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STATE OF THE PLANET Discussions

Sea Level Rise in Europe: Governance Context and Challenges

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Abstract

Sea-level rise (SLR) will affect Europe's coasts over the coming decades and beyond giving rise to challenges for governing coastal and marine areas. Progress is being made in adapting to and addressing these challenges at both national and sub-national levels across all major European sea basins. This chapter assesses progress in coastal adaptation governance in Europe by, first, characterizing the socio-economic and political contexts in European sea basins, and then reviewing coastal adaptation relevant policy frameworks in place at regional and national levels within each of these sea basins. Regional frameworks reviewed consist in Regional Sea Conventions and are assessed for their legal status and their inclusion of SLR information. National coastal policy frameworks reviewed include national adaptation plans focusing on coastal areas and marine spatial planning instruments for all European member states, as well as public financing arrangements for coastal adaptation, focusing on flood risk reduction measures. Key national policies for coastal adaptation are assessed for which coastal hazards they address, the extent to which they incorporate sea-level rise information, and their inclusion of SLR specific adaptation measures. Finally, the chapter presents governance challenges that arise due to the complexity of adaptation to SLR, i.e., time horizon and uncertainty, cross-scale and cross-domain coordination, and equity and social vulnerability, and discusses examples illustrating how each of these challenges are being addressed in different European sea basins. The chapter finds that for across all basins, regional policy frameworks generally do not include specific provisions for SLR or coastal adaptation, while at the national level, significant progress on SLR governance is being made. For all basins except for the Black Sea, all countries have reported observed and future SLR hazards, and have adopted adaptation strategies. The inclusion of adaptation measures specific to SLR is less advanced, as most sea basins have at least one country that does not include specific SLR adaptation measures in either their adaptation strategies or marine spatial plans. Regarding SLR governance challenges, key examples for how these are being addressed include approaches for incorporating flexibility into coastal planning, e.g., Dynamic Adaptation Pathways in the Netherlands, or dike crest widening in Germany, as well as, co-development of nature-based adaptation solutions in Italy. Examples for addressing equity and social vulnerability challenges include the emerging issue of climate ligation illustrated through several court cases on liability of major carbon emitters for SLR-related damages.

5.1 Introduction

Sea-level rise (SLR) will affect Europe's coasts over the coming decades and beyond giving rise to challenges for governing coastal and marine areas. The present chapter reviews progress in Europe on the governance of

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Preprint. Discussion started: 9 January 2024

adaptation to SLR. It does so by first setting out the socio-economic and geopolitical context in Europe relevant to governance of coastal and marine areas, focusing on key issues such as trade and the related energy sector, as well as regional interdependencies and cooperation between states within each of Europe's 6 major sea basins: the Mediterranean, the Black, the Baltic, the North, the Atlantic and the Arctic Sea Basins. The overarching regional challenge that European policy makers have set out is to balance policy objectives of a green transition, energy and supply-chain security, and analysis below puts these challenges into regional context by surveying socio-economic contexts, identifying priority economic sectors, and geopolitical challenges at the sea basin level. Further, we discuss EU policy priorities in each of the sea basins in order to describe the boundary conditions for governance of SLR in coastal and marine areas, which is largely carried out through national governance arrangements, supplemented in some cases by regional agreements. The chapter then reviews the status of regional and national policy frameworks, including public finance arrangements for coastal adaptation, governing coastal adaptation in each of the sea basins. The concluding section we discuss specific governance challenges given rise to by SLR and survey how these challenges are being addressed currently within each of the basins. Throughout the chapter specific examples of approaches to addressing these governance challenges have been highlighted in text boxes in the relevant sections.

5.2 Geopolitical and socio-economic context of SLR governance

5.2.1 Geopolitical context in European Sea Basins

European Sea basins have increasingly become geopolitical hotspots in recent years. Significant waves of migration and asylum-seeking migrants have crossed the Mediterranean from North Africa and Arab states (2023 Top Geopolitical risks), and the Russia and Ukraine conflict has disrupted supply chains, interrupting transport via the Black Sea, leading to soaring energy, oil and gas prices across the European region (Davos 2023: What you need to know about geopolitics). In this context, the European Union faces the challenge of calibrating long-term climate goals with short-term supply-chain security, and managing energy independence with risks and uncertainties deriving from the transition to a green economy and decarbonisation.

