025 (In German: Maritimes Forschungsprogramm 2025) The Federal Ministry for Economic Affairs and Climate (BMWK) supports maritime technology research and development through a dedicated Maritime Research Program (Maritimes Forschungsprogramm 2025). Two of the four cross-cutting focus areas of the programme are MARITIME.green and MARITIME.value.	X		X	
Maritime Agenda 2025 is a long-term framework for the targeted development of the maritime industry and its development into a maritime hub for the Federal Government. The Maritime Agenda 2025 sets out measures to be deployed across nine fields of action, with a special focus on sustainability in maritime transport.	X	X	X	
The National Masterplan for Maritime Technologies (Federal Ministry of Economic Affairs and Energy, 2023) is an integral part of the 2025 Maritime Agenda and the central instrument of the Federal Government to strengthen the maritime sector.	X	X	X	
National Strategy for Sea and Inland Ports (Federal Ministry for Digital and Transport, 2015) The Federal Cabinet adopted the National Strategy for Sea and Inland Ports on 20 January 2016. It provides strategic guidance, which covers ten years. The		X		

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strategy is developed by the federal states, social partners, trade associations, and the Ministry in line with the coalition agreement. The strategy highlights challenges concerning environmental protection, climate change mitigation, and alternative fuels.				

1.2.6. Latvia

1. Waterborne transport

The 'strategic' section of the Latvian Maritime Spatial Plan 2030 (Ministry of Environmental Protection and Regional Development, 2019) states that developing safe shipping and coastal tourism (including activities such as yachting) are one of Latvia's priorities and long-term economic interests. The Latvian Maritime Spatial Plan 2030 emphasises the need to develop a safe maritime sector and envisions large and minor ports of Latvia (Riga, Ventspils, Liepaja, etc.) playing a central part in sustaining local economies as well as playing a significant role in the cargo flow and the transport network in the wider Baltic region. The Latvian Maritime Spatial Plan 2030 acknowledges that shipping contributes to climate change and the adaptation challenges and needs of the shipping sector representatives raised at the Latvian Maritime Spatial Plan 2030 stakeholder consultations. The 2050 Climate Neutrality Strategy (2019) also acknowledges that transport dramatically contributes to greenhouse gas emissions. However, only 0.48% can be attributed to shipping and maritime transport. The strategy recommends reducing emissions through research and development of vessel design and efficiency, as well as innovation in the types of fuel used (e.g., electricity, biofuels, or hydrogen) (2050 Climate Neutrality Strategy, 2019).

2. Ports and associated facilities

Latvia's National Adaptation to Climate Change Plan 2030 requires the ports and marinas to consider the projected rise in sea level and adjust their infrastructure accordingly. Considering the climate change projections, the respective regulations on the infrastructure of ports should also be updated.

3. Renewable 'blue' energy production and storage facilities

Offshore wind farms are featured in the priority, long-term national interest list in the Latvian Maritime Spatial Plan 2030. Development of offshore wind farms were intensively consulted during the development of the first maritime spatial plan and continue to play a significant role in the evaluation and revision process. Offshore wind farm development is seen as a solution to reducing greenhouse gas emissions in line with EU-level regulations and perspective (The Latvian Maritime Spatial Plan, 2030). The Energy and Climate Plan 2020 states that among the Baltic States, Latvia could have the most significant number of offshore wind farms – altogether 29 – with an annual energy production capacity of 49.2 TWh. The Energy and Climate Plan 2020 also outlines the next step as the investigation of planned areas and then the preparation of infrastructure for offshore wind farms from the state's side, followed by tender for developers. An establishment of funds for promoting renewable energy solutions and energy efficiency is also foreseen to give loans for offshore wind farm project developers.

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Currently, there are no offshore wind farms in Latvia. However, areas designated for potential use for offshore wind farm development in the maritime spatial plan are undergoing suitability assessments. Hydroelectric power generated from hydroelectric plants contributes a substantial portion of the energy supply in Latvia. Hydroelectric power storage involves less extensive energy storage in the same way as battery storage. Instead, it manages reservoir water levels to ensure a consistent and reliable electricity supply when needed.

4. Low trophic aquaculture

It is mentioned in the Latvian Maritime Spatial Plan 2030 but is not considered a priority activity or designated space (Armoskaite et al., 2021).

Table 5 Latvia: key national documents to developing the national priorities for waterborne transport (1), port and associated facilities (2), blue energy (3) and low-trophic aquaculture (4).

Key document	BE Sector priorities			
	1	2	3	4
The Latvian Maritime Spatial Plan 2030 The Maritime Spatial Plan for the Marine Inland Waters, Territorial Sea and Exclusive Economic Zone Waters of the Republic of Latvia (Ministry of Environmental Protection and Regional Development, 2019) is a national-level long-term spatial development planning document.	X	X	X	
2050 Climate Neutrality Strategy (2019) (In Latvian: Latvijas stratēģija klimatneitralitātes sasniegšanai līdz 2050. Gadam, 2019) The Strategy for the low-carbon development of Latvia by 2050.	X	X		
Latvia's National Energy and Climate Plan 2021-2030 (2019) (In Latvian Par Latvijas pielāgošanās klimata pārmaiņām plānu laika posmam līdz 2030. Gadam) is ten-year plan required from each EU member state for the region to meet its overall greenhouse gas emissions reduction targets. The Latvian plan looks at decarbonisation, energy efficiency, energy security, internal energy markets and research, innovation and competitiveness.		X		
The Energy and Climate Plan 2020 (2020) (In Latvian: Par Latvijas Nacionālo enerģētikas un klimata plānu 2021.–2030. Gadam) is government order released in 2020 outlining the long-term energy and climate policy plan establishing the fundamental principles, objectives, and action directions for the next decade.			X	

1.2.7. Poland

1. Waterborne transport

According to the Polish Central Statistics Office, at the end of 2021, the Polish maritime transport fleet included 88 ships (7 less than in 2020) owned or co-owned by Polish ship owners and operators and 19.5 thousand passenger ships called at Polish ports in 2021 compared to 17.6 thousand in 2020. There is no existing national plan or strategy outlining how Poland intends to reduce emissions in maritime transport.

2. Ports and associated facilities

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A recent study by Bocheński et al. (2021) on the development of the four largest seaports in Poland – Gdańsk, Gdynia, Szczecin, and Świnoujście – showed that actions are being taken to support major port energy transformations. Namely, efforts have been made to develop the infrastructure to supply renewable energy from offshore wind farms to the four largest ports and supply onshore energy to ships during berthing at the quay. A list of maritime projects in implementing the Transport Development Strategy until 2020 (with a perspective until 2030) (2013) includes projects worth approx. EUR 3 billion. The focus of these projects is mainly on improving ports' infrastructure and port access infrastructure, such as roads and rails.

In Poland, bunkering of LNG ships is possible in five ports: Świnoujście, Szczecin, Police, Gdynia, Gdańsk. The bunkering service is also to be provided by the FSRU (Floating Storage Regasification Unit), i.e. a floating gas port - this is an investment planned in the Bay of Gdańsk, which Gaz-System wants to put into operation at the turn of 2027. 2028. The ports of Gdynia and Gdańsk have the status of "green ports" of the European TEN-T transport network.

3. Renewable ‘blue’ energy production and storage facilities

By the end of 2023, 19 permits to build and use artificial islands for offshore wind farm development were issued in two so-called offshore phases, the total power that will be generated by wind farms for which permits have been issued is up to approx. 15 GW. None of the permitted offshore wind farms is operational now. However, the PEP2040’s aim for offshore wind energy in Poland is to produce approx. 5.9 GW in 2030 up to approx. 11 GW in 2040.

The "We sail with the wind" campaign was launched in 2023, and the financing of the activities was provided by the National Fund for Environmental Protection and Water Management (https://plynie-myzwiatrem.pl/).

4. Low trophic aquaculture

This topic is so far not addressed in national-level documents.

Table 6 Poland: key national documents to developing the national priorities for waterborne transport (1), port and associated facilities (2), blue energy (3) and low-trophic aquaculture (4).

Key document	BE Sector priorities			
	1	2	3	4
Polish Integrated Maritime Policy covers all areas of political, economic, social, scientific and cultural life that are in any way related to the sea and its resources. The Operational Program "Fisheries and the Sea" for 2014-2020 (OP FISHES 2014-2020) is the national instrument for implementing this policy under the priority of the 6th: Measure1: Integrated Maritime Surveillance Support under this measure is intended to adapt national system solutions in the field of the Common Information Exchange Mechanism (CISE) to the guidelines in this regard of the European Commission. Measure 2: Promote the protection of the marine environment and the sustainable exploitation of marine and coastal resources Under this measure, environmental protection projects are financed - including mainly those related to the creation or implementation of NATURA 2000 protection plans in marine areas and the implementation of protective measures in marine protected areas,				

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as well as operations related to the purchase and use of specialized equipment for purposes of monitoring compliance with environmental requirements. Measure 3: Improving knowledge of the state of the marine environment. This measure finances projects promoting pro-environmental behavior both among the general public and entities closely related to the maritime economy. Additionally, the measure covers projects involving the development of expert opinions and analyzes on the state of the marine environment.				
Energy Policy of Poland Until 2040 - PEP2040 (2021) contains the strategic decisions regarding technologies to establish a low-emission energy system and sets the framework for the energy transition in Poland. The policy describes the status of the energy sector and proposes three pillars, eight specific objectives along with the measures necessary for their implementation and specific, strategic projects.			X	
Transport Development Strategy until 2020 (with a perspective until 2030 (2013) (In Polish: Strategia Rozwoju Transportu do 2020 Roku (z Perspektywą do 2030 Roku)) focusing on the development of transport up to 2020 but also outlining potential directions beyond that time frame.	X			
Sustainable Transport Development Strategy until 2030 (2019) (In Polish: Strategia Zrównoważonego Rozwoju Transportu do 2030 roku) aims to increase the transport accessibility of the country and to improve the safety of traffic and efficiency of transport sector participants by creating a coherent, sustainable, innovative and user-friendly transport system at national, European and global levels. It is focused on sustainable transport until 2030, is sustainability-driven approach for the specified period compared to the broader, longer-reaching perspective of the first strategy.	X			

1.2.8. The Netherlands

1. Waterborne transport

The Netherlands has been actively engaged in the "greening" of its shipping industry, reflecting its commitment to sustainability and environmental protection. The Dutch approach to reducing emissions and enhancing environmental performance in maritime transport involves a combination of innovative technologies, regulatory measures, and collaborative initiatives. The National Water Programme for 2022-2027 (2021) outlines the government's goals to strengthen and improve the sustainability of Dutch ports and shipping through the EU Green Deal. The Dutch government created 'the Green Deals policy instrument' in 2011 to support collaboration and communication between businesses and other stakeholders in industries, including the maritime sector, to support a greener and more sustainable economy. The maritime industry-focused green deal 'Green Deal on Maritime and Inland Shipping and Ports' (2019) outlines cross-institutional collaboration ambitions and goals for 2030, 2035 and 2050, incrementally moving towards a zero-emission industry. Additionally, in 2023, the Maritime Master Plan developed by the Dutch Maritime Network (a collaboration platform for various maritime industry stakeholders) was awarded 2010 million euros from the Dutch government's National Growth Fund to accelerate the energy transition in the marine sector and support the reduction of 230 megatons of CO_2 by 2050. The Maritime Master Plan focuses on developing, constructing, and commissioning 40 vessels fuelled by alternative fuels, i.e., hydrogen, methanol and LNG with carbon capture. Furthermore, creating a digital platform and a human capital programme support the development of carbon-neutral vessels, knowledge sharing and digital skills.

2. Ports and associated facilities

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Rotterdam and Amsterdam are among the busiest ports in Europe, with the Port of Rotterdam being the largest in Europe. The Netherlands has been at the forefront of greening its ports, recognising their vital role in both the economy and the environment. A prime example is the Port of Rotterdam, which has invested heavily in shore power. The municipality of Rotterdam, in cooperation with the Port of Rotterdam Authority, is implementing a strategy to expand and accelerate the introduction of shore-side electricity for seagoing vessels. The aim is to have a significant proportion of these vessels connected to shore power by 2030, allowing diesel generators to be switched off, improving air quality and contributing to carbon neutrality. Over the next five years, the city and port plan to work with port businesses and shipping companies to accelerate and expand the use of shore power. Based on the results of these efforts, the targets may be revised in 2025 (Port of Rotterdam, 2021).

In addition, the Port of Rotterdam Authority is leading a consortium to pilot sustainable and smart logistics in port operations (Port of Rotterdam, 2021a). In addition, the Port has a robust waste management system that supports circular economy practices (Port of Rotterdam, 2024).

A major focus is the development of infrastructure for alternative fuels such as LNG, biofuels and hydrogen. The Port of Rotterdam has particularly developed its capabilities as a major LNG bunkering hub, with LNG bunkering volumes set to reach record levels in 2023 (LNG Prime, 2023). Complementing these efforts, Shell announced plans to build Europe's largest renewable hydrogen plant in the Netherlands, which will be operational in the Port of Rotterdam by 2025 (TheMayor.EU, 2022).

Recognising the importance of these initiatives, the Dutch government allocated €1.25 million for innovative shipping projects in 2018 and announced a Green Deal on Maritime and Inland Shipping and Ports in 2019. This Green Deal, a collaboration between the shipping industry, knowledge institutions and the government, translates the UN International Maritime Organisation's agreements into national policy. It aims for a 40% reduction in CO2 emissions per ship by 2030 and a 50% reduction in global shipping emissions by 2050 (TNO, 2024.; Reuters, 2018; Green Deals, 2019; MARIN, 2024.).

Dutch ports, in particular the Port of Rotterdam, are often cited as exemplary models of how ports can effectively balance operational efficiency with environmental responsibility.

3. Renewable ‘blue’ energy production and storage facilities

As described in the Offshore Wind Energy Roadmap 2030 in 2018, the initial national goal was to develop enough offshore wind farms to produce 11.5 GW by 2030 and contribute to reducing carbon dioxide emissions by around four megatons by 2030. However, this target was further increased by the government in 2022 to 21 GW in the Additional Roadmap for Offshore Wind Energy 2030 to achieve the government’s climate targets of reducing CO2 emissions by at least 55% by 2030 compared to 1990. New areas for producing extra wind energy by 2030 are designated in the North Sea Programme 2022-2027.

So far, renewable energy development has focused on offshore wind farms. However, in the long run, the North Sea 2050 Spatial Agenda and the Dutch Maritime Spatial Plan 2016-2021 also highlight the need and opportunities for more diverse offshore energy production options in Dutch North

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Sea waters – tidal, wave, deep geothermal – and for these to be addressed in a long-term Energy Master Plan.

4. Low trophic aquaculture

The North Sea 2050 Spatial Agenda highlights areas suitable for mussel capture and farming. Furthermore, it highlights the possibility of co-location of seaweed and mussel cultivation in wind farms in the coastal waters of Zeeland and the environmental and social sustainability benefits of seaweed and mussel cultivation, including the low negative or even positive ecological impact of seaweed cultivation and the prospects of mussel and seaweed cultivation supporting fishers transition to a more sustainable source of livelihoods.

Table 7 Netherlands: key national documents to developing the national priorities for waterborne transport (1), port and associated facilities (2), blue energy (3) and low-trophic aquaculture (4).

Key document	BE Sector priorities			
	1	2	3	4
Maritime Master Plan Net Zero 2030 is a plan by a Dutch maritime sector actors network organization focused on accelerating the industry's transition toward sustainability.	X	X	X	
National Water Programme for 2022-2027 (2022) (In Dutch: Nationaal Water Programma 2022-2027) is a strategic plan that outlines the government's policies, goals, and investments concerning water management and safety in the Netherlands.	X	X	X	
Marine Strategy for the Dutch section of The North Sea 2022-2027 Programme aims at achieving a sustainable and safe use of the North Sea that contributes to the Netherlands' social, economic and environmental sustainability objectives. The plan is part of the National Water Program for 2022-2027.	X		X	
Offshore Wind Energy Roadmap 2030 and the Additional Roadmap for Offshore Wind Energy 2030 are strategic plans that describe the government's ambitions and next steps to develop offshore wind energy further from 2024 to 2030.			X	
Policy Document on the North Sea 2016-2021, including the Netherlands' Maritime Spatial Plan (The Dutch Ministry of Infrastructure and the Environment and The Dutch Ministry of Economic Affairs 2015), defines the framework for the spatial use of the North Sea concerning the marine ecosystem. It was developed in line with the North Sea 2050 Spatial Agenda.	X	X	X	X
The North Sea 2050 Spatial Agenda (2014) is a "Report of joint research into the long-term potential of sea and coastal areas, translated into a vision, series of ambitions, opportunities, points of action and maps" for the Dutch section of the North Sea.	X	X	X	X

1.2.9. Norway

1. Waterborne transport

The Norwegian maritime industry employs approximately 85,000 people and has a turnover of over NOK 416 billion (Action Plan for Green Shipping, 2019). Waterborne transport makes up around

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8.6% of Norwegian emissions, and the Norwegian government aims to halve emissions by 2030 (The Norwegian Government's Hydrogen Strategy, 2020). The Norwegian National Transport Plan (2021) indicates that the government has prepared a NOK 33 billion financial framework for supporting maritime infrastructure and coastal management and NOK 3 billion for initiatives across transport sectors, including efficient and environmental-friendly use of new technologies for the twelve years between 2022 and 2033. Furthermore, in addition to an expected increase of maritime traffic in the coastal and offshore areas, an increase in low and zero-emission solutions and automation is also expected by 2033. In its action plan for green shipping, the Norwegian government highlights the need to reduce emissions through research and innovation to support commercial zero or low-emission solutions. Further, the role of the government in building up skills and experience to make Norway internationally competitive. As it stands, the focus at the national level is on developing and testing technology for zero and low-emission technology, e.g., electric ferries, high-technology solutions in autonomy and development of commercially viable technologies for hydrogen storage and hydrogen-based systems such as ammonia as potential alternatives for the long-distance or high-energy vessels (The Norwegian Government's Hydrogen Strategy, 2020).

Norway has also joined as a co-lead the 'Zero-Emission Shipping Mission' international public-private partnership (see above part 1.2.2. Denmark and below 2.3.1. Waterborne transport).

2. Ports and associated facilities

In the Action Plan for Green Shipping 2019, the Norwegian government acknowledges that ports have a significant role in greening the maritime industry. The strategy encourages the Coastal Administration responsible for ports to use incentives and instruments, including differentiating rates based on environmental grounds and innovative procurement processes. The Environmental Port Index (EPI) was developed in Norway. It will be used across some Norwegian ports to assess the environmental performance of cruise ships while in port (The Action Plan for Green Shipping, 2019).

The Norwegian Government, municipalities and port authorities aim to make ports emission-free by 2030 and supply the shipping sector with onshore power, charging facilities and bunkering services for sustainable fuels (e.g., hydrogen and biogas). In 2019, the Norwegian government allocated NOK 50 million through a three-year grant scheme for investments in effective, sustainable ports and to make the whole logistics system more environmentally friendly. A funding body managed by the Ministry of Climate and Environment – Enova – has provided an additional NOK 0,5 billion for 80 onshore power projects (Action Plan for Green Shipping 2019).

Supplying cruise ships with onshore power is a high-cost emission mitigation measure. In 2018, the Port of Kristiansand opened Europe's largest onshore power facility for cruise ships, and the Port of Bergen followed in 2022 (Action Plan for Green Shipping 2019). The Port of Oslo aims to cut current emissions by 85 % by 2030; this includes emissions from all traffic entering and leaving the port and port operations (Action Plan for Green Shipping 2019). Thirteen large cruise ports in Norway, including Oslo, Kristiansand and Bergen, have also made 14 other commitments to make ports greener, primarily concerning cruise ship emissions.

3. Renewable 'blue' energy production and storage facilities

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The Norwegian government aims to designate areas with the potential for 30 GW offshore wind production by 2040. Fifteen regions are under consideration for the development of offshore wind farms and are subject to strategic environmental assessments. All 15 areas could produce around 4600–12.600 MW, with an estimated average production of 19–50 TWh (Offshore wind power in Norway Strategic Environmental Assessment, 2013). In spring 2023, the Norwegian Water Resources and Energy Directorate presented 20 new possible areas for offshore wind production. They began the strategic impact assessments of three areas that may already be deemed suitable tender in the 2025 licensing round and areas relevant for further future licensing rounds (Ministry of Petroleum and Energy, 2023).

4. Low trophic aquaculture

Aquaculture in Norwegian fjords, especially salmon farming, has been profitable since the early ’90s (Norwegian Aquaculture Analysis, 2022). Scaling up the farming of low-trophic species, including blue mussels, is critical to meeting national goals for more sustainable feed sources for farmed salmon and the upcycling of nutrients and CO_2 (Norwegian Aquaculture Analysis, 2022).

Table 8 Norway: key national documents to developing the national priorities for waterborne transport (1), port and associated facilities (2), blue energy (3) and low-trophic aquaculture (4).

