Future uses/needs of the seas: Integration of climate-smart trends and new technologies in maritime spatial planning

Background Technical Study

European Maritime, Aquaculture and Fisheries Fund (EMFAF)

Written by Patrycja Enet (MSP Assistance Mechanism North Sea Focal Point)
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Contact: *CINEA EMFAF CONTRACTS*

E-mail: *CINEA-EMFAF-CONTRACTS@ec.europa.eu*

European Commission
B-1049 Brussels
BELGIUM

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Written by **Patrycja Enet** (MSP Assistance Mechanism North Sea Focal Point).

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Contents

ACRONYMS

General acronyms	
BSH	Federal Maritime and Hydrographic Agency
EGD	European Green Deal
EIPN	Dutch North Sea Energy Infrastructure Plan
EU	European Union
EUCRA	European Climate Risk Assessment
EEZ	Economic Exclusive Zone
CCS	Carbon Capture and Storage
CO_2	Carbon Dioxide
DTO	Digital Twin of the Ocean
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSOG	European Network of Transmission System Operators for Gas
GHG	Green House Gas
GNSBI	Greater North Sea Basin Initiative
GT	Geospatial technologies
HELCOM-VASAB	HELsinki COMmission – Vision and Strategy Around the Baltic Sea
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ICZM	Integrated Coastal Zone Management
ILO	International Labour Organization
IMO	International Maritime Organisation
KMGBF	Kunming-Montreal Global Biodiversity Framework
LNG	Liquified Natural Gas
MITECO	Ministerio para la Transición Ecológica y el Reto Demográfico
MS	Member State
MSP	Maritime Spatial Planning
MT	Modelling Technologies
MPA	Marine Protected Area
NbS	Nature-based Solutions
NDC	Nationally Determined Contribution
NECP	National Energy and Climate Plans
NPI	Net-Positive Impact
ORE	Offshore Renewable Energy
OSPAR	OSlo-PARis Convention Organization
OWF	Offshore Wind Farms

General acronyms	
OOT	Ocean Observation Technologies
O&G	Oil & Gas
R&D	Research & Development
RES	Renewable Energy Storage
SEA	Strategic Environmental Assessment
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WRF	Weather Research & Forecasting Model

EU Member States acronyms	
BE	Belgium
BG	Bulgaria
HR	Croatia
CY	Cyprus
DK	Denmark
EE	Estonia
FI	Finland
FR	France
DE	Germany
GR	Greece
IT	Italy
IE	Ireland
LV	Latvia
LT	Lithuania
MT	Malta
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SI	Slovenia
ES	Spain
SE	Sweden

1. INTRODUCTION

Delivering the European Green Deal (2020) and a new approach for a Sustainable Blue Economy in the European Union (EU) (2021) [(1)] requires urgent integration of climate-smart trends and new technologies in all types of planning, including maritime spatial planning (MSP) and other country-led instruments. Today, maritime activities increasingly embrace climate change mitigation and adaptation [(2)] to meet goals to address the Triple Planetary Crisis of intertwined climate change, biodiversity loss and pollution. With the rapid growth of activities at sea, including the large-scale development and deployment of offshore renewable energy (ORE) infrastructure, the maritime sectors also face the challenge of congested space and competition. [(3)]

As shown by the recently published European Climate Risk Assessment (EUCRA, 2024) by the European Environment Agency, all of Europe's seas are heavily affected by climate change, with key climate risks including coastal erosion and inundation, the decline of pelagic primary production, and changes to marine ecosystems' functioning and species distribution, which have clear impacts on the blue economy. [(4)] The EU MSP Directive establishing a framework for maritime spatial planning [(5)] identifies climate change as a threat and highlights the need to take into consideration long-term changes due to climate change in MSPs, and thereby to incorporate climate mitigation and adaptation actions into national MSP policy. The 2022 report from the Commission to the European Parliament and the Council outlining the progress made in implementing the MSP Directive [(6)] emphasises that as a way forward Member States will need to better reflect the ambitions of the European Green Deal and the areas of climate change mitigation and adaptation in their MSPs, and to align their plans with these ambitions.

The development of technological advances across maritime sectors is an intrinsic part of the progress of a sustainable blue economy for the future use of the seas and for aligning climate change mitigation and adaptation with the biodiversity targets and many spatial claims, as communicated by the European MSP Platform's background technical study '*Review on how to preserve space for the future uses of the seas: what methods can we apply to address the needs of future generations?*' (2023). [(7)] The study highlights that the demand for green transition, large-scale renewable energy sources, aggregate

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[(1)] European Commission, 2023 (Websites)
[(2)] European Commission Directorate General for Maritime Affairs and Fisheries, 2023a (Studies & articles)
[(3)] European MSP Platform, 2023 (Websites)
[(4)] European Environment Agency, 2024 (Studies & articles)
[(5)] European Parliament and Council of the European Union, 2014 (EU Strategies & Policies)
[(6)] European Commission, 2022 (EU Strategies & Policies)
[(7)] European Commission, European Climate, Infrastructure and Environment Executive Agency - Enet, P., 2023 (Studies & articles)

extraction, food supply and geopolitical security, will play a more prominent role in the future in all EU sea basins with some of these sectors expected to develop quickly. In strengthening climate action to achieve the Paris Agreement (2015), it is recognised the increased role of the marine and coastal areas for the large-scale development and deployment of new and emerging ocean-related technologies, and the acceleration of existing technologies.

Building on this study review, [(7)] particularly the parts related to climate change mitigation and adaptation, the current study focuses on the topic of **climate actions in MSP**, and the incorporation of climate-smart technologies into the existing spatial planning frameworks and other country-led instruments, as well as the sea-basin strategies. The objective of this study is to **assess the evolving landscape of maritime plans in Europe and the integration of climate-smart trends and technologies into these plans**. Specifically, the study addresses the current state and future prospects of technologies to **advance ocean-based climate action** in terms of the development and deployment of climate-smart technologies, technological transformation and uptake in the plans, and demonstration of new and emerging ocean-related technologies.

Focusing on climate-smart elements of MSPs, the study showcases how Member States integrate future climate-smart trends and new technologies into their latest plans, and what the perspectives on the evolution of climate-related considerations and emerging sectors at a sea-basin level. In this study, *technology* refers to the practical application of knowledge to achieve particular tasks that employ both technical artefacts (hardware, equipment) and (social) information ('software', know-how for production and use of artefacts); and *technology transfer* refers to the diffusion of technologies and technological cooperation across and within countries that leads to the spread of technology for mitigation and adaptation. [(8)] Central to the study is an exploration of a range of climate-smart technologies, their rapid development, deployment and acceleration of existing innovation, transformation, and advance and demonstration of emerging technologies.

The study provides an overview of climate-smart actions and values in plans per country, focusing on climate change mitigation (low-carbon pathways) and adaptation - enhancing resilience of maritime activities, marine/coastal areas and ecosystems, as well as communities' socio-economic resilience to climate-related risks. The role of blue carbon ecosystems (seagrass beds, salt marshes, etc.) as pivotal components of nature-based solutions to climate change, offering both mitigation benefits and enhancing resilience, is highlighted in the study. However, Marine Protected Areas (MPAs) as well as conservation and restoration are not considered at length given that the minimum 30% protection with the required allocation of space for ecosystem protection will be part of MSP at the EU scale. Innovations in fisheries technology for sustainable

[(8)] Intergovernmental Panel on Climate Change, 2007 (Studies & articles) fisheries management are also not examined. The study focuses on **uses in the early stages for which the space reserved is relatively uncertain**, subject to social and environmental concerns, and which will require the identification and allocation of space in the future.

Looking through a lens of political, technological, environmental, economic and societal change, the study assesses where the countries are now and what their future plans are; their proposed actions - those currently included in the plans, and those planned as future actions/needs. The study identifies innovation in the sea-basins and national approaches across a range of maritime emerging sectors and related technologies, as well as new pioneering technologies. It also discusses the current state and future potential of technologies for advancing climate-based mitigation and adaptation actions, with the consideration of the broader socio-environmental implications of deploying climate-smart technologies, such as creation of employment opportunities.

For the preparation of this study, multiple publications on the topic of climate-smart MSP were reviewed. They are acknowledged throughout the study and summarised in the reference section. The primary source of information for developing the regional and national overviews (Chapters 3 and 4) were the national plans and regional strategies, available at the European MSP Platform [9] and national/regional sources.

[9] European MSP Platform, 2024 (Websites)

2. EU CONTEXT FOR FUTURE TRENDS AND NEW TECHNOLOGIES

The technological advancement of maritime sectors in Europe is steered by the EU policy context, where climate change considerations with climate-smart trends and technologies in maritime activities and planning are included in numerous EU regulatory frameworks and strategies. These include the European Green Deal (2020) [(10)] with the European Climate Law (2021) [(11)] and the Strategy for offshore renewable energy (2020), [(12)] Biodiversity Strategy for 2030 (2020) [(13)] with a Nature Restoration Law, [(14)] Strategy on Hydrogen (2020); [(15)] EU Adaptation Strategy (2021); [(16)] a new approach for a Sustainable Blue Economy in the EU (2021); [(17)] revised EU Maritime Security Strategy (2023); [(18)] Renewable Energy Directive (2018); [(19)] Directive on establishing a framework for MSP (2014); [(20)] Marine Strategy Framework Directive (2008); [(21)] EU Floods Directive (2007); [(22)] Recommendation concerning the implementation of ICZM in Europe (2002); [(23)] Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030, [(24)] the Communication 'Towards a strong and sustainable EU algae sector', [(25)] and the Communication Delivering on the EU offshore renewable energy ambitions. [(26)]

These regulatory frameworks and strategies play an important role in supporting global commitments and agreements, including the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC), the Kunming-Montreal Global Biodiversity Framework (KMGBF), and the 2030 Agenda for Sustainable Development. [(27)] They help to meet the EU's goal of climate neutrality by 2050 and lead Europe's biodiversity on a path to recovery by 2030. They help to reduce the negative impacts of climate change in marine areas. They also stimulate national and regional development, regulatory regimes and investments for

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(10) European Commission, 2019 (EU Strategies & Policies)
(11) European Parliament and Council of the European Union, 2021 (EU Strategies & Policies)
(12) European Commission, 2020a (EU Strategies & Policies)
(13) European Commission, 2020b (EU Strategies & Policies)
(14) European Commission, 2022b (EU Strategies & Policies)
(15) European Commission, 2020c (EU Strategies & Policies)
(16) European Commission, 2021c (EU Strategies & Policies)
(17) European Commission, 2021a (EU Strategies & Policies)
(18) European Parliament and Council of the European Union, 2023 (EU Strategies & Policies)
(19) European Parliament and Council of the European Union, 2018a (EU Strategies & Policies)
(20) European Parliament and Council of the European Union, 2014 (EU Strategies & Policies)
(21) European Parliament and Council of the European Union, 2008 (EU Strategies & Policies)
(22) European Parliament and Council of the European Union, 2007 (EU Strategies & Policies)
(23) European Parliament and Council of the European Union, 2002 (EU Strategies & Policies)
(24) European Commission, 2021b (EU Strategies & Policies)
(25) European Commission, 2022a (EU Strategies & Policies)
(26) European Commission, 2023 (EU Strategies & Policies)
(27) The EU and global policies of relevance to maritime development are described in the background study by the European MSP Platform: see European Commission, European Climate, Infrastructure and Environment Executive Agency - Enet, P., 2022 (Studies & articles)

technological innovation to support the development of maritime sectors, and to make the transition to the blue economy as envisioned in the European Green Deal.

Innovative sectors are evolving and growing,[(28)] such as offshore renewable energy with next generation offshore facilities (floating offshore windfarms, floating solar photovoltaic energy, offshore hydrogen generation, wave and tidal energy), the blue bio-economy, offshore aquaculture, bio-technology and desalination, with a string of enabling methods and technologies that stimulate the efficiency of emerging maritime activities as essential for the knowledge base of the European Green Deal. One strongly emerging trend in MSP at present is the integration of new economic sectors into spatial planning frameworks, which frequently requires additional development of the regulatory framework to incorporate the spatial requirements of proposed developments.

For example, offshore hydrogen generation is attracting significant attention as a promising avenue for decarbonising maritime industries, where spatial optimalisation will be linked to new hydrogen networks and existing electricity grids. Offshore wind farms have been identified as potential sites for hydrogen production, necessitating potential adjustments in MSP to accommodate the infrastructure and spatial requirements of this emerging sector. Similarly, the exploration of carbon capture and storage (CCS) technologies as a means of mitigating carbon emissions underscores the need for MSP to designate suitable areas for CCS infrastructure, either in isolation or in-combination with offshore windfarms, balancing environmental concerns with economic imperatives.

The concept of multi-use platforms has also gained traction within MSP discussions, offering a versatile approach to accommodate diverse activities, such as renewable energy generation, aquaculture, and biodiversity. In tandem with these developments, MSP provides a framework to integrate adaptation and resilience strategies to safeguard maritime activities (e.g., ports, coastal tourism), marine biodiversity, and coastal areas and communities. This includes identifying climate-sensitive areas, enhancing coastal adaptation, and promoting nature-based solutions within MSP plans.

As part of these new innovations, technological development and deployment at scale, is the creation of jobs, including across the energy supply chain with renewable energy generation and hydrogen production, and the transition to scalable zero-emission marine fuels. [(29)] The majority of these jobs will come from building the renewable energy generation capacity and will mostly be created over the 2030s when the intensity of investment will be highest. In view of the scale of potential job creation, international organisations, such as the International Maritime Organization (IMO) and the International Labour Organization (ILO) have developed guidance with the principles of just transition (e.g., ILO’s Just Transition Guidelines). The UN Global Compact has also developed guidance for businesses to start planning for a just transition based on social dialogue and stakeholder engagement that optimises the social, economic and employment impacts on the journey to net-zero emissions and

[(28)] European Commission, European Climate, Infrastructure and Environment Executive Agency Enet, P., 2023 (Studies & articles) sustainability. Based on this guidance, the UN Global Compact Ocean Stewardship Coalition's working group 'Offshore Renewables and Sustainable Ocean Planning' convened in 2024 key stakeholders to identify Just Transition strategies specific to the offshore wind industry.

Technological innovations have played a pivotal role and will continue to do so in enhancing the effectiveness and efficiency of maritime emerging sectors. Research and Development (R&D), blue-tech innovation, next generation numerical modelling (e.g., Weather Research & Forecasting Model -WRF- designed for atmospheric research and operational forecasting applications), automation, artificial intelligence (AI) and robotics are increasing as key enablers for the green transition and the digital twin ocean. (29) Among other innovations, technologies allow floating offshore windfarms to be installed in deeper waters to exploit higher wind speeds. The study '*Review on how to preserve space for the future uses of the seas: what methods can we apply to address the needs of future generations?*' (30) provides an overview of methods and technologies used to accommodate emerging sectors and developments, considering current and future use functions.

(29) European Commission, 2024 (Websites)
(30) European Commission, European Climate, Infrastructure and Environment Executive Agency - Enet, P., 2023 (Studies & articles)

3. EU SEA-BASINS OVERVIEW

Future needs and long-term prospects for the growth of maritime emerging sectors are closely linked to specificities, needs and trends in the sea-basins, which are contemplated in the sea-basin strategies and action plans. These schemes reflect sea basins' specific demands and requirements for emerging sector growth, determined by their geography, prevailing biodiversity and governance; and targets of synergies steered by key issues, socio-economics and the geopolitical situation in the region.

This chapter presents an overview of climate-smart emerging sectors, trends and technologies at a regional scale in the EU sea basins. It summarises the emerging sectors and expected developments that will result from the regional strategies and action plans making use of examples of technological innovations, including scientific and industrial projects, in the various sea basins. This overview gives a transboundary perspective, while Chapter 4 depicts the actions taken by individual countries.

Climate-smart considerations of regional trends and technologies encompass in this review the following:

- **Climate Change Mitigation** – low carbon pathway aspects in sea-basin action plans and strategies, such as offshore renewable energy (including wind energy and alternative renewable energy - solar photovoltaic energy, wave and tidal energy), offshore hydrogen generation and storage, carbon capture and storage (CCS), port planning for the energy transition and decarbonisation of maritime sectors, limiting areas used by sectors with high greenhouse gas emissions
- **Climate Change Adaptation** – enhancing climate resilience in marine and coastal areas in sea-basin action plans and strategies, including reducing vulnerability and negative impacts of climate change on maritime sectors (e.g., ports), coastal areas and infrastructure, coastal communities, marine and coastal ecosystems (resilience strengthening - coherent Marine Protected Areas [MPA] networks, climate refugia areas) through adaptation planning and adaptation measures, including nature-based solutions (NbS) and nature-inclusive designs; also aquaculture with the potential carbon sequestration and climate mitigation effect of algae (i.e., seaweed cultivation has the ability to absorb excess CO_2 from the sea, help alleviate the pressure of climate change on marine ecosystems, while producing a variety of low-carbon products, and help prevent coastal erosion; seaweed can also absorb excess nutrients and organic material, thus addressing water pollution and reducing eutrophication)

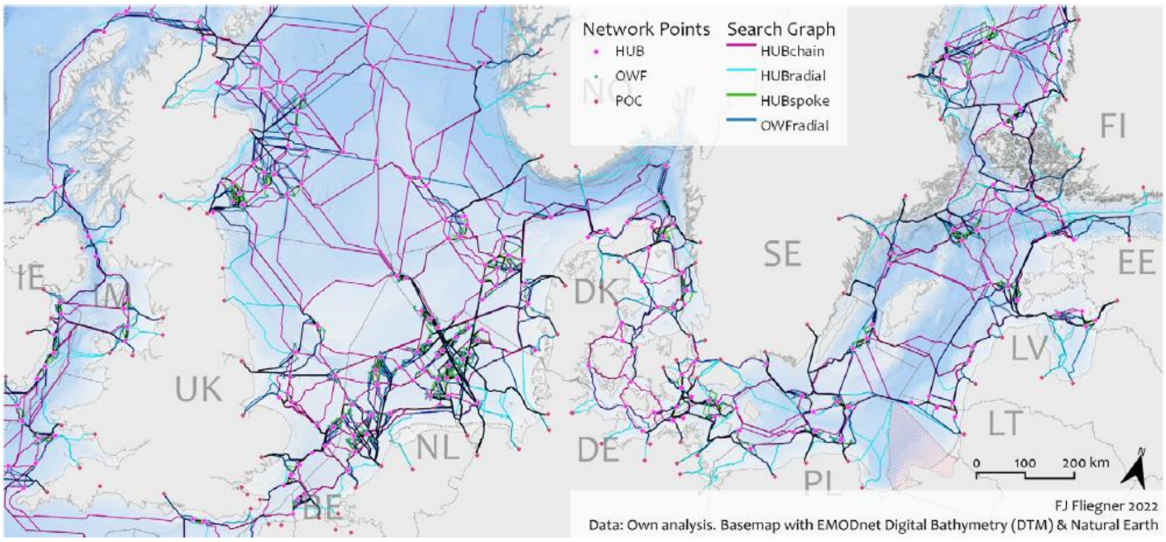
In relation to these climate-smart actions, emerging sectors with innovative technologies play a pivotal role and are considered in this study from the **maritime spatial planning perspective** as follows:

- **Offshore renewable energy (ORE) planning** encompasses fixed and floating offshore windfarms, floating solar photovoltaic energy (SPV), and wave and tidal energy infrastructure. Offshore wind energy is currently the only commercial deployment of an ORE source with wide-scale adoption in the European sea basins. It is an established sector in the North Sea given the significant development of the offshore wind sector in terms of the construction of wind parks (and space allocated to it), and of generation of clean electricity. The other EU sea basins are starting commercial deployment of offshore windfarms, where it is considered as an emerging sector. Most technologies required for an integrated offshore energy system have already attained a level of maturity suitable for large-scale deployment, e.g., in the North Sea, important for planning and operations of a highly complex, multinational energy system. Following the effective scale-up of conventional offshore wind, the technologies of floating offshore wind, ocean energy (wave and tidal), and floating SPV are emerging as valid options to contribute to the EU goals of reaching 111 GW of offshore renewable energy capacity by 2030 and 340 GW by 2050. Currently, the urgency for increased innovation and research to speed up the energy transition is emphasised, that also includes the alternative ocean energy (SPV, wave and tidal energy).
- **Offshore energy grid infrastructure planning** plays an important role for operations of an integrated interconnected offshore energy system (i.e., moving away from the separation of country interconnectors and radial, project-based connections of wind farms) that connects countries and foster spatial diversification of energy generation, establishes links between offshore energy generation assets and onshore infrastructure, and enables seamless connections to a range of off-takers, including storage facilities, carbon storage sites, hydrogen production assets and more. Most technologies required for it, have already attained a level of maturity suitable for large-scale deployment. This involves the development of an interlinked electricity grid for integrated offshore renewable energy, the conversion of power to hydrogen, and the construction of offshore electricity storage to increase the flexibility of the system. Currently system integration is being demonstrated at the project level in the North Sea, while legal frameworks can pose uncertainty surrounding ownership and responsibilities for cross-border infrastructure. Energy storage at sea for ORE is emerging for locating storage facilities offshore that would include the possibility of oversizing wind farms beyond their connection capacity, resulting in lower costs for transmission; and allow for the use of storage technologies in the offshore environment. Recent studies explore the topic of offshore energy grid infrastructure planning by different methods including modelling and high-resolution scenario building support in a geographical information system, for example, in the North Sea basin study [31] and in the North Sea and Baltic Sea study (Figure 1). [32]

(31) Brosschot, S., 2022 (Studies & articles)
(32) Fliegner, F.J. & Möst, D., 2023 (Studies & articles)

Figure 1 – Example of offshore energy grid infrastructure planning in a GIS-based scenario workflow to create large-scale, high-resolution search graphs for offshore grid optimisation (applied a least-cost path optimisation)

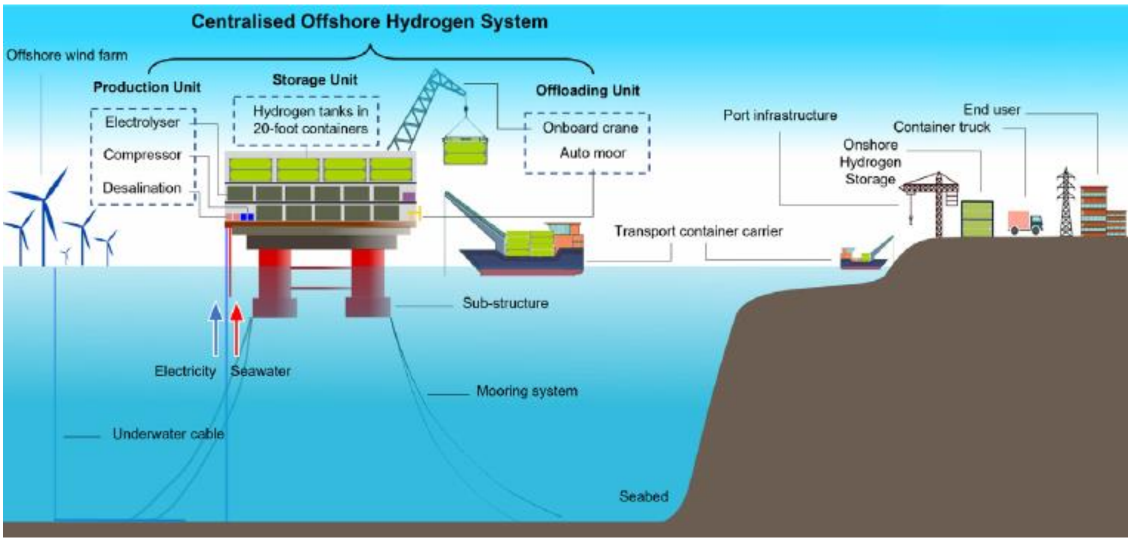
Refined and consolidated search graph for the Baltic and North Sea entails four link types and three network point types: offshore hubs (HUB), offshore wind farms (OWF) and onshore points of connection (POC), based on the national MSPs retrieved from the national data providers in the context of existing offshore wind power concessions and the onshore transmission grid



Source: Fliegner, F.J. & Möst, D., 2023

- **Offshore hydrogen production and storage planning** is an emerging consideration to efficiently channel offshore wind power for onshore energy demands with substantial green energy potential in grid integration. The role of green hydrogen is recognised as a solution to enhance flexibility of the offshore energy system (serving as both a storage medium and an energy carrier), while the production of offshore hydrogen may facilitate the establishment of wind farms far-offshore, benefitting from reduced costs and lower losses compared to direct current (DC) cables. Currently offshore hydrogen infrastructure efforts exist as pilots and are not developed at scale. Innovative designs of offshore hydrogen platforms present a promising solution to bridge the gap between offshore wind and hydrogen integration (Figure 2). The pilots, e.g., the PosHYdon project in the North Sea, and initiatives by pipeline operators demonstrate that these developments are technically feasible, and they can attract substantial financial support. Currently there is a lack of commercially established offshore platforms dedicated to the hydrogen industry, and offshore hydrogen production presents opportunities for the oil and gas (O&G) sector to repurpose existing infrastructure by locating production facilities on pre-existing offshore platforms or utilising established gas pipelines, which can extend the economic lifespan of O&G infrastructure and delay high decommissioning costs.