The **Mediterranean Sea basin** has long been a site of intersection of interests of major international actors (The Mediterranean challenge). Over the last decade, the emergence of state fragility, conflicts, and security threats have affected the region, posing environmental, economic, humanitarian, and military challenges. Economic crises and political-institutional breakdown on the southern Mediterranean shore (Statistics on migration to Europe: overall figures of immigrants in European society; Migration flows on the Central Mediterranean route: The EU and its member states have taken a number of measures to address the migration situation on the Central Mediterranean route.)[1] have led to unresolved wars and forced a growing number of migrants and displaced people to cross the sea and seek refuge in Europe. Moreover, energy and military challenges resurface regional tensions such as the geopolitical rivalry played out in Western Sahara between

[1] The main migration flows from the southern shore of the Mediterranean come from Libya, Tunisia, Morocco, and Algeria. In absolute terms and taking in consideration all the Mediterranean shores, the Syrian migrants are the largest ones accounting for 23.2% of all the irregular border crosses in 2021.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

Morocco and Algeria (Morocco and Algeria: A Long Rivalry), territorial disputes, the control of energy pipelines between Greece and Turkey, (Politico, 2022), the battle for control over the Libyan government (Civil Conflict in Libya) and the world's largest refugee crisis in Syria (UNHCR The UN Refugee Agency, 2022).

For the EU, strengthening a Mediterranean partnership is thus a strategic imperative (European Commission, 2021b). Key EU Policies in the Mediterranean include the 2021 European Neighbourhood Policy (European Commission, 2021b), which aims to enhance the cooperation with Southern Neighbourhood countries,[2] promote conflict prevention and peacebuilding, counter-piracy, maritime security, and counter terrorism. Migration policies based on human rights, shared responsibility and fighting human trafficking are also a priority for the region. For environmental concerns, there is a strategic priority of actively supporting measures to conserve, protect and restore the biodiversity of the Mediterranean, ensuring effective regional co-operation on the management of marine biological resources. To cope with climate change, the EU aims to establish a political strategy to facilitate solutions in areas where decreasing freshwater supply can lead to conflicts (European Commission, 2021b). Though advancing green and digital transitions the EU seeks to enhance climate resilience, energy security and environmental protection.

Finally, the Russia and Ukraine conflict has led to an adjustments of key trade and energy relationship in the region with Algeria emerging as the African gas exporter for Europe (Italy's "Wider Mediterranean": Is It Just About Energy?). This reinforces a new partnerships and particularly energy trades among the Mediterranean countries, which is likely to further develop due to the EU intention of decreasing reliance on Russian gas.

In the **Black Sea basin** major geopolitical actors, e.g the EU, the US, NATO, Russia and Turkey, compete for influence, and access to resources and ports (NATO Parliamentary Assembly, 2020) (Kayser, 2021). The Black Sea basin region has significant economic potential as a major area for trade and transit of materials, linking littoral countries and hinterlands to the global economy (NATO Parliamentary Assembly, 2020). The Black Sea has been a vital trade link for energy between Europe and Asia, and for food concerning Africa (The New Geopolitical Order in The BSEC Region). At the same time, these links and related economic potential are precarious due to regional rivalries and conflict, as recently came to the fore with the Russia and Ukraine conflict, and its related trade embargoes and shifting of energy trading patterns.

For the EU, the Black Sea is a core strategic region connecting Europe to important energy suppliers and trading partners. As such, the EU is a major player in economic development in the basin. with its interests in the region including long-term stability and conflict management, promotion of democratic institutions and the rule of law, securing a stable energy supply, and combating organized crime and terrorism. The Black Sea Synergy initiative – the EU's key regional policy framework for the region in force since 2007 – has established sectors of cooperation, such as (a) blue growth and economy to increase the sustainable use of sea and develop sustainable coastal areas; (b) fisheries, as to strengthen conservation measures for key species and support the livelihoods of coastal communities and secure their jobs; (c) environmental protection and climate change, aiming to further develop the knowledge about the sea ecosystems and biodiversity, lower the pressure of anthropogenic activities and adapt critical infrastructure to climate change; (d) cross-border cooperation, aiming at strength the integration

[2] Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria and Tunisia.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

among local and regional authorities, civil society and business; (e) civil society engagement, democracy and human rights, focusing on ensure citizen and civil society organisations participation in the public debates; (f) energy and transport, seeking to make the region an energy hub, and develop cooperation relations to energy efficiency, clean energy, renewables and decarbonisation (European Commission, 2019).

The Russia and Ukraine conflict has however reshaped the security situation in the region, highlighting the central role of the Black Sea to the European defence systems, while, at the same time, encouraging the EU to reduce its energy dependence on the region (Kakachia et al., 2022). Indeed, the EU is trying to diversify its energy security strategy, as conflicting political interests of Black Sea basin countries often hamper regional cooperation and limit further development the basin's natural resource-based potentials (European Commission, 2019).