Key document	BE Sector priorities			
	1	2	3	4
National Transport Plan 2022–2033 (2021) was submitted to the Parliament (the Sorting) in 2021 and presents policies and priorities within an economic frame for twelve years and provides perspectives towards 2050.	X	X		
The Action Plan for Green Shipping, Ministry of Climate and Environment (2019) presents the Government’s policy for reducing greenhouse gas emissions, strengthening the maritime industry and supporting global technological developments necessary to achieve emission reduction targets (i.e., the Paris Agreement).	X	X		
Offshore wind power in Norway Strategic Environmental Assessment – an English summary (2013) defines a set of 15 areas to be assessed and potentially opened for offshore wind development licence applications.			X	
The Norwegian Government’s hydrogen strategy towards a low-emission society by the Norwegian Ministry of Petroleum and Energy Strategy, Norwegian Ministry of Climate and Environment highlights the role of hydrogen as a key energy source and sets out a strategy to develop its low-carbon production and use by 2030 in a number of sectors including waterborne transport.			X	
The Norwegian Aquaculture Analysis 2022 is an overview of the development, risks and opportunities of the aquaculture industry in Norway between 2021-2022. Focus on salmon farming, distribution and the introduction of higher resource tax for salmon and trout producers utilizing fjords, which are a public good.				X

1.2.10. Sweden

1. Waterborne transport

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Shipping in Sweden has an annual turnover of around 85 billion SEK, and the maritime cluster – shipping companies, marine technology companies, ports, authorities, and academia – secures direct employment for approximately 30,000 people (Barquet et al., 2023). To achieve the International Maritime Organization's greenhouse gas reduction targets, Swedish waterborne transport companies collaborate with various research and innovation institutions in projects to develop concepts for commercial solutions and support decision-making (Barquet et al., 2023). The Lighthouse – Swedish Maritime Competence Centre is a platform that brings together the maritime transport sector stakeholders, ship owners, ship constructors, harbours, authorities, and research and innovation actors. The Lighthouse regularly updates the National Innovation & Research agenda with common strategic goals, challenges, and needs. The latest version is from 2021. Several 'new generation' vessels are under development or already in use thanks to public-private collaboration. Examples are the battery-powered Helsingborg – Helsingør ferries, electric and hybrid Northern Offshore Services offshore wind farm service vessels and the Oceanbird project wind-powered vessel development supported by the Swedish Transport Administration (Barquet et al., 2023). At the same time, the Swedish shipping fleet makes up only 1–2% of the annual fleet in the Baltic Sea, highlighting the international nature of the sector and the need for cross-border collaboration incentives.

2. Ports and associated facilities

The Swedish Maritime Strategy (2023) emphasises that zero-emission for the maritime cluster means improving the entire system's sustainability, starting from the raw materials used to build and run ships, ports, and other parts of the logistics chain (e.g., trucks and trains).

The Port of Gothenburg is a hub of around 3000 maritime companies and 20,000 employees, making up 45% of the country's number of employees in maritime industries (Barquet et al., 2023). Port of Gothenburg aims to reduce its CO2 emissions by 70% by 2030.

3. Renewable 'blue' energy production and storage facilities

In 2020, offshore wind power produced around half a TWh (Barquet et al., 2023). National aims are to have 110-120 TWh of electricity offshore and create 1500 to 4000 annual jobs by 2030 and up to 10,000 jobs by 2050 (Barquet et al., 2023).

The Swedish Maritime Strategy (2023) highlights Swedish investments in offshore wind, research and development in wave energy and national efforts in designating zones for offshore energy. Further, the strategy outlines goals for 100% renewable electricity production, more mature technologies for hydrogen and wave energy, and expansion of offshore wind energy in areas with the least possible negative impact on marine ecosystems (Barquet et al., 2023).

4. Low trophic aquaculture

The Swedish Maritime Strategy does not discuss the development pathways of low-trophic aquaculture. However, the benefits of research and development to support the progress and commercialisation of mussel and algae farming and barriers in regulatory frameworks hindering progress in this new sector are mentioned concerning the work done by Blue Food (Barquet et al., 2023). Blue Food is a centre for national sustainable aquaculture research and innovation, a cross-sectoral and private-public collaboration funded by the Formas Research Council (€48 million). Blue Food brings

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stakeholders from the entire food value chain together. Seaweed farming has the potential of becoming a profitable industry in Sweden (Hasselström, 2020). In Sweden, the legislative framework is favourable for environmentally sustainable businesses. Regulators tend to reject proposals for fish farms due to their potential environmental impact, but they are supportive of seaweed farms, recognizing their eco-friendly nature. On Sweden's west coast, especially in nearshore areas, there is capacity to produce at least 10,000 tonnes of seaweed (Fletcher, 2024). In Sweden, notable sea farms include Nordic Seafarm, which is recognized for cultivating seaweed such as sugar kelp and sea lettuce. Nordic Seafarm is known for its innovative seaweed cultivation off the west coast of Sweden.

On the national level, there are ongoing national commissions to develop national strategies for transitioning from fossil fuels to renewable, bio-based resources provided by marine and land ecosystems (Fossil Free Sweden, 2023). There is also an ongoing commission to develop a Blue Biomass Roadmap for the Ministry of Rural Affairs and Infrastructure.

Table 9 Sweden: key national documents to developing the national priorities for waterborne transport (1), port and associated facilities (2), blue energy (3) and low-trophic aquaculture (4).

Key document	BE Sector priorities			
	1	2	3	4
The Swedish Maritime Strategy (2023) – for people, jobs and the environment, is a policy document for socially, environmentally and economically sustainable development of the Swedish maritime sectors.	X	X		
Marine Spatial Plans for the Gulf of Bothnia, the Baltic Sea and the Skagerrak/Kattegat. National planning in Sweden's territorial waters and exclusive economic zone (Swedish Agency Marine and Water Management 2022) was adopted in 2022 but is undergoing amendments to meet new electricity generation targets from offshore wind energy.			X	
Towards a Sustainable Blue Economy in Sweden by Barquet et al. (2023) and the Stockholm Environment Institute. Identifies the barriers and opportunities of a sustainable blue economy in Sweden, and a roadmap for the implementation of Sweden's Maritime Strategy.	X	X	X	X

1.3 KEY TAKEAWAYS

The results of this study reveal that national-level documents throughout the BANOS area frequently discuss waterborne transport, ports and associated facilities, as well as the development of renewable blue energy production and storage (see Figure 1). While low-trophic aquaculture is mentioned less frequently, it still appears in over half of the cases examined.

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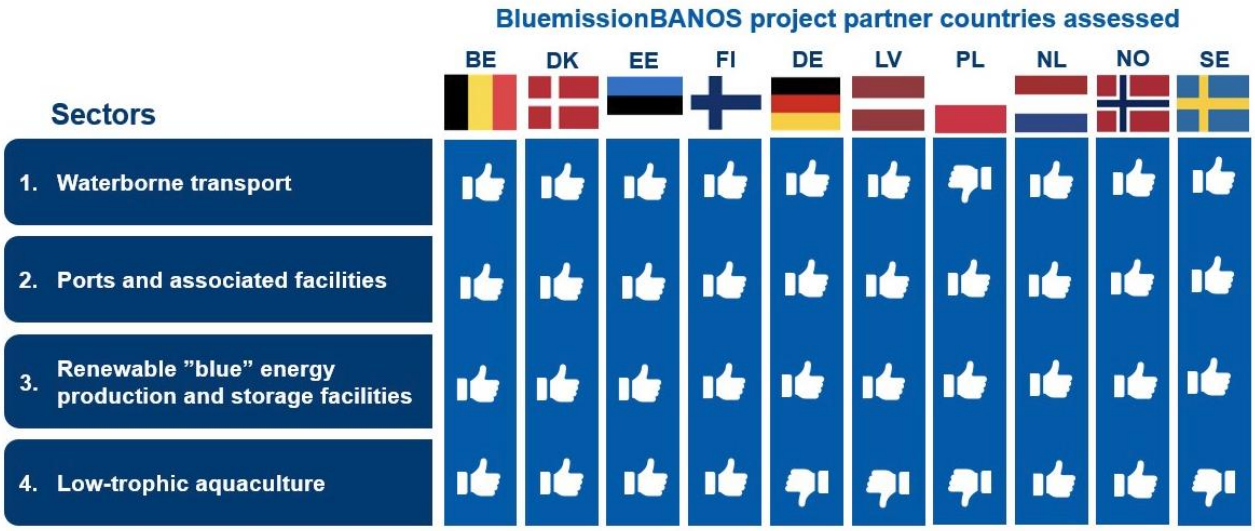

Figure 1 Summary of findings in response to the question: Are these sectors addressed in national-level documents? Thumbs up - Yes; Thumbs down – No; Blank – no response

Goals and objectives for improving the sustainability of the shipping sector and port facilities and maintaining national competitiveness by doing so are widely discussed. Efforts to support the offshore energy sector remain focused on the development of new offshore wind farms. Out of the four focus sectors, low-trophic aquaculture is by far the least recognised sector in official national document; even though the European Commissions Blue Growth Agenda for the Baltic Sea highlighted its importance already as early as by 2013. The lack of official, national low-trophic strategies may be due to a wide variety of reasons, including a lack of a clear understanding of the environmental, social and economic risks and benefits; a shortage of technological solutions and especially a currently still very small industrial lobby leading to a lack of political pressure on the national governments (Armoskaite et al. 2021; Barquet et al. 2023).

Waterborne transport, ports and associated facilities

In this subsection, the "waterborne transport" and "ports and associated facilities" sectors are combined because they are closely related.

A key focus is the drive towards climate neutrality in the shipping sector, which is closely linked with the transformation of port infrastructure. Across various countries, there is a strategic priority to reimagine port infrastructure. This includes developing facilities for supplying onshore power from renewable sources (often referred to as cold ironing) and supporting vessels that use alternative fuels. A critical aspect of this transformation is enabling vessels to switch off their engines while docked, significantly reducing local emissions at ports (Maes et al. 2022). For instance, some Norwegian ports are already providing green energy for bunkering vessels, while others, like in Poland, are developing the necessary supply chain infrastructure to facilitate this transition soon.

Danish ports are particularly ambitious, aiming to completely switch from fossil fuel energy to renewable energy for all port machinery by 2030. From an operational standpoint, several ports in Norway

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and Flanders are offering discounts to environmentally friendly ships, as indicated by the International Maritime Organization's Environmental Ship Index (ESI) (Action Plan for Green Shipping 2019, The Flemish Port Strategy 2020). Furthermore, Norway has developed an Environmental Port Index (EPI) to assess the environmental performance of cruise ships while in port, which is set to be implemented in several Norwegian ports (Action Plan for Green Shipping 2019). In Poland, the ports of Gdynia and Gdańsk have been recognized as "green ports" within the European TEN-T transport network, partly due to their capacity for bunkering ships using road tankers.

Renewable 'blue' energy production and storage facilities

Approximately 5% of the world's wind turbines are located offshore, with around three-quarters of these situated in Europe, particularly in the United Kingdom, Germany, the Netherlands, Denmark, and Belgium (Finnish Wind Power Association, 2023). The North Sea region is poised for significant expansion in offshore wind energy, with new zones being earmarked for development. Notable among these is Belgium's 281 km² 'Princess Elisabeth Zone' and the 20 new potential areas for offshore wind production identified by the Norwegian Water Resources and Energy Directorate in spring 2023. While the Baltic Sea currently hosts fewer offshore wind farms, numerous projects are underway or planned in Finland and Poland, with additional potential for cross-border projects in the Gulf of Riga, shared by Latvia and Estonia.

A key focus in regions like Estonia and Norway is streamlining the process for establishing new offshore wind farms, aiming to reduce risks and increase attractiveness for investors. Moreover, there's an effort to broadly communicate the societal benefits of these projects, as seen in Estonia and Poland.

Offshore renewable energy development in the BANOS area has primarily centred on wind farms. However, countries like the Netherlands and Estonia are exploring diversification into other offshore energy sources, including tidal, solar, wave, and deep geothermal energy, for long-term sustainability. Experiments with floating solar panels are also underway in Belgium and the Netherlands, as reported by Soltech (2024) and TNO (2024).

Low-trophic aquaculture

While most countries reviewed have strategies for sustainable aquaculture development, recognizing its potential to bolster food security and reduce seafood imports in Europe and the BANOS area (Barquet et al. 2023), detailed coverage of low-trophic aquaculture development is scarce in national-level documents. Low-trophic aquaculture, which includes the cultivation of mussels, oysters, and macroalgae, is often only briefly mentioned. However, survey responses suggest a growing interest and entrepreneurial activity in low-trophic aquaculture, particularly from public authorities in Finland and Estonia within the Baltic Sea region. In the North Sea region, the Danish Ministry of Food, Agriculture and Fisheries is reportedly developing a new approach to shellfish farming, following the recent prohibition of mussel farming due to environmental impacts and socio-governmental barriers.

Multi-Use Strategies in the BANOS area

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In Belgium, the concept of multi-use is central to the maritime spatial plan (2019) and the Long-Term Vision for the North Sea 2050 (Langetermijnvisie Noordzee 2050; 2017), aimed at reducing spatial competition among different users. A prominent example of multi-use discussed in these plans is the co-location of aquaculture, including low-trophic varieties, with offshore wind farms (e.g., Langetermijnvisie Noordzee 2050; Maar et al. 2023). Similarly, the Estonian and Polish Maritime Spatial Plans (2021) support the integration of tourism and fishing within offshore wind farm zones. The German government has recently launched an official study to analyze which areas within the German EEZ may be suitable for multi-use solutions.

However, in the BANOS area, there are only a few operational multi-use pilot projects. The two Ocean Mission Baltic & North Sea Flagship projects ULTFARM and OLAMUR have started in 2023 to get eight projects to such pilot level. An example of such an initiative is on Åland Island, where a collaboration between macroalgae and mussel cultivation entrepreneurs (Nemo Seafarms and Under Ytan) and an offshore energy company (OX2) is working on the Björkskär project. This project aims to create a 'maripark' that combines seafood farming, marine restoration, and offshore wind farms. This integrated approach seeks to enhance tourism, the food sector, and ecosystem restoration, with potential for replication across the Baltic Sea.

Implementing multi-use can be challenging due to regulatory, technical, and socio-economic obstacles. To overcome these barriers, Communities of Practice have been established in the Netherlands as a participatory approach (Nordzeeloket, 2024). These communities are informal networks that unite stakeholders with common interests to develop shared practices and foster learning. The Dutch Community of Practice North Sea, backed by the Dutch government, is focused on creating flexible policies under the North Sea 2030 strategy (Steins et al. 2021). This initiative particularly promotes innovative collaborations among offshore wind energy developers, seafood producers, and nature conservationists (Steins et al. 2021).

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2. EXISTING KEY POLICIES, MONITORING PRACTICES AND INDICATORS RELATED TO SUSTAINABLE BLUE ECONOMY IN THE BANOS AREA

Authors: Karoliina Koho (GTK) and Eero Asmala (GTK).

Blue growth has been an important policy topic both globally and within the EU for over a decade. Despite significant research and monitoring efforts by international organizations, the challenge of accurately measuring the blue economy persists. The current methodology, based on broad categorizations and assumptions, has led to calls for more precise data, as emphasized in the EU's Blue Economy Indicators, which seek "more and better data" (European Commission, 2021h; Kwiatkowski & Zaucha, 2023). The 2022 Blue Economy Report by the European Commission (2022a) also underscores the need to enhance monitoring and analytical capabilities in this sector.

The policy landscape of the blue economy sector in the Baltic and North Sea (BANOS) area has developed rapidly, following the publication of the EU Blue Growth Strategy in 2012. More recently, the European Commission's concept for a sustainable blue economy in the EU (European Commission, 2021a), in line with the publication of the European Green Deal and the United Nations' Sustainable Development Goals (especially Goal 14, which aims to conserve and sustainably use the oceans, seas and marine resources), have further emphasised the shift from an economic growth orientation towards sustainability as a whole. As a result, the policy landscape now calls for a new sustainable approach with a modern, resource-efficient, competitive, and carbon-neutral economy, while safeguarding the EU's natural capital (European Commission, 2021a). Sustainable development in the EU's regional seas has also been supported, for example, through the implementation of EU-wide national maritime spatial plans (MSPs). The policy encourages cooperation across borders and sectors to ensure that human activities at sea are carried out in an efficient, safe, and sustainable manner, while supporting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. Within the BANOS area, countries like Germany, Belgium and the Netherlands are the forerunners in developing and operationalizing MSPs already prior to the EU Directive. By now all BANOS countries have MSPs in plans and many are already updating or considering updating their plans due to increased activities in European regional seas, for example due to the expansion of the offshore energy sector.

The start of regular monitoring or reporting on the EU's sustainable blue economy dates back to 2018, with the publication of the first annual report on the EU Blue Economy (European Commission, 2018). The report was created to provide a baseline to support policy makers and stakeholders in the pursuit of sustainable development of oceans, seas and coastal resources, as well as to annually monitor sectoral developments in the EU blue economy and examine the drivers behind trends. An open-access Blue Economy Indicators (European Commission, 2024b) dashboard has been created to visualise the data in an easily accessible way. However, reporting through the Blue Economy Indicators Dashboard is currently focused on the economic aspects, which calls for a diversification of monitoring in terms of the sustainability of the sector.

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The Blue Economy Sustainability Framework (BESF) was outlined in the European Commission report (2021b), focusing on the four dimensions of sustainability: economic, environmental, governance and social. The development of the BESF was supported by extensive analysis of existing frameworks and is underpinned by both sector-specific and generic indicators that provide a set of criteria for assessing the sustainability of Blue Economy activities. However, additional input is needed to refine some of the indicators and the approach in general to implement the framework and monitor activities.

A preliminary blueprint for the 'Mission Restore our Ocean and Waters 2030' monitoring framework and indicators was outlined in the Mission Implementation Plan (European Commission, 2021c). The document highlighted the need for the future monitoring system and suggested that it should consist of 1) output, 2) outcome and 3) impact indicators. The document further suggests that the *output indicators* will measure the progress of Mission implementation for key Mission activities, *outcome indicators* will measure the degree of achievement of the Mission objective, and *impact indicators* will measure the actual real-time progress of ocean and water restoration based on European Green Deal, biodiversity restoration targets and on the upcoming EU Nature restoration targets. Examples for indicators were also provided.

The work for the development of monitoring approaches and indicators specific for the Mission objective 3 "Make the blue economy carbon-neutral and circular" was initiated by Technopolis Group that led to the baseline study for the implementation of the Mission lighthouse in the Baltic and North Sea basins (EU Commission 2023a). The report focused on blue economy sectors specific for mission targets: (i) net zero maritime emissions, (ii) zero carbon aquaculture and (iii) low carbon multipurpose use of marine space. The suggested approaches and indicators provide valuable input for further development of the Mission monitoring in the BANOS area, and multiple recommendations were outlined especially regarding data availability.

The purpose of this chapter is to contribute to the development of the monitoring system for the sustainable blue economy in the BANOS area in the context of the Mission Ocean & Waters. In particular, this chapter aims to provide the following:

- Section 2.2: An overview of the main policies relevant to the Mission and their associated assessment methods and indicators. The focus is on global, EU and macro-regional policies.
- Section 2.3: An overview of other assessment methodologies and potential roadmaps for achieving carbon neutrality and circularity in the blue economy in the BANOS area.
- Section 2.4: A list of mission-relevant indicators and relevant databases.

2.1. METHODS

2.1.1. Key Policy Analyses

A selection of existing Mission Objectives applicable policies was analysed in their relevance for the development of the sustainable blue economy in the BANOS area. In addition, indicators related to the monitoring of the policies were identified where available. In general, the analysis focused on

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key, existing EU-level policies, yet both macroregional (Baltic Sea, North Sea) and global policies were also included. In total 18 policies were included in the final analysis. The selection of the policies was based on previous policy analyses in the BANOS-area e.g. BANOS SRIA (Koho et al. 2021) with some modification and additions in response to developments in the policy landscape.

A quantitative approach based on keyword search was performed to analyse the sustainable blue economy relevance of the selected policies. The numerical approach was based on a list of words containing 43 unique entries ("keywords") (Appendix 2). Multiple keywords were chosen to represent the various aspects of the four different sectors relevant to the Mission Objective 3 (Waterborne transport, Ports and associated facility, Renewable energy and production facilities, and low-trophic aquaculture) as well as the multiuse concept as described in detail in the reports introduction. In addition, a 'general category' was included to represent the relevance to a sustainable blue economy in broader context. The key word analysis was carried out by counting the total number of keywords occurring in each of the policy documents. The used method disregards the context of the individual words. The keyword analysis was carried out in R environment using packages *tidyverse*, *pdftools* and *tidytext*. Results of the keyword analysis are presented alongside each policy (Section 2.2). The quantitative approach was complemented with subjective textual analyses of the policies. Here focus was given on the textual parts where the keywords were also often present. In addition, the main objectives of each policy were outlined. The main outcome of these analyses was a short summary of the policy relevance for sustainable blue economy accompanied by keyword results.

2.1.2. Existing indicators and databases

A desktop study was performed to carry out a non-exhaustive mapping of existing sustainable blue economy relevant indicators. The indicators were categorized based on the Mission relevant sectors (see 2.1.1). In addition, a general category was applied if the indicator was relevant to multiple sectors. Further categorization was performed for the level of the indicator i.e., output, outcome and impact, as well, the applicability of the sustainability framework dimension i.e., environmental, economy, social or governance. In addition, indicator relevant databases were identified. The searches were conducted on Google Chrome and Google web-search tool.