Figure 2 – Offshore centralised hydrogen platform in the hydrogen supply chain

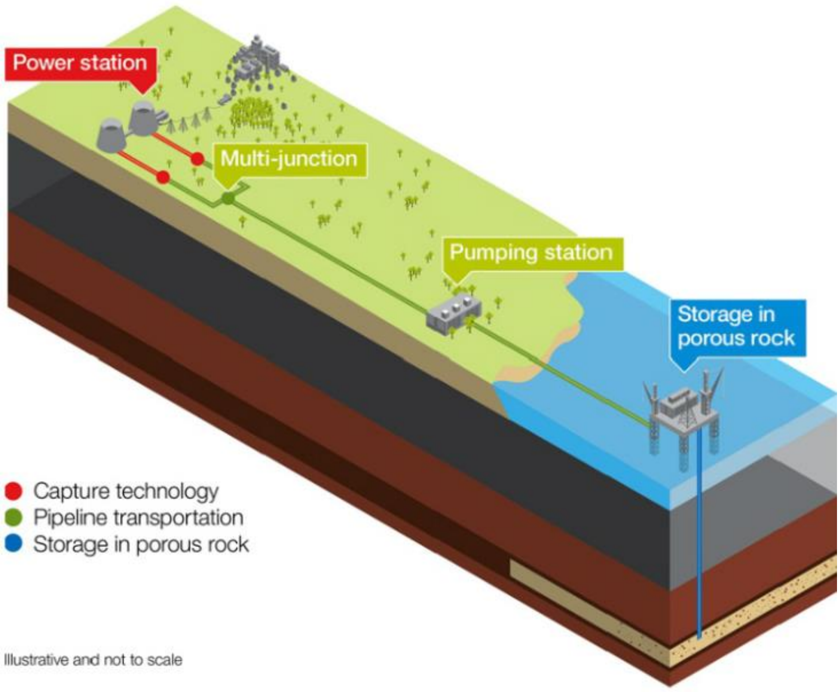


Source: Zhang, M. & al., 2024

- **Offshore carbon capture and storage (CCS) planning** concerns carbon storage/sequestration and capture carbon in the form of carbon dioxide (Figure 3). Carbon is stored in different underground reservoirs at sea, including old oil and gas workings/infrastructure with wells and pipelines that are repurposed for CO_2 transport and storage. The ultimate objective of CO_2 storage is to ensure permanent containment in geological formations, in a manner that avoids significant adverse consequences for the marine environment, human health and other legitimate users of the maritime area. The European Commission published a report in 2023 [33] on the implementation of the EU Directive on the Geological Storage of Carbon Dioxide (CCS Directive, 2009) that establishes a legal framework for the environmentally safe geological storage of CO_2. OSPAR has adopted a Decision (2007/2) to ensure safe storage of carbon dioxide streams in geological formations together with guidelines for risk assessment and management of storage of CO_2 streams in geological formations (OSPAR Agreement 2007-12). [34] OSPAR has also adopted a Decision (2007/1) to prohibit the storage of carbon dioxide streams in the water column or on the seabed, because of the potential negative effects. Most of the CCS programmes are governed by the regulations of the countries, and there are efforts towards international co-operation in the North Sea.

(33) European Commission, 2023 (Studies & articles)
(34) OSPAR, 2023 (Websites)

Figure 3 – Offshore carbon capture technology and storage schematisation



Source: OSPAR, 2023

- **Port planning for the energy transition and decarbonisation of maritime sectors** that allows for the advancement of the energy transition at sea and in port facilities, and environmental sustainability. The optimisation of space in ports for energy-efficient and environmentally sustainable behaviours concerns, for example, facilitating the supply of cleaner marine fuels (hydrogen, methanol, LNG, etc.) to promote the improvement of the technical energy efficiency of ports and ships; providing space for developing renewable energy infrastructure and installations in ports; linking maritime-port clusters where ports act as a location for energy infrastructure connecting maritime transport and the hinterland in the development of marine energies. Ports must also be resilient to the impact of climate change, such as rising sea levels or a more significant number of storms and waves that hinder port activity, which requires strategies for adaptation to climate change. (35)
- **Adaptation planning** encompasses reducing vulnerability to climate change and enhancing resilience in marine and coastal areas with holistic resilience planning, adaptive management and application of adaptation measures. It concerns maritime activities/infrastructure, marine/coastal areas and ecosystems, as well as communities' socio-economic resilience to climate-related risks. The efforts in Europe include the elaboration of national coastal adaptation plans, such as the Delta Programme 2024 (36) in the Netherlands, and a National Coastal Protection and Adaptation Strategy for the Maltese

(35) PIANC, 2020 (Studies & articles)
(36) Dutch Ministry of Infrastructure and Water Management, 2024 (MSP documents & National plans)

Islands 2023. [37] In Malta works are currently advancing towards creating a holistic framework to bridge multi-level planning instruments for coherent adaptation policy and planning with integrated knowledge and governance for management and monitoring of climate change risks with the development of technical and cooperation capacity for interdisciplinary surveillance and management of risks.[38] Specific adaptation measures from these national adaptation strategies will require space in maritime planning, for example sand nourishment (and thus sand extraction zones) and Nature-based Solutions (NbS) that address hazards, mitigate and adapt to climate change while enhancing marine and coastal biodiversity. The European Green Deal places NbS at the centre of climate adaptation and mitigation and highlights their role in ensuring healthy and resilient seas and oceans. The application of NbS is supported by several EU Green Deal initiatives, notably the Green Infrastructure Strategy (2013), [39] the Communication on a new approach for a sustainable blue economy in the EU Transforming the EU's Blue Economy for a Sustainable Future (2021), and the Strategy on Adaptation to Climate Change (2021).

- **Aquaculture planning** is critical to food supply and security in a changing climate and aims to support sustainable development of innovative and restorative aquaculture within appropriate sites in the marine and coastal areas. Offshore aquaculture, such as seaweed and shellfish farming, is expected to play a greater role in sustainable food production with the role of restorative ecosystem services through capture and utilisation of emissions (carbon dioxide (CO_2) and nutrients). Given the complex hydrological and ecological requirements for aquaculture, spatial strategies and development criteria are developed against which aquaculture planning is assessed in agreement with national and local policy guidance and legislation. These areas take into consideration the physical character of the area, elements of the physical dynamics of the water bodies and the consideration of a range of issues that have the potential to be affected by aquaculture development. Aquaculture is gaining traction in all the sea basins and multiple aquaculture (e.g., mussel) farms are identified along European coastlines. Currently aquaculture only emerges strongly in the Atlantic with shellfish farming, seabass and seabream aquaculture. To support the sector, the European

[37] The National Coastal Protection and Adaptation Strategy for the Maltese Islands was developed with a support of the European Union via the Technical Support Instrument (TSI) of the European Commission's Directorate General for Structural Reform Support (DG REFORM) following request of the Maltese Public Works Department, the Ministry for Transport, Infrastructure and Public Works, and the Malta Tourism Authority – TSI 2021-2023 MTCoastal 'Coastal-Climate Overall Vulnerability and Exposure Risk – Protection Strategy for the Maltese Islands' (Coastal-COVER): see European Commission Directorate General for Structural Reform Support, 2023 (Websites)

[38] TSI 2024-2026 Climate-MATCH 'Mainstreaming of Climate Adaptation for Horizontal Coordination in Malta" (TSI COMMONCOAST 'A common coast to cherish - Capping Climate Impact') following request from the Public Works Department of the Ministry for Transport, Infrastructure and Public Works, and the Ministry for Environment, Energy and Regeneration of the Grand Harbour: see European MSP Platform, 2024b (Websites)

[39] European Commission, 2013 (EU Strategies & Policies)

Commission published in 2021 Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021-2030. In 2024, two Commission Staff Working documents were provided to authorities and policymakers in Member States as guidance for the allocation of marine space to aquaculture activities and to improve the regulatory and administrative framework for aquaculture (SWD(2024) 95 final; SWD(2024) 107 final).

- **Desalinisation planning** is a rapidly growing sector with over 2300 seawater desalination units in the EU, mainly in the Mediterranean. (40) The majority of the EU's operational plants are located on or near the coast. Due to climate change many regions in the EU will face severe water scarcity by 2050 when water demand is expected to increase by up to 30% for domestic, industrial, and agricultural use through the desalination of seawater. Currently Spain has 65% of the EU's desalination capacity, with the rest in Italy, France, Cyprus, Malta and Greece. Most of the large plants recently established serve coastal cities in Spain. Desalination plants in Northern Europe -in Germany, the Netherlands, Belgium and Ireland, are primarily used for the production of drinking water and industrial water. Innovative approaches of coupling desalination and water reuse are currently being tested to supply fresh water for drinking and irrigation around the Mediterranean Sea. Due to high energy consumption of traditional desalination technologies, emerging trends in seawater desalination are new technologies using offshore renewable energy, including wind, ocean and SPV. Renewable energy-powered desalination plants gain popularity due to their environmental friendliness and cost-effectiveness that reduce greenhouse gas emissions and lower the operating costs of the desalination plant.

The below regional overview was prepared based on the Sea Basins summaries provided by the European MSP Platform (41) and in the 2023 Future Uses review study; (42) European sea-basin strategies and action plans; the EU blue economy reports 2022, 2023; WindEurope and other industrial sources; and the MSP Green (43) and eMSP NBSR (44) projects' deliverables. More detailed information can be found in these sources.

3.1. Baltic Sea

All Member States from the Baltic Sea have adopted MSPs. HELCOM-VASAB provides a political framework within the sea basin, that stimulates strategic planning, collaboration and consensus building among the countries. The sea basin's strategies and actions plans prioritise a healthy marine environment with diverse biological components functioning in balance, aiming at good ecological status and

(40) EU Blue Economy Observatory, 2020 (Studies & articles)
(41) European MSP Platform, 2024a (Websites)
(42) European Commission, European Climate, Infrastructure and Environment Executive Agency - Enet, P., 2023 (Studies & articles)
(43) MSP-GREEN, 2024 (Projects)
(44) eMSP NBSR, 2024 (Projects)

supporting a wide range of sustainable economic and social activities. That includes climate change mitigation and adaptation, with offshore renewable energy production targets (Marienborg Declaration, 2022), carbon storage as CCS and nature-based solution, and resilience building. Climate-smart emerging sectors and future developments in the Baltic Sea are summarised in Table 1.

Table 1. Baltic Sea Basin climate-smart emerging sectors and future developments

Baltic Sea basin *The sea basis is characterised by* the maritime activities: shipping, fisheries, tourism, aquaculture, energy production *The key issues are*: biodiversity, eutrophication, pollution, efforts of environmentally sustainable sea-based activities	Offshore renewables	Offshore hydrogen	CCS	Adaptation	Desalinisation
Climate change considerations: mitigation & adaptation					
Current climate-smart actions (now to short-term)	v			v	
Future climate-smart actions (mid- to long-term)	v	v	v	v	
***Strategy/Action plans*:** EU Strategy for the Baltic Sea Region - most of the countries have set strategic climate targets for 2030 and 2050; HELCOM-VASAB MSP Roadmap 2021-2030; VASAB Vision 2040; Baltic Sea Action Plan; CPMR Baltic Sea Commission – Renewable Energy Working Group; 2022 Marienborg Declaration					

Emerging climate-smart sectors and considerations:

- **Offshore renewable energy**: Offshore wind energy production is projected to develop rapidly. Today installed capacity of offshore wind is over 2.8 GW (mostly in DK and DE waters). The Baltic Sea countries have committed to increase capacity to 19.6 GW by 2030 (Marienborg Declaration) and a 2040 target will be considered at a later stage.
- **Offshore energy grid infrastructure**: A recent notable example of international collaboration on the interconnected offshore energy system is an agreement between Germany and Denmark for a multi-energy project to interconnect multiple countries while establishing hydrogen production facilities on the Island of Bornholm in the Baltic Sea. Along with offshore wind capacity, the focus will be on cooperation for international grid systems and liquefied natural gas (LNG) as a fuel in the short term. Maritime traffic is expected to increase significantly, driven by regional development, including the expansion of gas terminals in PL, EE and LT, and the development of cruise ship tourism.
- **Offshore hydrogen productions and storage**: Various projects explore this sector, including the Interreg project Baltic Offshore Wind Energy to Hydrogen (BOWE2H); project Baltic Sea Hydrogen Collector (BHC) that aims to create an offshore hydrogen pipeline infrastructure in the Baltic Sea, initiated by the FI and SE transmission system operators Gasgrid Finland Oy and Nordion Energi AB together with the wind power developers OX2 in SE and DK.
- **CCS**: Today the Baltic States do not have CO_2 transport and sequestration infrastructure and currently projects/initiatives explore this sector, such as the RouteCCS project - Routing Deployment of Carbon Capture, Use and Storage in the Baltic Sea Region; the BASRECCS network of CCS expertise in the Baltic Sea Region; CCS project 'Ørsted Kalundborg Hub' in DK (by Ørsted); CCS Baltic Consortium project, the BASTOR project, ORLEN Group project to store carbon beneath Baltic Sea following Horisont Energi deal
- **Decarbonisation of maritime transport**: Ongoing and future action, with the examples of transboundary projects that include the projects of the Interreg Baltic Sea Region Programme e.g.: EnviSuM project demonstrating the benefits of global environmental regulations of shipping, ECOPRODIGI project and its extension phase project EXOPRODIGI about using digitalisation to increase eco-efficiency in the maritime industry, GO LNG project on LNG as a green fuel for shipping, SEAMEASURES project on decarbonisation of Baltic and North Sea shipping (the analysis of different options for decarbonisation and minimising the harmful impacts of shipping on air quality and the marine environment), GREEN SMALL CRAFT project on emissions mitigation of small craft operation in the Baltic Sea; industrial efforts, e.g. SE shipping industry active in decarbonising shipping, and private sector actions, e.g. MAERSK
- **EbA Adaptation**: Ongoing and future action, including NbS, in the plans for the marine and coastal areas, especially with shallow waters and sandy coasts. Provisions in the plans include different measures, including coastal adaptation solutions, buffer zones and areas for sand extraction. Enhancement of nature conservation and applying other types of nature-based solutions to increase climate resilience, for instance climate refugia areas, are being developed, including in the regional projects, e.g. Green infrastructure concept for MSP and its application within Pan Baltic Scope Project. Research on climate risks is increasing in the region, e.g. the Danish Coastal Authority and Danish Meteorological Institute are conducting a study on impacts of high-water level during the worst possible storm surge today and in 100 years on the coastline of the Copenhagen metropolitan areas with several municipalities.
- **Aquaculture**: Aquaculture is gaining traction in the Baltic Sea and multiple mussel farms can be identified along the Baltic coast. The main technology used is the longline. Seaweed farming and Integrated Multi-tropic-aquaculture (IMTA) are also being increasingly explored. In 2023, HELCOM officially unveiled the comprehensive Best Available Technologies (BAT) and Best Environmental Practices (BEP) for sustainable aquaculture in the Baltic Sea region in the document 'BAT/BEP descriptions of sustainable aquaculture in the Baltic Sea region'. Various projects explore this sector, including the Interreg project AquaBest on innovative practices and technologies for developing sustainable aquaculture in the Baltic Sea region; the Interreg project Baltic Blue Growth for the farming of blue mussels in the Baltic Sea; the AquaVIP project addressing the use of innovative environmentally friendly production technologies in the South Baltic area, building on the AQUAFIMA and InnoAquaTech projects; AQUA-LIT project, etc. The new Horizon Europe project LOCALITY aims to create multiple innovative, local, and sustainable algae value chains in countries bordering the Baltic and North Seas. HORIZON Innovation Actions includes topics of low impact marine aquaculture and multi-purpose use of marine space in the Baltic and the North Sea basins (HORIZON-MISS-2021-OCEAN-04-01).

Specific climate-smart future developments**:** decarbonisation of maritime transport and tourism cruise shipping; offshore renewable energy production - securing areas for wind energy production and electricity transmission; BEMIP and ENTSO, transformation of ports; EbA-based adaptation

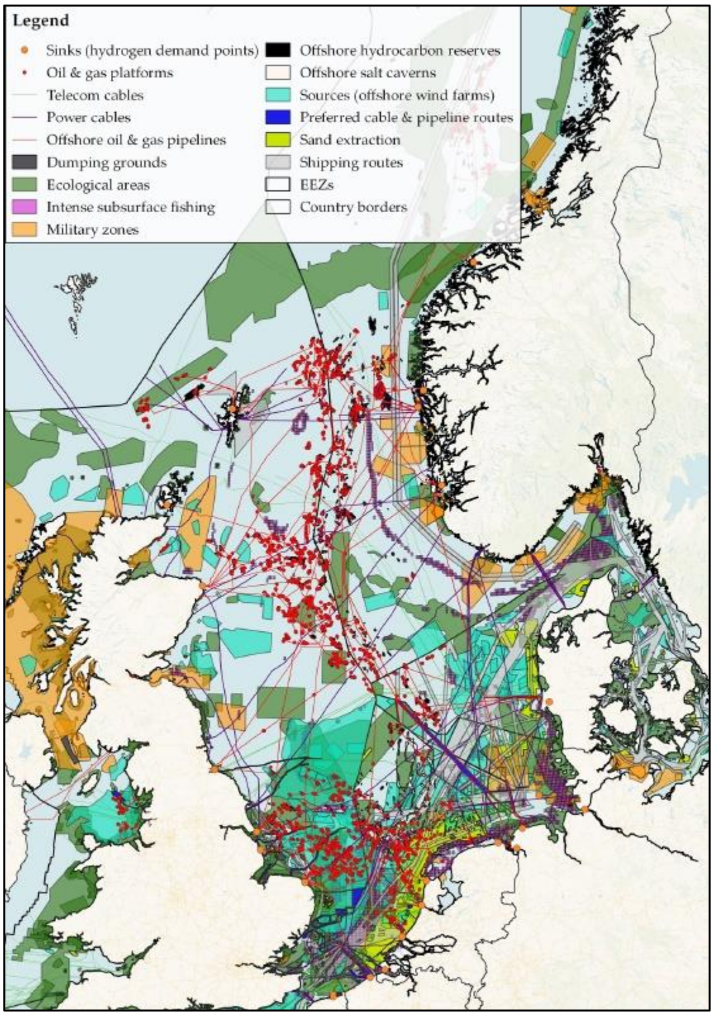
Other relevant projects to planning: Several methods have been developed for planning in the Baltic Sea by the public authorities, research institutes and other stakeholders, especially under VASAB and HELCOM or through the regional projects. Multiple regional projects developed tools and methods that provide opportunities for more efficient planning and collaboration on MSP. Examples: BalticScope project, Sea meets land project, BALANCE project, Plan4Blue, Capacity4MSP, Pan Baltic Scope, BONUS BASMATI, BalticLines, BalticScope, Seanergy 2020, BALTSPACE, PartiSEApate, Plan Bothnia, BaltSeaPlan, PlanCoast, BaltCoast, East-West Window, Baltic InteGrid, BalticRIM, Grass, Land Sea Act, eMSP NBSR, MAREA, Blue Platform, MSPGreen, Baltic Sea2Land, MSP4Bio

3.1. North Sea

All Member States from the North Sea have adopted MSPs. The North Sea Region 2030 Strategy, the North Seas Energy Cooperation (NSEC), the Greater North Sea Basin Initiative (GNSBI) and the OSPAR Convention provide a framework with strategic documents and commitments at basin level, that stimulate the strategic planning and cooperation at the sea basin level. The North Sea Strategy 2030, that is a steering document for the North Sea Commission, includes several priority areas for cooperation: a productive and sustainable North Sea (healthy marine environment, MSP, sustainable aquaculture and fisheries, sustainable blue economy), a climate-neutral North Sea Region, a connected and smart North Sea Region as a front-runner in sustainable blue economy innovation. The recently established Greater North Sea Basin Initiative [45] aims to provide a regional platform for tackling the spatial and ecological challenges of the congested North Sea basin (Figure 4), including through better coordinated cross border MSP. The work streams of GNSBI include governance, nature restoration and conservation, use of space for multiple functions, cumulative impacts, long-term perspective of fisheries, and knowledge sharing. Climate-smart emerging sectors and future developments in the North Sea are summarised in Table 2.

[45] Greater North Sea Basin Initiative, 2023 (EU Strategies & Policies)

Figure 4 – Spatial uses and infrastructure in the North Sea basin. Map was developed based on information from the EMODnet Human Activities with the added and refined data from other sources, such as national data repositories



Source: Brosschot, S., 2022.

Table 2. North Sea Basin climate-smart emerging sectors and future developments

North Sea basin *The sea basis is characterised by* the maritime activities: extensive shipping, fishing, aggregate extraction and energy production, such as hydrocarbon and offshore wind *The key issues are:* energy transition, nature, food, multi-use, congested space and environmentally sustainable activities	Offshore renewables	Offshore hydrogen	CCS	Adaptation	Desalinisation
Climate change considerations: mitigation & adaptation					
Current climate-smart actions (now to short-term)	v	v	v	v	v
Future climate-smart actions (mid- to long-term)	v	v	v	v	v

Strategy/Action plans: The North Sea Region 2030 Strategy (a steering document for the North Sea Commission and priority list for cooperation in the North Sea Region); the Greater North Sea Basin Initiative (GNSBI); the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR); the North Sea Energy Cooperation (NSEC) to facilitate the development of the large renewable energy potential and the offshore grid in the region; 2022 Esbjerg Declaration & 2023 Oostend Declaration on offshore energy cooperation between the North Seas countries for delivering cross-border projects and anchoring the renewable offshore industry in the North Sea.

Emerging climate-smart sectors and considerations:

- **Offshore renewable energy** (windfarm installations, alternative offshore energy): Offshore wind is an intensive development in the North Sea. Today installed capacity of offshore wind is over 25 GW (including the UK and Norway). The countries committed to increase the capacity to 76 GW by 2030, 193 GW by 2040, and 260 GW by 2050 (Esbjerg Declaration). Nine countries (Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, the UK) signed the Oostend declaration in 2023, in which they pledge to build 120 GW of offshore wind in the North Sea by 2030 and 300 GW by 2050. The North Sea countries have agreed to jointly develop the North Sea as a green power plant of Europe by connecting up countries with hybrid, multi-purpose and cross-border offshore projects and hubs.

- **Offshore energy grid infrastructure**: The North Sea countries recognise a need to move away from the separation of country interconnectors and radial project-based connections of wind farms towards an interconnected offshore grid. Today, collaborations on the offshore energy system include a few interconnectors, such as BritNed, NordLink and North Sea Link. Recent notable examples of international collaboration on the interconnected offshore energy system include the plans for a North Sea Wind Power Hub by the Netherlands, Denmark and Germany, and the Belgium energy island in the Princess Elisabeth Zone connecting wind parks of the North Sea countries. Energy storage at sea for ORE is emerging as a new consideration to locate storage facilities offshore that would include the possibility of oversizing OWFs beyond their connection capacity (resulting in lower costs for transmission) and allow for the use of storage technologies offshore, such as the ocean battery by Ocean Grazer. The Netherlands is preparing the North Sea Energy Infrastructure Plan (EIPN) for development of the infrastructure required for OWF in the 2030 to 2050 and how this will be integrated into the energy system (the plan will be published in 2024). The subject of OWF and offshore energy grid infrastructure in the sea basin is addressed in the NSEC study (2022) “Spatial study North Seas 2030: Offshore wind development 2030 North Seas”.[46]

- **Offshore hydrogen production and storage**: The role of green hydrogen is recognised as a solution to enhance flexibility of the offshore energy system, with the production and storage of offshore hydrogen to facilitate the establishment of far-offshore wind farms in the North Sea basin. The PosHYdon project explores production of green hydrogen offshore on an operational gas platform by integrating offshore wind, offshore gas and offshore hydrogen. This pilot as well as other initiatives by pipeline operators (e.g., NGT and NOGAT in the Netherlands) demonstrate that these developments are technically feasible.

- **CCS**: There are multiple programmes on carbon storage/sequestration in the North Sea by various states (EU and non-EU members) to capture carbon in the form of carbon dioxide. Carbon is stored under the North Sea in old oil and gas workings, or within saline aquifers. Most of the CCS programmes are governed by the regulations of the countries, and there are efforts towards international co-operation on CCS. DK run a project Greensand by a consortium of companies to store carbon in the Nini West oilfield 2.3 km below the sea (a drilling programme determined that it could store 450,000 tonnes of captured CO_2 over a ten-year period). NL and DE recognise the need for CCS and they consider storage under the North Sea.

- **Decarbonisation of maritime transport**: Ongoing and future action, with the maritime industry, including shipping and ports, undergoing a significant shift to clean-energy generated alternative fuels like electricity and hydrogen. Multiple industrial efforts and regional projects are ongoing, with the examples of transboundary projects that include the projects of Zero Emission Ports North Sea (ZEM Ports NS) that analyses how port infrastructure must prepare for carbon-free shipping; Future Proof Shipping to advance toward hydrogen-driven vessels; HyTrEc2 project to produce hydrogen locally. The refuelling station of PURE Energy Centre is a fully operating demonstrator with production and storage of hydrogen.

- **Adaptation**: Ongoing and future action, with countries using advanced technologies for different areas of climate change adaptation, including climate risk assessments in coastal and marine areas (incl. projections for extreme events), such as numerical simulation models to predict weather and ocean conditions, and flood and coastal erosion, to build historical records and to observe trends and define design conditions for civil structures and identify risks to human populations and human activities: e.g., XBeach, WaveWatch III to compute future extreme scenarios to design infrastructure including maritime/ports/coastal defences, bridges, wind farms, etc. Structural technologies to protect and prevent risks (e.g., storm surge barriers and closure dams, TetraPods, riprap, etc.), NbS (‘Building with Nature’ in NL) as well as nature-inclusive designs and hybrid technologies in coastal and marine applications are advanced and continuously expanding with ongoing research, such as on resilient, adaptive and flexible measures. NbS to protect and restore marine and coastal habitats are increasing with sustainable project design for long-term viability and effectiveness of these solutions in ecological, economic, social, infrastructural, and financial terms. Technologies for generating socioeconomic information to determine exposure, vulnerability and conduct risk assessments serve for the preparation of adaptation strategies and plans in the North Sea countries with comprehensive disaster and climate risk management, e.g.

Delta Programme in the Netherlands. Provisions in the plans include different measures, including coastal adaptation solutions, buffer zones and areas for sand extraction.

- **Aquaculture**: Offshore aquaculture in the North Sea, such as seaweed and shellfish farms, is expected to play a greater role in sustainable food production in the future with the role of restorative ecosystem services through capture and utilisation of emissions (carbon dioxide (CO_2) and nutrients). The EU programmes, such as Blue Growth Strategies, Interreg North Sea, Horizon 2020 and Horizon Europe, have funded multiple projects on the topic of offshore aquaculture with the inclusion of economic and social aspects, e.g. North Sea Aquaculture. The current status of aquaculture in the North Sea indicates that commercial exploitation of offshore areas for aquaculture is currently limited with challenges related to limited site availability and suitability, concerns about environmental sustainability and spatial conflicts. Thus, considerations of multi-use of offshore wind farms with offshore aquaculture is increasing as a way to provide sustainable energy, nutritious seafood, and restorative ecosystem services through nutrients and carbon capture and utilisation. Several projects in the North Sea have modelled and tested if offshore aquaculture could be spatially combined with OWF in the areas that are otherwise restricted due to the safety of OWF operations and excessive infrastructure costs, which demonstrated that the multi-use of OWF could be combined with aquaculture of blue mussels and sugar kelp in the North Sea. The pilots in the H2020 UNITED project addressed offshore aquaculture in BE, DE and NL. The new project ULTFARMS (Horizon Europe Ocean Mission) is set to transform the future of Low-Trophic Aquaculture (LTA) systems through the integration of innovative engineering, technical, ecological, and biological processes; with three pilots in the North Sea (BE, DE and NL).

***Specific climate-smart future developments*:** ORE production (incl. energy islands, hydrogen infrastructure and transport), decarbonisation of maritime transport, pioneering technologies (such as combined cycle gas turbine facilities with carbon capture technology in proximity to wind turbines) and approaches (such as artificial energy islands) to decarbonise industry, generate green hydrogen from solar farms and the offshore wind farms, and use space and existing infrastructure (e.g., decommissioned oil/gas platforms)

Other relevant projects to planning: C-SCOPE, PISCES, BLAST, NorthSEE,- Improving the co-existence of Offshore Energy Installations & Shipping, SEANSE, eMSP NBSR

3.2. Atlantic

All Member States from the Atlantic basin have adopted MSPs. The Atlantic Action Plan 2.0, Atlantic Strategy, and the OSPAR Convention provides an overarching framework in the sea basin, that stimulates strategic planning, collaboration and consensus building among the Member States. Atlantic ports as gateways and hubs for the blue economy, marine renewable energy, blue skills of the future and ocean literacy, healthy ocean and resilient coasts are the areas prioritised by the Atlantic Action Plan 2.0. Among synergetic objectives in the sea basin are: sustainable blue economy development, aligning offshore renewable energy initiatives with the objectives of the Strategic Energy Technology Plan, developing public awareness and strengthening cooperation in the European ocean energy community, the protection of the Atlantic's marine and coastal environment, and creating synergies for a socially inclusive and sustainable model of regional development. Climate-smart emerging sectors and future developments in the Atlantic basin are summarized in Table 3.

(46) DNV, 2022 (Studies & articles)

Table 3. Atlantic Basin climate-smart emerging sectors and future developments

Atlantic *The sea basin is characterised by* the maritime activities: shipping, tourism, living resources, fishing, port activities *The key issues are:* port connectivity, decarbonization, food, renewable energy, energy grid, nature, blue skills, ocean literacy, healthy ocean, resilient coasts	Offshore renewables	Offshore hydrogen	CCS	Adaptation	Desalinisation
Climate change considerations: mitigation & adaptation					
Current climate-smart actions (now to short-term)	v			v	v
Future climate-smart actions (mid- to long-term)	v	v	v	v	v
Strategy/Action plans: The Atlantic Action Plan 2.0, Atlantic Strategy, the OSPAR Convention					

Emerging climate-smart sectors and considerations:

Offshore renewable energy: Today installed capacity for offshore wind in the Atlantic is 537 MW (WindEurope). The countries are planning on increasing their ORE capacity to 12-14 GW by 2030, 21-26 GW by 2040 and 29-43 GW by 2050 (2023 non-binding agreement from TEN-E regulation). The total potential for offshore wind energy capacity in the Atlantic was assessed in a 2023 study [(47)] as 2650 GW. 54 projects are currently running, mostly dedicated to wind energy. Examples of pilot projects: tidal energy production project in Raz Blanchard (FR) with 4 turbines to be set up in 2027; SEM-REV (FR) - a multi-technology offshore testing site that is connected to the grid (floating offshore wind, tidal power, wave energy, offshore hydrogen and floating SPV); R&D&I facilities for marine energy in ES, e.g., open sea test centres: BIMEP, PLOCAN and Punta Langosteria - X1 Wind installs floating platform in the PLOCAN test site; Mutriku wave power plant built into a breakwater at the harbour in Mutriku (ES) with a capacity of 296 kW; DemoSATH floating offshore wind pilot project led by Saitec Offshore Technologies; CorPower C4 wave energy device under development at 4km offshore in northern PT. The WindFloat Atlantic project is the first semi-submersible wind farm in the world, installed in northen PT in 2020 with 25 MW. ES has the intention for reinforcing the network of test platforms, [(48)] deploying a "plug & play" enabling framework that aims to become the most agile in the environment for the testing of new prototypes, and activating at least 200 million euros in public support for technological innovation. 77 offshore wind farm projects are under development in IE with a target to reach 37GW by 2050, e.g., Saoirse Wave Energy project developed off the Co Clare coast is expected to produce 5MW by 2030. Wave and tidal energy projects will develop as well, considering the high potential of the Atlantic, especially in IE, with a total capacity of about 40 GW in the Atlantic (IE).

Offshore energy grid infrastructure: Along with offshore wind capacity the focus will be on cooperation for international grid systems. Various projects are currently running to develop the submarine network, e.g., the PISCES - Portugal Ireland Spain Connecting Europe Subsea – project aims at providing direct telecommunications connectivity between Ireland and the rest of EU through a trunk subsea cable to PT and branching links to ES; the West European Coast Festoon – project is a submarine cable system connecting PT, ES, FR, NL and IE.

Offshore hydrogen production and storage: This sector is at an early phase, with a small number of projects exploring this sector. Pilot projects include: e.g., Sealhyfe project off FR coast, which finished in January 2024 the experimentation phase; Hydrogen to Heat (H2Heat) project off the Canary Islands developed by PLOCAN that aims at combining floating offshore wind farms and green hydrogen production (ES); Jules Verne project in the Port of Vigo and a project in the Port of Huelva (ES); future joint development of offshore renewable hydrogen projects in ES and PT between the Spanish Capital Energy and the French Lhyfe companies, located in some of the 7.5 GW offshore wind farm sites.

CCS: Today the Atlantic states do not have CO_2 transport and sequestration infrastructure and currently projects/initiatives are exploring this sector. Pilot projects include: e.g., Horizon 2020-funded 3D (DMX Demonstration in Dunkirk) project developed in FR. A national study was published in IE on the suitability, costs and deployment options of CCS in 2022 which studied different scenarios to control future Irish CO_2 pathways. ES run three pilot projects for CO_2 capture and one for CO_2 storage between 2006 and 2014, however, currently no commercial or demonstration projects are planned. In PT several studies related to CCS have been developed with the involvement of Universities, State Laboratories, DGEG, and Companies of the industrial sector and of the energy sector, e.g., the KTEJO project (sequestering and geologically storing CO_2 at the Pego coal-fired thermoelectric power plant) and the COMET project (defining an integrated transport and storage infrastructure in PT, ES and Morocco) carried out a systematic analysis of the storage capacity in deep saline aquifers on a regional scale in an offshore environment.

(47) European Commission Directorate General for Energy - Dubranna, J., Fofack-Garcia, R., Verrecchia, C., Rodrigues, B., Langiano, S., Berque, J., Iglesias, G., Laino, E., 2023 (Studies & articles)
(48) Spanish Ministry for Ecological Transition and the Demographic Challenge – MITECO, 2022 (MSP documents & national plans)

Decarbonisation of maritime transport: Ongoing and future action, with the examples of transboundary projects. Pilot projects are running, e.g., HYDEA project, launched in November 2023, consists of pilot tests run by a consortium of partners from FR, IE, ES, PT for the development and application of hydrogen and methanol for the ports in the Atlantic; Salicórnia - first fully electric ferry in PT by Grupo ETE, co-financed by the EU through the Cohesion Fund; conversion in 2023 of a Cork Terminal owned by the UK biofuel supplier GBF into a GD+ fuel terminal in a joint initiative with GAC IE; initiatives by shipping companies towards boats fixed suction sails (e.g., FR Ayro company developing OceanWings technology for newbuild or existing ships; ES engineering company bound4blue in 2024 for the FR LDA company) and dual-fuel ships (e.g., CMA CGM received dual-fuel large containership using LNG). In ES there are many projects from the Port of Vigo, and other initiatives such as the Alianza NetZeroMar.

Climate Change Adaptation: Coastal adaptation strategies are developed by the Atlantic states due to growing pressures from climate change impacts. For example, ES developed the regional coastal strategies (Cádiz, Málaga, Almería and the Balearic Islands) and a National Strategic Plan for Coastal Protection considering the effects of climate change through a European Commission's DG REFORM TSI following the request of the Spanish Ministry for the Ecological Transition and the Demographic Challenge (MITECO). FR created a new type of cooperation structure between national and local levels named partnership plans for planning (PPA) to encourage local processes of spatial withdrawal in coastal areas, in parallel with the National Strategy (GIZC 2012). The Coastal Communities Adapting Together (CCAT) pilot project co-funded by the European Regional Development Fund used another approach based on stakeholders and citizens and aimed at supporting coastal communities to understand and how to adapt to climate change.

Aquaculture: The sector has emerged quite strongly in EU Atlantic. Algae, shellfish farming – which is the principal type of aquaculture in FR[49]-, seabass and seabream aquaculture have experienced an important growth. Important research effort for the last 30 years in FR led to the emergence of an aquaculture sector based on the production of marine fish (e.g., red drum, sturgeon caviar). Pilot projects include: AquaWind - a multi-use offshore platform, which combines ORE and aquaculture (fish farming) in the Atlantic Sea Basin (FR, ES and PT). Co-funded by the EMFAF and coordinated by the Government of the Canaries, it started in 2022 and is expected to finish in 2025. Innovative technologies to improve aquaculture production are developed in IE, e.g., the Oyster Pitch, based on sounds to monitor oysters' welfare and reduce their mortality. A large-scale fish farm is under consideration in northern FR (Boulogne-sur-mer), which could produce about 9000 tons of salmons each year.

Desalinisation: Desalinisation projects are under development in the area. Pilot projects include: e.g., construction of a new seawater desalinisation plant in the Algarve region (PT), in Albufeira; desalinisation power plant based on solar pv under development in Andalousia (ES).

Specific climate-smart future developments: construction of new ports and extending the existing ones; offshore renewable energy on a big scale including hybrid floating offshore platforms (offshore wind farms - floating and fixed-, wave and tidal energy; offshore aquaculture on a big scale; biotechnology (e.g., algae); submarine power cable lines; big-scale extraction of seabed marine minerals

Other relevant projects to planning: SIMCelt, TPEA, Celtic Seas Partnership, SIMNORAT, EU-ATLAS: A trans-Atlantic assessment and deep-water ecosystem based spatial management plan for Europe, SIMAtlantic, MarSP: Macaronesian Maritime Spatial Planning, MSP-OR, REGINA-MSP, Green MSP

3.3. Mediterranean Sea

Not all Member States from the Mediterranean Sea have adopted MSPs. The Mediterranean Action Plan of the Barcelona Convention, the Mediterranean Strategy for Sustainable Development (2016-2025), and the Ministerial declaration on Sustainable Blue Economy (2021) integrated in the Union for the Mediterranean, deliver a political framework for the sea basin. The sea basin's strategies and actions plans prioritise a prosperous and peaceful Mediterranean region, that includes investing in the environment as a mean to secure long-term, sustainable job creation and socio-economic development, and as an essential process for the achievement of long-term development for present and future generations. Addressing climate change is among the key synergetic objectives together with the transition towards a green and blue economy and improving governance for sustainable development.

(49) Dosdat & De La Pomelie, 2003

Climate-smart emerging sectors and future developments in the Mediterranean Sea basin are summarised in Table 4.

Table 4. Mediterranean Sea Basin climate-smart emerging sectors and future developments

Mediterranean Sea basin *The sea basis is characterised by* the maritime activities: tourism, shipping, port activities *The key issues are*: coastal erosion, energy production, nature, pollution, environmentally sustainable sea-based activities	Offshore renewables	Offshore hydrogen	CCS	Adaptation	Desalinisation
Climate change considerations: adaptation					
Current climate-smart actions (now to short-term)	v			v	v
Future climate-smart actions (mid- to long-term)	v	v	v	v	v
Strategy/Action plans**:** Mediterranean Strategy for Sustainable Development (MSSD, 2016-2025), Ministerial declaration on Sustainable Blue Economy (2021) integrated in the Union for the Mediterranean (UfM), Mediterranean Action Plan (MAP) Barcelona Convention, Ecosystem Approach (EcAp) and its 11 Ecological Objectives, UNEP/MAP Conceptual Framework for ICZM/Marine Spatial Planning (ICZM Protocol articulated with MSP), The Protocol on the Protection of the Mediterranean Sea against Pollution from Land-Based Sources (2006), Initiative for the sustainable development of the Blue Economy in the Western Mediterranean (WestMED), Community of Practice on MSP for the Mediterranean					
Emerging climate-smart sectors and considerations: • **Offshore renewable energy:** Currently, offshore wind capacity in the Mediterranean Sea represents 0.1% of total capacity in Europe. In many countries, the projects are on hold, at initial stage, or cancelled. Currently, offshore wind is mostly deployed in the Northern Mediterranean, with many wind projects in the pipeline, most of which are in the planning and permitting development stages. In 2022, the first offshore wind farm in the Mediterranean was inaugurated off the coast of IT: the Beleolico wind project featuring ten bottom-fixed 3 MW offshore wind turbines, which have a total combined capacity of 30 MW. Three pilot projects for floating offshore farms have been approved in FR and are being constructed in the Gulf of Lion: EolMed project (a total capacity of 30 MW), Provence Grand Large project (three 8.4 MW wind turbines), and EFGL project (Les Eoliennes Flottantes du Golfe du Lion - three 10 MW wind turbines). Two other Mediterranean floating wind farms are going to be developed in Sicily and Sardinia (IT). The OWF in Sicily will have a capacity of 250 MW (21 turbines) and it should start running in 2026, while the OWF in Sardinia consisting of 42 wind turbines with a power of around 12 MW each (a total capacity of more than 500 MW) is scheduled to enter commercial operation in 2028. The floating technology should lead to a more rapid deployment in the Mediterranean Sea. New and more ambitious targets have been set by the Mediterranean countries in their revised National Energy and Climate Plans (NECPs) leading to new offshore renewables strategies, and several projects by private investors. Based on final assessments of new NECP objectives, action plans for offshore RES present a range that is between 24 GW and 57 GW to the 2035 horizon, compared to 7 GW in 2030 as resulting from 2019 NECP objectives. • **Offshore hydrogen productions and storage**: In line with EU's 'External Engagement Strategy' and 'REPpowerEU' Plan [50], the Mediterranean is starting to contribute to the production of hydrogen. A considerable amount of imported hydrogen is likely to come from Sub Saharan Africa and the Middle East via pipeline, where companies are currently signing agreements with local governments and the EU is channeling up to €300 billion funding via the 'Global Gateway'. Some Eastern Mediterranean countries are seeking ways to maximize the potential of their natural gas resources while simultaneously focusing on hydrogen as part of their energy transition strategies. Recently, a €100 million green hydrogen refueling infrastructure for recreational boating, a project led by NatPower H, has been set to see its first station installed in IT in 2024. While much of the discussion regarding additional natural gas exports from the Eastern Mediterranean region has focused on LNG, pipeline options have also been considered. The EastMed gas pipeline project, which proposed to bring regional gas to mainland GR and IT via CY and Crete, completed a series of feasibility studies in 2018 and attracted support. In November 2021, GR and Egypt signed an MoU on energy cooperation that included a proposal to build a pipeline to bring regional gas to Europe via Egypt along an alternative, shorter, and more cost-effective sub-sea route. • **CCS:** Export hubs and CO_2 shipping routes are considered, with transport via sea emerging as a key transport modality. Greece's first carbon capture, utilization and storage (CCUS) project (Prinos CO2 Storage), is to be conducted by the National Natural Gas System (DESFA) and Energean, expects to conclude important regulatory and financial issues within 2024 and hopes to enter its first phase of					

[50] European Commission, 2022c (EU Strategies & Policies)

operations in 2025. In Italy, the Callisto (CArbon LIquefaction transportation and STOrage) Mediterranean CO_2 Network integrated CCS project jointly proposed by Eni and Snam with the collaboration of Air Liquide, which is also its coordinator and which is anchored on the Ravenna CCS CO_2 storage hub, has been selected by the European Commission to join the list of Projects of Common Interest (PCI). Callisto aims to develop a CCS value chain in southwestern Europe, focusing on the decarbonization of the Italian industrial areas, starting with those of Ravenna and Ferrara and the Fos-Marseille Hub in France. The project by leveraging the large total storage capacity of the Ravenna CCS hub, estimated at more than 500 million tons, aims to develop the largest network in the Mediterranean for CO_2 capture, transport, and storage by offering a decarbonization solution for Hard to Abate industries (such as cement plants, fertilizers, steel mills, etc.), acting as a reference for Southern Europe.

- **Decarbonisation of maritime transport:** With the growth of the O&G sector and the increased pollution risks it implies the Mediterranean Strategy for the prevention, preparedness, and response to marine pollution from ships (2022-2031) was developed. The Strategy starting on 1 May 2025 will become an Emission Control Area, where vessels will be required to burn marine fuel with sulphur content capped at 0.1pc, down from 0.5pc sulphur. There are some initiatives like POSEIDON MED that are focusing on LNG as a fuel in short-term, considering the heavy traffic in the region and the expansion of cruise ship tourism.

- **Adaptation**: The Mediterranean coastal blue carbon ecosystems (saltmarshes and seagrasses) represent important climate adaptation and mitigation opportunities. The inclusion of blue carbon programmes in climate change strategies of Mediterranean countries requires knowledge on the extent of the capacity and variability of these ecosystems, the development of policy instruments, such as carbon offsets frameworks, and the ability on how to best develop coastal environmental management frameworks at local and national scales. Projects like Life Blue Natura, POSBEMED2 or MPA-ADAPT Interreg Med projects focused on building coastal resilience through NbS. Regarding the coastal erosion and flooding challenges, the countries in the regions develop coastal adaptation plans and initiatives. For example, in MT a National Coastal Protection and Adaptation Strategy for the Maltese Islands (enhancing the archipelago's resilience to climate change consequences) was developed within the EU TSI of DG REFORM following the request of the Department for Public Works of the Ministry for Transport, Infrastructure and Public Works, and the Tourism Authority. Similar works took place in ES, including all the ES islands in the Mediterranean Sea.

- **Aquaculture:** Mediterranean marine fish aquaculture, specifically seabass and seabream, faces a challenge in terms of production as productivity is stagnating or growing at a sluggish pace. EU-funded projects like MedAID aim to assess technical, environmental, market, socio-economic and governance weaknesses in the industry, by exploring innovative solutions and providing comprehensive toolboxes, to enhance the sector's competitiveness and sustainability holistically. Collaboration between Mediterranean countries and northern European R&D institutions, takes place with a focus on innovative tools, integrated plans and improved governance, leading Mediterranean marine fish aquaculture into a transformative future. Innovative projects on value chains exist, like PerformFISH that integrate innovative approaches for competitive and sustainable performance across the value chain are ensuring the sustainable growth of the Mediterranean aquaculture industry. Interest has been given to examine opportunities for Multi-use activities between the aquaculture and renewable energies like the MEDAQUA project.

- **Desalination:** Innovative approaches of coupling desalination and water reuse are currently being tested to supply fresh water for drinking and irrigation for a large proportion of the population around the Mediterranean Sea. Suffering from a heightened vulnerability to climate change, the Mediterranean basin is projected to experience a significant decrease of freshwater supply and water stress over the next decades. The region's water demand is expected to double or triple by 2050 (UNEP, 2023). The European Mediterranean countries are well integrated in the desalination market, and they are also rapidly expanding their shares in the regional desalination market. Additionally, there are innovative European projects, like the EU-funded W2W – Water to Water project, that are promoting an innovative desalination system that uses renewable energy and provides clean water from seawater or salty groundwater. The bilateral cooperation between Mediterranean countries (i.e. GR) and EEA grants are focusing to improve the operational intelligence of seawater desalination industry, using a satellite-assisted forecasting service line for coastal waters. It also creates an operational decision support system for seawater desalination plants.

***Specific climate-smart future developments*:** floating offshore windfarms; coastal adaptation for securing tourism services; desalination on a bigger scale and innovative approaches of coupling desalinization and water reuse to supply freshwater for a large share of the population around the Mediterranean and irrigation

***Other relevant projects to planning*:** MEDTRENDS, MAREMED, COCONET, PERSEUS, PEGASO, MESMA, Coastal Area Management Programme – CAMP, COASTGAP, COASTANCE, Co-Evolve, PHAROS4MPAs, PANACEA, SUPREME, SHAPE, ADRIPLAN, THAL-CHOR 1 (ΘΑΛ-ΧΩΡ), Paving the Road to MSP in the Mediterranean: MSP MED – Greece, PLANCOAST, COEXIST, PORTODIMARE, MARISCA, PROTOMEDEA, DORY, Med-Iamer, AMPMED, SIMWESTMED, SwitchMed, THAL-CHOR 2, REGINA-MSP, MSP Green

3.4. Black Sea

The Member States from the Black Sea have adopted MSPs. The Common Maritime Agenda for the Black Sea and the Strategic Action Plan for the Environmental Protection and Rehabilitation of the Black Sea provide a framework for the sea basin. They prioritise the preservation of the ecosystem as a valuable natural legacy of the region with Long-term Ecosystem Quality Objectives (EcoQOs) and ensuring the protection of marine and coastal living resources for sustainable development of the Black Sea states, well-being, health and security of population. Specifically, synergetic objectives of EcoQOs include: preservation of commercial marine living resources (sustainable use of commercial fish stocks and other marine living resources; restore stocks of commercial marine living resources); and conservation of Black Sea Biodiversity and Habitats (reduce the risk of extinction of threatened species; conserve coastal and marine habitats and landscapes). Climate-smart emerging sectors and future developments in the Black Sea basin are summarised in Table 5.

Table 5. Black Sea Basin climate-smart emerging sectors and future developments

Black Sea basin *The sea basis is characterised by* the maritime activities: shipping, tourism, port activities, fishing, gas exploration *The key issues are*: preservation of ecosystem - conservation of biodiversity and habitats, protection of marine and coastal living resources, sustainable use of commercial fish stocks and other marine living resources	Offshore renewables	Offshore hydrogen	CCS	Adaptation	Desalinisation
Climate change considerations: mitigation & adaptation					
Current climate-smart actions (now to short-term)				v	
Future climate-smart actions (mid- to long-term)	v			v	
Strategy/Action plans: Common Maritime Agenda (CMA) for the Black Sea, Strategic Action Plan for the Environmental Protection and Rehabilitation of the Black Sea, Black Sea Strategic Research and Innovation Agenda, Convention on the Protection of the Black Sea Against Pollution (“Bucharest Convention”), EU Joint Operational Programme Black Sea Basin 2014-2020, Agreement on the Conservation of Cetaceans in the Black Sea Mediterranean Sea and Contiguous Atlantic Area, EU Black Sea Synergy					
Emerging climate-smart sectors and considerations: • **Aquaculture and renewable energy** (bottom-fixed and floating wind farms) are emerging sectors in the region, currently in early stages and are expected to develop pilot projects in the coming years. • **Offshore renewable energy:** offshore wind energy represents a good way of diversifying the energy sources that make up the national energy mix, thus ensuring the fulfilment of the objective of economic development, but, most importantly, that of consolidating the country's energy security. As assessed based on World Bank studies, RO’s offshore wind energy potential has a theoretical capacity of 76 GW, 22 GW in the form of fixed turbines and 54 GW in the form of floating turbines. From the point of view of the cost-benefit ratio, the first turbines to be installed are the fixed ones. • **Aquaculture:** Aquaculture is more developed in BG. There are some initiatives to develop mariculture in Romanian waters in the future, as well as similar initiatives, including legislative changes, to support multi-use approach aquaculture facilities and offshore wind farms in the Black Sea basin. • **Decarbonisation** of maritime transport by using green hydrogen for vessels is mentioned as a possible way for pollution reduction. • **EbA Adaptation** Extending the network of natural marine protected areas to at least 30% of the marine surface (both in the territorial waters area and in the EEZ); Identification and designation of protected natural areas with strict protection, of at least 10% of the marine surface; Effective management of natural					

marine protected areas by establishing conservation measures and developing management plans. The growth of future activities will be determined by the level of environmental degradation currently affecting the sea basin, and the wider geopolitical landscape shaped by the commercial and strategic importance of the Black Sea.