2.1.3 Case studies

The method for selecting case studies (Section 2.3) in this research was guided by the aim to cover diverse aspects of the sustainable blue economy, focusing on four key sectors: waterborne transport, ports and associated facilities, renewable blue energy production, and low-trophic aquaculture. We provide an overview of various assessment methodologies and potential roadmaps for achieving carbon neutrality and circularity in the blue economy in the BANOS area. The selection was non-comprehensive, but still aiming to ensure a broad representation of activities within these sectors. The focus is on offering insights into a selection of activities, rather than an exhaustive analysis, to encourage further interest and research in this area.

Case studies were chosen to show different types of activities including political resolutions, roadmaps, and research projects. This range was selected to provide a snapshot of various approaches and initiatives across the sectors. Political resolutions reflect the strategic direction,

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roadmaps outline steps for sustainable development, and research projects showcase innovation.2.1.4. Expert input to themed questions

Additional input to complement the desktop studies was also collected from the BlueMissionBANOS CSA project partners. In the survey, three questions were presented:
1) What assessment practices, if any, are currently in place in [your country] for the above sectors to evaluate carbon neutrality and circularity in the blue economy? Please provide national and/or regional examples.
2) Do you know of any national or regional plans or roadmaps for achieving carbon neutrality and circularity in any of the blue economy sectors above?
3) Are there any national case studies of successful assessments in any of the blue economy sectors above that you can share with us?
In total, responses were collected from 11 countries in the BANOS region.

Stakeholder input for possible additional key performance indicators (KPIs) were also collected during the 1st Mission Arena in Gothenburg, Sweden on 16th of November 2023. For this purpose, an interactive workshop titled *Monitoring the Future Success of Sustainable Blue Economy in the BANOS* area was arranged. The workshop was well attended and received. For more information on the workshop arrangements and format, see Appendix 3 (Workshop summary).

2.2. KEY MISSION RELEVANT POLICIES FOR BANOS AREA

Mission relevant policy analyses focused on macroregional, EU-level and global policies. The indicators and/or monitoring approaches identified are listed in Table 12.

2.2.1. Macroregional policies

EU STRATEGY FOR THE BALTIC SEA REGION

The EU Strategy is the first macro-regional strategy in the European Union for the Baltic Sea Region (EUSBSR) and was launched in 2009 with the latest update of its action plan in 2021 (European Commission 2021e). It aims to strengthen the cooperation between the countries bordering the Baltic Sea to meet the shared challenges and to benefit from common opportunities facing the region. The Strategy has three objectives:

- saving the sea
- connecting the region
- increasing prosperity

The objectives are further linked to 14 specific policy areas (PA), which are implemented through 44 specific actions.

In conjunction, the EUSBSR objectives are closely linked to *The Our Baltic Declaration (*European Commission, 2020d) that was signed by EU ministers for agriculture, fisheries and environment from all the Baltic States committing to step up efforts to improve the environmental status of the Baltic

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Sea, by phasing out marine pollution, promoting sustainable agriculture, and building up a sustainable blue economy.

Relevance to SBE in the BANOS area:

6 of the 14 PAs detailed in EUSBSR are highly relevant for the sustainable Blue Economy sector:

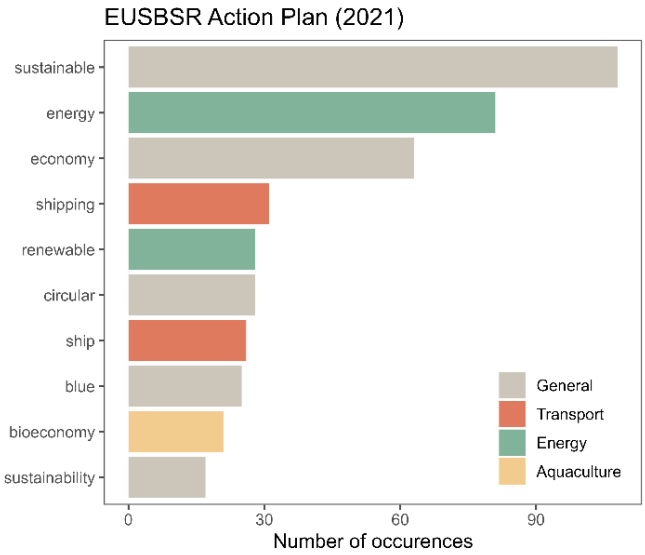

Figure 2 EUSBSR Action plan, occurrences of keywords.

1. **Bioeconomy,** including fisheries and aquaculture, aims to strengthen the role and importance of the bioeconomy for achieving increased sustainability, productivity and adaption to climate change as well as resilience. The circularity of products and natural resources is especially highlighted, actions aiming to accelerate resource efficiency while reducing waste.
2. **Ship,** aims to facilitate clean and safe shipping with the transition to sustainable shipping industry. Specific Blue Economy actions have been developed to target emission reductions, minimize environmental impacts of shipping and to developed shore-side facilities and offshore infrastructure to enhance clean shipping.
3. **Energy,** aims to provide reliable energy markets for the Baltic Sea regions. Specific Blue Economy actions have been proposed to increase share of renewable energy, including marine renewables, in the market and to ensure climate proof infrastructure development.
4. **Transport,** aims to enable good transport with improved foreign trade and international exchange of knowledge and services and, in a longer perspective, increase global competitiveness and the region's prosperity. Blue economy relevant actions include development of measures towards climate-neutral and zero pollution transport, and facilitation of innovative technologies and solutions for the transport sector of the Baltic Sea region.
5. **Innovation,** aims to promote a globally competitive position within innovation for sustainable economic growth in the Baltic Sea region, and providing a strong platform for an enhanced macroregional innovation ecosystem. Specific actions including challenge driven innovation flagships (e.g. SUBMARINER Network for Blue Growth, Blue Platform and Smart Blue Region). In addition, digital innovation and transformations are expected to be of importance as they are directly connected to ocean observation and transformation of (blue) bioeconomy /circular economy.
6. **Tourism,** aims to reinforce sustainable tourism development in the Baltic Sea region. Sustainable Blue economy and marine tourism rely on good and sustainable transport systems and connectivity. In addition, actions related to value and protection of natural resources in tourism destination are of high relevance.

HELCOM BALTIC SEA ACTION PLAN

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The Baltic Sea Action Plan (BSAP) is HELCOM's program for achieving a healthy Baltic Sea. Originally adopted in 2007, it aimed to achieve good ecological status by 2021, a target which was not met. The updated BSAP maintains the same level of ambition and includes both previously agreed actions and new measures to address emerging concerns and strengthen existing efforts (HELCOM 2021). It is a strategic program endorsed by the nine Baltic Sea countries and the European Union.

The updated BSAP is structured into four segments, aligned with HELCOM's vision for a healthy Baltic Sea:

- **Biodiversity**, with its goal of a "Baltic Sea ecosystem is healthy and resilient",
- **Eutrophication**, with its goal of a "Baltic Sea unaffected by eutrophication"
- **Hazardous substances and litter**, with its goal of a "Baltic Sea unaffected by hazardous substances and litter", and
- **Sea-based activities**, with its goal of "Environmentally sustainable sea-based activities".

Each segment focuses on specific goals and contains concrete actions to be implemented by 2030. The segments address pressures from land, sea-based activities, biodiversity, and include cross-cutting topics such as climate change, monitoring, and financing. Actions within all segments are designed to strengthen the overall resilience of the Baltic Sea, thereby improving its ability to respond to the impacts of climate change.

Relevance to SBE in the BANOS area:

Segment "sea-based activities" is highly relevant, but also "biodiversity" segment addresses some relevant aspects.

Relevant topics addressed in segments:

<u>Biodiversity</u>

- Coherence of the marine protected area (MPA) network

<u>Sea-based activities</u>

- Discharges from offshore platforms
- Recreational boating
- Pollution from ships

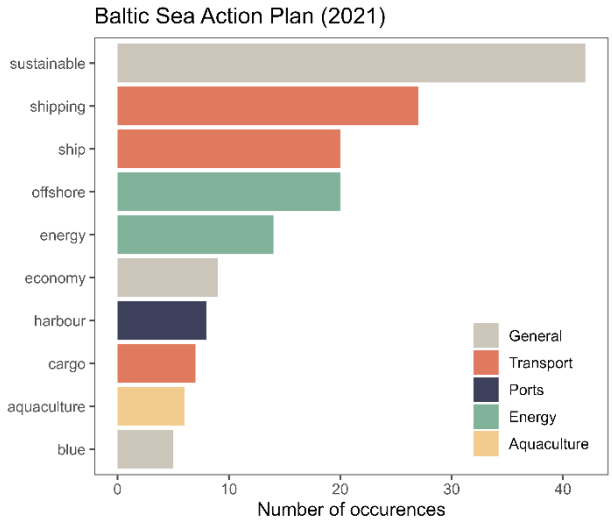

Figure 3 Baltic Sea Action Plan, occurrences of keywords.

SBE is mentioned twice:

"*Maritime spatial planning supports sustainable development and sustainable marine economy/ blue economy by applying an ecosystem-based approach.*"

"*The private sector, financial institutions as well as non-profit foundations and non-Baltic Sea states are therefore invited to join in the efforts to restore the good environmental status of the Baltic Sea, which also supports a growing sustainable blue economy in the region.*"

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VASAB VISION 2040

VASAB (Vision and Strategies Around the Baltic Sea) is intergovernmental multilateral co-operation of 11 countries in the Baltic Sea region, including Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Norway, Poland, Russia, Sweden, and the European Commission. The main goal of VASAB is to promote territorial cohesion and sustainable development in the Baltic Sea region.

The latest strategy "VASAB Vision 2040" sets a long-term territorial perspective for a vibrant, resilient, well-connected Baltic Sea Region, comprising the land-based and maritime spatial elements of the Region, respecting its diversities and specificities, and embracing sustainability, integration and cooperation throughout (VASAB, 2022). Its primary focus is on policymaking and to address complex challenges that span multiple levels, sectors, and borders, enhancing the region's ability to anticipate and prepare for future development paths, fostering sustainability and territorial cohesion until 2040.

Relevance to SBE in the BANOS area:

VASAB Vision 2040 strongly supports the development of SBE in the Baltic Sea region by proposing multiple potential actions to fulfil the Vision and respond to sustainability challenges of the future.

The Vision describes 'green' waterborne transport that has become a sustainable and well-connected way for the transport of people and goods, reducing congestion and pollution. It is facilitated through green ports with renewable energies and offering incentives for sustainable port charges.

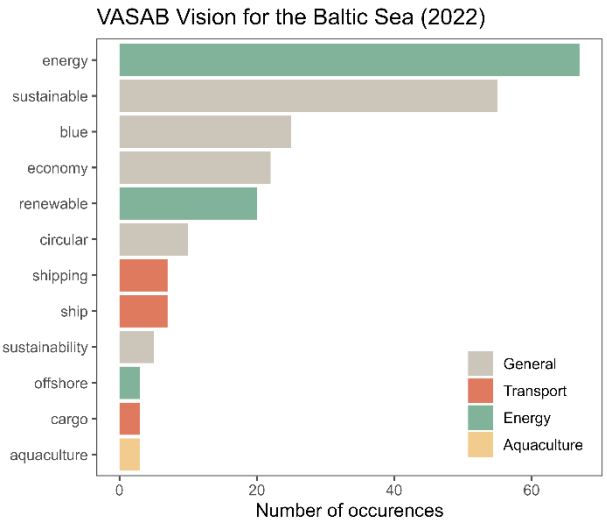

Figure 4 VASAB Vision for the Baltic Sea, occurrences of keywords.

Energy sector and offshore renewable energy production is also described in detail, outlying its importance as a future source for energy production, including a decentralized and well-connected energy grid, which is efficiently coordinated throughout the region. Other renewable innovative energy resources are included e.g., energy from algae. The importance of hydropower for the northern part of the region is also highlighted. Offshore renewable energy production, particularly wind power and innovative methods like energy from algae, is a key component of the Baltic Sea Region's blue economy, effectively balanced with ecosystem services, nature protection, and maritime spatial planning.

Economic activities are aligned with nature. The Vision promotes sustainable blue economy activities that provide social and economic benefits for current and future generations and restores, protects and maintains the diversity, productivity, resilience, core functions, and intrinsic value of marine ecosystems, and is based on clean technologies, renewable energy, and circular material flows.

NORTH SEA REGION 2030 STRATEGY

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The North Sea Region 2030 strategy is a steering document for the North Sea Commission and priority list for cooperation around the North Sea Region (North Sea Commission, 2020). The strategy highlights the leading role of the North Sea region in the transition towards the green economy and delivering on the European Green Deal, the Paris Agreement, and contributing to the UN Sustainable Development Goals.

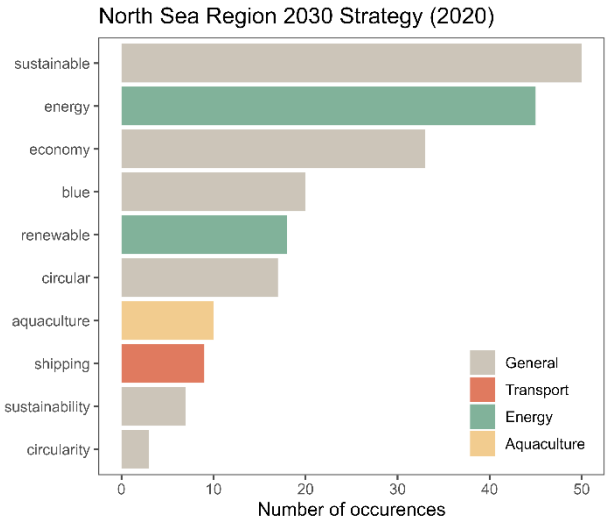

Figure 5 North Sea Region 2030 Strategy, occurrences of keywords.

Relevance to SBE in the BANOS area:

The North Sea Region 2030 Strategy is highly relevant to the sustainable blue economy sector in the BANOS area. The strategy not only recognizes the importance of the sustainable blue economy but actively integrates it into its priority areas, visions and key topics. The strong emphasis on innovation, cross-sectoral collaboration, sustainability, and climate neutrality aligns the document with the core principles of a sustainable blue economy in the BANOS area.

The strategy identifies four priority areas for cooperation: 1. A productive and sustainable North Sea (Healthy Marine environment; Maritime Spatial Planning; Sustainable aquaculture and fisheries; Sustainable blue economy) 2. A climate-neutral North Sea Region, 3. A connected North Sea region, 4. A smart North Sea Region all of which are discussed below.

Priority area: a productive and sustainable North Sea

Vision: Sustainable marine and maritime development

Emphasizes the significance of sustainable marine and maritime development for maintaining a healthy marine environment. Sets goals for lower emissions, reduced waste disposal, and emphasizes maritime spatial planning for sustainable aquaculture and fisheries. Strives for a balanced approach to various activities, including shipping, oil and gas, wind energy, fishing, aquaculture, tourism, and recreation, to achieve an overall sustainable North Sea.

Key topics included are Healthy Marine environment, Maritime Spatial Planning, Sustainable aquaculture and fisheries and Sustainable blue economy.

Priority area: Climate-neutral North Sea region.

Vision: A resilient and adapted North Sea region which has achieved climate neutrality at the very latest by 2050

Aligns with broader climate goals, striving for a climate-neutral North Sea Region. Focuses on renewable energy, energy efficiency, carbon capture, utilization, and storage (CCUS), and climate adaptation, emphasizing the role of sustainable practices in achieving a climate-neutral region.

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Key topics included are Renewable energy/alternative fuels; Energy efficiency; Carbon Capture, Utilization and Storage and natural carbon sinks; and Climate adaptation.

Priority Area: A Connected North Sea Region

Vision: Fossil-free, safe and user-friendly accessibility for all and in every territory of the North Sea Region

With largest Ports in Europe, the North Sea Region is a crucial transportation center in Europe, contributing to the competitiveness and facilitating both internal and external trade for the EU and surrounding areas. As such, achieving efficient, sustainable and carbon-neutral transportation of passengers and goods within and between countries is essential for fostering positive development of the region.

Key topics included are Transnational accessibility; Clean shipping, climate neutral and inclusive Transport; and Intelligent transport solutions.

Priority Area: A Smart North Sea Region

Vision: A front-runner in sustainable economics and democracy - a macroregion maximizing its competitive advantages through innovation and blue and green economies

The North Sea Region characterized by its specialized industries that are rooted in cutting-edge research, abundant resources, and a proficient workforce. Also in future, the region aims to maintain its position as a leading, competitive, appealing, and socially sustainable area. Sustainable growth in the North Sea Region hinges on responsible resource utilization and adherence to circular economy principles, while also leveraging opportunities presented by the digital economy. The active engagement of civil society, coupled with collaboration with citizens, will also empower the North Sea Region to devise local solutions for societal challenges.

Key topics included are Smart specialisation strategies; Skills/competences and mobility of researchers, students and the work force; and Circular use of resources.

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OSPAR NORTH-EAST ATLANTIC ENVIRONMENT STRATEGY

The North-East Atlantic Environment Strategy (NEAES) 2030 was adopted in October 2021 (OSPAR, 2021). This was supported by a high-level review of OSPAR's previous strategy for the decade 2010-2030.

The strategy is grouped under 4 themes which are further divided into 12 strategic objectives.

- *Clean seas*: strategic objectives focusing on eutrophication, hazardous substances radioactive substances and marine litter.
- *Biologically diverse and healthy seas*: strategic objectives focusing on protection, conservation and restoration of species and habitats.
- *Productive and sustainably used seas*: strategic objectives focusing on sustainable use of the marine environment and its resources, underwater noise and protection of the seabed.
- *Resilient to the impacts of climate change and ocean acidification*: strategic objectives focusing on raising awareness, facilitate adaptation and mitigation actions to climate change and ocean acidification.

Relevance to SBE in the BANOS area:

In general, NEAES focuses on the marine environmental protection, and therefore the strategy acknowledges the many challenges associated with the rapidly developing blue economy and associated expansion of human activities at the sea. In response, by 2024 OSPAR will aim to review the risks from new, emerging and increasing pressures on the marine environment, and to prioritize them for action and the adoption of measures where necessary. In addition, NEAES outlines that OSPAR aims to specifically develop common principles and guidance to promote and facilitate sustainable development and scaling up of offshore renewable energy in a way that cumulative environmental impacts are minimized. The strategy also highlights:

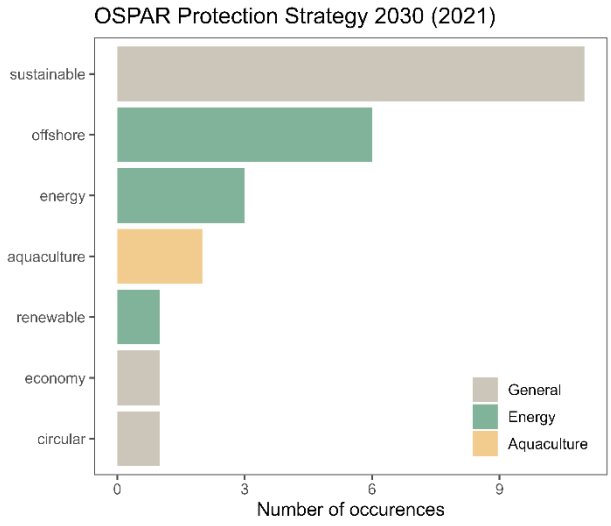

Figure 6 OSPAR Protection Strategy, occurrences of keywords.

- the importance of integrated management approaches of current and emerging human activities,
- the need for review of existing disused offshore installations, including advancement of decommissioning technologies and derogations based on the best available scientific knowledge,
- the need for safeguarding the marine environment's role as a natural carbon store through safeguarding the structure and functions of the seabed/marine ecosystems by preventing significant habitat loss and physical disturbance due to human activities.

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2.2.2. EU-level policies

EUROPEAN GREEN DEAL

The European Green Deal (European Commission 2019a) is a comprehensive plan to address climate and environmental challenges, aiming to transform the EU into a sustainable and prosperous society. It focuses on no net emissions of greenhouse gases by 2050, protecting natural resources, ensuring citizen well-being, and promoting a just transition. The plan requires public participation, international collaboration, and substantial investment. It aligns with the UN's sustainable development goals and will be integrated into EU policymaking and economic coordination.

The European Climate Law commits the EU to reducing its net greenhouse gas emissions by at least 55% by 2030 and delivering its Green Deal. To achieve this, the 'Fit for 55' legislative package aligns all sectors of the EU's economy with this target, ensuring a fair, cost-effective, and competitive approach to meeting its climate goals (European Commission, 2024a).

Overall, the European Green Deal provides a comprehensive framework and set of objectives that support the transition to a sustainable blue economy in the North Sea-Baltic Sea region. By promoting renewable energy, circular economy practices, sustainable resource management, cross-border cooperation, and providing funding and investment opportunities, the Green Deal can drive the region's sustainability goals, economic growth, and environmental protection in the blue economy sector.

Relevance to SBE in the BANOS area:

The European Green Deal is highly relevant to the sustainable blue economy sector in the BANOS area. The plan promotes the development of renewable energy, circular economy practices, sustainable resource management, and cross-border cooperation, all of which are essential for achieving the region's sustainability goals and driving economic growth while ensuring environmental protection, as specified below:

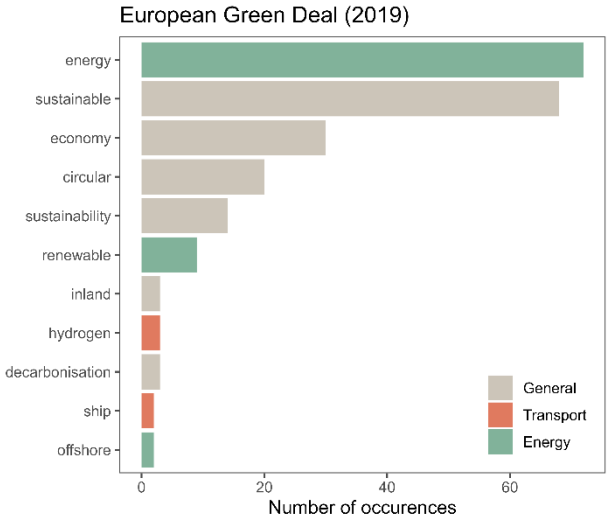

Figure 7 European Green Deal, occurrences of keywords.

1. Clean Energy Supply: The Green Deal's emphasis on decarbonizing the energy sector and increasing the share of renewable sources aligns with the development of offshore wind energy production in the region. The plan encourages regional cooperation to enhance offshore wind capacity, promoting a clean and secure energy supply.

2. Circular Economy: The Green Deal's focus on transitioning industries to a sustainable and circular model, offering opportunities for new business models and job creation in the blue economy sector.

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3. Sustainable Resource Management: The Green Deal recognizes the importance of sustainable resource management in the BANOS area, including its marine environment. The plan highlights the need to leverage low-emission technologies and ensure a stable supply of critical raw materials for clean technologies, aligning with the region's focus on sustainable resource extraction.

4. Cross-Border Cooperation: The Green Deal emphasizes the importance of cross-border and regional cooperation, which is crucial in the BANOS area encompassing several countries. Enhanced cooperation in areas such as energy infrastructure, innovation, and value chains can facilitate the deployment of innovative technologies and drive the development of the blue economy.

5. Offshore Renewable Energy Potential: The Green Deal recognizes the potential of offshore renewable energy in mitigating climate change and promotes the development of the sector. This aligns with the BANOS area's focus on offshore wind energy production and its efforts to transition to a cleaner and more sustainable energy mix.

6. Ecosystem Preservation and Restoration: The Green Deal's objectives of preserving and restoring ecosystems and biodiversity align with the BANOS area's commitment to protecting marine habitats and promoting sustainable fisheries. The strategy emphasizes cross-border cooperation to protect and restore marine protected areas.

7. Funding and Investment: The Green Deal's Sustainable Europe Investment Plan aims to mobilize both public and private investment to support sustainable projects, including those in the blue economy sector. This funding can support the development of offshore wind energy, marine conservation efforts, and sustainable fisheries in the BANOS area.

EUROPEAN CLIMATE LAW

The European Climate Law (ECL) was entered into force in July 2021 (European Commission, 2021d). The policy writes into law the goal set out in the European Green Deal, while delivering on the implementation of the Paris Agreement adopted under the United Nations Framework Convention on Climate Change (the 'Paris Agreement') and directing Europe's economy and society to become climate-neutral by 2050[1]. The law also sets the intermediate target of reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.

[1] Climate neutrality by 2050 means achieving net zero greenhouse gas emissions for EU countries as a whole, mainly by cutting emissions, investing in green technologies and protecting the natural environment.

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Objectives of the ECL are:

- Set the long-term direction of travel for meeting the 2050 climate neutrality objective through all policies, in a socially fair and cost-efficient manner.
- Set a more ambitious EU 2030 target, to set Europe on a responsible path to becoming climate-neutral by 2050.
- Create a system for monitoring progress and take further action if needed.
- Provide predictability for investors and other economic actors.
- Ensure that the transition to climate neutrality is irreversible.

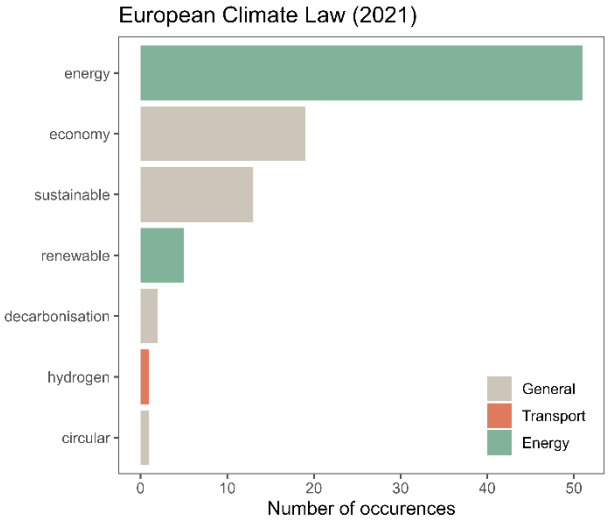

Figure 8 European Climate Law, occurrences of keywords.

Relevance to SBE in the BANOS area:

The ECL stipulates that achieving climate neutrality should require a contribution from all economic sectors for which emissions or removals of greenhouse gases are regulated in the Union law. As such, the policy is highly relevant to the all-blue economy sectors, from waterborne transport to aquaculture in the BANOS area, irrespective of whether those sectors are covered by the system for greenhouse gas emission allowance trading within the Union ('EU ETS'). The policy encourages to decouple economic growth from greenhouse gas emissions, while simultaneously encouraging the Union blue economy sectors to secure industry leadership in global green innovation.

To ensure a transition to a safe, sustainable, affordable, and secure energy system relying on the deployment of renewables, as stipulated in the ECL, the offshore wind energy sector is expected to be highly relevant for the BANOS area. The North Sea region is already a global leader in the field and the expansion is expected to grow in future reaching up to 300GW by 2050 (Taylor, EurActiv, 2023). The offshore energy sector is also currently rapidly developing in the Baltic Sea region, current plans being 46.8 GW (European Commission 2023b, website)

Carbon neutral economy requires the development of regulatory framework for certification of carbon removals based on robust and transparent carbon accounting to monitor and verify the authenticity of carbon removals, while ensuring that there are no negative impacts on the environment, in particular biodiversity, on public health or on social or economic objectives. Here, the blue carbon, carbon stored in coastal sediments and ecosystems, is gaining attention, yet prior to its application in carbon accounting many challenges are still to be solved (European Marine Board 2023).

BLUE GROWTH STRATEGY

The "Blue Growth Strategy" is a long-term initiative by the European Commission (DG MARE) aimed at promoting sustainable growth in the marine and maritime sectors (European Commission 2012). It seeks to unlock the untapped potential of Europe's oceans, seas, and coasts as drivers for a green

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economy, with a focus on innovation, enhanced competitiveness, and quality job creation to align with the Europe 2020 strategy for smart, sustainable, and inclusive growth. This strategy recognizes that marine economic activities should not be viewed solely through a sectoral lens and encompasses all economic activities related to oceans, seas, and coasts, including emerging sectors such as marine renewable energy, biotechnology, desalination, and more. Blue Growth emphasizes the role of Smart Specialization[2] in identifying and promoting innovation in these sectors while addressing the challenges of limited data and information for measuring economic and innovation impacts.

Relevance to SBE in the BANOS area:

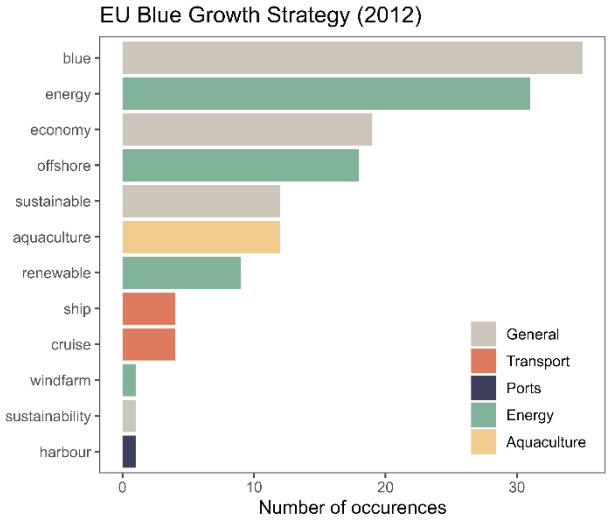

Figure 9 EU Blue Growth Strategy, occurrences of keywords.

The Blue Growth Strategy serves as a long-term strategy to harness the potential of Europe's oceans and seas, promoting innovation, competitiveness, and quality job creation in alignment with the goals of the Europe 2020 strategy for smart, sustainable, and inclusive growth. The Blue Growth concept recognizes that maritime economic activities cannot be solely defined by industrial classification, emphasizing that the marine and maritime sectors are essential drivers for the European economy. The EU's Blue Economy encompasses all economic activities related to oceans, seas, and coasts, and the Blue Growth Strategy aims to promote sectors like offshore renewable energy, marine biotechnology, and deep-seabed mining. Furthermore, the Smart Specialisation approach plays a crucial role by supporting regional and national authorities, research, and innovation in bridging blue growth investment platforms and regional initiatives, thereby identifying and developing economic activities in emerging sectors of the blue economy. This strategy encourages place-based innovation, which allows regions to specialize in domains that align with their strengths and potential, such as marine biotechnology and deep seabed mining in Azores and cross-sectorial dimensions in Ida-Viru, Estonia, among others. It also promotes interregional cooperation and value networks, facilitating the development of value chains associated with marine resources, ultimately contributing to economic development. Through initiatives like the Interregional Partnership on Smart Specialisation in Marine Renewable Energy, the Blue Growth Strategy enables collaboration between regions to improve the competitiveness of European companies in areas like offshore wind and ocean energies. These efforts address technological challenges and operational issues in marine renewable energy and aim to offer

[2] Smart Specialization is a place-based approach characterized by the identification of strategic areas for intervention based both on the analysis of the strengths and potential of the economy and on an Entrepreneurial Discovery Process (EDP) with wide stakeholder involvement. It is outward-looking and embraces a broad view of innovation including but certainly not limited to technology-driven approaches, supported by effective monitoring mechanisms. https://ec.europa.eu/regional_policy/policy/communities-and-networks/s3-community-of-practice_en

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cost-competitive solutions for the European industry. In summary, the Blue Growth Strategy is closely linked to the sustainable blue economy sector in the BANOS area by promoting innovation, collaboration, and economic growth in various maritime activities and emerging sectors.

SUSTAINABLE BLUE ECONOMY STRATEGY

The "Sustainable Blue Economy - A New Approach for a Sustainable Blue Economy in the EU" communication was published in 2021 and is motivated by the central role of the European Green Deal and the Recovery Plan for Europe in shaping the European economy, with a recognition of the indispensable contribution of the blue economy to environmental and climate objectives (European Commission 2021a). The primary objectives are to align with and support the European Green Deal's goals while complementing other Commission initiatives across various sectors. These objectives involve mitigating climate change through offshore renewable energy, greening maritime transport, and fostering a circular economy. Additionally, the initiative seeks to promote green infrastructure in coastal areas, conserving biodiversity and landscapes while boosting tourism and coastal economies. Rather than an exhaustive action plan, the approach emphasizes fostering coherence and synergy across blue economy sectors while highlighting the necessity of investments in research, skills, and innovation to drive sustainability and economic growth within the blue economy. It underscores the intrinsic link between the green and blue economies for a sustainable and climate-resilient future.

Relevance to SBE in the BANOS area:

Transforming the EU's blue economy for a sustainable future is intrinsically linked to the European Green Deal objectives. The plans to promote sustainable blue economy focus on reducing pollution, protecting marine biodiversity, promoting circular economy practices, and fostering sustainable food systems while creating economic opportunities and jobs. This strategic goal aligns with the European Green Deal's objectives and emphasizes the importance of integrating ocean policy into broader economic policies. The policy encompasses a comprehensive vision aimed at transitioning to a sustainable blue economy, which is intrinsically linked to the objectives of the European Green Deal. This strategy addresses a multitude of facets, ranging from addressing pressing environmental challenges and integrating ocean policy into the broader economic agenda, as summarized below.

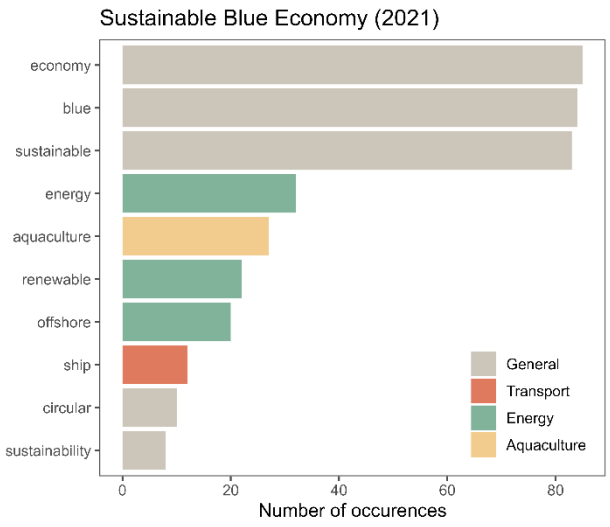

Figure 10 Sustainable Blue Economy, occurrences of keywords.

1. Economic Relevance: The text emphasizes the economic importance of the blue economy in Europe, providing 4.5 million direct jobs. Many of these jobs are located in regions around the BANOS area, where the blue economy plays a vital role in providing employment opportunities and

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economic sustenance. The strategy also acknowledges the need for significant investments in the blue economy. In the BANOS area this investment is crucial for developing offshore renewable energy projects, sustainable fishing practices, and marine conservation efforts. EU funding and cooperation with financial institutions support these investments in the region.

2. Sustainability Transition: The strategy advocates for transitioning from "blue growth" to a "sustainable blue economy." This transition aligns with the goals of the European Green Deal and is directly relevant to the BANOS area. It highlights the need to protect the region's natural capital, promote sustainable practices, and ensure the economic growth of the blue sectors in the region is environmentally responsible.

3. Marine Protection and Climate Goals: The text mentions the EU's aims to increase marine protection and meet ambitious depollution targets and climate neutrality goals. These objectives are directly connected to the BANOS area's need for marine protection, particularly due to the region's vulnerability to climate change and pollution.

4. Stakeholder Engagement: The strategy calls for the involvement of blue economy operators and stakeholders, including businesses and local groups. In the BANOS area, the engagement of local stakeholders is crucial to ensure that blue economy activities are carried out sustainably and in harmony with local communities.

5. Climate Adaptation and Coastal Resilience: The strategy underscores the importance of nature-based solutions for climate adaptation in coastal regions. This approach aligns with the needs of the BANOS area, which faces challenges like rising sea levels and extreme weather events that require sustainable, nature-based solutions to protect coastal assets and communities.

6. Responsible Food Systems: The strategy promotes responsible fishing and sustainable aquaculture. It highlights the importance of low-trophic aquaculture, offering opportunities to reduce environmental pressures in the BANOS area.

7. Ocean Knowledge: The strategy emphasizes the importance of accessible, reliable, high-quality, and harmonized ocean data to support decision and management efforts. In the BANOS area, this data is crucial for various sectors, such as fisheries and aquaculture, shipping, and environmental monitoring. Access to such data allows stakeholders in the region to make informed decisions, manage resources effectively, and navigate safely.

8. Research and Innovation: The text highlights the role of research and innovation in achieving a sustainable blue economy. In the BANOS area, research and innovation are essential for advancing offshore renewable energy, maritime security, and sustainable fisheries practices.

9. Blue Skills and Jobs: The text recognizes the potential for job creation in the blue economy, including in sectors like offshore wind energy. In the BANOS area, there is a growing demand for skilled workers in these sectors. Training and upskilling programs are essential for addressing skills gaps and ensuring a qualified workforce.

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10. Maritime Spatial Planning: Maritime spatial aims to help reconciling nature conservation with economic development, which is particularly relevant in this BANOS area to its high population density and diverse economic activities.

11. Promoting a Sustainable Blue Economy Abroad: The strategy emphasizes the EU's role in promoting a sustainable blue economy internationally. This is relevant to the BANOS are because many of its blue economy value chains are interconnected with global markets.

CIRCULAR ECONOMY ACTION PLAN

The new Circular Economy Action Plan (CEAP) was adapted by the European Commission in March 2020 (European Commission 2020a, b). It is one of the main building blocks of the European Green Deal aiming to accelerate EU's transition to circularity, leading to a reduction in pressure on natural resources, while creating sustainable growth and new jobs. It is also a prerequisite to achieving the EU's 2050 climate neutrality target and halting biodiversity loss.

Objectives of the CEAP is to introduce specific measures that

- make sustainable products the norm in the EU;
- empower consumers and public buyers;
- focus on the sectors that use most resources and where the potential for circularity is high such as: electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, food, water and nutrients;
- ensure less waste;
- make circularity work for people, regions and cities;
- lead global efforts on circular economy.

Relevance to SBE in the BANOS area:

The CEAP holds significant relevance for development of SBE in the BANOS area, as it actively promotes sustainability across all economic sectors. Its primary focus lies in transforming product design, usage, and recycling processes to reduce waste and minimize environmental impact. This legislative initiative aims to expand the scope of the existing Ecodesign Directive beyond energy-related products. As a result, the Ecodesign framework will become applicable to a broader range of products, ensuring it fosters circularity, reduces carbon and environmental footprints, and curtails single-use practices while combating premature obsolescence.

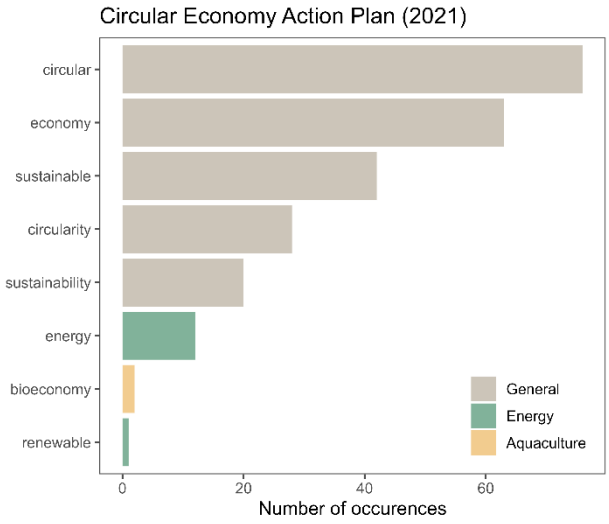

Figure 11 Circular Economy Action Plan, occurrences of keywords.

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One concrete example of how this policy action is directly linked SBE, and specifically to the electrification of waterborne transport, is via battery development and recycling of the raw materials, which the CEAP emphasizes. Additionally, new planned and mandatory regulation on recycled content for certain materials, could have implications for end-of-life vehicles, making them relevant to both ships and ferries alike.

The CEAP has also a high affinity to low-trophic aquaculture, as marine polymers which can be derived from seaweed, for example, are a prime candidate for production of biodegradable packing materials in future (e.g. Lomartire et al 2022).

BIODIVERSITY STRATEGY

The EU's biodiversity strategy for 2030 is a comprehensive, ambitious and long-term plan to protect nature and reverse the degradation of ecosystems (European Commission, 2020c). The strategy aims to put Europe's biodiversity on a path to recovery by 2030, and contains specific actions and commitments.

Relevance to SBE in the BANOS area:

The EU Biodiversity Strategy for 2030 addresses the need for biodiversity conservation and restoration within the European Union, encapsulating several facets relevant to the concept of a sustainable blue economy. It underscores the economic dependency on nature, emphasizing that various industries rely on genes, species, and ecosystem services, particularly within sectors such as construction, agriculture, and food and drink. The document highlights the potential economic gains achievable through the conservation of marine stocks, projecting a substantial increase in annual profits in the seafood industry. Furthermore, the strategy recognizes the economic benefits of safeguarding coastal wetlands, presenting an avenue to save the insurance industry significant sums by mitigating flood damage losses. It acknowledges the connection between global GDP and nature, emphasizing the significance of biodiversity, including marine ecosystems, in economic activities. Despite the absence of the explicit term, the strategy outlines measures and commitments that resonate with the principles of sustainable blue economy practices in the BANOS area. These encompass the promotion of natural capital investment, the establishment and enlargement of Marine Protected Areas (MPAs), and the encouragement of investments in ecological corridors and green and blue infrastructure. The strategy also underlines the economic benefits of such endeavours, reflecting a commitment to marine conservation and the sustainable use of marine resources. In conclusion, while the terminology may differ, the strategy

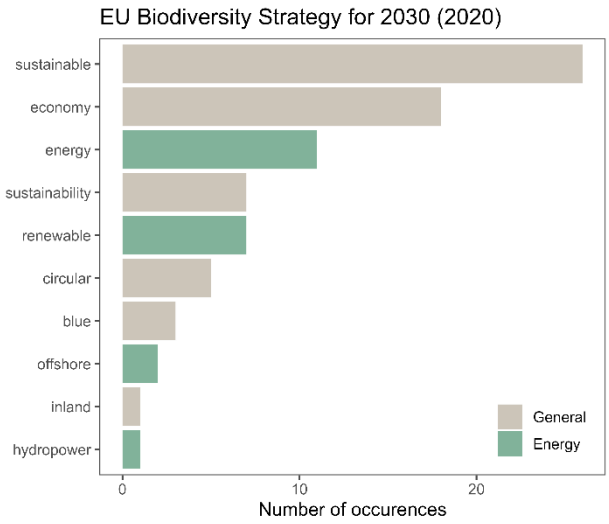

Figure 12 EU's biodiversity strategy for 2030, occurrences of keywords.