***Specific climate-smart future developments*:** Aquaculture and renewable energy are emerging sectors in the basin, currently in early stages and are expected to develop pilot projects in the coming years.

***Other relevant projects to planning*:** PlanCoast, PEGASO, COCONET, MARSPLAN-BS, MARSPLAN-BS-II, ECOAST (COFASP), MISIS, SymNet/CBC-Black Sea, ICZM/CBC-Black Sea, SRCSSMBSF, CREAM, MARSEA, ANEMONE, TEAM4SEAS, MSP Green, MSP4BIO, DOORS, JUST4MPA, ResPonse, DTE-Climate

4. EU MEMBER STATES CLIMATE-SMART ACTIONS

Over the last three years Member States across all EU sea basins have been incorporating the elements of the European Green Deal (EGD) into their MSPs, including climate change mitigation and adaptation, and aligning their plans to the ambition of the EGD. [(51)] At the sea-basin scale, countries jointly commit to deliver energy transition and the fight against climate change, for example through the Esbjerg, Oostend and Marienborg declarations, and they establish the frameworks for collaboration among countries to address the challenges of the impacts of climate change on the sea, coasts, and marine ecosystems, healthy biodiversity, and to ensure there is space for all uses and transitions in the sea basins.

This chapter presents an overview of **how all EU coastal Member States integrate climate-smart trends and actions into their plans**, with the evolution of climate-related considerations and emerging sectors. The primary source of information for the preparation of this synthesis were the national plans and strategies, i.e., the MSPs and other national plans relevant to emerging sectors / climate-smart actions in marine and coastal areas, available at the European MSP Platform [(52)] and national/regional sources.

The previous overviews, which covered a restricted number of countries, were also considered in the preparation of the current synthesis. These overviews include the eMSP NBSR policy brief on climate-smart MSP in the North and Baltic Sea Regions (2023),[(53)] the MSPGreen project deliverable "Green Deal Component of the EU MSP Plans" (2023),[(10)] and the Regina-MSP project results at the regional level (2024).[(54)]

In this study, climate-smart actions and values are mapped into the categories of climate change mitigation, climate change adaptation, ecosystems and society, considering actions now established in the plans (**current actions**), and also projections, i.e., actions that will be considered in the future by countries (**future actions**) and which are now included in the amendments / new plans. The EGD, approved in 2020 before the finalisation of the MSP cycle in 2021, might not have been integrated into many MSPs given that most MSs had already prepared their MSPs by that time. Thus, this synthesis provides information about the climate-smart actions that are being included by MSs for the future, e.g., in the amendments to MSPs that encompass the increased ORE and biodiversity targets, and which will be integrated into the next national MSP cycles.

Given the different nature of the plans in each country in Europe, the mapping of national efforts in climate-smart areas also distinguishes functions in terms of spatial provisions/designations and targets. The former refers to the allocation of space and specifying uses that contribute to climate-smart efforts as spatial designations in the plans. The latter refers to the delivery of strategic objectives and specifying targets that embrace climate-smart considerations. For example, regarding offshore

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[(51)] MSPGreen - Cornet, A., Arki, V., Bocci, M., Ramieri, E., & al., 2023 (Studies & articles)
[(52)] European MSP Platform, 2024a (Websites)
[(53)] eMSP-NBSR - Varjopuro, R., Rekola, A.and K. Gee, Policy Brief on Climate-smart MSP, 2023 (Studies & articles)
[(54)] Regina-MSP - Ramieri, E., Bocci, M. & al., 2024 (Studies & articles)

renewable energy production, some MSs specify spatial allocations for ORE without identifying production targets for these sites (e.g., FI, LV, ES), while other MSs include only ORE production targets with no spatial provisions (e.g., FR). Some plans include both targets and spatial allocation (e.g., DE). These specificities of plans are also mapped in the synthesis.

Climate-smart actions and values in the plans encompass in this review the following elements:

Mitigation - considers low-carbon pathways:

- Renewable energy transition
    - wind energy (fixed and floating offshore wind platforms)
    - alternative renewable energy (solar photovoltaic energy, wave and tidal energy)
    - offshore hydrogen generation and storage
    - prohibition of hydrocarbons' exploration/exploitation
- Decarbonisation of maritime sectors
    - decarbonisation of shipping
    - transformations in ports
    - carbon capture and storage
    - multi-use and co-existence

Adaptation - considers reducing vulnerability and enhancing resilience of maritime activities, and marine and coastal areas to climate-related risks:

- Climate risk assessments (incl. projections for slow onset and extreme events)
- Adaptation strategies with comprehensive disaster and climate risk management
- Adaptation measures, including emerging sectors for adaptation, such as:
    - resilient and adaptive/flexible measures
    - aggregate extraction
    - desalinisation
    - aquaculture
- Ecosystem-based Adaptation (nature-based solutions, nature-inclusive designs)

Ecosystems - consider enhancing the resilience of marine and coastal ecosystems to climate-related risks:

- Ensured effective protection (incl. coherent MPA networks)
- Ensured conservation and restoration
- Ensured protection of climate refugia areas

Society - considers enhancing coastal communities' socio-economic resilience to climate-related risks:

- Promoting climate literacy and strengthening understanding of the climate risks (for fostering societal support and understanding for climate solutions at sea) - endorsing understanding of impacts of, and vulnerability to, climate change, current and future climate variability and extreme events, and the implications for sustainable blue economy development; it includes multidisciplinary research on ocean-climate nexus
- Climate-smart technological innovations
- A just transition (reskilling, upskilling and new skills) to a sustainable blue economy - ensuring that the transition to a zero-emission maritime industry and the development of sustainable blue economy is safe and just (reskilling, upskilling and new skills in maritime sectors)
- Environmental justice (public-private and cross-sectoral) - ensuring the fair treatment and meaningful involvement of all people with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies, including providing new prospects and creating jobs

In addition to MSPs, the efforts of countries' work in the climate-smart MSP areas, which are not included in MSPs yet were mapped, e.g., on enhancing resilience to coastal flooding and erosion due to climate change. These are the climate change adaptation actions, which might not be incorporated in the MSPs yet as these works were finalised after the previous MSP cycle, but they are relevant to this synthesis as it addresses the climate adaptation and resilience building of coastal areas.

The MSP status in the EU's Member States with the climate-smart features in MSP is presented in Table 6. Detailed mapping of climate-smart considerations in the Member States' plans, including MSPs and other plans, is presented in Table 7.

The sections after the tables offer insights gained from Table 6 and 7 (as well as Tables 1-5), i.e., plans adopted by Member States drawn from the national sources, comprising the MSPs as well as coastal adaptation plans/strategies (if available) and the National Energy and Climate Plans (NECPs). NECPs leading to new offshore renewables strategies were relevant in this review particularly for countries without adopted MSP.

Table 6. MSP status in the EU Member States – current status and next steps regarding climate-smart actions. The table has been elaborated by the European MSP Platform

	Current MSP status and examples (E.g.) of climate-smart features in MSP	Next steps regarding climate-smart actions
BE	2019: Belgium Maritime Spatial Plan for the Belgium Part of the North Sea: Revision started in 2023 and MSP is in public consultation 2023-2024. Study on additional zones for ORE. E.g.: ORE, CCS development	Progress on the revised MSP. Public and international consultation to take place before the election in June 2024
BG	2023: Marine Spatial Plan of the Republic of Bulgaria (developed under the MARSPLAN projects): Revision process started end 2023, E.g. Preservation of ecosystems and food, Blue carbon	In 2024, the results and conclusions for the areas of revision change and scope and activities for the update
HR	NO MSP: Croatia MSP legislative framework entered into force in July 2023. Ongoing SEA process.	MSP to be adopted
CY	2023: Cyprus Maritime Spatial Plan: E.g. Conservation areas, desalinization	
DK	2021: Maritime Spatial Plan of Denmark (legally binding map): Revision of MSP for raising the offshore renewable energy and biodiversity targets, with the consultation on the draft amendment on executive order on Denmark's MSP and the environmental assessment. E.g. ORE, energy islands, CCS	Integration of the public and transboundary consultations responses. The agreement will be an amendment to the current Danish MSP, allowing for allocation of more areas to ORE and biodiversity
EE	2022: Estonian Maritime Spatial Planning: Monitoring phase. E.g. Renewable energy targets	Implementation of offshore wind park development projects; MSP revision planned for 2027
FI	2020: Finnish maritime spatial plan: The revision was launched in 2024; E.g. Climate refugia	Studies on offshore wind energy and stakeholder involvement process; work on update of coastal zone strategy
FR	2022: French National Strategy for the Sea and Coast + Documents strategiques de façades: Endorsement of the new national strategy (decree in March/April 2024). Ongoing revision with public consultation with a focus on OWF E.g. OWF. Vocational charts for future OWF settlement (fixed and floating) and on some areas use of current OWF	On the basis of the consultation which includes proposed maps, edition of new MSP for each maritime “façades” with higher ambition for OWF production on each of them
DE	2021: German Maritime Spatial Plan of the North Sea and the Baltic Sea + 3 plans for the coastal federal States: Initiation of the Offshore Site investigations for wind turbines for tendering in 2026 and 2027 for the German EEZ of the North Sea. E.g. ORE, nature conservation and restoration	Revision of the preliminary draft of site development plan to be published and consulted internationally in 2024.
GR	NO MSP: Submission of a proposal for the Strategic Environmental Assessment (SEA) for the maritime spatial unit where the pilot study has been carried out (North Aegean), and for the elaboration of the Maritime Spatial Planning Frameworks (MSPFs), for the rest of maritime spatial units in Greece	Ministerial Decision for the technical specifications for the MSPFs to be issued in 2024. MSP expected within 3 years
IE	2021: Irish Marine Planning Policy Statement: Implementation of MSP within national thematic/sectoral strategy E.g. protection (MPA), ORE	National Industrial Strategy for Offshore Wind to be published in 2024
IT	NO MSP: Received the assessment comments for their submitted Technical Committee Assessment (need for 3-4 months to revise the proposed plans according to the received comments)	Address the received comments and amend the plans

LV	2019: Maritime Spatial Plan for Internal Waters, Territorial Waters and Exclusive Economic Zone of the Republic of Latvia. Interim evaluation report published end 2023. E.g. GHG emissions, Renewable energy, Coastal erosion	Integration of the coastal zone thematic in the next MSP (after 2025)
LT	2021: Lithuania Comprehensive Plan. Publication of the Implementation action plan. E.g. Renewable energy, Coastal erosion	Offshore wind farm tenders, implementation of the action plan. Revision of the MSP planned in 2030
MT	2015: Malta Strategic Plan for Environment and Development; Ongoing revision of the MSP. Economic scenarios analysis delivered	A background paper to analyse how Ecosystem-based assessment is included in the MSP and how it could be further included in future revision of MSP
NL	2022: The Netherlands North Sea Programme 2022-2027 (Annex to the National Water Programme): In 2023 started the Partial Revision and the Strategic Environmental Assessment of the North Sea Programme 2022-2027, including revision of MSP for raising the offshore renewable energy targets (50 GW by 2040). Transboundary consultation in the scoping process for SEA for the Partial Revision of the Dutch North Sea Programme. Preparation of the North Sea Energy Infrastructure Plan (EIPN). E.g. Offshore renewables, nature conservation, nature-based adaptation	The Partial Revision of the North Sea Programme 2022-2027 is expected to be finalized in September 2025, including revision of MSP for raising the ORE targets (50 GW by 2040)
PL	2021: Maritime spatial plan for the internal marine waters, the territorial sea and the exclusive economic zone on a scale of 1: 200,000. At that time MSPs for Szczeciński Lagoon, Kamieński Lagoon, Vistula Lagoon and for port areas waters (4 plans) were still under adoption. Ongoing process on the adoption of several MSPs for small ports and bays. E.g. GHG emissions, Renewable energy, Resistance to climate change	Licensing and auctions of offshore wind park areas
PT	2019: Portugal Plano de Situacão do Ordenamento do Espaço Maritimo Nacional (PSOEM) - The National Ocean Strategy 2021-2030 was approved in 2021. As part of the PSOEM, the ORE Allocation Plan (PAER) – West Coast of the Continent subdivision in Portugal, refers to the definition of areas for the exploration of ORE for commercial purposes. PAER constitutes an important contribution to the country's ability to achieve the goals established in the Roadmap for Carbon Neutrality 2050 (RNC 2050). One of newly published reports is on the implementation and development of ORE (2023). Report's findings will feed the new development of MSP Plans. E.g. the Allocation Plan for ORE	The public consultation phase on the allocation plan for offshore renewable energies ended. The ambition of achieving an installed offshore wind energy capacity of 10 GW by 2030 in the national maritime space of the Mainland subdivision
RO	2023: Romania Maritime Spatial Plan (developed under the MARSPLAN projects); Approval of the Offshore Energy Law in December 2023. E.g. ORE	Start of a study to prepare procedures for concession, exploitation activities, turbines construction and to determine the suitable perimeters for concession
SI	2021: Slovenia Pomorski prostorski plan Slovenije	
ES	2023: Spain Planes de Ordenación del Espacio Marítimo (POEM): Ongoing revision of the MSP. Currently working on developing the contracts to fulfil the measures stated under 2.3 (Medida OEM1 – OEM9). E.g. ORE, Hydrocarbons exploitation and exploration prohibition, MPAs, 'blue corridors' – Marine Green Infrastructure	Once the OEMs results are obtained + results from the EU projects, that the revision of the MSP Plans will be done MPA (current and future) are considered under the MSP and will be reviewed for the next MSP phase
SE	2022: Sweden Maritime Spatial Plan: Ongoing revision (focus on offshore wind energy development and nature areas) - proposal to be submitted to the government by December 2024. Espoo transboundary consultation process in 2024. E.g. Acidification, Climate refugia, multi-use	Bilateral meetings (Finland, Demark, potentially also Poland) about the revisions and impact assessment; Licencing, permitting process ongoing

More information about the national MSPs can be found at the European MSP Platform country pages: **https://maritime-spatial-planning.ec.europa.eu/msp-practice/countries.**

Table 7. Scan of climate-smart considerations in the Member States' plans. *Legend*: Plans with spatial allocation (in blue), with targets (in yellow), with both spatial allocation and targets (in green); Actions currently considered in plans (C), to be considered in the future (part of the revised but not yet published plan) (F); Information not available (N/A); Item not included in the national plans (N/I). The grey columns correspond to MSs without published MSP. The table has been elaborated by the European MSP Platform

	Belgium	Bulgaria	Croatia	Cyprus	Denmark	Estonia	Finland	France	Germany	Greece	Italy[55]	Ireland	Latvia	Lithuania	Malta	Nether-	Poland	Portugal	Romania	Slovenia	Spain	Sweden
	BE	BG	HR	CY	DK	EE	FI	FR	DE	GR	IT	IE	LV	LT	MT	NL	PL	PT	RO	SI	ES	SE
1. Mitigation (Low-carbon pathways)																						
1.1. Renewable energy transition																						
1.1.1. wind energy (fixed and floating offshore wind platforms)	C+F	C+F[56]		F	C+F	C+F	C+F	C+F[57]	C+F		C+F	C+F	C+F	C+F	F	C+F	C+F	C	C+F	N/I[58]	C+F	C+F
1.1.2. alternative renewable energy (solar photovoltaic energy, wave and tidal energy)	C+F	C+F[59]		N/A	C	C	N/A	C+F	N/A		C+F	N/A	N/A	N/A	F	C+F	C	N/A	F	N/I	C+F	C
1.1.3. offshore hydrogen generation and storage	N/A	N/A		N/A	N/A	F	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A	C+F	N/A	N/A	N/A	N/I	N/I	F
1.1.4. prohibition of hydrocarbons' exploration/exploitation	N/A	N/A		N/A	N/I	N/A	N/A	C	N/I		N/A	F	N/I	N/I	N/A	N/A	N/I	N/A	N/A	N/A	C	C
1.2. Decarbonization of maritime sectors																						

(55) The Italian MSP Plan has not been published yet but was analysed in MSP-GREEN - Cornet, A., Arki, V., Bocci, M., Ramieri, E., & al., 2023 (Studies & articles).

(56) MSP-GREEN - Cornet, A., Arki, V., Bocci, M., Ramieri, E., & al., 2023 (Studies & articles): "Bulgarian plan points to the potential for developing renewable energy production, including offshore wind energy, but does not formulate an explicit quantitative objective or zones allocated for offshore renewable energy development." – thus, no color in the cell.

(57) Ongoing spatial local allocation as was not meant to be so far in MSPs ("vocation zone") - recent legislative update – the updates of MSP will allocate dedicated areas on each "façade"

(58) Not considered due to limited spatial possibilities (unfeasible)

(59) Idem.

	BE	BG	HR	CY	DK	EE	FI	FR	DE	GR	IT	IE	LV	LT	MT	NL	PL	PT	RO	SI	ES	SE
1.2.1. decarbonization of shipping	N/A	N/A		C+F	N/A	N/A	F	C	N/A		C+F	C	C	N/A	C+F	C+F	N/A	N/I [60]	F	N/A	C+F	C
1.2.2. transformations in ports	N/A	F		C+F	N/A	N/A	F	C	N/A		C+F	C	N/I	N/I	C+F	C+F	N/I	N/I	F	N/A	C+F	N/I
1.3. Carbon capture and storage	C	F		N/A	C	N/A	F	N/A	/[61]		N/A	C	N/A	C+F	N/A	C+F	C[62]	N/A	N/A	N/A	N/I	C+F
1.4. Multi-use and co-existence	F	C		C	C	C	F	C[63]	C		C+F	C[64]	C	N/A	N/A	C+F	N/A	F[65]	F	C+F[66]	C+F	C
2. Adaptation (Enhancing resilience of maritime activities and coastal areas to climate-related risks)																						
2.1. Climate risk assessments (incl. projections for slow onset and extreme events)	N/A	N/A		N/A	F	C	C+F	C+F	F		C+F	N/A	C+F	N/A	C	F	C+F	C	N/A	N/A	C	C+F
2.2. Adaptation strategies with comprehensive disaster and climate risk management	N/A	C		C	N/A	N/A	C+F	C+F	C+F		N/A	C	N/A	C	C+F[67]	C+F	N/A	C	C+F	N/A	C	C
2.3. Adaptation measures, including emerging sectors for adaptation such as:																						

(60) MSP encompasses only the activities that require the reservation of an area of volume for the use of the marine environment, resources or ecosystems services (no fishing or shipping)
(61) Illegal in Germany
(62) Underground storage of carbon dioxide may be carried out in basins with the basic function of reserve for future development with extraction allowed on the basis of separate provisions
(63) Within vocational maps and in accordance with activity compatibility.
(64) Co-existence only
(65) Through pilot plans
(66) Due to limited spatial possibilities and the presence of various interests, important national will to ensure conditions for a long-term coexistence of all activities
(67) Ongoing (cf. TSI projects)

2.3.1. resilient and adaptive/flexible measures	C+F	N/A		C[68]	N/A	C	F	C+F	N/A		N/A	C	C[69]	C[70]	C+F	C+F	C[71]	C	N/A	N/A	C+F	C
2.3.2. aggregate extraction	C	N/A		N/A	C[72]	N/A	N/A	/[73]	N/A		N/A	/	N/A	C	N/A	C+F	C	N/A	N/A	N/A	C[74]	C
2.3.3. desalinization	N/A	N/A		C	N/A	N/A	N/A	N/A	N/A		C+F	C[75]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C	N/A
2.3.4. aquaculture	C	C		C	C	C	N/A	C	C		C+F	C[76]	C	C	C	C	C	C	F[77]	C+F[78]	C+F	C
2.4. Ecosystem-based Adaptation (incl. nature-based solutions and nature-inclusive designs)	F	N/A		C+F	F	N/A	C+F	F	C		C+F	N/A	C	C	C+F	C+F	C	N/A	F	N/A	C+F	C

(68) coastal zone adaptation to Climate Change management project 2009-2012
(69) coastal protection approach
(70) coastal protection approach
(71) coastal protection approach
(72) mainly in the energy field
(73) only for construction purposes
(74) only allowed for beach nourishment purposes
(75) Republica Portugesa,2021: SG5
(76) Republica Portugesa,2021: PIA5 (focus on locally sourced production)
(77) "incoherent and unreasonably restrictive legislation constrains development of the aquaculture sector" (European Commission, European Climate, Infrastructure and Environment Executive Agency – Riclet, E., Huntington, T., Herpers, F., 2023)
(78) Republic of Slovenia – Ministry of Economic Development and Technology, 2017: eco-tourism development

	BE	BG	HR	CY	DK	EE	FI	FR	DE	GR	IT	IE	LV	LT	MT	NL	PL	PT	RO	SI	ES	SE
3. Ecosystems (Enhancing resilience of marine and coastal ecosystems to climate-related risks)																						
3.1. Ensured effective protection (incl. coherent MPA networks)	C	C		C	C	N/A	C	C+F	C+F		C+F	C+F[79]	C+F	C	C	C+F	F	N/A	C+F	N/A	C+F	C+F
3.2. Ensured conservation and restoration	C	N/A		C	C+	C	C+	C+	C+		C+	C+	C+	C	C	C+	C	C	N/A	C	C	C+
3.3. Ensured protection of climate refugia areas	N/A	N/A		N/A	N/A	N/A	F	N/A	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C	F
4. Society (Enhancing coastal communities socio-economic resilience to climate-related risks)																						
4.1. Promoting climate literacy and strengthening understanding of the climate risks (for fostering societal support and understanding for climate solutions at sea)	N/A	N/A		C[80]	N/A	N/A	N/A	C+F	F		F	C	F	C	C+F	C+F	C	C	N/A	N/I[81]	C	C+F
4.2. Climate-smart technological innovations	C	N/A		C[82]	C+F	N/A	F	F[83]	C+F		N/A	C	F	N/A	N/A	C+F	N/A	C[84]	N/A	C[85]	C+F[86]	C+F
4.3. A just transition (reskilling, upskilling and new skills) to a sustainable blue economy	C	C+F		N/A	C	N/A	C+F	C+F	C+F		C+F	C	N/A	N/A	C	C+F	N/A	N/A	F	C+F	C	N/A

(79) Republica Portugesa, 2021: PIA3
(80) specific studies during the MSP's drafting to collect data and close some data gaps (e.g. for offshore wind and wave potential and hydrography)
(81) insufficient research (e.g. on underwater cultural heritage, cf. European Commission, European Climate, Infrastructure and Environment Executive Agency – Kyvelou, S. & Henocque, Y., 2022)
(82) development of a web-GIS service to map relevant maritime uses
(83) especially linked to ORE, objectives depend on facades
(84) geoportal developed
(85) only data sharing tools
(86) geoportal and GIS developed

4.4. Environmental justice (public-private and cross-sectoral)	N/A	C[87]		C	C	C	N/A	C+F	N/A		N/A	C	N/A	N/A	N/A	C+F	N/A	N/A	C[4]	N/A	N/A	N/A

(87) not all stakeholders were involved in the creation process
(88) difficulty faced by some stakeholders in conceptualizing planning at a façade scale

As shown in Table 7, Member States have integrated climate-smart trends and new technologies into their latest plans, addressing both climate mitigation and adaptation actions. In planning, currently, these climate actions are predominantly referred to separately with the dominance of mitigation in MSPs. In particular, the development of offshore renewables steers spatial planning and is a key driver for revisions of MSPs in response to the EGD's Strategy on Offshore Renewable Energy and the Strategy on Hydrogen. Examples include the revision of MSP in DK to increase offshore renewable energy with an allocated 30% area coverage of zones for ORE and energy islands, and an ongoing partial revision of the North Sea Programme 2022-2027 in NL, including revision of MSP to increase ORE targets to reach up to 50 GW by 2040 in the Dutch waters.

Co-benefits of climate change mitigation and adaptation actions, in a broader context, for low-emission economy and climate resilient development, are mentioned in plans, while climate-smart synergies are being sought across several maritime sectors, including offshore energy, infrastructure development, ecosystems and food systems. Provisions for the protection of the marine environment are increasing in plans in response to the EGD's Strategy for Biodiversity 2030 targets, with allocated NbS to address hazards, mitigate and adapt to climate change while enhancing marine/coastal biodiversity, following the Green Infrastructure Strategy and the Strategy on Adaptation to Climate Change. For example, MSP in ES considers resilience of marine ecosystems through the Marine Green Infrastructure.

The sections below provide further insights gained from national plans, comprising the MSPs as well as other plans/strategies (if relevant to MSP), as summarized in Tables 1-7.

Mitigation

Climate change mitigation actions are included in the MSPs in all sea basins with the objective to reduce or capture greenhouse gasses. All Member States (except SI) have included approaches in their MSPs that integrate climate change mitigation into planning. The most direct contributions of all MSPs is the allocation of the production of offshore renewable energy.

Offshore wind farms: The main effort has been dedicated to developing offshore wind production for the EU target of 111 GW of offshore wind by 2030, and 340 GW by 2050. Nearly all countries have designated offshore wind farms (OWF) in their MSPs as space allocation and/or production targets. The North Sea countries have included both space allocation and production targets in their MSPs, while ES and some countries from the Baltic Sea (e.g., FI, LV) included only OWF spatial provisions, and others provided only production targets (e.g., FR, IE). Though BG provides neither space nor production targets, its MSP mentions the OWF potential in the future.