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effectively addresses key elements of the sustainable blue economy, fostering a balance between economic activities and the preservation of marine ecosystems in the specified region.

In relation to biodiversity protection, it is also worth to mention that the Commission has proposed a new *Nature restoration law* to restore ecosystems for people, the climate and the planet (European Commission 2022b). The proposal for the new law was adopted in June 2022. Specific targets for Marine Protected Areas are also outlined in the Biodiversity Plan of the Convention of Biological Diversity with target 3 stating that by 2030 at least 30 per cent of terrestrial, inland water, and of coastal and marine areas should be protected (Convention on Biological Diversity, 2023).

INTEGRATED MARITIME POLICY

The Integrated Maritime Policy (IMP) was set up in 2007 (European Commission, 2007). It recognizes that all matters relating to Europe's oceans and seas are interlinked, and that sea-related policies must develop in a joined-up way if we are to reach the desired results. As such, it is a coherent, holistic approach to all sea-related EU policies (European Commission, 2023d)

The IMP has five main objectives:

1. Maximising the sustainable use of the oceans and seas in order to enable the growth of maritime regions and coastal regions as regards shipping, seaports, shipbuilding, maritime jobs, the environment and fisheries management.
2. Building a knowledge and innovation base for maritime policy through a comprehensive European Strategy for Marine and Maritime Research
3. Improving the quality of life in coastal regions by encouraging coastal and maritime tourism, creating a Community Disaster Prevention Strategy and developing the maritime potential of the EU's outermost regions and islands
4. Promoting EU leadership in international maritime affairs through enhanced cooperation at the level of international ocean governance and, on a European scale, through the European Neighbourhood Policy and the Northern Dimension
5. Raising the visibility of maritime Europe through the 'European Atlas of the Seas' internet application, as a means of highlighting the common European maritime heritage, and by celebrating an annual European Maritime Day.

Relevance to SBE in the BANOS area:

The integrated marine policy and development of the SBE in the BANOS area are closely intertwined. The IMP is an integration of various sectoral policies (e.g. Blue Growth Agenda and Maritime spatial planning among other) with direct impact on multiple blue economy sectors

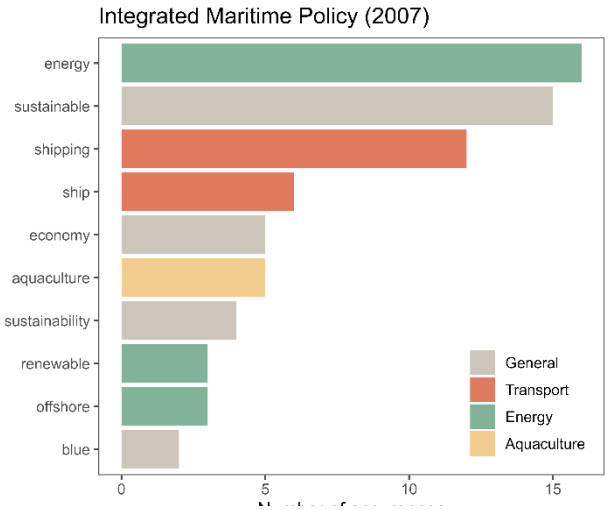

Figure 13 Integrated Maritime Policy, occurrences of keywords.

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like (low-trophic) aquaculture, fisheries, waterborne transport, ocean energy, ports, tourism etc. Where the IMP aims to foster sustainable development of all sea-based activities and coastal regions, including use and conservation of marine resources, the SBE aspires to promote economic growth and job creation while ensuring the health and integrity of marine ecosystems and the equitable distribution of benefits.

MARITIME SPATIAL PLANNING DIRECTIVE

The Maritime Spatial Planning Directive (MSPD) was adopted in 2014 and by 2021 the national MSPs were adapted by the member states (European Commission, 2014). It is part of the overarching EU IMP policy, and its objective is to work across the borders and sectors to ensure human activities at sea take place in an efficient, safe and sustainable way, while supporting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources.

Relevance to SBE in the BANOS area:

Efficient MSP is an essential element for development of the SBE in BANOS area. As the coastal seas are becoming increasingly crowded by various economic interest groups the competition for sea-space accelerates. Thus, MSPs provide Member States crucial tools to plan and organize their sea-based activities, while ensuring the sustainable development of economy and protection of marine environment and resources.

The MSP encourages member states to consider economic, social and environmental aspects to support sustainable development and growth in the maritime sector. It also strongly supports an ecosystem- based approach for management, as well as coexistence of relevant activities and uses.

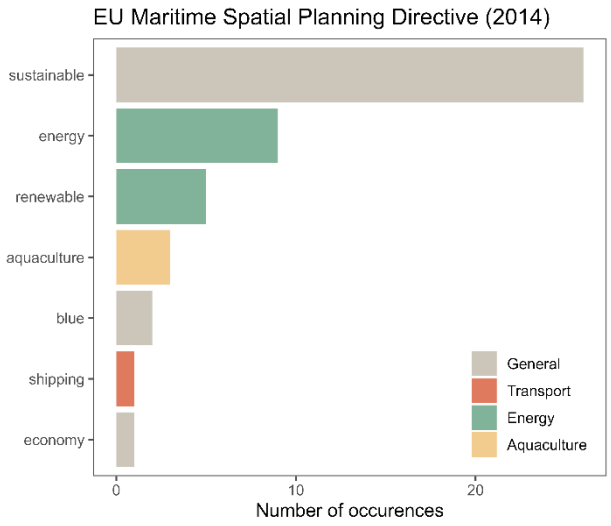

Figure 14 Maritime Spatial Planning Directive, occurrences of keywords.

MARINE STRATEGY FRAMEWORK DIRECTIVE

The Marine Strategy Framework Directive (MSFD) was adopted in 2008 (European Commission 2008), aiming to achieve the good environmental status (GES) in EU marine waters and to protect the resource base upon which marine-related economic and social activities depend. For this purpose, 11 Descriptors have been identified.

Relevance to SBE in the BANOS area:

Key points related to sustainable blue economy in the BANOS region include:

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Thematic strategy for marine environment: The directive aligns with the thematic strategy for the protection and conservation of the marine environment, aiming to promote the sustainable use of seas and conserve marine ecosystems.

Biodiversity conservation: The directive acknowledges the importance of protecting and preserving the marine environment as a precious heritage. It emphasizes the need to maintain biodiversity and ensure clean, healthy, and productive oceans and seas.

Ecosystem-based approach: An ecosystem-based approach is advocated for managing human activities in the marine environment, prioritizing the achievement or maintenance of good environmental status. This includes ensuring sustainable use of marine goods and services.

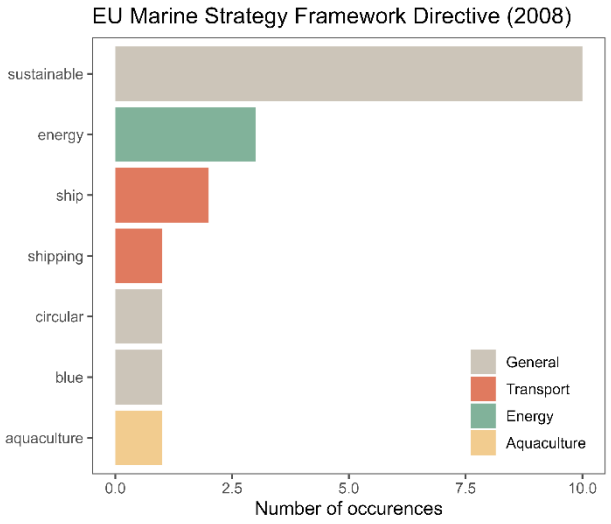

Figure 15 Marine Strategy Framework Directive, occurrences of keywords.

Marine protected areas (MPAs): The establishment of marine protected areas is highlighted as a crucial contribution to achieving good environmental status. This involves areas designated under the Habitats Directive, Birds Directive, and international or regional agreements.

Integration with other policies: The directive emphasizes the need for a transparent and coherent legislative framework that fosters the integration of environmental concerns into various policies, such as the Common Fisheries Policy, Common Agricultural Policy, and other relevant community policies.

Cooperation and coordination: Due to the transboundary nature of the marine environment, Member States are encouraged to cooperate and coordinate the development of marine strategies. This involves close collaboration with other Member States, third countries, and existing institutional structures like Regional Sea Conventions.

Public involvement: The directive emphasizes the active involvement of the general public in the establishment, implementation, and updating of marine strategies. It calls for proper public information and access to relevant information in accordance with community legislation on public access to environmental information.

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WATER FRAMEWORK DIRECTIVE

The Water Framework Directive (WFD) is a key piece of EU legislation established in 2000 (European Commission, 2000). It commits EU Member States to achieve good quality and quantitative ecological status of all water bodies, including rivers, lakes, estuaries, groundwater and coastal marine waters (up to one nautical mile from the base line of territorial waters).

Its primary objective is to protect and, where necessary, restore water bodies in order to reach good status, and to prevent deterioration. Good status means both good chemical and good ecological status.

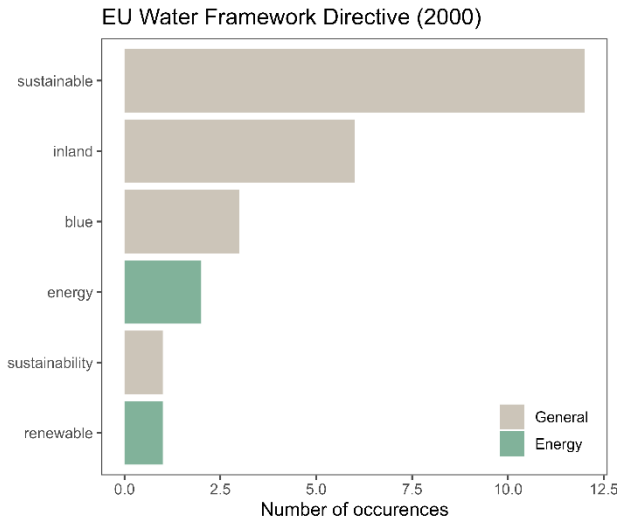

Figure 16 The Water Framework Directive, occurrences of keywords.

Relevance to SBE in the BANOS area:

Many land-based activities have a direct impact on the quality of the marine environment via freshwater input to seas and oceans. In addition, many blue economic sectors e.g. waterborne transport, aquaculture and fisheries, tourism and energy operate in both environments. Hence, the WFD is interlinked to SBE in the BANOS area.

WFD also recognizes the need for policy integration among the closely connected fields and aims to provide a basis for a continued dialogue and for the development of strategies towards the integration of policy areas.

COMMON FISHERIES POLICY

The Common Fisheries Policy (CFP) was introduced in the 1970s and it also stipulates rules on aquaculture. The latest reform is from 2013 (European Commission, 2013) and it is the first comprehensive legal framework, featuring:

- attention to the environmental, economic and social dimensions of fisheries,
- fish stock management at maximum sustainable yield for all managed stocks,
- gradual introduction of a landing obligation by 2019,
- continued application of the so-called multiannual plans (MAPs) to manage fisheries in different sea basins,
- regionalisation to allow EU countries with a management interest to propose detailed measures, which the Commission can then adopt as delegated or implementing act and transpose them into EU law,
- fleet capacity ceilings per EU country in combination with the obligation for EU countries to ensure a stable and enduring balance between fishing capacity and fishing opportunities over time. EU countries may need to develop action plans to reduce overcapacity (for which they can use scrapping money).

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Relevance to SBE in the BANOS area:

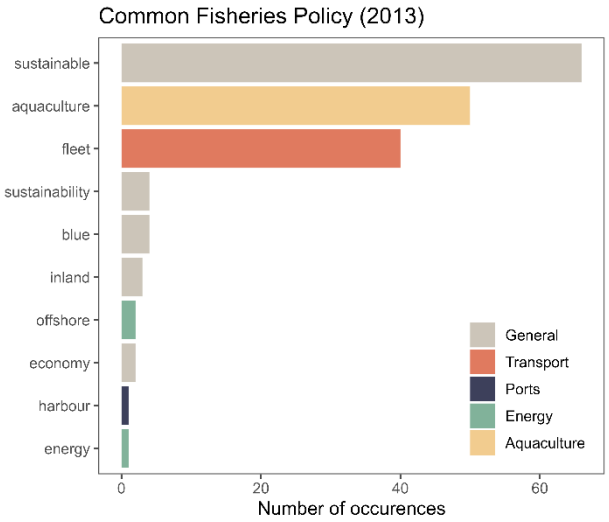

Figure 17 Common Fisheries Policy, occurrences of keywords.

Fisheries and aquaculture sector is one of the important sectors of blue economy. EU goal is to have climate neutral fisheries and aquaculture sector by 2050, including freshwater biological resources and aquaculture activities. One of the central challenges is the energy used by the industry. Two main directions of change, and innovative solutions, are required: (1) an increase in energy efficiency, including a decrease in fuel-use intensity and in overall fuel consumption in the sector in the short to medium term; and (2) a switch from fossil fuels to renewable and low-carbon energy source consumption and demand. Like waterborne transport in general, fishing fleets rely on diesel for their operation. In aquaculture energy is needed for multiple purposes, including e.g feeding systems, water circulation, service fleets. To ensure sustainable and climate neutrality fuel efficiency and switching to renewable, low-carbon power sources is critically needed.

The CFP recognizes the need for reduces waste and calls for circularity. Specifically, it emphasizes the need for reducing the current high levels of unwanted catches and to gradually eliminate discards. Unwanted catches and discards constitute a substantial waste and negatively affect the sustainable exploitation of marine biological resources and marine ecosystems. Further, 'low impact fishing' is emphasizes, meaning utilization of selective fishing techniques which have a low detrimental impact on marine ecosystems, or which may result in low fuel emissions.

Aligned with the CFP, the Commission has also adopted new strategic guidelines of aquaculture in 2021 and EU countries have reviewed their national strategies in light of the new guidelines (European Commission 2021f).

2.2.3. Global policies

UN Sustainable Development Goals – AGENDA 2030

This Agenda is a comprehensive plan for global development, peace, and sustainability. It aims to eradicate poverty, protect the environment, and ensure equal rights and opportunities for all. Through collaborative efforts, the 17 Sustainable Development Goals and 169 targets will guide transformative actions to create a resilient and inclusive future for the next 15 years (United Nations, 2015).

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Relevance to SBE in the BANOS area:

Of the 17 SDGs, **Goal 14** is especially relevant for sustainable blue economy, which aims to protect and sustainably manage the oceans, seas, and marine resources. The key targets include reducing marine pollution, protecting and restoring marine ecosystems, addressing ocean acidification, regulating fishing practices, conserving coastal and marine areas, eliminating harmful fisheries subsidies, promoting sustainable economic benefits for developing countries, advancing scientific knowledge and technology transfer, supporting small-scale fishers, and implementing international laws for ocean conservation and sustainable use.

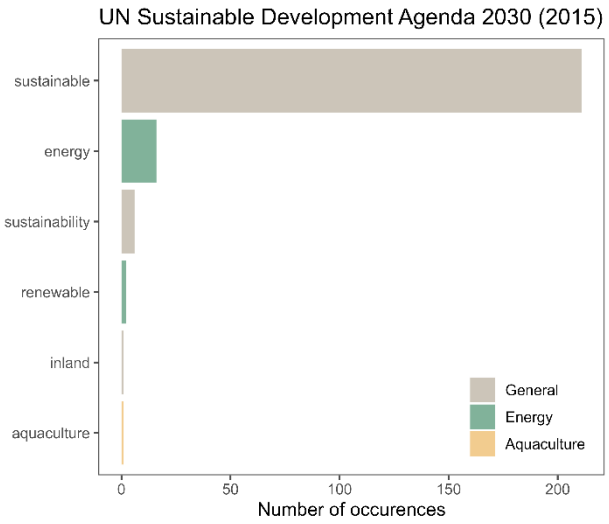

Figure 18 UN Sustainable Development Agenda 2030, occurrences of keywords.

In addition, the following goals are of relevance:

- Goal 1. End poverty in all its forms everywhere
- Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- Goal 6. Ensure availability and sustainable management of water and sanitation for all
- Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable
- Goal 12. Ensure sustainable consumption and production patterns
- Goal 13. Take urgent action to combat climate change and its impacts
- Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

UN Ocean Decade (Implementation Plan)

Through the vision ‘the science we need for the ocean we want’, the *UN Ocean Decade of Ocean Science for Sustainable Development* (2021-2030) aims to stimulate ocean science and knowledge generation to reverse the decline of the state of the ocean system and create new opportunities for sustainable development of marine ecosystems (later the term UN Ocean Decade is used). It provides a common framework of ocean scientist and stakeholders from diverse sectors, which can support countries’ actions to sustainably manage the ocean, seas and coasts. The Ocean Decade has been declared to address the alarming deterioration of ocean health. The Intergovernmental

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Oceanographic Commission (IOC) of UNESCO was tasked with coordinating the preparatory process for the Decade, rallying the global ocean community to plan and implement comprehensive ocean science and technology initiatives for a sustainable future. As part of the UN Ocean Decade, the UN Ocean Decade Vision 2030 process assesses current trends, gaps, and user needs, establishing common measures of success for the challenges by identifying targets, milestones, and the necessary resources (UNESCO-IOC 2021). Through concrete indicators and methodologies, it contributes to evaluating the impact of the Ocean Decade, prioritizing resource mobilization, and ensuring the ongoing relevance of the Challenges.

Relevance to SBE in the BANOS area:

The goals and objectives laid out in the UN Ocean Decade Vision 2030, are operationalized in the Ocean Decade – Implementation Plan, which is relevant to the sustainable blue economy sector in the North Sea-Baltic Sea region through various key aspects:

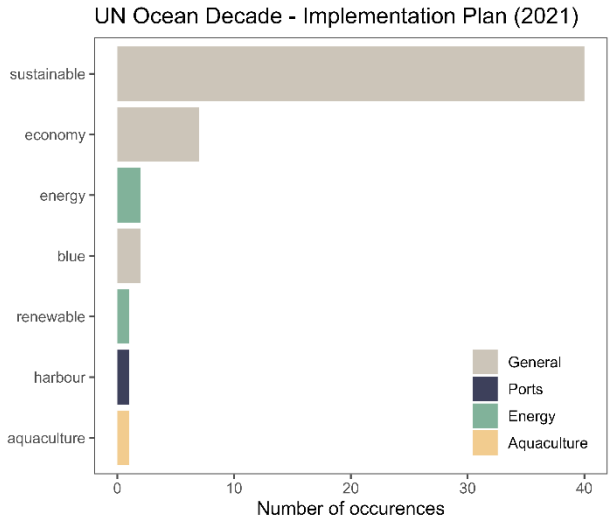

Figure 19 UN Ocean Decade, occurrences of keywords.

Recognition of economic importance. The Implementation Plan recognizes the economic significance of the ocean, highlighting its role in generating jobs and contributing to the global economy.

Vision and mission. The vision of the Ocean Decade, emphasizing "the science we need for the ocean we want," aligns with the scientific approach needed for sustainable blue economy practices.

Ocean Decade challenges. Challenge #4 specifically addresses the need for sustainable development in the ocean economy under changing conditions. This aligns with the principles of the blue economy and is relevant to the challenges faced by the North Sea-Baltic Sea region in balancing economic activities with environmental and social considerations.

Monitoring and evaluation. The outlined monitoring and evaluation framework ensures adaptive management, aligning initiatives with the evolving needs of the sustainable blue economy in the North Sea-Baltic Sea region.

Table 10 Existing indicators/monitoring frameworks related to mission related policies where identified. See also more details on indicators in Appendix 4.