The space allocation for OWF in the MSPs of the countries in the North Sea and the Baltic Sea is around 38,184 km^2, that includes 23,587 km^2 and 14,597 km^2, respectively (Table 8). The current space occupied by OWF installations in these sea basins is 2,027 km^2, that includes 1,531 km^2 in the North Sea and 497 km^2 in the

Baltic Sea. That means, according to OWF provisions in the current MSPs, in the North Sea the OWF space will increase 15 times, while in the Baltic Sea it will rise 29 times.

The current MSP designations for OWF in the North Sea and Baltic Sea provide the required space for countries' 2030 pledges from the Esbjerg and Oostend Declarations (76-120 GW) in the North Sea (except BE), and from the Marienborg Declaration (19.6 GW) in the Baltic Sea. For 2040 commitments from the Dublin Joint Declaration (193 GW), the currently allocated space in MSPs of BE, DE and NL will not be sufficient (**Error! Reference source not found.**Table 9). The MSP revisions will allow for the increase in spatial provisions for OWF, however, more considerations will require attention, such as congested space and wake losses.

Table 8. Offshore Wind Farms Planning in the EU Member States in terms of production, space and power density: A) current status of operational OWFs (based on information from the EMODnet Human Activities Energy - Wind Farms, and Wind Europe); B) national MSP allocations (based on information from the EMODnet Human Activities MSP and national MSPs); C) projections for 2030, 2040 and 2050 for production (based on national commitments in regional ORE declarations, such as Esbjerg, Oostend and Marienborg, and/or non-binding agreements per Member State/sea basin). The table has been elaborated by the European MSP Platform

	A) Operational OWFs				B) MSP	C) OWF projections							
Country	Capacity (GW) - Wind Europe	Capacity (GW) - EMODnet Wind Farms	Area (km^2) - EMODnet Wind Farms	Power Density (MW/km^2) - calculated average	**Space for OWF (km^2) - EMODnet MSP / MSPs**	Capacity 2030 (GW) - national pledges	Capacity 2030 (GW) - non-binding	Area for OWF 2030 (km^2) - extrapolated	Power Density 2030 (MW/km^2) - extrapolated	Capacity 2040 (GW) - national pledges	Capacity 2040 (GW) - non-binding	Capacity 2050 (GW) - national pledges	Capacity 2050 (GW) - non-binding
BE	2.26	2.26	238	9	510[89]	6	6	632	9	8	8	8	8
DE	8.1 (tot)[90]	6.73	745	9	5100	30	26.4	3321	8	50-75[91]	60	75	66
DK	2.3 (tot)[90]	0.78	141	5	13508[92]	12.8	5.3	2331	2	19	19	35	35
NL	3.45	3.51	406	9	4469	21	16-21	2427	7	30-50	30-50	70	38-72
North Sea:		***13.28***	***1531***	***8***	***23587***	***76-120***	*53.7*	***8711***	***7***	***193***	*135-158*	***260-300[93]***	*171-218*
DE	8.1 (tot)[90]	1.08	106	10	334	3.8	4.1	373	11	4.1		4.1	
DK	2.3 (tot)[90]	1.98	390	5	2286	6.3	7.9	1240	6	N/A		N/A	
EE	0	0	0		1781	1	1			3.5	3.5	N/A	
FI	0.07	0	0		4070	0.7	1			5	5	12	12
LT	0	0	0		N/A	1.4	1.4			0.4	2.8	0.4	4.5
LV	0	0	0		1649[94]	0.4	0.4			2.8	0.4	4.5	
PL	0	0	0		2311	5.9	5.9			11	10.9	N/A	
SE	0.19	0	0		2166	0.7	0.7			N/A		N/A	

(89) Based on the Belgium MSP. The Belgium MSP (2020-2026) designated the area of 225 km² of the eastern wind farm zone and an additional area of 285 km² (the Princess Elisabeth Zone) that is reserved for the development of OWF in three zones: Noordhinder North (Zone 2), Noordhinder South (Zone 3) and Fairybank (Zone 4)

(90) Total capacity for the North Sea and Baltic Sea

(91) DE has a target of 75 GW in 2045

(92) In DK two large areas are allocated for OWF (MSPDK16 of 10079.28 km^2 in the North Sea and MSPDK17 of 5713.91 km^2 between the North Sea and Baltic Sea basins) - the EMODnet Human Activities MSP

(93) The Esbjerg and Oostend declarations pledge 260 GW and 300 GW, respectively, by 2050 for the North Sea states, including non-EU members. The North Sea Member States are currently working on revisions of MSPs to increase their OWF targets and align with the ambitions in the energy declarations. Current MSP targets for 2030: BE: 5.8 GW; DE: 30 GW; DK: 12.8; NL: 21 GW

(94) Based on the Latvian MSP that has allocated 5 research areas for OWF development with a total area 1648,76 km2, which is 5,82% of total MSP areas

Baltic Sea:		***3.06***	***497***	***8***	***14597***	***19.6***[95]	*22.5*	***2762***	***9***	*N/A*	***34.6***	*N/A*	***46.8***
ES	0.005	0	0		3250[96]	1-3	0.5-1.6			N/A		N/A	
FR	0.48	0	0		N/A	1.7	1.7			5.2-7.5	4.2-7.5	36-51[97]	4-16
IE	0.025	0.025	3.49	7	N/A	7	0.5-1	977		20	7	37	15
PT	0.025	0.025	52.03	0.5	N/A	10	10	20812		10	10	10	10
Atlantic:	***0.53***	***0.05***	***55.5***	***4***		***12-14***	*12.7-14.3*			***21-26***	*22-26*	***29-43***	*30-43*
CR	0	0	0		NO MSP		0.51				1.2		3
CY	0	0	0		67		0.1				0.1		0.1
ES	0	0	0		1698[96]		0.5-1.5						
FR	0	0	0		N/A		0.6				1.6-6.5	4-7.5[98]	1.6-14
IT	0.03	0	0		NO MSP		4.5				4.5		4.5
GR	0	0	0		NO MSP		2.7				10		17.3
MT	0	0	0		N/A		0.05				0.4		0.4
SL	0	0	0		N/A		0				0		0
Mediterranean:							***8.5***				***24-57***		***24-57***
BG	0	0	0		N/A		0				0		0
RO	0	0	0		N/A		1				1		1
Black Sea:		***0***	***0***				***1***				***1***		***1***

The table has been elaborated by the European MSP Platform based on various national and sea-basin overviews, including: Wind Europe;[99] EMODnet Human Activities [100] Energy and Maritime Spatial Planning themes; national MSPs collected at the European MSP Platform country pages;[101] Esbjerg Declaration (2022),[102] Oostend Declaration (2023),[103] Marienborg Declaration (2022);[104] non-binding agreements per sea basin;[105] North Sea Energy Cooperation (NSEC) study "Spatial study North Seas 2030:

(95) The Baltic Sea states committed in the Marienborg Declaration to increase the OWF capacity to 19.6 GW (The Baltic Sea Energy Security Summit, 2022 – Strategies & Regulations)

(96) "Zonas de alto potencial para el desarrollo de la energía eólica marina " based on Royal Decree 150/2023, of February 28, which approves the maritime space management plans of the five Spanish marine demarcations: (Spanish Ministry for Ecological Transition and the Demographic Challenge – MITECO, 2023 - Strategies & Regulations)

(97) Target for 2050 in the 3 French facades (except the Mediterranean) (French Ministry for Ecological Transition and Terriorial Cohesion, 2024 – Websites)

(98) Target for 2050 in the French Mediterranean façade (French Ministry for Ecological Transition and Territorial Cohesion, 2024 – Websites)

(99) Wind Europe, 2024 (Websites)

(100) European Marine Observation and Data Network – EMODnet, 2024 (Websites)

(101) European MSP Platform, 2024b (Websites)

(102) NSEC, 2022a (EU Strategies & Policies)

(103) NSEC, 2023 (EU Strategies & Policies)

(104) The Baltic Sea Energy Security Summit, 2022 (EU Strategies & Policies)

(105) European Commission Directorate General for Energy, 2023 (Websites)

Offshore wind development 2030 North Seas” [106] (2022); EC study on the offshore energy potential in the Atlantic Ocean (2023);[107] national energy overviews. The detailed OWF industrial projects can be found per country on TGS website.[108] Extrapolated values in the table for space and power density for 2030 and 2040 assume the technological development of OWF as of today.

Table 9. Offshore Wind Farms production and required sea space until 2050 in the North Sea basin for Belgium, Germany, Denmark and the Netherlands

	A) Operational OWFs			B) MSP	C) OWF projections								
Country	Capacity (GW) - EMODnet Wind Farms	Area (km²) - EMODnet Wind Farms	Power Density (MW/km²) - calculated average	**Space for OWF (km²) - EMODnet MSP / MSP**	Capacity 2030 (GW) - national pledges	Area for OWF 2030 (km²) - extrapolated	Power Density 2030 (MW/km²) - extrapolated	Capacity 2040 (GW) - national pledges	Area for OWF 2040 (km²) – extrapolated	Power Density 2040 (MW/km²) - extrapolated	Capacity 2050 (GW) - national pledges	Area for OWF 2050 (km²) – extrapolated	Power Density 2050 (MW/km²) - extrapolated
BE	2.26	238	9	510	6	632	9	8	842	9.5	8	842	9.5
DE	6.73	745	9	5100	30	3321	8	50-75	5535-8302	9	75	8302	8
DK	0.78	141	5	13508	12.8	2331	2	19	3515	5.5	35	6374	5.5
NL	3.51	406	9	4469	21	2427	7	30-50	3468-5779	8.7	70	8091	8.9
	13.28	***1531***	***8***	***23587***	***76-120***	***8711***	***7***	***193***	***13359-18438***	***8***	***260-300***	***23609***	***8***

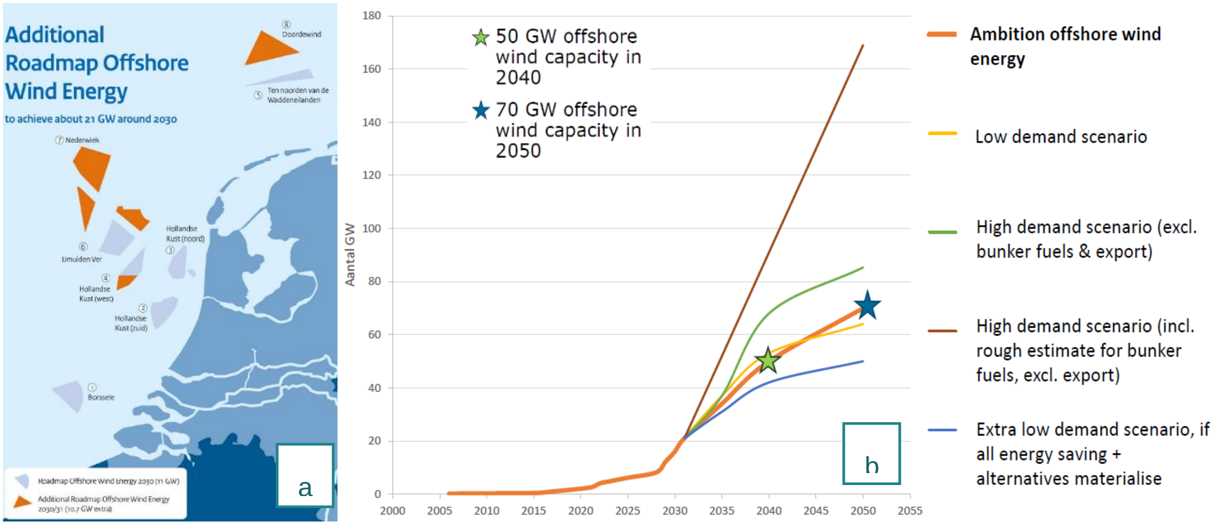
The table has been elaborated by the European MSP Platform based on sources as indicated above.

(106) DNV, 2022 (Studies & articles)
(107) European Commission Directorate General for Maritime Affairs and Fisheries, 2023b (Studies & articles)
(108) TGS, 2024 (Websites)

Table 9 with estimates for the North Sea shows calculated (for current capacity) and extrapolated (for projections) values for the current state of technology. Today the power density is in the range of 5 to 9 MW/km^2, and approximate density projections are around 7-8 MW/km^2. That means, from the spatial perspective, that with the allocated areas in MSP increased capacity could be achieved with extra OWF, without considering the wake effect. The estimates indicate that current total MSP designations for OWF of 23,587 km^2 could be sufficient up to 2050 (23,609 km^2), and that is largely due to the large space provisions for OWF in DK. The other North Sea countries are densely planned – while DE and NL will require additional space from around 2040 (with new areas in NL possible), in BE it will be around 2030. It can also be expected that future OWF technology trends, such as taller wind turbines and reduced wake losses, could increase the capacity factor of OWF.

The current MSP revisions concern increasing OWF production targets and the OWF-related studies (e.g., DK, NL, BE). In NL, additional areas were designated in 2022 to match the ambition for wind energy (from 11 GW to 21 GW until 2031) in the North Sea Programme 2022-2027 (Figure 5 (a)). The ongoing Partial Revision of the North Sea Programme 2022-2027 is required to designate additional space for at least 23-26 GW of additional OWF after 2031 to continue the development of OWF towards a target of 50 GW offshore wind capacity in 2040. NL is preparing different scenarios of increased energy demand and set (Figure 5 (b)). To match the NL target of 50 GW, the designation of new MSP areas is undertaken in the partial revision of the North Sea Programme due to long lead time for energy infrastructure. Additional space for the 2050 ambition (70 GW) will be developed at a later stage in the new North Sea Programme (2028-2033). In view of OWF expansion and the need for more robust, reliable and efficient energy systems, NL is currently preparing the North Sea Energy Infrastructure Plan (EIPN) that provides a strategic plan for development of the infrastructure required for OWF in the 2030 to 2050 period and how this will be integrated into the existing energy system. The EIPN plan will be published in 2025.

Figure 5 – Offshore wind energy ambition production and demand in the Netherlands: a) added areas in 2022 (in orange); b) OWF ambition and different scenarios depending on developments and (policy) decisions on export, bunker fuels, H2 storage and alternatives for sustainable energy production

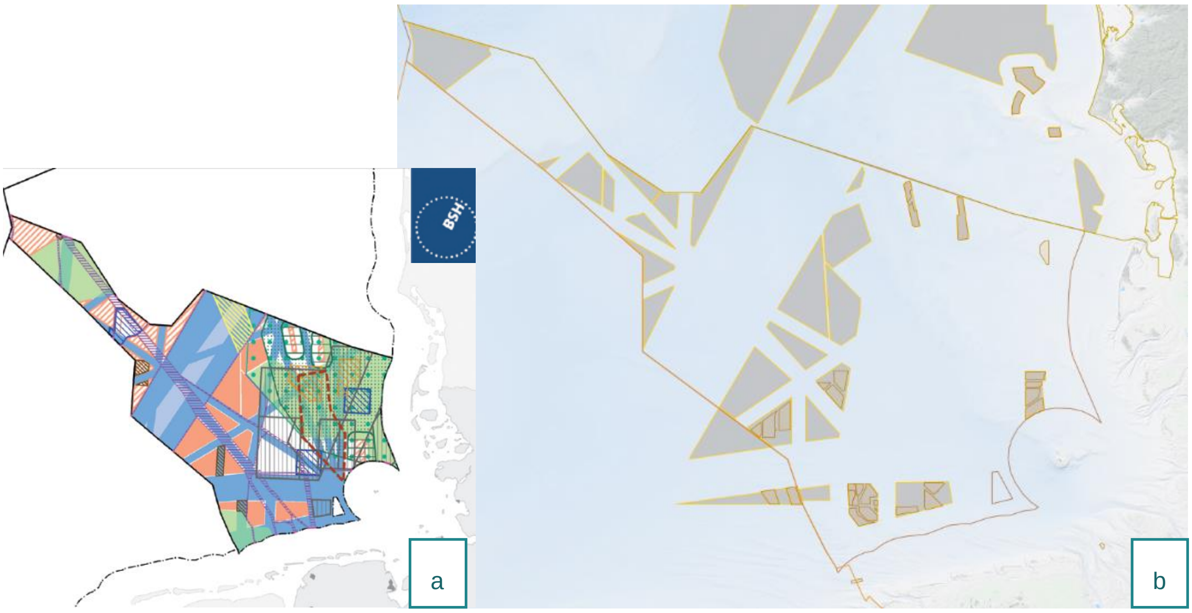


Source: The Ministry of Infrastructure and Water Management, webinar 'Procedure and background of the Partial Revision and the Strategic Environmental Assessment of the North Sea Programme 2022-2027'; 17 January 2024)

MSP in DE specifies the priority areas, reservation areas, conditional priority areas and conditional reservation areas for OWF, in the allocated space of about 5,100 km^2 in the EEZ in the North Sea and 334 km^2 in the Baltic Sea (Table 8 based on EMODnet Human Activities MSP). These spatial provisions are sevenfold the current OWF space in the North Sea, i.e., 745 km^2 for a capacity of 6.7 GW (Figure 6), and threefold the current OWF space in the Baltic Sea, i.e., 106 km^2 for the production of 1.1 GW. The space requirements for the 2030 projected capacity of 30 GW in the North Sea and 3.8 GW in the Baltic Sea will increase to about 3,321 km^2 and 373 km^2, respectively, which can be accommodated within the current MSP spatial provisions, particularly in the North Sea. Bringing total capacity to 70 GW by 2045 (more than double the capacity from 2030) will require additional space for OWF to what is currently provided in MSP. It is estimated that in 2040 OWF in DE will need approximately 5,500 km^2 in the North Sea and 400 km^2 in the Baltic Sea, with the current state of OWF technology.

Providing more space for OWF in DE in the future might, however, present a challenge given how busy their marine space is with activities in the current MSP (Figure 6 (a)). Another challenge will lie in wake losses of energy generation capacity of the downstream turbines (i.e., the wind speed is reduced) that can significantly impact energy production. The German MSP Authority (BSH - Federal Maritime and Hydrographic Agency) carried out a study on estimation of long-term offshore wind energy yield in the German EEZ that analyses the impact of capacity density and turbine technology on energy yield through use of modelling methods to show future wake losses (to be published in 2024).

Figure 6 – a) German MSP from 2021 for the EEZ in the North Sea with designated multiple activities - priority areas for shipping are indicated in blue; b) Offshore wind farms allocations in German MSP for the EEZ in the North Sea (polygons in grey) against the current OWF areas (contours in orange)



Source: a) German Federal Maritime and Hydrographic Agency - BSH; b) EMODnet Human Activities MSP and Wind Farms layers

The Baltic Sea and Atlantic states committed to increase OWF capacity to 19.6 GW (Marienborg Declaration) and 12-14 GW by 2030 (non-binding agreement TEN-E regulation), respectively. Non-binding agreements pledge to build 47 GW of offshore wind in the Baltic Sea by 2030 and 30-43 GW in Atlantic states by 2050. The countries from these sea basins are in the phase of inclusion of targets in their MSPs and developments are expected later as provisions (e.g., IE, FI) or they have chosen a spatial approach by allocating space for OWF without necessarily setting specific production targets in their MSPs (e.g., SE, LI, LV, PL, PT).

ES included high spatial provisions for OWF in its MSP that are linked to the national Roadmap for offshore wind and marine energy development in ES. [109] MSP will define the High Potential Areas for OWF development in ES in both Atlantic and the Mediterranean waters. In other countries from the Atlantic basin and the Mediterranean Sea, spatial provisions for OWF development are not directly specified in their MSPs. In IE that has the National Marine Planning Framework for the future development of the marine planning system in Ireland towards 2040, the Maritime Area Consent is a first step in the new planning process of OWF developments under the Maritime Area Planning Act.

In FR, there is no spatial provision for OWF in MSP, but following the amendment of the MSP legal basis to include the designation of potential zones for OWF development within the scope of MSP, there are currently several provisions under

[109] Spanish Ministry for Ecological Transition and the Demographic Challenge – MITECO, 2022 (MSP documents & National plans)

the public consultation for each façade for the designation of offshore renewable energy areas. [110] CY's MSP includes an area for Renewable Energy Storage (RES) that will be further investigated for the development of offshore floating wind platforms.

For the Member States who have not officially adopted their MSPs yet, some specific climate mitigation actions have been included in other plans, which will have implications for future maritime plans. For example, in GR, there are regional climate change strategies, which after consultation and strategic environmental assessment are now approved by the Regional Councils. They will have implications for the spatial planning of the coastal and marine areas of each region. There are also plans for the fair energy transition for some regions (e.g., Peloponnese) that are defining strategies for decarbonization.

All Member States have developed National Energy and Climate Plans (NECPs),[111] where they have presented their climate and energy objectives and targets, as well as the policies and measures to achieve them until 2030 (with an outlook to 2040 and the longer term). In addition, national long-term strategies [112] were developed by all Member States to meet their Paris Agreement commitments and the energy union objectives that should be consistent with countries' integrated NECPs for the period 2021-30. NECPs and national long-term strategies are acknowledged, however, they were not analysed.

Alternative offshore renewable energy: The development of alternative renewable energy, i.e., solar photovoltaic, wave and tidal energies, is considered by fewer countries in all sea basins. Following the EU ORE Strategy of at least 1 GW of ocean energy by 2030, and 40 GW by 2050, technological innovations are expected. Alternative ORE has already been included in the plans of FI, FR, IE, LV, and space allocation has been specified in BE, DE, DK, ES, NL. In DK, PL, SE the alternative ORE is foreseen in the same spatial allocations as OWF as the functional zone is called '*energy production'*. In EE alternative renewable energy is considered as multiuse with aquaculture. Currently, the biggest ORE production capacity is in the Atlantic basin. The ORE production is also in BE (wave/wind ORE of capacity 600 kW), NL (tidal ORE of capacity 2090 kW), SE (wave ORE of capacity 3000 kW, and tidal ORE 10 kW), ES in the Mediterranean Sea (wave ORE of capacity 7000 kW), IT (wave ORE of capacity 7711 kW, tidal 300 kW, and wave/tidal 50 kW) (based on EMODnet Ocean Energy Facilities). Currently, total ORE production for the EU is 360,436 kW, from which 339,551 kW is in the Atlantic (Table 10). Tidal ORE production in FR alone is 260,620 kW. The EU's first grid-connected wave energy array was launched in ES (Gibraltar), supplying 100 kW with an expansion plan to 1–5 MW.

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[110] French Ministry of Economy, Finances and Industrial Sovereignty and Digital Technologies, 2024a; 2024b; 2024c; 2024d (MSP documents & National plans)

[111] NECPs were introduced by the Regulation on the governance of the energy union and climate action (EU)2018/1999, agreed as part of the Clean energy for all Europeans package which was adopted in 2019

[112] https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-long-term-strategies_en

Table 10. Alternative Offshore Renewable Energy production in the Atlantic (based on information from the EMODnet Human Activities Energy - Ocean Energy Facilities). In the brackets is information about the number of projects by country for which the energy production is provided and/or for which the end year of the site is not provided

Country	Tide ORE		Wave ORE		Total alternative ORE production
	Number	Capacity (kW)	Number	Capacity (kW)	Capacity (kW)
ES	0	0	12 (7)	46318	46318
FR	8 (7)	260620	6 (3)	12300	272920
IE	1 (0)	0	4 (1)	5000	5000
PT	1 (0)	0	4 (3)	15313	15313
Atlantic	***10 (7)***	***260620***	***26 (14)***	***78931***	***339551***

The table has been elaborated by the European MSP Platform based on sources as indicated above

Offshore hydrogen generation and storage: Offshore hydrogen development is currently considered in the MSPs by DK and NL, while it is being explored in some other countries (e.g., SE, FI) through various projects. EE and SE have mentioned offshore hydrogen in their plans as a future activity, yet there are no spatial allocations or targets. It raises issues of transport and transboundary cooperation for pipelines. Projects of artificial islands are under development in the north - in BE and DK. There are a few projects on offshore hydrogen production platforms in BE, DE, DK, FR, IE, NL (Table 11).

Table 11. Offshore hydrogen production platforms in Europe

Country/Site	Project	Capacity	Operation
Belgium: Oostende	Hyport Oostende Hydrogen Project of DEME Group and H_2 Energy	50 MW	2025
Denmark: Esbjerg	Esbjerg Offshore Wind-to-Hydrogen Project, Swiss energy company H_2, Energy Europe	1 GW	2024
France: SEM-REV, Centrale Nantes offshore test site	Offshore Hydrogen Production of Lhyfe and Centrale Nantes	10-100 MW	2022
Germany: Helgoland	AquaVentus Project	10 GW	2035
Netherlands	PosHYdon of NEPTUNE Energy	-	2023
Ireland: Bantry Bay	Bantry Bay green energy facility of Zenith Energy and EI-H2	3.2 GW	2028
United Kingdom: Grimsby	OYSTER of ITM Power, Ørsted and Siemens Gamesa	MW scale	2024
United Kingdom: Peterhead	Salamander Project	5 GW	2028
United Kingdom: Scotland	DOLPHYN Project	4 GW	2035

Source: Zhang, M. & al., 2024

Prohibition of hydrocarbons exploration and exploitation: ES, FR and SE adopted laws to prohibit hydrocarbons' exploration and exploitation, and IE has started working on it. Many countries foresee in their plans to use hydrocarbons, e.g., DE, DK, LT, LV, PL.