Policy	Indicator/monitoring description	URL (all accessed 1 Dec 2023)
EU Strategy for The Baltic Sea Region	Indicators for each policy area listed in the strategy. Monitoring framework not outlined (European Commission 2021e).	*not applicable*

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HELCOM Baltic Sea Action Plan	Comprehensive set of 59 HELCOM indicators primarily focusing on the environmental and ecological state of the Baltic Sea.	https://indicators.helcom.fi/
OSPAR North-East Atlantic Environment Strategy	Comprehensive set of indicators for monitoring environmental and ecological state of the OSPAR region.	https://www.ospar.org/work-areas/cross-cutting-issues/ospar-common-indicators
European Green Deal & European Climate Law	Statistics for the European Green Deal; also includes indicators relevant for reductions in greenhouse gas emissions.	https://ec.europa.eu/eurostat/cache/egd-statistics/
Blue Growth Strategy	The annual publication of Blue Economy Report (European Commission 2023c), and dash board of Blue Economy Indicators	https://blue-economy-observatory.ec.europa.eu/blue-economy-indicators_en
Sustainable Blue Economy Strategy	The annual publication of Blue Economy Report (European Commission 2023c), Blue Economy Indicators.	https://blue-economy-observatory.ec.europa.eu/blue-economy-indicators_en
Circular Economy Action Plan	Framework focusing on the (i) production and consumption, (ii) waste management, (iii) secondary raw materials, (iv) competitiveness and innovation, (v) global sustainability and resilience	https://ec.europa.eu/eurostat/web/circular-economy
Biodiversity Strategy	EU Biodiversity Strategy Dashboard	https://dopa.jrc.ec.europa.eu/kcbd/dashboard/
Integrated Maritime Policy	European maritime safety agency (EMSA) – Integrated Maritime Services (IMS) provides a comprehensive maritime picture.	https://www.emsa.europa.eu/we-do/digitalisation/maritime-monitoring.html
Directive on Maritime Spatial Planning	The sea basin and country specific MSP profiles are updated and maintained.	https://maritime-spatial-planning.ec.europa.eu/
Marine Strategy Framework Directive	Good Environmental Status (GES) is described through the eleven descriptors, and the level of achievement of these descriptors determine whether GES is achieved or not..	https://indicators.helcom.fi/ https://www.ospar.org/work-areas/cross-cutting-issues/ospar-common-indicators
Water Framework Directive	Percentage of water bodies, not in good ecological status	https://www.eea.europa.eu/en/analysis/indicators/ecological-status-of-surface-waters

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	or potential, per river basic district.	
Common Fisheries Policy	Data is repoted annually by different Fisheries committees, and extensive fisheries and aquaculture data also reported in Eurostat database.	https://ec.europa.eu/eurostat/web/fisheries/database https://stecf.jrc.ec.europa.eu/documents/43805/1035398/STECF+23-01+adhoc+-+CFP+Monitoring.pdf/791ff920-33a6-42a9-9e61-820a29886062
UN Sustainable Development Goals	The global indicator framework includes 231 unique indicators	https://unstats.un.org/sdgs/indicators/indicators-list/
UN Ocean Decade	A monitoring framework has been developed by expert working groups and published in early 2023: Monitoring and Evaluation Framework Implementation Manual. Indicators have been developed for the Decade outcomes, specific challages and beyond.	https://oceanexpert.org/downloadFile/52060

2.3. SECTOR SPECIFIC CASE STUDIES OF CARBON NEUTRALITY & CIRCULARITY

2.3.1. Waterborne transport

Assessment practices and associated indicators in waterborne transport focus on reducing greenhouse gas emissions through the adoption of various new technologies and operational practices, such as energy-efficient vessels, alternative fuels, and hybrid propulsion systems. The overall aim is a transition to alternative fuels, improve vessel energy efficiency, and develop low-emission vessels, with international regulations and agreements guiding environmental impact assessments.

Case study: Government Resolution on reducing greenhouse gas emissions from maritime and inland waterway transport (Hokkanen and Hänninen 2021)

In 2021, the Finnish government made a principal decision to reduce greenhouse gas emissions in maritime and inland waterway transport, aligning with the roadmap for fossil-free transportation. The aim is to transition to alternative fuels and support the improvement of existing vessel energy efficiency and the development of low-emission vessels. The reduction of emissions in maritime and inland waterway transport is crucial for achieving national and international emission reduction targets. The International Maritime Organization (IMO) is expected to decide on global market-based regulations to reduce greenhouse gas emissions from international shipping by at least 50% compared to 2008 levels by 2050. Achieving emission reduction goals requires a comprehensive range of measures and international cooperation. The progress of implementing the decision will be monitored through various ministerial working groups and committees. The focus is on improving vessel

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efficiency, renewing the fleet, and considering the development of alternative fuels and international negotiations at the IMO and EU level.

Roadmap: Flemish Green Deal Inland Shipping

The Flemish Green Deal Inland Shipping is an initiative within Flanders, Belgium, contributing to the vision of a sustainable blue economy. Aligned with European, national, and regional sustainability objectives, the Green Deal focuses on three key pillars: emission reduction, environmentally conscious mobility, and achieving a modal shift, with the ultimate goal of achieving zero-emission inland shipping by 2050. The collaboration of key stakeholders, including De Vlaamse Waterweg nv, the Department of Mobility and Public Works, Port of Antwerp-Bruges, North Sea Port, Knowledge Center Inland Navigation Flanders, and the Belgian Inland Navigation Federation, underscores a collective commitment to visible change. The strategic approaches encompass technological, financial, and policy solutions, emphasizing the importance of seamless implementation (European IWT Platform, 2023).

Roadmap: Carbon-Neutral Central Finland

Central Finland Region has a roadmap for carbon neutrality by 2030. The roadmap includes e.g. water transport. The assessment evaluated the roadmap's effects qualitatively across economic, social, cultural, environmental impacts, and climate emission reduction. Each category used 3-5 criteria, and the overall assessment aggregated individual criteria. Carbon neutrality and circular economy assessment focused on sustainability principles. Positive or neutral impacts aligned with sustainability were emphasized. Effects varied across sectors, including conflicting economic impacts for businesses, positive environmental effects through emission reduction, but potential negative impact on wildlife and cultural landscapes from wind power. Energy efficiency had cost-saving effects, shifting away from peat had positive impacts on water bodies and biodiversity, while increased wood usage threatened biodiversity. Transportation investments increased regional equity, reduced car usage and emissions, but electrification required more metal consumption. Sustainable practices in agriculture and forestry had mixed economic impacts but positive environmental effects. Behaviour changes and renewable energy investments were important at the individual and community level, promoting local cooperation and resource utilization. Challenges and trade-offs emphasized the need for continuous evaluation and adaptation (Hiilineutraali Keski-Suomi 2030, 2023).

Roadmap: Zero-Emission Shipping Mission

An international public-private partnership called *Zero-Emission Shipping Mission*, a part of the global Mission Innovation, functions as an international public-private innovation alliance; focusing on the development, demonstration, and deployment of zero-emission fuels, ships, and fuel infrastructure to drive the decarbonization of the shipping sector. Members in the partnership are Denmark, the United States, Norway, Global Maritime Forum and Mærsk Mc-Kinney Møller Center. Aiming for net-zero emissions by 2050 and a significant reduction in shipping's total annual greenhouse gas emissions by 2050, the Mission is structured into three pillars: Ships, targeting at least 200 vessels on zero-emission fuels by 2030; Fuels, aiming for at least 5% of the global deep-sea fleet to run on hydrogen-based zero-emission fuels by 2030; and Fueling Infrastructure, envisioning 10 major trade ports supplying zero-emission fuels by 2030. The Mission identifies 5 innovation groups and

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120 individual innovation gaps related to safety, policy, market development, technology, and market analysis, emphasizing the importance of public-private collaboration and commitment to achieve these ambitious goals. The Roadmap provides a comprehensive overview of existing progress and innovation needs across the industry to realize the Mission's objectives (Industry Roadmap for Zero-Emission Shipping 2021).

2.3.2. Ports and associated facilities

Ports and associated facilities engage in assessment practices that include climate plans, adherence to sustainability standards, and decarbonization strategies. Specific port initiatives, like the Port of Tallinn, Port of Helsinki, Port of Antwerp-Bruges, North-Sea Port and the Port of Rotterdam, aim for carbon neutrality through dynamic programs addressing emissions from ships, machinery, road transport, and port operations. The emphasis is on transitioning to carbon-free electricity, optimizing energy consumption, and supporting partners in adopting sustainable practices.

Case study: Port of Helsinki

The Port of Helsinki is working towards sustainable operations, aiming to achieve carbon neutrality in its own activities by 2035 (Port of Helsinki, Vuosikertomus 2021). The port's carbon neutrality program is a dynamic document that includes numerous impactful measures. Progress was made in 2021, with initiatives such as transitioning to carbon-free electricity. However, reducing the port's energy consumption remains vital. The program addresses emissions from ships, machinery, road transport, and the port company's own operations. While changing their own operations is easier, supporting partners in adopting better practices is also crucial, considering the port company's relatively small share (2.4% in 2021) of the port area's carbon dioxide emissions.

Example of assessment: Port of Tallinn

The Port of Tallinn aims to achieve climate neutrality across its entire port operations by 2050, recognizing the maritime industry's significant environmental impact. The assessment of greenhouse gas emissions (GHG) involved calculating emissions from 2019 data, attributing 53% to ship traffic, followed by electricity consumption (23%), emissions from mobile vehicles (11%), heat consumption (10%), and stationary equipment (3%). With a clear focus on addressing emissions from ships at berth, the port has already implemented solutions, such as installing shore power facilities at five Vanasadam quays. If green shore power were extended to all ports, emissions related to ship traffic could decrease by 47,646 tons of CO_2 equivalent (Port of Tallinn, 2021).

2.3.3. Renewable ‘blue’ energy production and storage facilities

The evaluation of renewable "blue" energy production and storage facilities involves life-cycle assessments, considering factors like greenhouse gas emissions, energy efficiency, and environmental impact. Companies, such as Vaasan Sähkö, are committed to achieving carbon neutrality through comprehensive planning, long-term commitment, and significant investments in projects like offshore wind farms.

Case study: Vaasan Sähkö

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Vaasan Sähkö, an energy company in Finland, is committed to achieving carbon neutrality in its production since 2021 (Vaasan Sähkö Oy 2021). They prioritize reducing their own and their customers' carbon footprints and believe in incremental progress through comprehensive planning, long-term commitment, and significant investments. Over the past decade, they have successfully halved their production emissions, and their goal is to reach near-zero emissions in the coming years. One of their major investments is the Norrskogen wind farm in Närpes, which is expected to produce over 300 gigawatt-hours of emission-free electricity annually. Vaasan Sähkö owns about 40% of EPV Tuulivoima, a subsidiary of EPV Energia, and their wind power projects in various locations will significantly contribute to their renewable energy supply.

Case study: Carbon neutral Finland 2035 - Environmental impact assessment of energy and climate policy actions

A report “Carbon neutral Finland 2035 - Environmental impact assessment of energy and climate policy actions” was published in 2021, which presents a Strategic Environmental Impact Assessment (SOVA) of the Carbon Neutral Finland 2035 -strategy (Soimakallio et al 2021). The SOVA assessment focuses on the identified potential environmental impacts. Due to the large scale of the topic, much of the evaluation is qualitative. In the report, water transport is not included, since it is planned to be included in the emissions trading system not earlier than 2026. In the report, shifting from fossil fuel based energy production to offshore wind energy is projected to reduce Finnish GHG emissions by 2.4 MtCO2 by 2030.

2.3.4. Low-trophic aquaculture

Assessment in low-trophic aquaculture, promoting environmentally sustainable practices like shellfish and seaweed farming, involves measuring the carbon footprint of production processes, resource use efficiency, and the impact on local ecosystems.

Case study: ULTFARMS project

The ULTFARMS project is set to establish six Low-Trophic Aquaculture Pilots (LTAPs) within offshore wind farms in the North and Baltic Seas, spanning locations in Belgium, the Netherlands, Germany, and Denmark (Ultrafarms official website). These pilots, situated in challenging offshore conditions and low-salinity environments, aim to optimize low-trophic aquaculture (LTA) production. The project's approach involves integrating engineering, technical, ecological, and biological processes to address the complexities of offshore aquaculture. The initiative seeks to advance cultivation structures, grow-out systems, and eco-friendly design measures, while integrating monitoring and management platforms to enhance technical services. By developing sustainable solutions, ULTFARMS aims to optimize marine space and contribute significantly to the circular economy, aligning with the EU's goals for climate neutrality and environmentally sustainable aquaculture practices by 2050.

A package of measures to improve the sustainability and resilience of the EU's fisheries and aquaculture sector.

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The European Commission is currently in the process of developing a comprehensive package of measures to enhance the sustainability and resilience of the EU's fisheries and aquaculture sector, focusing on four elements: a Communication on the Energy Transition, an Action Plan for marine ecosystem protection, a Communication on the common fisheries policy, and a Report on the Common Market Organisation (European Commission 2021g). The key objectives include promoting cleaner energy sources, reducing dependence on fossil fuels, and minimizing the sector's impact on marine ecosystems. The proposed actions will be phased in gradually, and a 'Pact for Fisheries and Oceans' will facilitate the implementation of the Common Fisheries Policy in collaboration with stakeholders. The overarching goal is to achieve a net-zero emissions fisheries and aquaculture sector by 2050, aligning with the European Green Deal's climate neutrality objective. The measures address the sector's vulnerability to fossil fuel price fluctuations and propose strategies for energy transition, improved fuel efficiency, and the adoption of renewable, low-carbon power sources. The Energy Transition Partnership for EU Fisheries and Aquaculture will play a pivotal role in uniting stakeholders to collectively navigate the challenges of the sector's energy transition. Moreover, the package aims to protect marine ecosystems by proposing a marine action plan, reinforcing the Common Fisheries Policy's contribution to environmental objectives, and addressing issues like seabed disturbance and by-catch. The action plan aligns with the EU Biodiversity Strategy for 2030, emphasizing the protection and management of marine protected areas (MPAs) to support biodiversity and reduce fishing's impact on the seabed. The 'Pact for Fisheries and Oceans' seeks to strengthen the common fisheries policy by fostering a united vision for the future of the fisheries and aquaculture sector, encouraging dialogue, and facilitating adaptations to policy objectives as needed. The overarching approach focuses on sustainability, environmental resilience, and socio-economic considerations, reflecting a commitment to the sector's transformation and its contribution to climate neutrality.

2.4. INDICATORS AND DATABASES

In total 419 highly relevant indicators were identified (Figure 20, Appendix 4). Of these 246 could be classified as output indicators, 146 outcome indicators and 26 impact indicators. For each Mission relevant sector and multi-use concept several indicators were identified, Indicators were also identified for each sector, with most found for waterborne transport and energy sectors. In addition, ample indicators were also identified to be applicable to blue economy in general. Fewer indicators were identified for ports and multi-use concept.

In respect to sustainability framework dimensions, 188 indicators were directly linked to economic dimension, 97 to environmental dimension, 75 to social dimension and 58 to governance dimension.

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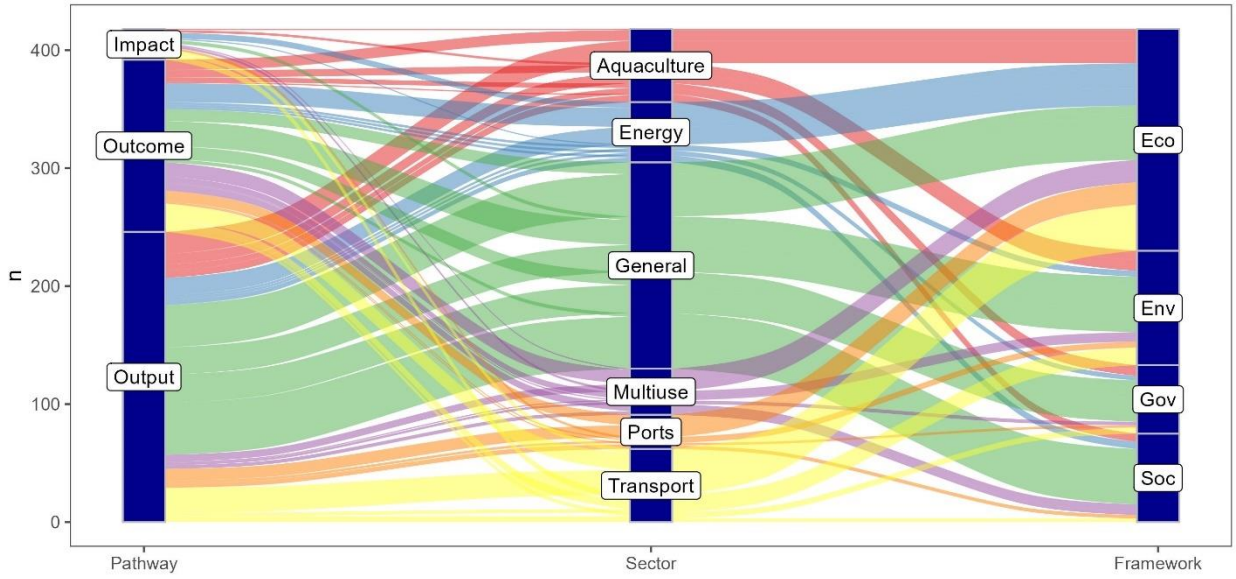

Figure 20 A summary of the mapped indicators relevant for the blue economy in BANOS area. Left: Pathway; Middle: Sector; Right: Sustainability framework dimension (Eco = economic, Env = environmental, Gov = governance, Soc = social). Total number of KPIs identified is 419.

Twelve highly relevant databases and/or data sources were identified that can support the development of the Mission relevant indicators (Table 12). Below a short description of each database/data source is provided.

1) EMODnet: Human Activities

EMODnet Human Activities deals with a diverse set of marine and maritime human activities. As a result, data feeding into the portal comes from a multitude of public and private data sources at EU, international, national, and local level. It makes available information such as algae production, aquaculture, underwater cables, ocean energy, ports, shipping density and MSP etc.

2) European Environment Agency: Data Hub

The EEA's knowledge work relies on high-quality data. Through EEA network and other institutional partners across 38 European countries, EEA collect, quality-assure and quality-check data on a wide set of topics and legislation related to the environment, climate and sustainability. This datahub is open access and allows everyone to explore and download these data.

3) EuroStat: Renewable energy statistics

A publication outlining recent statistics on the share of energy from renewable sources overall and in three consumption sectors (electricity, heating and cooling, and transport) in the European Union (EU). Renewable energy sources include wind power, solar power (thermal, photovoltaic and concentrated), hydro power, tidal power, geothermal energy, ambient heat captured by heat pumps, biofuels and the renewable part of waste. Data can also be extracted from Eurostat: Energy data base.

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4) Eurostat: Fisheries

This database provides information on: (i) catches of fish products made by vessels in fishing regions, (ii) aquaculture production, including organic aquaculture, both in marine and fresh water, (iii) landings of fishery products in ports, and (iv) fishing fleets. Data is available for EU countries, Norway, and Iceland. On a voluntary basis, EU candidate countries can also provide data. Data reported annually. Aquaculture data available per species (including data on mollusk).

5) Eurostat: Aquaculture statistics

A publication giving an overview of recent statistics relating to aquaculture production in the European Union (EU). The statistics support the implementation of the common fisheries policy (CFP) of the EU, aiming at an environmentally, economically and socially sustainable use of the common resource including aquaculture production. The statistics are reported annually with the most recent data from 2021.

6) Eurostat: Transport

Eurostat data on transport covers five main types of transport modes: (i) Air, (ii) Inland waterway, (iii) Rail, (iv) Road, and (vi) Maritime (Sea).
In addition, specific data is collected for oil pipelines. In general, transport statistics cover: Transport of goods, Transport of people, Traffic, Transport safety, Other available data include aggregated statistics on businesses, employment, infrastructure and equipment.

7) Eurostat: Statistics for the European Green Deal

Data in this dashboard is constantly updated with the latest data available in the Eurostat database. Data is reported for, for example, greenhouse gas emissions, renewable energy, environmental tax revenue.

8) OECD: Maritime Transport CO2 Emissions (experimental)

This database includes annual, quarterly, and monthly information on CO2 emissions from maritime transport based on ship-tracking information collected via the Automatic Identification System (AIS). These CO2 emissions are estimated by the OECD, based on a consistent methodology across countries.

9) OECD: Renewable energy feed-in tariffs

Feed-in tariffs (FITs) are prevalent support policies for scaling up renewable electricity capacity. They are market-based economic instruments, which typically offer long-term contracts that guarantee a price to be paid to a producer of a pre-determined source of electricity per kWh fed into the electricity grid. This OECD dataset provides FITs values derived in a manner that is comparable across countries, years and renewable energy sub-sectors. The data include country-level values on the tariff (in USD/kWh), and length of the awarded power-purchasing agreement. The dataset covers seven renewable electricity sub-sectors: wind, solar photovoltaic (concentrated solar power is excluded), geothermal, small hydro, geothermal, marine, biomass and waste.

10) OECD Policy Instruments for the Environment (PINE Database)

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Policy Instruments for the Environment (PINE) is a unique database gathering detailed information on policy instruments relevant for environmental protection and natural resource management. Work to build the database started in 1996, initially with a limited scope, and it was progressively expanded. Today, the database contains information on over 3900 policy instruments implemented in more than 130 countries globally. This platform presents summary statistics, dashboards, and allows country specific data search and download for the Policy Instruments for the Environment (PINE) database. Separate categories for freshwater and ocean policies.

11) OECD Sustainable Ocean Economy database

The OECD Sustainable Ocean Economy database (2023a) provides the international community with data and evidence to support decision-making, including on Sustainable Development Goal 14 to conserve and sustainably use the oceans, seas and marine resources.

The Database synthesizes available ocean-related datasets and indicators from across the Organisation to improve their discoverability and comparability. Indicators for the following main themes are provided: Natural capital of the ocean, Environmental dimension of wellbeing and resilience in coastal communities, Environmental and resource productivity of the ocean economy, Economic opportunities from pursuing ocean sustainability, Policy responses directed at ocean sustainability, The socio-economic context. New indicators may be added to the database as they become available.