The **decarbonization of maritime sectors** is the subject of ongoing efforts for many countries. Decarbonization of shipping is currently included in the MSPs of ES, FR, IT, LV, LT and SE, and many pilot transboundary projects are running, especially in the Baltic and North Sea regions. This topic is mainly mentioned as being important to consider in MSP, while often not specifying targets. Transformation of ports is also required to support the maritime transport efforts. NL is particularly advanced by setting a target of at least 70% reduction of CO_2 emissions from shipping by 2050, compared to 2008.

Carbon capture and storage through which MSP can contribute to climate change mitigation is included in the MSPs from the northern countries: development targets were set in BE, IE, NL, PL, while areas have already been allocated in DK and are planned to be allocated in FI. In DK, 8 zones are designated for CO_2 storage, and they mostly overlap with other sea uses, like OWF or Nature and environmental protection zones. In PL underground storage of carbon dioxide may be carried out in basins with the basic function of '*reserve for future development with extraction allowed on the basis of separate provisions'*. Projects and initiatives are emerging in the other EU countries (e.g., in the Baltic Sea) to explore the sector. DE's plan makes no reference to CCS and no concrete projects exist because it is prohibited under the German legislation.

Multi-use and co-existence approach of maritime activities is considered by many countries to address the increased spatial demands for energy, nature and food by combining different uses where possible. Pilot projects have been running in different EU sea basins. [113] Almost all Member States have considered the integration of multi-use in their plans (e.g., LV, DE, IT, FR as options, CY, IE, ES, SI as targets) or will include it in their next MSPs (e.g., BE, FI, PT, RO). For example, DE designed a new type of area used both as a priority area for offshore wind and a reservation area for scientific research. Countries like DK, NL and SE have already allocated areas for multi-use of space initiatives, especially regarding different renewable energy production methods (wind and alternative renewables).

Adaptation

Climate change adaptation is another area of climate-smart action in MSPs, aiming at reducing exposure and vulnerability, and strengthening resilience of maritime activities and sectors, as well as marine and coastal areas to climate-related risks. Many countries have planned actions to enhance the resilience of their sectors and marine/coastal areas to climate-related risks, which are not necessarily included in the current MSPs, e.g., the national coastal adaptation strategy in the NL, ES, MT. The majority of MSPs do not refer to comprehensive disaster or risk management in marine/coastal areas.

Climate risk assessments, including projections for sea-level rise and extreme events, have been prepared in EE, FI, FR, IT, LT, MT, PL, PT, ES, SE; and are planned in DE, DK. These assessments are used by the countries to improve the **adaptation strategies with comprehensive disaster and climate risk management**, which exist in the majority of them. Various **climate change adaptation measures** are delivered in the plans, including:

[113] European MSP Platform, 2023 (Websites)

Resilient and flexible measures are included in the national plans of BE, CY, EE, FI, FR, LT, MT, NL, PL, PT, ES, SE to enhance the adaptability of the maritime and coastal areas and sectors (e.g., MT developed a National Coastal Protection and Adaptation Strategy for the Maltese Islands in 2023).

Aggregate extraction sector (for coastal protection and adaptation purposes) is emerging in BE, DK, NL, LI, PL, SE with specific areas allocated. Other countries only consider the extraction for building and industrial purposes (e.g., FR). LT is foreseeing to use the extracted sand due to infrastructure (mainly port) development for beach nourishment. In NL, sand extraction is an activity of national importance to prevent the Dutch coastline from eroding - the extracted sand is used to maintain the current coastline (currently about 12 million m^3 per year) and as fill material on shore (currently about 13 million m^3 per year). [(114)] In NL's MSP, an area is reserved for sand extraction out to 12 NM limit that covers 5,134 km^2 (Figure 7). In that zone, sand extraction is given priority, but other uses are also possible. As part of the ongoing Partial Revision and the Strategic Environmental Assessment of the North Sea Programme 2022-2027, possible expansion of spatial reservation for sand extraction is considered up to 14 NM for the purpose of coastal safety due to climate-induced sea level rise. With the extended limit to 14 NM, the total area for sand extraction would reach about 6,000 km^2. Given the location of the sand extraction zone along the entire national coastline, the setting of new cables in the extraction zones will need to be re-considered earlier to allow the targeted ORE development.

[(114)] Dutch Ministry of Infrastructure and Water Management, 2023 (Websites)

Figure 7 – Raw material extraction zones (in dark blue) extend in NL along the entire coastline, and are also considerable in BE, DK and DE

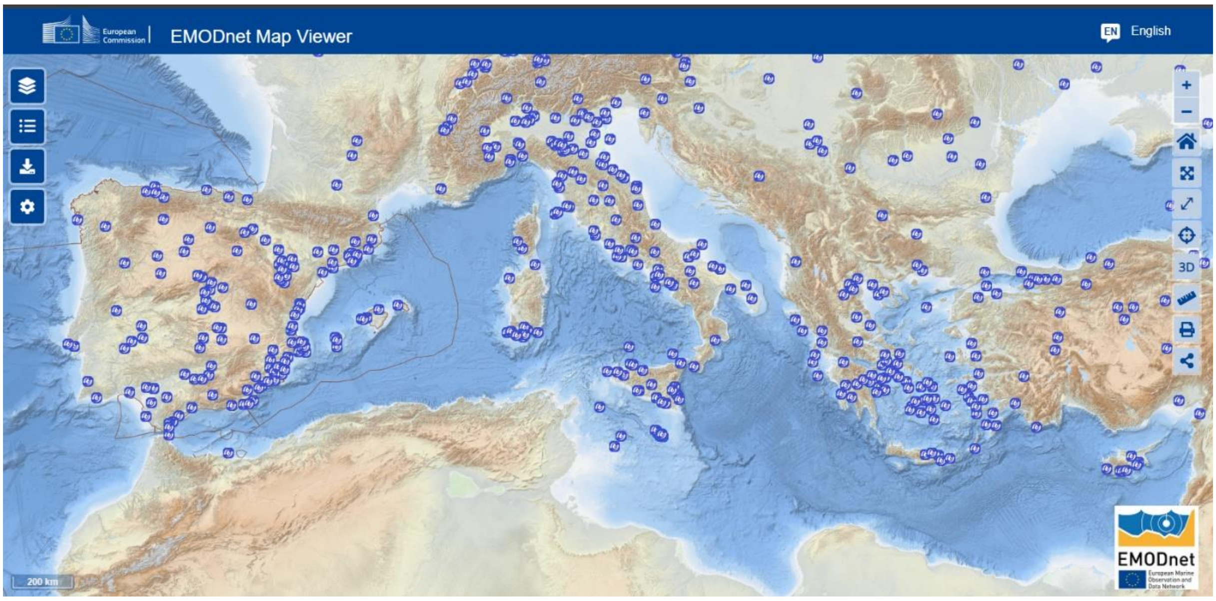
Source: EMODnet Human Activities MSP

Desalinisation, as an adaptation to droughts, is mostly under development in the Mediterranean countries in the form of pilot projects, without being specified in the national MSPs (except CY). Most of the desalinisation plants are placed on the coast or near the coast (Figure 8 - EMODnet Human Activities). In addition to the majority of plants in ES, IT, FR, CY, MT and GR, there are also plants in BE, DE, NL and IE (primarily used for the production of drinking water and industrial water).

Currently in the majority of MSs, even though its future development is planned, there are no spatial **offshore aquaculture** designations, but some plans aim to provide a framework for the establishment of marine aquaculture (e.g., DE). The countries who have aquaculture designations in their plans include BE, CY, DK, IE, MT, PL, PT. Mostly there is no reference to algae at this stage. The planning objective for aquaculture of some countries (e.g., DE, NL) aims to encourage co-use with existing installations, such as offshore wind farms, to achieve greater spatial efficiency. In many cases, the plans talk about the impacts, e.g., on aquaculture, while measures are not yet proposed in MSP. EMODnet Human Activities MSP provides information about aquaculture designations in six Member States (Figure 9). The significant spatial provisions for aquaculture are in the MSP from ES in the Atlantic basin (12,738 km^2 in 3 zones including the Canary Islands) and in the Mediterranean Sea

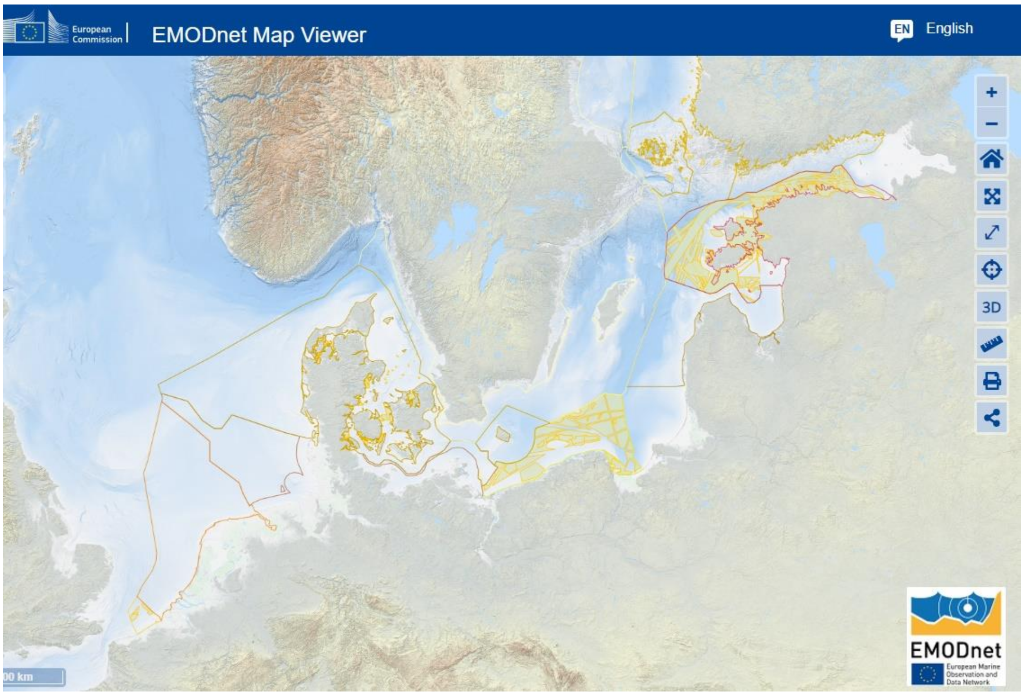
(5,585 km^2 in 2 zones); and in PL (17,425 km^2 in 30 zones). BE reserved 518 km^2 in 4 zones, and many zones have been allocated for aquaculture in DK, EE and FI.

Figure 8 – Location of desalinization plants in the Mediterranean Sea



Source: EMODnet Human Activities MSP

Figure 9 – Aquaculture designations in the Baltic Sea and North Sea



Source: EMODnet Human Activities MSP

Ecosystem-based adaptation is considered in ongoing and future actions, including nature-based solutions for established approaches that use natural, regenerative and adaptive methods, in the plans for the marine and coastal areas of DE, ES, FI, IT, MT, NL, PL, SE. It is planned to be included for BE and FR in the next revisions. NbS can be broadly categorized into protection and (active and passive) restoration (next section). Provisions in the plans include different measures, including coastal adaptation solutions, buffer zones (e.g., in ES) and areas for sand extraction (e.g., in DE and NL – see section on aggregate extraction) to help the coastline and marine areas adapt to climate-related risks. Besides areas for sand extraction, the NbS serving protection and adaptation currently do not have big spatial designations in plans. In the past decade, NbS were mostly applied to terrestrial/urban systems, and much less in marine and coastal areas. [115] In view of the EGD and the Green Infrastructure Strategy, which place NbS at the centre of climate adaptation and mitigation, spatial provisions for NbS adaptation are expected to increase in the future in MSPs to leverage the national seas for societal and biodiversity benefits that includes contribution to a sustainable blue economy.

For the countries who have not officially adopted their MSPs yet, some specific climate adaptation actions are provided for coastal areas, e.g., through the application of the Protocol on Integrated Coastal Zone Management (ICZM) in the Mediterranean.

Ecosystems

Actions to enhance the resilience of marine and coastal ecosystems to climate-related risks are included in all plans. They comprise the identification and allocation of spaces for ecosystem protection, restoration and conservation of existing "blue carbon" ecosystems, that is, marine and coastal ecosystems that sequester and store large amounts of carbon dioxide from the atmosphere (e.g., seagrass beds, kelp forests and salt marshes). The MSPs include these measures as such, while they are not analysed from an established based on climate change considerations (no criteria or factors).

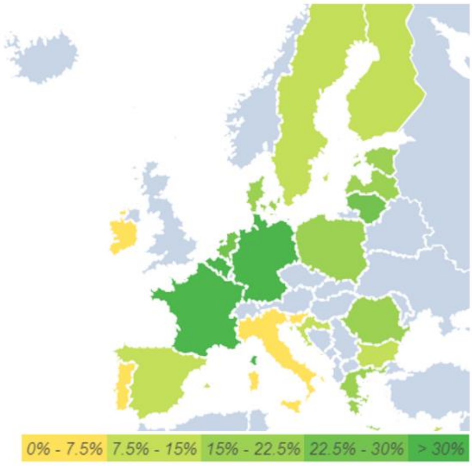
Measures to **ensure the conservation and restoration** of ecosystems are included in all national MSPs, mostly through the designation of marine protected areas (MPAs) which can be specified differently by countries. For example, ES has defined one type of nature conservation areas, i.e., priority use areas for the protection of biodiversity, while in EE nature conservation areas are contained in six different categories (i.e., Conservation areas, Nature reserves, Natura 2000 Special Protection Area, Natura 2000 Sites of Community Importance, Proposed protected areas, Proposal for offshore protected area). Different rules, especially on co-existence with other activities like fishing or shipping, also apply in these nationally designated areas.

Measures to **ensure protection** (including coherent MPA networks) are being developed to ensure a high level of protection of marine and coastal zones. The

[115] O'Leary, B. & al, 2023 (Studies & articles)

dashboard of the EU Biodiversity Strategy [116] shows the progress of Member States towards the targets set for 2030 for protection of a minimum of 30% of the EU's sea area, considering both nationally protected areas and Natura 2000 sites. Figure 10 presents the status of marine protected area coverage of the EU's seas in 2023 (12% of the EU's seas), based on data reported by countries and provided every year to the European Environment Agency.

Figure 10 – Marine protected area coverage (%) of the EU's sea area



BE	37.8	LV	15.8
BG	8.0	MT	5.5
CY	8.6	NL	26.1
DE	45.4	PL	21.9
DK	18.7	PT	4.5
EE	18.7	RO	21.4
ES	12.0	SE	14.9
FI	10.9	SI	5.0
FR	37.6		
GR	19.8	Average: 12	
HR	9.5		
IE	2.3	[%]	
IT	6.9		
LT	22.8	Year 2023	

Source: EU Biodiversity Strategy Dashboard

FI and SE created climate refugia areas, which are zones that remain relatively buffered from the effects of climate change over time, enabling them to play a vital role in safeguarding biodiversity. DK has revised its MSP to increase biodiversity targets (as a revision to MSP) - the proportion of strictly protected areas at sea will gradually increase to 8% of the sea area in 2028 and 10% strict protection by 2030.

Restoration has not been addressed by all MSP, while the debate is ongoing on conservation measures, largely not from climate perspective.

Society

Climate-smart actions for enhancing communities' socio-economic resilience to climate-related risks were assessed in the areas of promoting climate literacy and reinforcing the importance of social knowledge, equity and change. This social dimension is important in plans as it strengthens socio-economic resilience, facilitates environmental justice (by enabling meaningful involvement of stakeholders in decision-making), and **fosters societal support and understanding for climate mitigation and adaption actions in MSP**.

The measures for **promoting climate literacy** and the strengthening of understanding of impacts of, and vulnerability to climate change, current and future climate variability and extreme events, and the implications for sustainable blue

[116] European Commission Digital Observatory for Protected Areas, 2023 (Websites)

economy development are included in several plans. That includes multidisciplinary research on the ocean-climate nexus. For example, it has been developed in DE and ES where special zones are developed for marine research. In LI studies are being developed on the biological values in the national marine areas. **Climate-smart technological innovations** include, for example, marine ORE and biotechnologies in NL, data-sharing tools in PT, and ORE-related research in FR.

Measures for a **just transition to a sustainable blue economy**, to ensure the transition to a zero-emission maritime industry by 2050 and the development of sustainable blue economy is safe and just (reskilling, upskilling and new skills in maritime sectors), are included in multiple plans. For example, ES included it in its MSP specific objectives for pollution prevention, while GR developed plans for fair energy transition for some regions (e.g., in Peloponnese and western Macedonia).

The creation of jobs across the energy supply chain and the transition to scalable zero-emission marine fuels is vital in supporting climate action, furthering climate ambition and the wider economy, and ensuring that the climate-smart maritime sectors create opportunities for the people affected. The new jobs could also be a replacement for the jobs of the high-carbon sectors (O&G), fishermen going out of business due to dwindling fish stocks, new opportunities for the tourism sector or new multi-use/marine parks' rangers. Hereby, new jobs in climate-smart sectors would provide more diverse opportunities for the currently established sectors and they would be a driver for wider decarbonisation across national economies at a large scale. In MSP, the potential climate-smart job creation comes as a starting point for further work with stakeholders on exploring the scale of this opportunity and how to turn this potential into action.

Environmental justice, to ensure the fair treatment and meaningful involvement of all people with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies, is addressed in most of the countries (e.g., creation of Communities of Practices in NL).

5. KEY CONSIDERATIONS OF CLIMATE-SMART EMERGING SECTORS

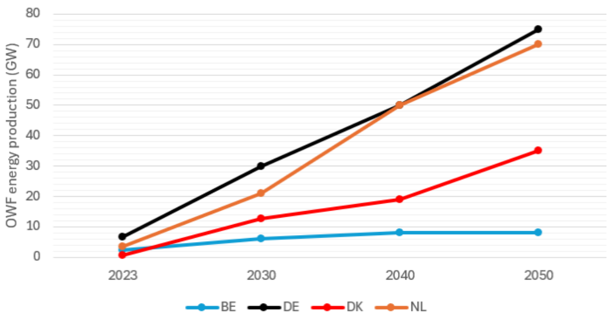
This chapter addresses opportunities, challenges and needs in steering climate-smart technologies and innovation for planning at sea, drawn from the sea-basin strategies and plans of Member States (Chapters 3 and 4), and technological and innovation advances with cutting-edge technologies.

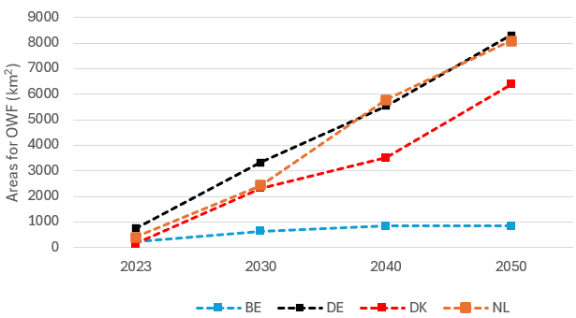
Planning driving climate-smart innovation at sea

The development of technological advances across emerging maritime sectors is growing, led by offshore renewable energy with the next generation offshore facilities, as essential for the European Green Deal. Through planning for space of climate-smart actions in the marine and coastal zones, MSP supports (national and sectorial) strategies for the spatial management of those emerging sectors. It also provides views to the space needed at sea for long-term development according to other policy mechanisms, such as climate mitigation plans, as included in NECPs and national long-term strategies.

Driven by national offshore renewables energy targets, spatial provisions for OWF in MSP provide perspectives to spatial management of ORE pledges by countries. For example, in the North Sea basin, from the currently utilised space for OWF there is fifteenfold increase in spatial provisions for OWF in national MSPs, which will be insufficient for the majority of countries (national OWF pledges) in the next 6 to 16 years (Figure 11). While the addition of new areas for OWF will be possible for some countries, for other Member States it will be challenging due to densely planned activities in their MSPs.

Figure 11 - Projections of Offshore Wind Farms production until 2050 and estimations of the required space for OWF in Belgium, Germany, Denmark, and the Netherlands





Source: Projections are based on national pledges; space estimations are extrapolated based on the information in the EMODnet Human Activities Energy (Table 9). The figure has been elaborated by the European MSP Platform

Constrained space available to the offshore wind sector, expanding to produce 23 times (in the North Sea) its current energy capacity within the next 26 years, will drive innovation at a fast pace. This will include construction of taller and more powerful wind turbines and more efficient configurations of turbines within a wind farm to reduce wake losses, as well as the development of an interlinked electricity grid for integrated offshore renewable energy, the conversion of power to hydrogen (production and storage), and the construction of offshore electricity storage to increase the flexibility of the system. The consideration for planners is how ORE technology and grid technology are likely to evolve between now and 2050, and how locations of OWF will be chosen to maximize their energy output and their social benefits, while ensuring they have the minimum impact possible on the environment.

While ORE is presumably the most space-demanding of all emerging sectors, other climate mitigation and adaptation actions will also claim space, and thus their priorities, needs and uptake of technologies are equally important to mainstream into planning and spatial management.

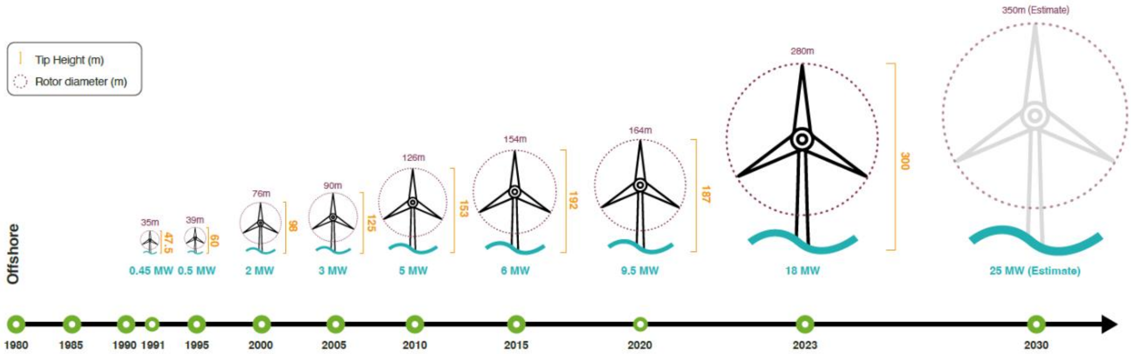
Technological needs and uptake of emerging sectors in climate-smart planning

MSP can drive climate-smart innovation in facilitating, accelerating and scaling up technology transfer for mitigation and adaptation. Spatial needs and space availability included in MSP, based on spatial data analysis, (will) allow for example for the integration of ORE systems with the large scale deployment of infrastructure, including high voltage direct current (HVDC) electrical interconnectors and high voltage alternating current (HVAC) interconnectors, as well as transformers, offshore energy hubs, and integration of flexible resources in the system for stable offshore electricity production.

Technology needs for mainstreaming climate change actions into planning and development policy can be in various areas. They can include, for instance, the need to improve efficiency and technologies specific to particular locations and climate change-related hazards, or the need to balance technologies' maximized output, socio-economic benefits and the minimum impact of technologies on the environment. The increased size of wind turbines while maximizing energy efficiency will also have bigger impacts on the environment that need to be carefully considered by planners. The current diameter of turbine rotors is estimated to increase in 2030 up to 350 m and a power of 25 MW (Figure 12). To support the delivery of ORE in a biodiversity-positive manner, i.e., in ways that responsibly contribute to avoiding and reducing impacts and restoring and enhancing biodiversity (including species, habitats, ecological connectivity and function), the concept of net-positive impact (NPI) is being advanced at the project level by sequential and iterative actions. [117]

[117] UN Global Compact, 2024 (Studies & articles)

Figure 12 - Trend of offshore turbine size, 1980-2030



Source: GWEC, 2024

For implementing the renewable energy goal through MSP, the development of the energy grid is an important milestone with planning of the national energy grid systems and cross-border grid integration that connects countries and foster spatial diversification of energy generation. For the planning and operation of a complex, integrated and multinational offshore energy system, most required technologies have already attained a level of maturity suitable for large-scale deployment. This involves the development of an interlinked electricity grid establishing links between offshore energy generation assets and onshore infrastructure, the conversion of power to hydrogen, and also the construction of offshore electricity storage to increase the flexibility of the system, including storage facilities, carbon storage sites, hydrogen storage assets, and more.

Similarly, planning for reduced vulnerability and enhanced resilience of maritime sectors, marine/coastal areas and ecosystems, as well as communities' socio-economic resilience, continuously stimulates technology development and transfer with advanced systematic observation, information and knowledge, solutions to protect and prevent risks, including Nature based Solutions to protect and restore marine and coastal habitats, as well as capacity-building for climate adaptation. While the use of advanced technologies in adaptation enables more informed planning to protect and prevent vulnerabilities and risks, the social dimension fosters societal support and understanding for climate actions planning in MSP for long-term viability and effectiveness of these technologies.

In addition to existing technologies, there are also needs to develop new technologies in all Member States in support of all emerging sectors, including new products, processes and services, such as capacity-building with training in climate-smart techniques.