12) OECD Green Growth Indicators 2017

The OECD Green Growth database (2023b) contains selected indicators for monitoring progress towards green growth to support policy making and inform the public at large. The database synthesises data and indicators across a wide range of domains. It draws on a range of OECD databases as well as external data sources. The indicators have been selected according to well-specified criteria and embedded in a conceptual framework, which is structured around four groups to capture the main features of green growth:

- Environmental and resource productivity: indicate whether economic growth is becoming greener with more efficient use of natural capital and to capture aspects of production which are rarely quantified in economic models and accounting frameworks.
- The natural asset base: indicate the risks to growth from a declining natural asset base.
- Environmental dimension of quality of life: indicate how environmental conditions affect the quality of life and wellbeing of people.
- Economic opportunities and policy responses: indicate the effectiveness of policies in delivering green growth and describe the societal responses needed to secure business and employment opportunities.

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Table 11 Databases and data sources identified relevant for the development of indicators for Mission objective 3 and its associated targets.

Organisation/Provider of data	Name of the data base/ data source/ data set	Mission relevant sectors	Sustainability framework dimensions covered
EMODnet	Human activities	Aquaculture, Waterborne transport, Energy, Ports, Multi-use (	Economy, Environment
European Environment Agency (EEA)	Data Hub	Energy, Waterborne transport, Multi-use (or MSP)	Environment, Economy
Eurostat	Renewable energy statistics	Energy	Economy
Eurostat	Fisheries	Aquaculture	Economy, Social
Eurostat	Aquaculture statistics	Aquaculture	Economy
Eurostat	Transport	Waterborne transport	Economy
Eurostat	Statistics for the Green Deal	Energy, Waterborne transport	Economy, Environment, Governance, Social
OECD	Maritime Transport CO2 Emissions (experimental)	Waterborne transport	Economy
OECD	Renewable energy feed-in tariffs	Energy	Governance
OECD	Policy Instruments for the Environment | PINE | Database	Energy, Fisheries/Aquaculture	Governance, Environment

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OECD	Sustainable Ocean Economy database	Waterborne transport, Aquaculture, Energy, General	Economy, Environment, Governance, Social
OECD	Green Growth Indicators 2017	Energy, General,	Economy, Environment, Governance, Social

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3. ANALYSIS OF CURRENT INDUSTRY APPROACHES, STRATEGIES, AND FRAMEWORKS FOR ACHIEVING AND ASSESSING CARBON NEUTRALITY AND CIRCULARITY

Authors of this chapter are Aurelija Armoskaite and Anda Ikauniece (LIAE).

In this section, we identify and describe the key challenges per sector and describe industry approaches, strategies and frameworks developed to overcome these challenges and achieve carbon neutrality and circularity. Strategies and frameworks by industries are a response to specific challenges or gaps and present research and development, technological and regulatory innovation-centred solutions, and ways of monitoring progress.

3.1. METHODS

The knowledge base for this study is industry association and company sustainability reports, as well as material featured in company communications (e.g., statements released on websites). Specific sources of literature and search criteria varied across sectors. The analysis focuses on the following research questions*: a) What are each sector's central challenges? b) What are the current industry strategies and frameworks for addressing these challenges and assessing and achieving carbon neutrality and circularity?*

The industry strategy analysed for **waterborne transport** was the Maritime Decarbonisation Strategy (2022) by Mærsk McKinney Møller Center for Zero Carbon Shipping, supplemented by the findings of the findings of interviews held by Houlder with senior executives from companies across the shipping sector aimed at identifying and addressing decarbonisation challenges and opportunities (Houlder Whitepaper 2022). European Sea Ports Organisation incentives, BANOS area port strategies and targets were reviewed to summarise central challenges and strategies decarbonisation presents **ports and associated facilities**. WindEurope proposals, 'blue' energy producer Ørsted and RWE development strategies, and research and development initiatives by ports and private actors were reviewed for the **renewable 'blue' energy production and storage facilities section. Low-trophic aquaculture** challenges and principles for decarbonisation were described based on a recent scientific study. Renewable 'blue' energy production and low-trophic aquaculture practices are generally low carbon. Therefore, the analysis here focused on the strategies and challenges for these sectors to become more circular and potentially carbon-neutral.

3.2 WATERBORNE TRANSPORT

A reduction of emissions by 45% by 2030 compared with 2010 levels, that is, limiting global fleet consumption of fossil fuels to 6 EJ In 2030 and reaching net zero by 2050, is required from the maritime industry to limit global warming to 1.5°C (Mærsk McKinney Møller Center for Zero Carbon Shipping 2022). The International Maritime Organisation forecast (2020) that emissions will likely increase from approximately 90% of 2008 emissions in 2018 to 90-130% by 2050 under various likely long-term economic and energy scenarios.

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To lower emissions, several technical, commercial and regulatory challenges and gaps need to be overcome related to four key sector areas identified in the Maritime Decarbonisation Strategy (2022) by Mærsk McKinney Møller Center for Zero Carbon Shipping. These include improving vessel energy efficiency and enabling fuel flexibility, promoting industry commitments and regulatory reform, and supporting and reducing risk for 'first movers' – early actions/actors and pilot projects accelerating the transition away from fossil fuels. The topics presented in the Mærsk McKinney Møller Center for Zero Carbon Shipping Maritime Decarbonisation Strategy (2022) are used to structure the rest of this section.

Improving vessel energy efficiency and enabling fuel flexibility

Increasing energy efficiency is not a new concept but a continuous goal for businesses as it reduces operating costs. Fuel supply chains and clean technologies have different maturity levels and technological innovations. Therefore, **technical solutions** and **operational measures** must be matured and implemented across different ship types.

It is commonplace that vessels operate at a lower speed than the design intends (Houlder 2022). A good place to start reducing emissions and costs is reviewing current designs, retrofitting vessels, and designing and building vessels optimized for running at lower speeds and, therefore, using less fuel (Houlder 2022). An engineering company – Man Energy Solutions (2023) – highlight that the shipping sector must simultaneously boost efficiency and increase fuel flexibility. That is, invest in solutions like waste heat recovery systems and batteries for hybrid solutions, up-to-date propeller systems and pumps, as well as adopt legacy fossil-based fuels (e.g., LNG, methanol, LPG, ethane) and alternative fuels like ammonia, synthetic methane, and green hydrogen. Certain fuels are more likely suitable for certain maritime industry segments e.g., solutions for passenger vessels may differ from ro-ro. Ammonia, for instance, is unlikely to be used for passenger carriers due to safety concerns and the odour of the fuel. Methanol has positive environmental and climate properties and is making strong progress in international shipping. Maersk Line has 19 larger methanol-propelled container ships on order (Maersk press release 2022). X-Press Feeders is another major player that will start launching eight methanol-propelled vessels this year (X-Press Feeders press release 2021). At the same time, a single solution may not apply to the ship's entire life. Fuel flexibility - engines running on carbon-free fuels without further technical adaptions – is key to securing long-term efficiency and emission reduction. In the medium term, LNG may meet environmental standards and support the reduction of emissions; however, synthetic carbon-free fuels are generated from renewable energy, and zero-emission is the end goal (Man Energy Solutions 2023). In addition to technological challenges, alternative fuels also face safety, commercial, and regulatory challenges – incompatible supply and demand, a need to scale up all alternative fuel production, as well as a lack of regulations and measures that ensure alternative fuels are commercially attractive are used safely and are environmentally and socially sustainable (Mærsk McKinney Møller Center for Zero Carbon Shipping 2022).

Implementation of **operational measures** such as voyage optimisation (voyage planning, weather routing, trim and draft optimisation, energy management, hull and propeller fouling management) and fleet strategies (fleet portfolio optimisation, vessel deployment and utilisation, scheduling and speed optimisation) require particularly low investment and offer large fuel savings and in turn a reduction of emissions (Mærsk McKinney Møller Center for Zero Carbon Shipping 2022). Aside from

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the internationally required energy efficiency monitoring, there is a shortage of useful performance data and data sharing due to competition, making adopting new technologies challenging and risky for shop owners (Houlder 2022). High-quality, relevant operating data can help better understand how the current supply chain can be improved and the savings new technologies can deliver (Houlder 2022).

Industry commitments and regulatory reform

Clear policy instruments drive the implementation of solutions to mitigate climate change; for instance, while some technical solutions may be readily available to improve vessel energy efficiency, a lack of commercial incentives and gaps in regulation mean technology uptake is limited (Mærsk McKinney Møller Center for Zero Carbon Shipping 2022). Ammonia, for instance, is a promising alternative fuel for its production and use and generates zero carbon emissions. However, it is also toxic and exposes crews and the environment to risks; therefore, regulations, standards, and safety guidelines by the International Maritime Organisation must be revised to include ammonia and other new alternative fuels (Mærsk McKinney Møller Center for Zero Carbon Shipping 2022).

The IMO has already developed a whole toolbox of measures for improving vessels' operational and technical energy efficiency (IMO 2020). The industry can be seen asking for stricter regulation of greenhouse gas emissions by the IMO (Bach and Hansen, 2023; Mærsk McKinney Møller Center for Zero Carbon Shipping, 2022). In their decarbonisation strategy, Mærsk McKinney Møller Center for Zero Carbon Shipping (2022) suggested more ambitious energy efficiency-related regulations (Figure 21), additional emissions intensity and efficiency targets, intermediate targets for 2030 and 2040, global greenhouse gas pricing, transparent emission reporting, fast-tracked development of international regulations to support alternative fuels and decarbonisation technologies and regional, national, and local policy roadmaps to drive investment in green energy and infrastructure to support the maritime industry transition from fossil-fuels.

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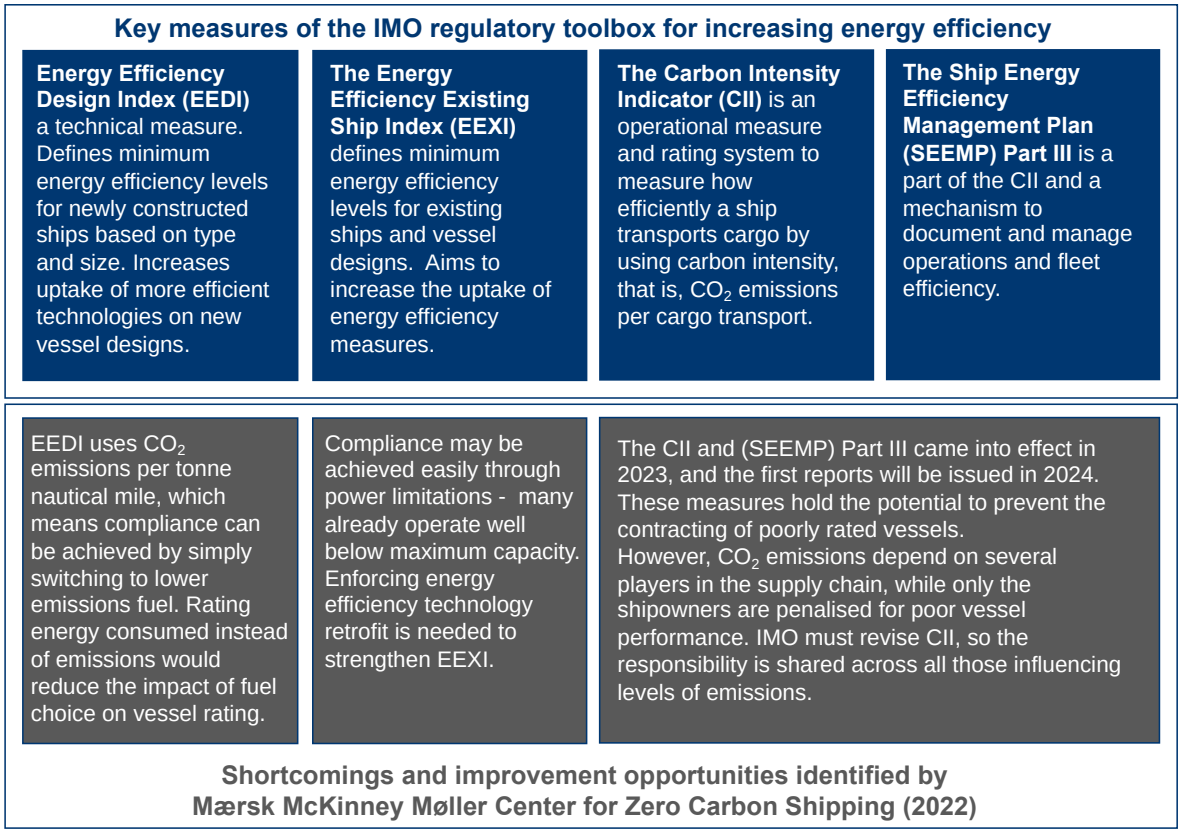

Figure 21 Shortcomings and improvement opportunities for the International Maritime Organisation energy efficiency measures as identified by Mærsk McKinney Møller Center for Zero Carbon Shipping (2022).

Risk for early actions and pilot projects

Taking action early is risky and can be costly. Sometimes, ship owners find savings less significant than they initially hoped (Houlder 2022). However, pilot projects demonstrate new technologies, pitfalls and ways to overcome them, which is valuable for mainstreaming new approaches and cutting costs. To support early starters, Mærsk McKinney Møller Center for Zero Carbon Shipping (2022) suggest costs, risks, and benefits must be shared across the value chain (e.g., alternative fuel producers, ports and ship owners) and regulations must be reformed to reduce the risks for early investors. Different actors across the shipping value chain have a role to play in enabling early action and pilot projects, starting from alternative fuel producers resolving challenges in commercially viable fuel supply to cargo owners and customers sharing some of the costs and risks that come with adopting new technologies (Figure 22).

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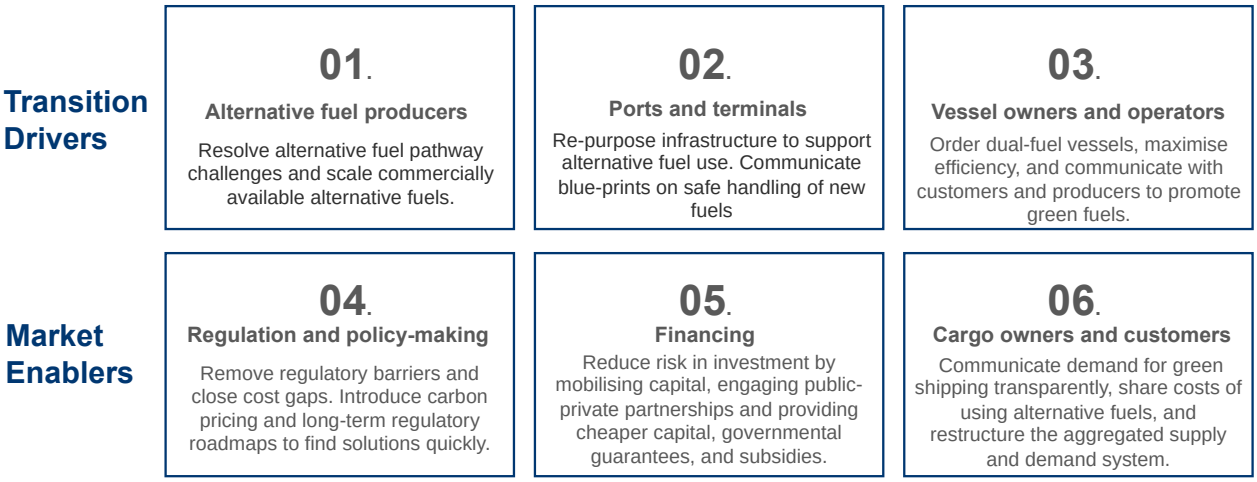

Figure 22 Mærsk McKinney Møller Center for Zero Carbon Shipping (2022) recommended actions for actors across the shipping value chain to support early action and pilot projects.

3.3 PORTS AND ASSOCIATED FACILITIES

Most ports handle large quantities of fossil fuels to support vessels, and cargo transport through ports depends on fossil fuels (European Sea Ports Organisation 2020). Ports themselves are also largely sustained by various energy sources, including electricity from non-renewable sources and diesel fuel (InnovateUK 2021). A decarbonised port is sustained by 'clean' energy, thereby has low/zero greenhouse gas emissions from port operations (buildings, fleet and machinery) and provides clean energy-fuelled services and sources of clean energy available to visiting transport, including road, rail and vessels (InnovateUK 2021). Low emissions and improved efficiency of port operations have a trickle-down effect on other parts of the shipping, fishing and tourism sectors (Alzahrani et al. 2021). Ports face interconnected operational and infrastructure development challenges en route to decarbonisation, which needs to be addressed through decreased use of fossil fuels and increased use of renewable resources to sustain ports and their services, intelligent/smart technologies to make operations and services more efficient and 'clean', optimised costs, as well as revised rules, regulations and new guidelines for 'green' ports (Alzahrani et al. 2021).

Various initiatives like the European Sea Ports Organisation's (ESPO) ECOPORT define environmental performance indicators for port authorities to support the reduction of emissions and environmental impacts. Almost 100 ports partake in the ECOPORT Network. Network members employ a Self-Diagnosis Method to generate scores to review and improve port environmental performance. The assessment includes monitoring the availability of 'green services' and port interest in offering these services in the future including:

1) the availability of **on-shore power supply** also known as cold ironing
2) **liquefied natural gas (LNG) bunkering** facilities
3) and environmentally **differentiated port fees** to reward front-runners going the extra mile beyond international regulations.

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On-shore infrastructure is essential to support alternative fuel-run vessels; thereby, the availability of infrastructure at ports affects the uptake of new, low or zero-emission technology, making ports a central driver of maritime sector decarbonisation (Mærsk McKinney Møller Center for Zero Carbon Shipping 2022). The on-shore connection of a ship at berth while its auxiliary power is off is an opportunity to reduce emissions if the electrical power comes from a renewable source. The European Federation for Transport and Environment (2022) recommends a timeframe that all ports provide shore-side electricity at a) passenger terminals from 2025, b) all terminals for containerships, tankers and refrigerated-bulk carriers from 2030 and c) across all terminals by 2035.

The port of Rotterdam was found to be the most CO_2-emitting port in Europe emitting approximately (Federation for Transport and Environment 2022). The Port and the Energy Cluster Rotterdam-Moerdijk it is part of aims to become carbon neutral by 2050 by following a four-pillar strategy and implementing projects to develop infrastructure to capture, store and use locally produced CO_2, increase the capacity of the energy infrastructure for electricity and hydrogen by 2030, and scale up the supply of green electricity and hydrogen to match supply and demand for alternative fuels in the maritime sector and beyond and provide an on-shore clean energy power supply to maritime traffic (Rotterdam-Moerdijk Industry Cluster Work Group 2018). Numerous ports in the BANOS area already offer on-shore power, including Antwerp, Gdynia Nowy Publiczny Terminal Promowy, and Port of Gdansk.

The European Commission (Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014) requires that refuelling points for LNG be available at least by the end of 2025 at all ports part of the Trans-European Transport Network (Ten-T core). Transport & Environment (2022), however, argue that the mandate to install LNG bunkering facilities should be discontinued for ports to avoid stranded assets in fossil fuels. Instead, the European Federation for Transport and Environment (2022) suggests policymakers should ensure that half, if not all, shipping emissions are covered by the EU Emissions Trading Scheme (ETS), Endorse the installation of hydrogen, ammonia and other green, **alternative fuel refuelling services** and infrastructure, and ETS revenue could fund this transformation. Port of Gothenburg is now offering facilities for methanol bunkering and was the first in the world to publish operating regulations for it in April 2022.

Port of Amsterdam strategy 2021-2025 (2021) outlines seven targets for 2025 directly and indirectly linked to the decarbonisation of port operations, facilities and services (Figure xxx). The Port of Amsterdam aims to create space for the production and storage of alternative fuels and the growth of non-fossil cargo flow and have over half of its turnover fossil-fuel-free (Goals 2 and 4). Further, together with the shipping sector, reduce CO_2 emissions by 10% (Goal 6).