Optimising sea space utilisation with new technologies for planning

MSP can drive climate action with new technologies that concurrently support the effort to optimize space utilization at sea within spatial planning frameworks. Limited space, particularly in the congested sea basins and coastal areas, will increasingly require identification of spatial management solutions to accommodate emerging sectors, which will be expanding due to the compulsory climate actions of Member States. As such, a vital consideration for planners is accommodating the infrastructure and spatial requirements with designated suitable areas for deployment of emerging sectors for climate action either in isolation or in-combination, for example, with offshore windfarm development. This considers allocating the OWF with the alternative offshore renewable energy (solar photovoltaic energy, wave and tidal energy), grid infrastructure, offshore electricity storage assets, as potential sites for hydrogen production and storage, CCS infrastructure, aquaculture and nature/NbS sites, as well as desalinization sites in the future. These multi-technological implications account for co-existence and multi-use solutions, requiring innovation advances with cutting-edge technologies.

The utilization of the (co-existing) climate-smart technologies at sea is today largely limited to emerging attempts in national MSPs (e.g., SE and NL allocated areas for multi-use mainly regarding different ORE technologies; in DE, EE and NL, ORE is considered as multiuse with aquaculture), pilots (e.g., hydrogen pilots, multi-use pilots), and research/industrial projects (examples in Tables 1-5), while acceleration - both technological and practical deployment by planners- will be required for the larger-scale application in MSPs. The initial plans mentioning offshore hydrogen (EE, SE) currently are without spatial allocations or targets in MSPs. Also, the designation of offshore hub locations is in general without including spatial data analysis, and similarly most of the studies about the offshore grid system are with little consideration for space. [118] Currently grid system integration is demonstrated at the project level, but new EU regulations ENTSO-E (European Network of Transmission System Operators for Electricity) and ENTSOG (European Network of Transmission System Operators for Gas) are expected to lead to an unprecedented planning of offshore energy system integration.

Large-scale application of climate-smart technologies in an integrated way will necessitate potential adjustments in MSP to accommodate the infrastructure and spatial requirements of the emerging sectors while balancing environmental concerns. More detailed and high-quality data, resourceful information, application of advanced and new generation modelling, as well as evidence-based assessments, will enable the comprehensive spatial analyses in planning for larger-scale deployment of emerging sectors. For this purpose, the emerging initiatives, such as the Digital Twin of the Ocean [119] and the application of high-quality and real-time data continuously collected at operational sites of the ORE industry, [120] could offer many benefits to planners. For example, it could improve information at various temporal and spatial scales for development of all-inclusive and integrated spatial plans; to facilitate advances in data integration [121] and interoperability for cross-sectoral collaboration and information sharing; and to address knowledge gaps and uncertainties concerning potential effects from individual/multiple activities for evidence-based decision-making and stakeholder engagement.

Innovations in technologies of the emerging sectors, as well as those technologies serving the development and deployment of the emerging sectors, are the facilitator of blue growth and climate action, including climate change mitigation and adaptation

(118) Martínez-Gordón, R. & al., 2022 (Studies & articles)
(119) European Commission, 2024 (Websites)
(120) UN Global Compact, 2023 (Studies & articles)
(121) Davret, J. & al., 2023 (Studies & articles)

within a maritime spatial planning system. The examples of innovative technologies and approaches in climate-smart areas of maritime planning are presented in Table 12, describing the current status and future prospects of relevance to planning.

Complexities and challenges with mainstreaming and the uptake of technologies in planning

Today, Member States face various challenges and needs related to technology uptake and transfer, underscoring the need to enhance technological innovation in order to implement their climate-smart plans. Across all emerging sectors, various barriers, gaps and challenges can complicate the development and uptake of technologies in planning. These barriers, gaps and challenges exist in many areas, including policy and regulatory barriers, research and innovation needs, information gaps, financial and economic constraints, cultural and social barriers, capacity-building gaps. At the same time, good practices for advancing technology development can be identified for mitigation and adaptation actions in the MSPs, which for example include embedding technology development and use in wider systemic approaches to sectoral action, such as the North Sea offshore energy system policies and the international collaborations on the interconnected offshore energy system (Table 2). [122]

One of the key challenges in emerging sectors for climate mitigation is that the offshore energy system integration currently faces barriers impeding the integration of offshore energy systems relating to regulation and technology. At the same time, grid systems in many countries can take only limited additional capacity, while the permits for ORE development with accelerated production are ambitious and above the existing capacity. Today energy grid system integration is being demonstrated at the project level, while legal frameworks can pose uncertainty surrounding ownership and responsibilities for cross-border infrastructure. Regarding energy storage at sea for ORE, currently none of the countries have established an official licensing procedure, which impedes the advancement of offshore-compatible storage technologies and large-scale project plans, including collaborative efforts.

Regulatory frameworks are currently missing for the establishment of offshore hydrogen infrastructure at scale. There is a lack of a functional international hydrogen market and a comprehensive certification scheme, both required for investments in hydrogen production facilities offshore. Currently there is a lack of commercially established offshore platforms dedicated to the hydrogen industry, for which the O&G sector presents opportunities for repurposing existing infrastructure by locating hydrogen production facilities on pre-existing offshore platforms or utilizing established gas pipelines, which can extend the economic lifespan of O&G infrastructure and delay decommissioning costs. However, the current regulations in the EU do not offer a certification or permitting scheme for the repurposing of existing pipelines for hydrogen transport. Also, a limited number of studies in the literature address the topic of integration of offshore hydrogen production in the energy system. One of the few studies that analysed the role of offshore hydrogen focusing on its integration in the energy system, was based on different scenarios for offshore hydrogen production pathways in 2035 and 2045. [123]

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(122) Court of Editors, 2023 (Studies & articles)
(123) Gea-Bermúdez, J. & al, 2021 (Studies & articles)

A lack of studies about emerging sectors in MSP from the spatial planning and future scenarios perspectives, can impede mainstreaming and uptake of these sectors and technologies into MSP frameworks by the planners. Exchange of knowledge at the technical level among planners is therefore necessary on the topic of climate-smart emerging sectors, within and beyond each sea basin, especially that methodologies applied in one sea basin can possibly be transferred to other sea basins.

For example, a recent study [124] that analysed the benefits of the North Sea Offshore Grid design in 2050 using an enhanced version of the IESA-NS optimization energy system model, [125] modelling different scenarios with all the sectors of the energy system, developed a methodology to link the IESA-NS model with GIS data to integrate the spatial analysis of the sea basin, including space availability, co-existence of offshore activities and multi-use of space. The study projected the locations of the offshore hubs of the North Sea Offshore Grid using spatial data clustering and considering space use, where future potential for wind energy production was estimated based on space availability including competing activities. Though the area of the study was the North Sea, the developed methodology can be applied to any other sea basin.

Complexities and challenges with mainstreaming and up-take of technologies in planning for climate adaptation are listed in Table 12. Among the key issues are that planners might not always be familiar with technological advances, such as solutions offered by numerical models (e.g., next-generation mesoscale numerical model prediction systems) that are able to capture all relevant processes at sea; geospatial technologies for more accurate risk assessments and mapping; technologies for generating socioeconomic data and scenarios to assess socioeconomic trends; continuously developed and validated international ocean observatory networks and systems; and other technological opportunities for informed planning and policy/decision making.

Aquaculture faces technological and regulatory challenges in addition to the remote locations of farms, information and data gaps, and inadequate planning methods. Regarding the application of nature-based solutions, the engineering solutions are repeatedly prioritized mainly due to concerns of planners over reliability and cost-effectiveness of NbS compared to engineered alternatives, and their resilience to climate change. [126] While advancements in desalination technology, including reverse osmosis and renewable energy integration, are continuously improving efficiency, reducing costs, and minimizing environmental impact, they have yet to fully mitigate these challenges. In community-based adaptation, the key challenge is that not all stakeholder groups play a role in developing and deploying climate-smart technologies. Overall, the application of risk-informed planning methods is mostly limited.

In cross-sectoral settings, the issues are, for example, disparate level of digitalization by sectors (no sectoral unifying digitalization principles), limited understanding of the interaction between spatial complexities by sectors, and a limited understanding of

[124] Martínez-Gordón, R. & al., 2022 (Studies & articles)
[125] Martínez-Gordón, R. & al., 2021 (Studies & articles)
[126] Seddon, N. & al, 2020 (Studies & articles)

the effects of climate change on managed systems, [127] which present a challenge for enabling cross-sectoral leveraged input into whole system planning for spatial management of emerging sectors. Evidence-based adaptation and mitigation actions in MSPs are a prerequisite for it, supported by national climate mitigation and adaptation plans with targets for mitigation and adaptation defined in the Nationally Determined Contributions (NDCs).

[127] Queirós, A. & al, 2021 (Studies & articles)

Table 12. Examples of technologies, approaches and techniques in climate-smart MSP – current status, challenges and future prospects in planning

Climate category	Examples of frontier and innovative technologies for climate-smart MSP (non-exhaustive list) – current status and challenges	Future prospects in the uptake of technologies for climate actions in MSP
Mitigation	1. **Offshore Wind Farm -** Fixed offshore wind turbines with the most common foundations currently used being mono-pile and gravity-based structures, followed by space frame structures (for intermediate and deep-water depths). Innovation will include construction of taller and more powerful wind turbines, and more efficient configuration of the turbines within a wind farm to reduce sea space and wake losses. **Floating Offshore Wind Farm** will increase in areas with deeper water (>100 m) extending the available space for development and installation of plants. Longer distance to shore implies energy losses during transport as well as higher costs for both distribution infrastructures and for construction and maintenance. 2. **Wave energy** – there are several systems at the full-scale prototype stage 2GW. Based on their orientation, the predominant types of Wave Energy Converters (WECs) are the attenuator, the point absorber, the oscillating wave surge converter, the oscillating water column, the overtopping device and the submerged pressure-differential device. In the last decade the opportunity of combining offshore wind and wave energy technologies has arisen and research is being conducted on hybrid systems. 3. **Tidal energy -** Tidal current or tidal stream energy converters (TECs) involve installing turbines underwater in fast flowing tidal streams. TECs may have gravity, piled or floating structures. Many converters are still in the R&D phase. 4. **Solar energy** - deployment is increasing, and new policies and targets proposed in the REPowerEU Plan and The Green Deal Industrial Plan are expected to be important drivers of solar PV investment in the coming years. 5. **Eco-efficient technologies** and energy sources that tend towards "zero emissions", such as new propellers based on renewable energies, alternative fuels and propulsion systems, etc. -> in MSP allocation of spatial permits to marine activities that use these eco-efficient technologies and green energy sources *Challenges*: OWF bottom-fixed technology is well established, while alternative ocean energy is lagging behind. National plans set ambitious targets to develop ORE with the countries and private sector investing over the last ten years in research and pilot projects on ocean energy, while there is continuous need for technological progress in ORE.	1. Development of ORE technology between now and 2050 will be significant ➔ Choose locations of ORE in order to maximize their energy output while ensuring they have the minimum impact on the environment and safeguarding social sustainability ➔ Investigate long-term estimations for OWF development as DE in planning with the use of new generation (numerical modelling) methods and enhanced databases ➔ Diligent planning of sea space for the timely updates of the national energy and climate plans ➔ Apply technologies for addressing environmental aspects linked to planning ORE deployment to limit the environmental footprint of renewables development ➔ Implement the co-existence of different ORE technologies in planning, for which practices from current co-using sea space can be useful 2. Energy storage at sea for ORE will develop for locating storage facilities offshore that would include the possibility of oversizing wind farms beyond their connection capacity, resulting in lower costs for transmission; and allow for the use of storage technologies in the offshore environment. E.g. the ocean battery by Ocean Grazer. 3. Development of hybrid systems for ORE (e.g. OWF and wave energy technologies) due to the opportunity of using the multipurpose platforms for other marine uses e.g. aquaculture; accelerated development of wave energy technologies by using the experience of OWF; the integration of multiple sea energy converters leading to smoother power output and minimum energy production at a constant rate (independently of meteorological conditions); a significant cost reduction. ➔ Plan to combine climate-smart technologies when technically feasible. E.g. in GR, the Wave2Water device was installed that can be used for desalination or for producing electricity or both and is modular (more units can be assembled in the configuration), capable of producing energy even at low sea conditions.

Deploying ORE faces practical, social and environmental challenges that have not yet been sufficiently addressed. Permitting procedures of some MSs slow down ORE development. While facilitating the development of ORE, national MSP are not fully resolving conflicts of use yet. Despite transboundary consultation and numerous cooperation forums, cross-border ORE projects are not yet common practice. The impact of offshore installations on the marine environment has not been adequately analysed and addressed, while the social implications of ORE development have not yet been comprehensively taken into account. More details on these (and other challenges) are provided in the Special Report of the European Court of Editors (2023) 'Offshore renewable energy in the EU'[128] that examined ORE and MSPs.

6. **Grid system** - with the expansion of installed OWF, transmission of significantly increased levels of energy to shore requires optimization of a spatial network for offshore electricity networks in the sea basins. Innovation includes development of an interlinked electricity grid for integrated offshore renewable energy, the conversion of power to hydrogen (production and storage), and the construction of offshore electricity storage to increase the flexibility of the system. New/upgraded methods are applied for analysing offshore infrastructure routing options for planning, e.g. modelling of offshore connections to onshore energy sinks for efficient and cost-effective networks at sea.
7. Methods to designate internationally interconnected electricity corridors for an offshore electricity grid are increasing to limit the routing deviations and thus decrease both the costs and spatial footprint of connections at sea. E.g., currently, infrastructure corridors are defined in the Belgian and German MSPs.
8. **Hydrogen production and storage** to enhance flexibility of the offshore energy system (serving as both a storage medium and an energy carrier). Currently offshore hydrogen infrastructure efforts exist as pilots and are not developed at scale, while innovative designs of offshore hydrogen platforms present a promising solution to bridge the gap between offshore wind and hydrogen integration in the energy system.
9. Offshore hydrogen production presents opportunities for the O&G sector to repurpose existing infrastructure by locating production facilities on pre-existing offshore platforms or utilizing established gas pipelines, which can extend the economic lifespan of O&G infrastructure and delay high decommissioning costs. E.g., the PosHYdon project in the North Sea explores production of green hydrogen offshore on an operational gas platform by integrating offshore wind, offshore gas and offshore hydrogen. This pilot as well as other initiatives by pipeline operators (e.g., NGT and NOGAT in NL) demonstrate that these developments are technically feasible (for transporting hydrogen offshore, the pipeline operators have sought validation through private certification companies, attaining a 'fit for purpose' label for their pipelines).

4. Increase of marine activities that use eco-efficient technologies -> Increase of marine activities that use energy sources that tend towards zero emissions

5. Development of holistic offshore renewable energy system with an interlinked electricity grid for ORE, the conversion of power to hydrogen, and the construction of offshore electricity storage to increase the flexibility of the system

➔ Considering in planning how ORE, grid, hydrogen production and storage technology are likely to evolve until 2050, and how locations of these technologies will be chosen in order to maximize their energy output and their social benefits, while ensuring they have the minimum impact possible on the environment. E.g., NL is currently developing the North Sea Energy Infrastructure Plan that is a strategic plan for development of the infrastructure required for OWF in the 2030 to 2050 period and how this will be integrated into the existing energy system.

➔ Considering in planning cross-border grid integration for multinational offshore energy system that connects countries and foster spatial diversification of energy generation. E.g. the North Sea Offshore Grid

➔ Recent studies explore the topic of offshore energy grid infrastructure planning by different methods including modelling and high-resolution scenario building support in a geographical information system, e.g. in the North Sea basin and the Baltic Sea study.

➔ Offshore infrastructure and maritime ports to play a vital commercial and societal role in ORE systems, will require to apply risk-informed planning methods, in order to ensure their resilience to climate change. Careful risk-informed planning for maritime infrastructure resilience as a method for planning at sea uses risk in the planning process to improve the effectiveness of protection plans and disaster reduction plans, while addressing the socio-economic development, natural requirements and impact of sustainable design in the long-term. The use of these approaches for risk-informed planning and risk-based designs will be further supplemented using other methods, such as decision-making tools, to support the risk-based planning process of decisions in the face of present and future uncertainties.

(128) European Court of Editors, 2023 (Studies & articles)

	10. Port Planning for the energy transition for decarbonization of maritime transport: Ports have a vital role in the construction, operation and maintenance of ORE systems –planning of port facilities with socio-economic benefits for local communities. *Challenges*: Grid systems in many countries today can take only limited additional capacity, while the permits for ORE development above this capacity. Offshore energy system integration currently faces barriers impeding the integration of offshore energy systems relating to regulation and technology. Legal frameworks can pose uncertainty surrounding ownership and responsibilities for cross-border infrastructure of the energy grid system. Currently, the countries have not established an official licensing procedure for offshore energy storage, which impedes the advancement of offshore-compatible storage technologies and large-scale project plans. Regulatory frameworks are currently missing for the establishment of offshore hydrogen infrastructure at scale. There is a lack of commercially established offshore platforms dedicated to the hydrogen industry, while the current regulations in the EU do not offer a certification or permitting scheme for the repurposing of existing pipelines for hydrogen transport. A lack of studies about emerging sectors in MSP from the spatial planning and future scenarios perspectives, which can impede mainstreaming and uptake of these sectors and technologies into planning frameworks.	
Adaptation	A. **Ocean observation technologies** (OOTs) for understanding climate-ocean interactions and the impact of global phenomena and drivers, including thermal expansion, mass redistribution and sea level rise, which are needed for generating projections and climate scenarios, and for forecasting hydro-meteorological conditions in order to facilitate accurate marine and coastal risk assessments. OOTs serve for climate change related issues: forecasting of weather/climate extremes (operational forecasting, mid- and long-term projections), storm surge prediction, ocean temperature, sea level rise, ocean acidification, bottom water oxygenation, the Atlantic Meridional overturning, etc. ➔ *Status*: Networks and systems of OOTs are installed in the European territories and globally, including platforms that provide specific measurements (e.g. for sea level rise: ARGO with Euro-Argo ERIC, arrays, GRACE, satellite altimetry, SST observations, Coastal Water Level Observation System / Système d'Observation du Niveau des Eaux Littorales - SONEL that serves as the GNSS data assembly centre for the Global Sea Level Observing System - GLOSS) and OOTs that measure many different variables (e.g. EuroGOOS). Structured ocean data infrastructures are well-founded in Europe that includes the Copernicus Marine Service (CMS), the European Marine Observation and Data Network (EMODnet), the Sea Data Net/Cloud. They offer global and pan-European quality-controlled ocean observation data, forecasts, analysis and projections. Planners benefit from data and information from OOTs, e.g. EuroGOOS for better storm surge prediction, Euro-Argo and Copernicus Climate Change Service (C3S) for climate modelling, EMODnet for the	a. Increasingly emerging technologies will be expanding the capabilities and coverage of existing OOTs systems, including sea surface observation technologies (e.g. moored buoys, drifters, space-borne sensors, autonomous surface vehicles), profile observation technologies (e.g. Argo floats, underwater gliders), seafloor observation technologies (e.g. autonomous underwater vehicles, cabled seafloor observatories). In the future, the capabilities and coverage of OOTs systems will be enlarged by combination of the static and dynamic observing technologies where advances will be progressing from the conventional single node, static and short-term modalities to multiple nodes, dynamic and long-term modalities, to increase the density of both temporal and spatial samplings at the sea. Planning should embrace the existing OOTs, e.g. through MSP authorities' participation in OOTs exchange of knowledge and experiences and striving for harmonization to enhance comparability of monitoring between countries in networks such as JERICO RI, EurOcean, European Marine Board, which enable understanding of expanded capabilities and coverage of OOTs systems in the future of MSP. Next Generation Multiplatform Ocean Observing Technologies for Research Infrastructures (GEORGE) develop novel technologies with high-precision sensors and platform technology to provide planners and policymakers with high-quality and reliable data

integrated maritime planning and policy (e.g. EMODnet Human Activities – the MSP layer).

➔ *Challenges*: Not all Member States participate in international OOTs networks, systems, projects and programmes on ocean data collection and management, and hence not all planners are aware of existing OOTs possibilities and how make better use of data in their informed policy/decision making. A few countries are advanced in OOTs, such as France (e.g. CMS), Germany (AtlantOS), Belgium (IODE/IOC).

B. **Geospatial technologies** (GTs) - remote sensing, global positioning systems (GPS), digital elevation models (DEMs) and geographic information systems (GIS) for gathering and creating baseline data for planning (supporting data collection, developing a spatiotemporal change-sensitive plan, enforcing and monitoring the plan)

➔ *Status*: GIS and web mapping are widely used for planning and for specific MSP needs - collecting and processing location-associated data, while other geospatial technologies might be less used, such as repeated airborne light detection and ranging technology (LiDAR) and unmanned aerial vehicle optical photogrammetric surveys (UAV). A single technology in relation to MSP uses is frequent. In order to establish exposure trends and projections of the exposure of the marine and coastal areas, accurate geospatial data are used, including GTs such as DEMs, LiDAR information, high-quality sea/land cover data.

➔ *Challenges*: static management for dynamic conditions in marine and coastal areas; more accurate mapping is required to assess exposure to coastal erosion and flooding, with the use of technologies for generating socioeconomic data and scenarios to assess socioeconomic trends. Planners might not always be aware of technological GTs solutions available for the development and implementation of MSPs.

C. **Modelling technologies** (MT) – numerical and physical models for predicting weather and ocean conditions and flood and coastal erosion, that can also serve to build historical records to observe trends and define design conditions for civil structures or identify risks to human populations and human activities

➔ *Status*: There has been an increase in the number of numerical models being developed and improved to reliably predict a possible hazard event and its possible damage. Today's numerical models can capture different processes: atmospheric change, ocean circulation, wave and current action, tides and storm surges, sand transport, morphological changes and damage to vegetation, e.g., XBeach, WaveWatch III to compute future extreme scenarios to design infrastructure including coastal defences, bridges, wind farms, etc. Planners use modelling technologies for different areas of climate change adaptation, including climate risk assessments in coastal and marine areas (incl. projections for extreme events), to predict weather and ocean conditions, and flood and coastal erosion. The focus of numerical models typically varies depending on the scale; they can be used to study

on the ocean condition to make informed decisions on how to adapt to climate change and reduce its impacts.

b. Given all GTs address the needs of MSP/coastal planners, in each planning stage, they will thus all be increasingly used in planning for evidence-based decisions and in effective helping stakeholders recognize, manage and operationalize informed marine management. Planners shall be incorporating GTs in all MSP stages, including supporting data collection, developing a spatiotemporal change-sensitive plan, enforcing and monitoring the plan. Also, there is needed anticipation that in the future GTs will support dynamic ocean management enabling a more spatiotemporal-sensitive approach to managing mobile human uses and mobile marine fauna conservation, which should be incorporated in MSP by planners.

c. The MTs/models are constantly being upgraded and new technologies are emerging with the ability to model changing processes and conditions better and faster and providing more reliable trend analyses and projections. New models will enable planners to study large areas and broad combinations of processes like extreme winds, storm surges, waves and currents and their action on the maritime infrastructure, coastline or on civil structures. A next-generation mesoscale numerical weather prediction system - the Weather Research and Forecasting Model (WRF), designed to serve both atmospheric research and operational forecasting needs, is an example of next generation numerical modelling. WRF serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometres and it offers operational forecasting a flexible and computationally efficient platform, while reflecting recent advances in physics, numerics, and data assimilation. In EU, building on existing core data infrastructures and ocean services of CMS, Copernicus Data large-scale weather and ocean phenomena, or they can be used to downscale large-scale phenomena to the regional and local scale. Based on the downscaled data dedicated models can be used to simulate the actual impact (or exposure) at the local scale, for example, in terms of flooding, erosion and associated damages. The impact models can include many effects and take into account coastal erosion and breaching of sea defences, flash flows from rivers and rain bursts, and the impact of these phenomena on specific rural and urban topographic settings, including impacts on drainage systems.

➔ *Challenges*: With the computational power increasing, numerical models that are able to capture all relevant processes are expensive in the computational sense, and today there is a limited availability of technologies for combined effects. As a consequence, different models are coupled together to combine processes occurring at different scales, such as cyclone atmospheric processes and storm surges, storm surges and local wave action, and ocean currents and sediment transport in coastal zones. Further, in risk assessments, socioeconomic information is crucial to determining exposure and vulnerability. That includes establishing trends and providing projections of the exposure of the human environment that depends on the availability of historical information and future projections of a large variety of socioeconomic data (e.g. population, assets, infrastructure, economic activity).

D. Technologies to ensure that maritime installations and coastal/port areas and structures can cope with the climate of the future and uncertainties

➔ *Status*: There is a common use of the structural technologies to protect and prevent risks in planning (e.g., detached breakwaters, storm surge barriers, closure dams, groins, seawalls, revetments, TetraPods, riprap, and other coastal protection barriers), beach nourishment and reclamation, nature-based solutions or hybrid solutions to integrate ecosystem-based adaptation considerations into the construction of structures such as seawalls and riverbanks to protect and restore marine and coastal habitats, relocating and rebuilding endangered structures, early warning systems based on the operational forecasting system and on the trend analysis and decision-support system.

➔ *Challenges*: The provision of laboratories and equipment to collect and analyse related data. The structural/engineering solutions are often prioritized over the nature-based solutions, while NbS use marine/coastal ecosystems for prevention and mitigation as well as adaptation and response/recovery. The challenge is also the uncertainty relevant to adaptation policy and planning that encompasses uncertainty about the dynamic nature of risks, and uncertainty in the scale and direction of changing risks, which are difficult or impossible to foresee on the temporal and spatial scales needed in policy and planning.