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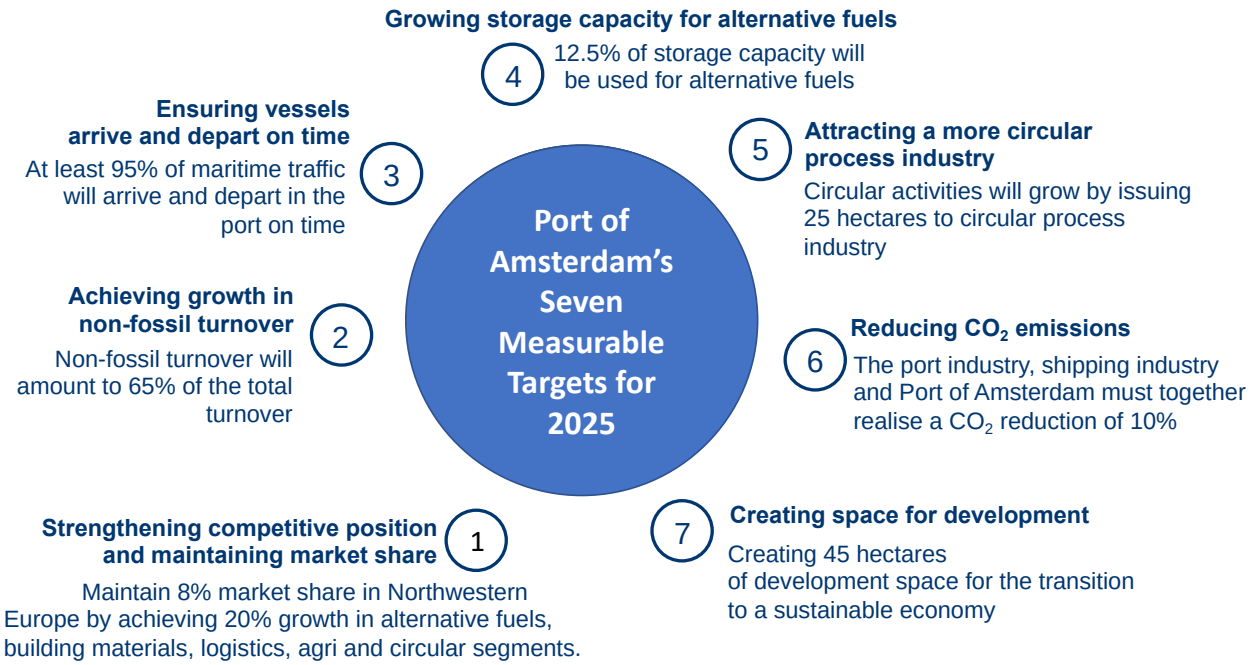

Figure 23 Seven targets for 2025 for the Port of Amsterdam (Port of Amsterdam strategy 2021-2025 (2021))

The Environmental Ship Index (ESI), an international port industry incentive scheme, is used to evaluate the environmental performance of ships with a score from 0 to 100. Flemish ports are an example of many that often use ESI scores as the basis **for port fee differentiation**. This way, the best performing, greenest vessels get rewarded. The Flemish authorities also offer operators running vessels fuelled by alternative fuels reduced fees (Maes et al. 2022).

3.4 RENEWABLE 'BLUE' ENERGY PRODUCTION AND STORAGE FACILITIES

Renewable technologies like wind and solar generate carbon-free electricity, but emissions result from their construction and decommissioning. No technology has yet achieved complete carbon neutrality over its entire lifecycle. Indeed, offshore wind generation is not carbon neutral, but it is very low carbon — just 6 grams of carbon dioxide for every kWh of electricity produced. In the BANOS area, offshore wind farms (OWF) are the most technologically advanced, commercially viable form of renewable 'blue' energy production (see Chapter 1). However, the sector still faces development challenges as it competes for space with other maritime activities and has difficulties recirculating composite material blades of turbines.

Decarbonising offshore wind energy production

Over the last decade, the impact of **energy technologies**, inter alia climate change and on the local environment, has been questioned mostly in academic research (Jordaan et al., 2021), specifically by life cycle assessment (LCA) scholars. It is argued that LCAs should be a pillar for decision-making in the electric sector due to regional variability and the fast-paced, evolving sectors across the supply

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chain. When estimating greenhouse gas emissions of offshore wind power through LCA (Radaal et al., 2014), specific platform/foundation steel masses are the most important factor causing emissions. Other relevant parameters when comparing the environmental performance of offshore wind concepts are the lifetime of the turbines, wind conditions, distance to shore, and installation and decommissioning activities. The offshore wind power industry needs to develop methods for recycling submarine cables to reduce the impact of copper on the environment. The steel sector should also optimise production by increasing the share of electric arc furnace (EAF) production routes. Also, the need to recycle the turbine components is obvious for carbon neutrality. The industry is gradually taking up the findings of LCAs regarding carbon neutrality and emissions.

The renewable 'blue' energy production company Ørsted has impressive decarbonisation targets in the energy sector and aims to become a carbon-neutral company by 2025. It has announced its goal to achieve zero carbon emissions in 2040 and implements devoted programmes, such as "Decarbonisation of supply chain and natural gas wholesales" and "Decarbonisation of energy generation and operations". Ørsted activities to implement decarbonisation of the supply chain include:

1) Tracking carbon progress based on life cycle assessments (LCAs) of emissions.
2) Engagement with strategic suppliers, which are part of the most carbon-intensive parts of the company's supply chains, to help them: i) set science-based targets and report on their emissions, ii) cover their electricity consumption with 100 % renewable electricity by the end of 2025, and iii) optimise vessel routes and develop road maps for transitioning to renewable energy.
3) Cross-sector collaboration with leading companies facing similar challenges to send crucial demand signals form partnerships to mature decarbonisation solutions and engage with global policymakers.

The company has started reporting asset-specific carbon calculations, i.e., life cycle assessments (LCAs) of emissions for each offshore asset, to increase the transparency of the supply chain emissions linked to the offshore wind farms. It is a change from the previous practice of relying on LCA studies of an average wind farm to calculate the supply chain emissions – a common approach in the industry. The next step is to work towards standardising LCA methodologies for offshore wind farms to enable comparability. A task force in WindEurope is founded, and a joint industry programme is established to develop a common standard for measuring life cycle emissions from offshore wind farms. A common standard will improve transparency within the industry and allow customers to compare the carbon footprint of different solutions from different offshore wind developers to help incentivise investments in low-carbon solutions.

Activities in the programme "Decarbonisation of energy generation and operations" focus on reducing emissions intensity in energy generation and operations by at least 98 % from 2006 to 2025. This covers emissions from generating heat and power and our operations, including vessels, vehicles, and sites. The company has entered into a pioneering agreement with a supplier to invest in the world's first service operation vessel (SOV) that can operate entirely on green fuels. Ørsted also no longer buys or leases fossil-fuelled vehicles, and by the end of 2025, the entire light vehicle fleet should be fully electric (currently, it is 51 % electric, including plug-in hybrids).

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From the industry perspective, solutions are firstly sought in the areas being more directly under the control of wind farm developers, where electrification can reduce emissions in the short to medium term, for example, by electrifying the offshore vessels necessary for wind farm construction. The so-called electric mothership project is already taking place in Japan. UK/Canadian company Zephyrus Marine has signed a memorandum of understanding with Japan's Mirai Ships to build a 'mothership' capable of recharging electrically-powered, zero-emissions crew transfer vessels (CTVs). The mothership acts as an offshore recharging point, with a modular concept being employed when a fully-charged battery – 'an e-pod' — replaces one with a low charge. This swap-in, swap-out process is expected to take less than 15 minutes — faster than refuelling a fossil fuel-powered vessel. The e-pod can then be recharged on the mothership, while the CTV maximises its useful time on the water with a fully-charged battery. In conjunction with Zephyrus Marine's vessels, this system is expected to reduce fuel costs and emissions from the emergent Japanese wind sector.

Ørsted also has a **circular resource use** programme in its sustainability framework. Raw materials such as steel, concrete, and aluminium are part of many products' supply chains, which are already scarce and under pressure. Therefore, circular principles are incorporated across the entire company's operating model to eliminate waste and maximise the reuse and recycling of key components and materials. Although the newest renewable energy assets have an expected lifetime of 30-35 years and up to 90 % of the total material volumes can be recycled upon decommissioning, there is still a big potential to increase the overall circularity in the renewables industry. Three key areas have been selected where the company sees the highest possibility to impact resource use:

1) Reducing the use of virgin resources through design and sourcing: ~75 % of Ørsted's carbon footprint from offshore wind assets comes from the extraction and processing of materials – steel alone accounts for more than 50 %. A 'circularity road map' for offshore monopile foundations has been developed, with strategic levers including design optimisation (e.g. thinner blades), lifetime extension, use of scrap steel, and decarbonisation of the steel supply chain.
2) Optimising use of assets and key components: the ways are explored to extend the lifetime of the oldest offshore assets from ~25 to up to 35 years.
3) Ensuring recyclability upon decommissioning: the aim is to reach 100 % recyclability of renewable energy assets.

Other renewable 'blue' energy producers have also addressed the circularity and sustainability aspects of wind turbines (Offshore Wind Market report, 2021), and the industry has committed to stopping landfilling wind rotor blades by 2025. RWE, another leading energy company, has announced to be net zero by 2040. RWE has set Science-based targets covering its operations and the entire value chain. The company is committed to reducing specific emissions by 2030 by 50% to 296 g CO_2e / kWh of electricity produced (reference - emissions of 591 CO_2e / kWh in 2019). Circularity is another important topic for RWE, as renewable energy assets are already up to 90 % circular. The main sticking point is the rotor blades. RWE is the first company worldwide to introduce fully circular rotor blades at the new Kaskasi wind farm off the Heligoland coast, which was completed in late 2022. Three of the wind farm's 38 wind turbines, supplied by Siemens Gamesa, feature rotor blades made from a new type of resin that separates the different materials at the end of life. The aim is to ramp up recyclable blades with the ambition to have 100 % recycled blades installed for new assets by 2030. In January 2023, RWE and other offshore wind developers joined in a project partnership

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with the UK's Carbon Trust to develop a clear methodology to measure and address offshore wind's lifecycle carbon emissions. The aim is to achieve carbon neutrality via the Offshore Wind Sustainability Joint Industry Programme.

A recent initiative partly funded by Innovation Fund Denmark is DecomBlades, a three-year innovation project that seeks to commercialise sustainable recycling routes for wind turbine blades. Ten project partners from the wind and recycling industry and academia carry it out. The DecomBlades project addresses the missing market of composite material with a new specification for disposal, making it easier to dismantle and recycle the blades. This will help industrialise the blade recycling industry and further reduce the footprint of the wind industry.

From a policy point of view, the sector is inviting national governments to improve waste management schemes to recycle and reuse blade materials (ETIPWind, 2023). In the field of technological developments, the sector sees a need to improve composite recycling technologies for the reuse of blade materials. A design of new "smart" (equipped with sensors for material health) and sustainable materials for blades is also of importance.

Non-price criteria in national renewable energy auctions are being increasingly considered in Poland, Belgium and the Netherlands, including factors such as environmental sustainability, energy system integration, innovation, and the resilience of the clean technology supply chains.

The offshore wind sector sees itself a priori as a part of the carbon-neutral future in Europe (Wind Europe, 2019). Therefore, an increase in offshore wind power production is foreseen as a combination of technology development or upscaling and quite numerous activities are requested from the national governments. The strengthening and implementation of the Net Zero Industry Act (NZIA), where sector-specific targets like the annual 36 GW production capacity of wind turbines are included, is strongly supported by the wind energy sector (Wind Europe, 2023).

The carbon footprint for floating wind turbines is estimated to be smaller than for other types of renewable energy production (Yuan et al., 2023), and they are seen as a way to harvest wind power in offshore areas deeper than 50 m, thereby providing a solution to an increasing demand for space in shallow coastal areas. In this respect, floating wind power is competitive in promoting the transformation of energy systems. It is calculated that to become climate-neutral in 2050, Europe must have 150 GW of floating offshore wind (ETIPWind, 2020). An operational floating turbine wind park has been present in Scotland since 2017. Still, the challenges the floating offshore wind farm industry faces are similar to those faced by more conventional offshore wind farm developers. Several policy adjustments and developments for maturing technologies and for large-scale deployment of floating turbines in the Northern Seas are required (ETIPWind, 2023).

Storage facilities for renewable 'blue' energy

Out of currently tested prospects, hydrogen is unique as a renewable chemical fuel that can be utilised across various end uses, including storage. Thus, combining energy systems and energy storage that uses hydrogen with offshore wind can offer a holistic energy solution. As the concept transfer to the industrial scale is very recent, almost none of the carbon neutrality issues have been considered yet. The hydrogen is seen as a zero-emission tool itself, and, up to our knowledge, only

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records of storage solutions are available now. The world-first installations are now in the Milford Haven: Energy Kingdom (MH:EK) project (UK) that is exploring how renewable, or 'green' hydrogen and electricity can meet Milford Haven's future energy demand. Milford Haven currently hosts a range of hydrocarbon facilities, including a gas power plant, an oil refinery, and liquified natural gas terminals, which allow it to receive up to 30% of the UK's gas imports. The project has investigated how renewable energy, including future offshore wind, could develop the case for accelerating an economy that would see green hydrogen power buildings, transport, and local industry. North Sea Port is engaged in creating a fully carbon-emission-free hydrogen (blue hydrogen) production and distribution network. Currently, hydrogen is produced in the North Sea Port area using natural gas; however, in the future, the Port aims to capture and store the carbon produced and power the production process using energy produced by wind farms, making the process climate neutral. Other ports in the North Sea, such as Port of Oostende and Port of Antwerp Bruges, aim to produce green hydrogen using renewable energy, store and potentially use it to run the ort fleet in the coming years.

Rockstar and Ørsted have teamed up to investigate and upscale solutions for energy storage like flow batteries by RFC Power, liquid air energy storage and technologies improving battery operations. The acceleration of these technologies is seen as the next mandatory step for including renewable power generation in the overall energy systems.

3.5 LOW-TROPHIC AQUACULTURE

Food coming from marine aquaculture is known to have some of the lowest carbon footprints among animal products. Seaweed production has a positive or at least a net zero carbon footprint, and mussels and oysters have a footprint of just 6 % of poultry's footprint (LTA BOOST project). Thus, like the renewable 'blue' energy sector, low-trophic aquaculture (LTA) is seen as a tool for reducing carbon emissions and achieving climate neutrality. As the national overviews suggest (Chapter 1), while not a widely popular sector, activities and incentives to strengthen LTA establishment and growth in the BANOS region can be seen.

A recent review by Jones et al. (2022) summarised the most relevant approaches for climate-friendly production in LTAs, specifically mussel, seaweed, and finfish production. The review found large differences in the median GHG emissions footprint between fed finfish, bivalve and seaweed sectors and considered able variability within sectors. In particular, and that can also be expected, the post-harvest transport method greatly impacts the final GHG emissions footprint of mariculture products. Shortening supply chains and building regional markets could reduce GHG emissions simultaneously, potentially contributing to greater food security and industry resilience in times of crisis.

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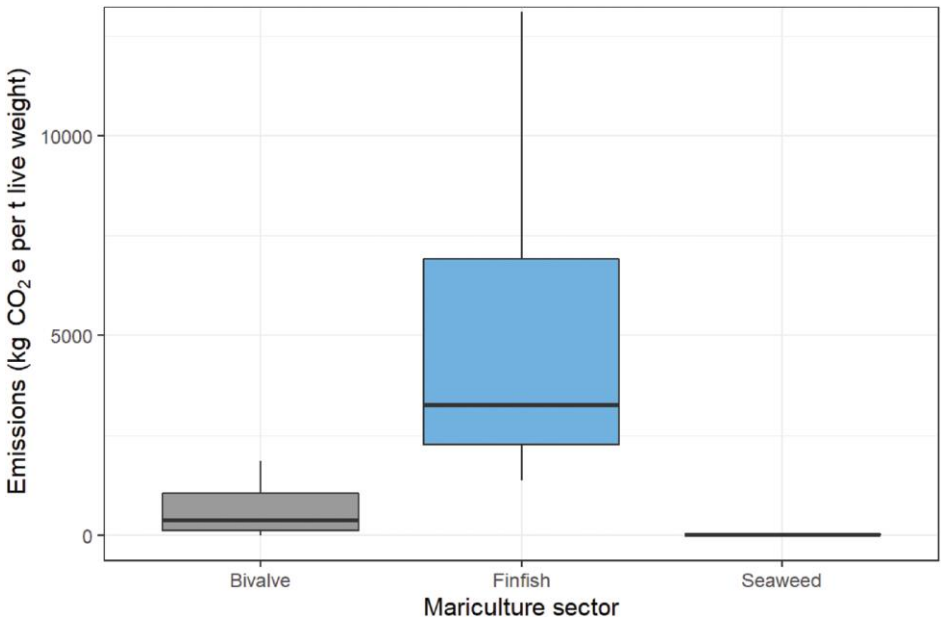

Figure 24 Comparison of total greenhouse gas emissions across all stages of the mariculture supply chain for bivalve, fed finfish and seaweed (excluding post-harvest transport emissions) (Jones et al. 2022).

Six principles have been identified when synthesising across the three sectors that can help enable climate-friendly mariculture approaches. These are quite theoretical and still require future research and development, cost–benefit analysis, detailed assessments of trade-offs with other environmental or socioeconomic factors, and investigations of the feasibility of scaling up.

1) On-farm production should use climate-friendly operations, e.g., lower on-farm energy usage, shift to low-emissions energy sources, the use or reuse of low-emissions, durable materials for farming infrastructure, use of biofuels and clean energy sources to power on-farm operations.
2) Interactions with surrounding marine environments influence GHG emissions and can be avoided through farm design and operational changes: siting fed finfish operations away from sensitive blue carbon habitats in deeper or faster-flowing waters and minimizing feed waste to the environment, using suspended bags and trays and manual harvesting methods for bivalve cultivation.
3) Polyculture (IMTA) can support on-farm GHG emissions reductions: co-farming bivalves with seaweed can lead to a net reduction in CO2 emissions, co-farming fed finfish with seaweed or bivalves. Still, the emissions abatement potential of such cross-sector synergies remains dependent on the fate of the farmed seaweed and bivalve shell waste.
4) For carbon sequestration and GHG offsets, the product's fate and operation scale are key. Barriers to the effective implementation and scaling of both seaweed and bivalve sequestration and offsetting strategies are a lack of recognition of seaweed carbon in current carbon accounting and trading markets, the potentially high costs of large-scale seaweed farming compared with terrestrial carbon farming and the lack of large-volume markets for bivalve shell waste.
5) Thorough carbon accounting is critical. There is a clear need for more standardized reporting of GHG emissions to ensure comparability across studies within and between sectors, a

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challenge of LCAs that is not limited to the mariculture industry. An increase in the availability of LCA tools and software that can be more easily used by a wide range of practitioners and that include appropriate options for the parameterisation of mariculture operations (including environmental emissions) would improve the accuracy and feasibility of GHG accounting in mariculture.

6) Availability of infrastructure, investment and value of end products may affect the uptake of climate-friendly practices at farm, country, and regional scales. Some of the more innovative emissions reduction and sequestration practices may need to be adopted specifically in the regions with greater resources for research and development and greater capacity for investment in nascent technologies.

Another approach towards sustainability and general environmental impact reduction in aquaculture is promoted and followed by Aquaculture Sustainability Council (ASC). Here, the driving force should be the market, where more demand for ASC-certified seafood is created, hopefully leading to more producers improving their farming practices.

3.6 FINDINGS

National governments, the European Union targets and technical and operational energy efficiency measures by the International Maritime Organisation (IMO) are not enough for the shipping sector to reach net zero by 2050, and additional strategies for incentivising further government action come from industry (Mærsk McKinney Møller Center for Zero Carbon Shipping 2022 and Houlder 2022). Themes highlighted in industry strategies are related to improving vessel energy efficiency and enabling fuel flexibility, promoting industry commitments and regulatory reform, and supporting and reducing risk for early actions, actors and pilot projects by all actors in the supply chain. **Port-level development strategies** often present holistic solutions to challenges regarding decarbonising port operations and supplying clean, green services to maritime, rail and road transport. Alternative fuel production, storage and supply play a key role in the decarbonisation of ports and one common thread, the development of which is emphasised across the different parts of port systems, starting from vessel support through on-shore power supply to the greening of port buildings and machinery. **Renewable 'blue' energy production by offshore wind farms** faces several challenges related to recycling and reusing materials and circular resource use, specifically to the maritime context – competition for space. **Low trophic aquaculture** faces different challenges, some specific issues with the development of the sector in the Baltic due to specific environmental conditions. However, regulation barriers are significant across the BANOS area, and streamlined regulations to support the development of this low-carbon sector are needed from decision-makers.

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APPENDICES

APPENDIX 1. TEMPLATE OF THE SURVEY

See the template of the survey that was used for National outlook for sustainable blue economy sectors in the BANOS Area (paragraph 1) and Sector specific analyses of assessments of carbon neutrality & circularity (paragraph 2.3). For a detailed description, please refer to the provided link: Appendix 1.xlsx

APPENDIX 2. KEYWORDS USED FOR POLICY ANALYSES

Term	Sector	Term	Sector
algae	Aquaculture	hydropower	Energy
ammonia	Transport	inland	General
aquaculture	Aquaculture	ironing	Ports
bioeconomy	Aquaculture	low-trophic	Aquaculture
blue	General	methanol	Transport
boat	Transport	multipurpose	Energy
carbon-neutral	General	multi-use	Energy
cargo	Transport	mussel	Aquaculture
circular	General	non-fossil	Transport
circularity	General	offshore	Energy
cruise	Transport	ports	Ports
decarbonisation	General	power-to-x	Energy
decarbonization	General	renewable	Energy
dock	Ports	ro-ro	Transport
economy	General	seaweed	Aquaculture
energy	Energy	ship	Transport

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ferries	Transport	shipping	Transport
ferry	Transport	sustainability	General
fleet	Transport	sustainable	General
harbor	Ports	windfarm	Energy
harbour	Ports	windmill	Energy
hydrogen	Transport		

APPENDIX 3. WORKSHOP SUMMARY

The workshop titled "Measuring the Future Success of Sustainable Blue Economy in the Baltic and North Sea" was held in Gothenburg, Sweden, on November 16, 2023, during the 1st Mission Arena. For a detailed description and outcomes of the workshop, please refer to the provided link: Appendix 3.pdf

APPENDIX 4. LIST OF IDENTIFIED INDICATORS

See the list of identified indicators in Excel format (Appendix 4.xlsx) or in PDF format (Appendix 4.pdf).

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