E. **Aquaculture**

➔ *Status*: Marine and coastal aquaculture produces one of the most sustainable and fastest-growing sources of animal protein. Aquaculture farms have become

and Information access services (DIAS), and EMODnet, the European Digital Twin of the Ocean (European DTO) is being developed for using real-time and historical data to represent the past and present and numerical models to simulate future scenarios. DTO will provide for planners consistent high-resolution, multi-dimensional descriptions of the ocean that includes its physical, chemical, biological, socio-ecological and economical dimensions, with forecasting periods ranging from seasons to multi-decades. The European Blue Economy Observatory with data from administrations, international organizations, and private sector sources, will give more consideration to marine environment-economy linkages and ecosystem services to provide a comprehensive base for planning of the marine areas.

d. Promoting resilient maritime and coastal infrastructure in planning to protect infrastructure and communities against climate-induced sea level rise and extreme events. In this, expanding nature-based solutions / hybrid solutions in marine/coastal/port planning for integrating ecosystem-based adaptation considerations into the construction of maritime and coastal structures, considering resilient, adaptive and flexible measures in planning with sustainable project design for long-term viability and effectiveness of these solutions in ecological, economic, social, infrastructural, and financial terms. In planning, use of holistic approaches for adaptation planning with integrated knowledge and governance for climate change with the application of disaster risk reduction and management for minimizing vulnerabilities, and for dealing with uncertain future conditions and changing risks, e.g. through the application of adaptation pathways for more anticipatory and more adaptive ways of planning, with transferable climate change adaptation science and data into evidence-based planning and policy-making in MSP.

e. Cutting-edge tools, including new satellite technologies, will help aquaculture expand, reduce its environmental impact and make farmed

	increasingly efficient with the growth of technologies to monitor fish health and growth rate, water quality and other aspects of the farm. Tools to remotely control feed timings and other interventions have also improved production. ➔ *Challenges*: There's a trend towards establishing farms up to several kilometres off the coast (where presumably farming has a reduced impact on the environment), but access is challenging (no fiber connection so far offshore). Aquaculture farms in remote locations that lack connectivity rely on staff visiting the sites to monitor the farm. This limits when and how much information can be gathered, and slows the interventions, for example when farms can be cut off for days by storms. Another challenge are overlapping other sector activities in the limited sea space. Problems for optimal planning processes in marine aquaculture development usually relate to inadequate planning methods and human capacity, as well as information and data gaps. F. **Desalinisation** ➔ *Status*: Seawater desalination technology exists for several decades and has become an important source of freshwater for many countries. The process of seawater desalination is expensive, energy-intensive, and requires large-scale infrastructure. With advancements in technology and innovations in design, seawater desalination process has become more affordable and efficient. ➔ *Challenges*: Seawater desalination processes' energy consumption leads to a high dependence on fossil fuels and contributes to greenhouse gas emissions. While advancements in desalination technology, including reverse osmosis and renewable energy integration, are continuously improving efficiency, reducing costs, and minimizing environmental impact, they have yet to fully mitigate these challenges.	fish more efficient to produce. Combining advanced satellite communication technology with advanced analytics will provide to manage aquaculture operations in a more efficient way. These new technologies will also enable aquaculture to move farther out to sea. Currently pilots running. Co-existence and multi-use is an important consideration for aquaculture, currently applied in pilots in all sea basins. An ecosystem-based approach to aquaculture, with a range of instruments for access to space, will be needed to ensure the long-term economic, environmental and social sustainability of the sector, and its ultimate contribution to blue economic growth. f. The seawater desalination technology based on offshore renewable energy and ocean thermal energy is considered to have significant development potential in the future due to its vast reserves and stable energy supply. In particular it is suitable for low latitude regions, such as the Mediterranean Sea, with the most effective method of flash evaporation technology. Currently, pilots are implemented.
Ecosystems	• **Ocean observation technologies** for marine and coastal ecosystems include the technologies described above for adaptation purposes (A), needed for understanding geophysical and hydrobiological conditions, in order to systematically observe changes in the climate system. These technologies are completed by specific tools dedicated to the observation of marine life (marine habitats and plankton). ➔ *Status*: The on-going efforts to monitor biodiversity and ecosystems includes through the establishment of baseline estimates of ecosystems in cooperation with environmental protection agencies. Current techniques used for observing marine environment are based on satellites, autonomous stationary or moving assets (moorings, surface ships, free-floating floats, guided gliders, etc.), and formalized single- and multi-platform observing networks (e.g., ARGO with ABiogeochemical-Argo Programs, the Ocean Observatories Initiative (OOI), OceanSITES, the Marine Biodiversity Observation Network (MBON), and the Long-Term Ecological Research (LTER) Program). To observe marine ecosystems in deeper waters (i.e. beyond divers' reach, >200m depth), new technologies have been developed like remotely	➔ In addition to (a), due to the multiplication of ocean observations' programmes and structures, there is a growing need to "build an intelligent ecosystem observation network by integrating three observation methods with the help of network, IOT (Internet of Things), improving ecosystem observation ability and realizing fine observation" (Hou, 2023) to help aggregate existing data and guide planners.

operated vehicles (ROVs), autonomous underwater vehicles (AUVs), landers and crawlers are operating thanks to manipulators and multiparametric sensor arrays.

➔ *Challenges*: discrepancy across different methods and approaches, making it difficult to compare observations across multiple time series; lack of synergy among databases also makes it more challenging for end-users to find comparable data sets of interest from within and across regions; limited incentive to invest time in sharing data that have been collected with a great deal of effort (Benway & al., 2019)

- **Geospatial technologies** (GTs)

➔ *Status*: Tools include satellites and water-based platforms carrying various sensors and receivers for environmental ocean data and animal telemetry via multispectral, acoustic, radar, and other means.

➔ *Challenges*: lack of data on the marine environment, high mobility of both animals and humans

- **Modelling technologies -** numerical and physical models for predicting the state of the marine environment and marine populations, and also the potential consequences of human activities on them.

➔ *Status*: Increasing demand for more complex multi-component models, increased number of existing marine ecosystem models. Development of "end to end models" (="key instrument for implementing an ecosystem approach to marine management", by opposition to environmentally-oriented models) that can encompass the entire food web and physical components of an ecosystem at a fine spatial scale. E.g., Atlantis is a spatial deterministic model designed for exploited marine ecosystems which considers 4 areas (biophysical, fishing, management and socio-economic) and has already been used to evaluate management strategies as it includes fishing and other types of anthropogenic activities that can affect the environment. Some of them are "individual-based models" (IBM) (focus "on bottom-up construction and on explaining how macro-phenomena arise as a result of relatively simple local interactions of organisms") which are useful for studying the issues from small-scale interactions to the consequences of non-stationarity of the natural environment affected by climate change → models can incorporate decision-making algorithms to reconstruct the behaviour of individuals, e.g. OSMOSE for environmental and fisheries issues; InVitro for the management of different human activities (fisheries, tourism, shipping, oil and gas production, etc). Hybrid approach with EURO-BASIN project. (Bernikov & al., 2022).

➔ *Challenges*: Uncertainties related to the models' performances – a need to encompass the modelling of other marine dimensions such as hydrophysical, hydrochemical, hydrobiological aspects of the functioning of marine ecological systems. Need to include humans as the highest trophic level, responding and adaptation to changing conditions. No mechanisms for taking into account the adaptative ability of populations to environmental changes and external influence).

➔ GTs - support of dynamic ocean management enabling a more spatiotemporal-sensitive approach to managing mobile human uses and mobile marine fauna conservation. Due to the dynamic characteristic of the marine ecosystems, there is a need for planners to adopt dynamic management approaches.

➔ The models are constantly being upgraded and new technologies are emerging with the ability to model changing processes and conditions better and faster and thus provide more reliable trend analyses and projections. New models will enable planners to study large areas and broad combinations of processes.

➔ For deployment of offshore energy system infrastructure in a space-efficient and nature-friendly way, application of methods will be needed that give priority to environmental and social criteria to address the twin crises of climate and biodiversity. E.g., an ecosystem-based MSP approach could act as a foundation to a centralized approach to tendering for offshore renewable energy projects.

➔ The need for provision of evidence-based cumulative impact assessments will increase based on detailed data at various temporal and spatial scales.

➔ Broad interconnection corridors for future infrastructure as well as allocated ecologically or biologically significant marine areas (for conservation and restoration) at various scales in seas, between countries and in different sea basins, will increasingly require

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• **Prioritisation -** tools and methods to prioritize ecosystem services for marine management, such as prioritizing ecosystem services for marine management through stakeholder engagement (Custodio, et al, 2022).-The engagement methodology can help planners capture stakeholders' perceptions regarding the importance of local Ecosystem Services, thus providing a baseline for establishing priorities during Ecosystem Services modelling and management.

• **Sensitivity mapping** – spatial representation of the sensitivity of an area or species to an environmental change (e.g. new human activity, climate variability)
➔ *Status*: Used worldwide to prepare contingency planning e.g. for oil spills or wind farm installations. Enhancement of original sensitivity maps by combination to visual analysis, remote sensing and GIS technologies or radar satellite data. Simple tool which facilitates the consideration of various aspects like seasonal variability and the interpretation of environments with strong geomorphological dynamics.
➔ *Challenges*: Consideration of two dimensions for ocean resource sensitivity while the marine environment is tri-dimensional (Venegas-Li et al., 2018): “mapping marine habitats from the water surface to the ocean floor is also necessary since marine environments and biotic processes vary with depth”
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development and utilization of new/upgraded methods for planning at sea.
➔ Development and application of decision tools for prioritization of conservation and restoration sites within planning will be at a larger scale than today, considering the linkages between environmental, economic and social elements and identifying the potential risks of adverse effects for biodiversity.
➔ Environmental (and social) aspects will be increasingly considered in all methods for preserving space for the future uses of the seas and addressing the needs of future generations, for aligning climate change mitigation with the biodiversity strategy targets, and other urgent challenges at sea. For example, within the planning sites, spatial distribution of EBA-metrics will need to be produced at adequate spatial scales to quantitatively assess dispersal and movement corridors of different life stages (i.e., structural and functional connectivity) as well as spatial conservation and restoration of biodiversity.
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<td>**Society**</td>
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○ **Community-based Adaptation** – to help ensure that communities play a role in the adoption of climate-smart technologies in maritime planning, which in turn increases the sustainability and social acceptance of these technologies.
➔ *Status*: Currently different stakeholder groups participate in developing and deploying climate-smart technologies in MSP, including national governments (their role is mainly establishing policies to support climate-smart technologies in planning, and facilitating an enabling environment for climate-smart technologies), local governments (supporting technology users, assist with scaling up small-scale or community-led technologies), communities (selecting and deploying technologies), research community (developing and testing new technologies).
➔ *Challenges*: Not all stakeholder groups play a role in developing and deploying climate-smart technologies in MSP. Planning for a just transition based on social dialogue and stakeholder engagement, which optimizes social, economic and employment impacts towards net-zero emissions and environmental sustainability, is limited today. There is also a lack of understanding of the effects of climate change on marine and coastal areas, and managed systems.

○ Member States start planning their space in an adaptive manner with the participation of different groups of stakeholders. Participatory processes and capacity building will are needed to make the climate-smart technologies effective.
○ Collaboration for synergistic approaches is increasing with more support and coordination of legislation and regulations, and with related services. E.g. in NL a nature-inclusive ‘Maripark’ aims at delivering an overarching approach to make the
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○ Through innovative approaches for engaging stakeholders (beyond the traditional avenues), planners should engage various groups of stakeholders in climate-smart technology development, selection, deployment and upscaling of technologies, and to advance particular climate-smart technology options for MSP at the national or sectoral level. Mobilizing technology champions can for example include private sector actors, including startups and small and medium-sized enterprises (for developing technologies and providing related services, building capacity for technology implementation), youth (for identifying priorities and suitable technologies, implementing technologies), non-governmental/civil society organizations (for researching, implementing, facilitating, monitoring and evaluating climate-smart technologies, facilitating communication among multiple stakeholders, promoting appropriate technologies), etc.
○ A comprehensive base for supporting decision-making for planning, management and protection of the seas will be increasingly through the use of information for improved blue economy statistics that will enable assessment of how complex interactions may affect the integration of ecological and socio-economic objectives in planning.
○ Adaptive approaches will allow for adjustment of the current methods for planning focused on the short-term (to medium-term) perspective, to methods for capturing medium- and long-term forecasting of changes at the sea. Adaptive management tools will be able to continuously evolve planning methods, to assist environmental assessments and cumulative impact assessments to include suitable long-term scenarios.
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	implementation of shared use of space within wind farms economically viable with a positive effect on the ecosystem.	○ Improvements in planning of the climate-smart emerging sectors to take place through more inclusive involvement of stakeholders who can stimulate enabling technologies for lessening risks from climate change, biodiversity loss and other environmental issues.

Complementarity of climate-smart actions and technologies in plans

Among Member States, climate mitigation actions are most prioritised for trends and technology needs, and as such are well documented in national maritime spatial planning and national planning cycles, while adaptation actions to reduce vulnerability, bolster resilience and enhance adaptive capacity are less widespread in national MSPs, being included largely in other national and subnational/sectoral plans. Despite the expanding landscape of mitigation and adaptation technologies, there are still urgent and growing technology related needs that must be met for these technologies to fulfil their potential for planning low carbon pathways and reducing vulnerability.

Focusing on either mitigation or adaptation in maritime planning as a point of entry for climate action can lead to competition for space and resources between mitigation and adaptation. In contrast to prioritisation of climate actions in complementarity, planning in the future might be considered as synergic approach focused on the optimal mix of mitigation and adaptation actions and technologies in a functionally sustainable planning system. It is particularly important in view of enhancing positive synergies between mitigation, adaptation, and sustainable development while minimising potential trade-offs between them.

The plans also address less the specific linkages between mitigation and adaptation actions, mainly in the form of potential mitigation co-benefits resulting from adaptation actions and vice versa, which would feed into planning to drive climate-smart innovation in emerging sectors at sea. For example, countries planning mitigation options that deliver potential adaptation co-benefits in the energy sector, and adaptation options that deliver potential co-benefits for mitigation, would result in mitigation with adaptation actions' co-benefits, such as socio-economic benefits - job creation, and improved electricity access and security. Thus, it is vital to integrate mitigation action planning into long-term adaptation plans to enhance resilience with technological innovations.

Furthermore, applying adaptive management to continuously evolve planning (as new data and information become available) will be required for spatial management in view of the ongoing technological advances in emerging sectors that are inevitable for the planning of the future uses of seas and oceans.

6. CONCLUSIONS

Understanding the evolving landscape of national maritime plans and how climate actions, trends and technologies are considered in them, is important for mainstreaming and the uptake of emerging sectors into climate-smart planning. Based on the assessment done in this study of the latest national plans and at sea-basin level, key considerations and recommendations for the integration of climate trends and climate-smart technologies are identified for planners/MSP practitioners as outcomes:

- The Member States increasingly integrate future climate-smart trends and new technologies in their national plans and national targets with implications for quick development of emerging sectors in all EU sea basins, stimulated by the European Green Deal and EU regulatory frameworks and strategies, and the NDC obligation under the Paris Agreement. The use of climate-smart technologies is, however, currently limited to emerging attempts in national MSPs, pilots and projects, while accelerated and larger-scale inclusion in the national MSPs is required.

- Technological innovation of emerging sectors plays a pivotal role in enhancing the effectiveness and efficiency of climate mitigation and adaptation actions in the marine and coastal areas, and it will play a more prominent role in the future in all EU sea basins. These include offshore renewable energy with next generation offshore facilities, resilient approaches for adaptation, aquaculture and desalination, with a string of enabling methods and technologies. The emerging sectors will also enhance each other’s technological advances, such as offshore wind farms enhancing the advancement of offshore renewable energy system planning with the interconnected grid system, hydrogen infrastructure and offshore storage technologies for energy; or offshore aquaculture and seawater desalinisation (energy supply). The regulations are, however, frequently based on old technologies and old approaches, making it challenging to implement new technological advances.

- Adept planning can drive climate-smart innovation at sea to meet climate action needs and to facilitate acceleration and scaling up of technology transfer for climate change mitigation and adaptation to all Member States. Finding suitable areas and enough space to accommodate over 300 GW of offshore renewable energy and other climate-smart emerging sectors, while ensuring they have the minimum impact on the environment, requires cautious spatial planning with cutting-edge technologies for spatial management solutions. The rapid development of new and innovative technologies will provide opportunities to apply novel practices and techniques in the service of climate-smart planning at sea, and in some cases to improve upon the existing techniques by making them more efficient and environmentally sustainable.

- MSP can drive climate action with new technologies, and it is expected that climate-smart emerging sectors will have considerable implications for the stimulation of advances and the efficiency of the spatial planning frameworks. For example, technologies can offer a way to address challenges related to restricted space and climate change impacts, as well as providing opportunities for synergies between different emerging (and established) sectors. As such, pushing innovation into spatial co-location of technologies aims to make best use of the physical space available at sea. Knowledge about spatial provisions and targets in MSP as well as integrated development of emerging sectors (today they largely grow in a sectoral way) are critical to the effort of space optimalisation at sea in national and also transboundary settings, e.g., for sea-basin integrated energy system planning.

- Large-scale application of climate-smart technologies in a holistic and coherent way will necessitate potential adjustments in MSP in order to accommodate the infrastructure and spatial requirements of the emerging sectors while balancing environmental concerns. Rapidly growing demand and long lead times of new technologies require timely planning today. Technologies, such as multi-use platforms at sea, advanced and new generation numerical models, technologies supporting evidence-based assessments, will require more detailed high-quality data and advances in data integration in order to improve information at various temporal and spatial scales and to develop all-inclusive and integrated spatial plans, assuring interoperability for cross-sectoral collaboration.

- Current national MSPs focus on either climate mitigation or adaptation as a point of entry for climate action with mitigation actions mostly prioritised for trends and technology needs, while adaptation actions are less widespread in national MSPs, being included mainly in other national/subnational plans. The MSPs also address less the specific linkages between mitigation and adaptation actions, while co-benefits of mitigation with adaptation actions could be, for example, socio-economic benefits. Both climate mitigation and adaptation emerging sectors will claim space and their priorities, needs and uptake of technologies are equally important for mainstreaming into spatial planning. Thus, it is important to integrate evidence-based climate mitigation and adaptation actions in national MSPs, supported by national climate mitigation and long-term adaptation plans.

- In addition to existing technologies, there are also needs to develop new technologies, including new products, processes and services, such as capacity-building with training in climate-smart techniques. To enable cross-sectoral leveraged input into whole system planning for spatial management of emerging sectors, it is important to address the disparate level of digitalisation by sectors; required standards and standardisation with best practices; limited understanding of the interaction between spatial complexities by sectors; considerations for economic, environmental and social constraints; a lack of understanding of the effects of climate change on managed systems; participatory processes and capacity building for climate-smart planning with adaptive management, as well as short-term decision-making with a long-term perspective for the development of climate-smart emerging sectors.

The study shows that it is necessary that the links between spatial planning and the advances of ocean/sea-based technologies for climate actions are continuously strengthened. To enhance the coherence and impact of climate-smart technologies in maritime planning, the study offers the following recommendations based on the above analysis, from the planning perspective:

- ➔ Being cognizant of the links between maritime spatial planning and the advances of sea-based technologies for climate actions in order to enhance understanding of future prospects of spatial claims and the interaction between spatial complexities for the optimum sustainable development of all emerging sectors

- ➔ Working towards cross-sectoral leveraged input into system planning for spatial management with an enabling environment that is conducive to the application of emerging sectors, including appropriate policy and regulatory frameworks, accrued digitalisation, standards and standardization

- ➔ Taking a holistic approach to climate-smart technologies in timely planning that incorporates emerging sectors in tandem (e.g., OWF-grid system-hydrogen production/storage-CCS, and their respective plans) to fulfil their potential for delivering efficient and effective climate actions

- ➔ Ensuring that climate mitigation and adaptation trends, actions and technologies are integrated into MSP, supported by national climate mitigation and adaptation plans, to enhance positive synergies between climate actions and sustainable development while minimizing potential trade-offs

- ➔ Taking advantage of emerging frontier technologies for planning (e.g., Digital Twin of the Ocean) alongside established technologies to reinforce informed and evidence-based spatial management as well as better understanding of future conditions for consideration in current planning

- ➔ Applying adaptive planning to integrate climate change trends and allow for update of climate technologies to stimulate transformation to climate-smart MSP and effective processes to explore synergies and trade-offs between climate actions, resulting in synergistic approaches in planning

- ➔ Considering the need for climate-smart technology transfer and capacity-building to facilitate the uptake of novel practices and techniques in the service of climate-smart planning, particularly in the transboundary and sea basins settings for more efficient and sustainable development in the EU

To help Member States meet these needs, encapsulate the knowledge on related good practices and take advantage of the opportunities identified for integration of future climate-smart trends and technologies in MSP as presented in this document, in particular Chapter 4 ‘Key considerations of climate-smart emerging sectors’. Further, this study built on the European MSP Platform’s technical background study from 2023 ‘*Review on how to preserve space for the future uses of the seas: what methods can we apply to address the needs of future generations?*’, [129] where broader considerations can be found regarding preserving space for future uses of the seas across sectors and sea basins, based on indications of future maritime growth, existing methods, and the projected increase in risks to marine areas from climate change, biodiversity loss and other environmental issues.

[129] European Commission, European Climate, Infrastructure and Environment Executive Agency - Enet, P., 2023 (Studies & articles)

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- Alianza NetZeroMar: https://netzeromar.org/who-we-are/?lang=en
- AMPMED - Areas Marinas Protegidas del Mediterráneo: https://maritime-spatial-planning.ec.europa.eu/projects/ampamed-areas-marinas-protegidas-del-mediterraneo
- ANEMONE - Advanced next generation Mobile Open Network: http://www.anemoneproject.eu/
- AQUA-LIT: https://cinea.ec.europa.eu/featured-projects/aqua-lit_en

- AQUAFIMA - Integrating Aquaculture and Fisheries Management towards a sustainable regional development in the Baltic Sea Region: https://keep.eu/projects/1854/AQUAFIMA-Integrating-Aquacul-EN/

- AquaVIP - Aquaculture virtual career development platform for the South Baltic region: https://southbaltic.eu/-/aquavip

- BALANCE - Baltic Sea Management - Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning: https://maritime-spatial-planning.ec.europa.eu/projects/baltic-sea-management-nature-conservation-and-sustainable-development-ecosystem

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- Baltic Blue Growth: https://interreg-baltic.eu/project/baltic-blue-growth/

- Baltic InteGrid - Integrated Baltic Offshore Wind Electricity Grid Development: https://interreg-baltic.eu/project/baltic-integrid/

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- BONUS BASMATI - Baltic Sea Maritime Spatial Planning for Sustainable Ecosystem Services: https://maritime-spatial-planning.ec.europa.eu/projects/basmati-baltic-sea-maritime-spatial-planning-sustainable-ecosystem-services

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- EolMed: https://eolmed.qair.energy/en/
- EXOPRODIGI: https://ecoprodigi.eu/exoprodigi
- Future Proof Shipping: https://futureproofshipping.com/
- GO LNG – LNG Value Chain for Clean Shipping, Green Ports and Blue Growth in Baltic Sea Region: https://interreg-baltic.eu/project/go-lng/
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- GREEN SMALL CRAFT - Green Cruising for High-Speed Small Craft in the Baltic Sea: https://interreg-baltic.eu/project/green-small-craft/
- H2Heat - Hydrogen to Heat: https://h2-heat.eu/
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- MAREMED - MAritime REgions cooperation for the MEDiterranean: https://maritime-spatial-planning.ec.europa.eu/projects/maritime-regions-cooperation-mediterranean

- MARISCA - Maritime Spatial Planning for the protection and conservation of the biodiversity in the Aegean Sea: https://maritime-spatial-planning.ec.europa.eu/projects/marisca-maritime-spatial-planning-protection-and-conservation-biodiversity-aegean-sea

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- MARSPLAN-BS-II - Cross-border Maritime Spatial Planning for Black Sea, Bulgaria and Romania: https://maritime-spatial-planning.ec.europa.eu/projects/cross-border-maritime-spatial-planning-black-sea-bulgaria-and-romania
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- SIMWESTMED - Supporting Maritime Spatial Planning in the Western Mediterranean region: https://maritime-spatial-planning.ec.europa.eu/projects/supporting-maritime-spatial-planning-western-mediterranean-region

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- TEAM4SEAS: https://planificare-maritima.unibuc.ro/

- THAL-CHOR 1 - Cross border cooperation for Maritime Spatial Planning Development: https://maritime-spatial-planning.ec.europa.eu/projects/cross-border-cooperation-maritime-spatial-planning-development

- THAL-CHOR 2 - Cross-border Cooperation for Maritime Spatial Planning 2: https://maritime-spatial-planning.ec.europa.eu/projects/cross-border-cooperation-maritime-spatial-planning-2

- TPEA - Transboundary Planning in the European Atlantic: https://maritime-spatial-planning.ec.europa.eu/projects/transboundary-planning-european-atlantic

- ULTFARMS: https://ultfarms.eu/

- UNITED - Explore United Project Technology Transfer Training Hub: https://www.h2020united.eu/

- W2W – Water to Water project: https://cordis.europa.eu/project/id/873854/en

- X1 Wind: https://plocan.eu/en/x1-wind-instala-su-plataforma-flotante-en-el-banco-de-ensayos-de-plocan-2
- ZEM Ports NS - Zero Emission Ports North Sea: https://northsearegion.eu/zem-ports-ns/

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