The **Baltic Sea basin** includes countries with high degrees of interdependence and long traditions of cooperation (European Parliament, 2022). Currently, the Baltic states have heavy reliance on Russian energy networks. Critical maritime infrastructure is thus a salient issue for the Baltic Sea countries due to their role in energy security, underwater security, and military planning (Swistek and Paul, 2023).

For the EU, key security issues in the basin are energy security, trade and business, transnational crime as well as targeted influence on societies in information and cyberspace. EU long term strategic interests are thus based on enhancing sustainable development and adaptation to climate change. The key EU policy instrument in the region is the Interreg Baltic Sea Region 2021-2027, which focuses on governance cooperation, as well as promoting innovative, water-smart, and climate-neutral societies. This initiative aims to build resilient economies and responsive public services, improve water resources conditions and their adaptative capacity to climate change impacts, strengthen the blue economy and mitigate potential conflicts regarding the sea, and support decarbonization of energy systems with renewable energy from locally available resources (Interreg Baltic Sea Region, 2018).

The Russia and Ukraine conflict changed drastically the geostrategic and security environment of the Baltic Sea, intensifying concerns about the potential threat of military action in the sea basin bordering countries, notably after Finland officials' entrance in NATO (Finnish Government, 2023). Further, energy security concerns prompted by the conflict have lead (Berling et al., 2022) the Baltic Sea basin states to consider investments in liquefied natural gas (LNG) terminals and new pipelines interconnections with European neighbours to rely less on Russian sources.

The **North Sea basin** contains countries with accountable democratic institutions, high environmental standards, well-functioning welfare systems, and low corruption rates. Among the most intensively used seas in the world, the North Sea Basin is a major transport hub in Europe, hosting the biggest ports of the region, and having a strong transport and logistics industry (CPMR North Sea Commission, 2020). Further, the North Sea is an attractive setting for offshore wind farms, with renewable energy potential expected to increase as new technologies emerge and the European's electricity networks are modernized (Mjahed, 2023). North Sea off-shore wind farms at present include 41 wind farms with approximately 2630 turbines giving a total capacity of approximately 100,133 MW.

Over the next decades, the North Sea is likely to play a key role in Europe's energy transition for net zero emissions, and achieving EU's climate targets, which requires further policies and investment in green energy sources, technologies and grid infrastructure (CPMR North Sea Commission, 2020). Sea-based energy supplies

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

and maritime energy infrastructure are becoming increasingly relevant within European infrastructural decoupling from land-based supplies, and offshore wind farms and undersea power cables are likely to cover a relevant part of the electricity demand of Europe in the maritime region this basin (Just Climate, 2022). Moreover, North Sea basin countries have been an attractive option for investors, due to their political stability, and continued investment in energy from the North Sea is likely to lead to economic growth, job creation and business opportunities.

For the EU, the key policy in the basin is the North Sea Region 2030 Strategy, which focuses on four priority areas: a productive and sustainable sea, climate-neutral, connected, and smart[3] region. The Strategy set outs goals in environmental, economic, infrastructure, and socio-economic spheres, and builds on the strong industrial and research clusters already located in North Sea basin countries (CPMR North Sea Commission, 2020). Environmental and climatic goals for 2030 include the creation of a healthy marine environment with the enhancement of blue economy sectors and sustainable aquaculture and fisheries, the production of more renewable energy, the increasing restoration of degraded ecosystems and the fostering of climate adaptation measures (see Sea Level Rise in Europe: adaptation measures and decision-making principles, section 4.1) to become climate resilient (CPMR North Sea Commission, 2020). For marine infrastructure, the region seeks to develop a clean shipping and an accessible transnational transport affordable for all societal groups. For the socio-economic sphere, the region is focused on smart specialisation strategies by fostering new industries based on marine resources, sustainable energy and tourism, circular economy and digitalisation that may increase employment rates with more skilled workforce and strive to include migrants in this process.

The European **Atlantic Ocean basin** countries play a vital role in maintaining international stability and security to balance the power distribution within the region (Adhitama, 2019). Key issues in the basin maritime surveillance, the exercise of sovereignty at sea, and the sustainable exploitation of natural resources (see section 5.2.1). Further, international cooperation on aspects of communication systems such as submarine cables or cooperation between islands and Atlantic spaces are also important geopolitical and security in the basin (Instituto de Defesa Nacional, 2022). The basin also has great economic potential as the Atlantic coastal zone may significantly contribute to the blue economy of the EU.

For EU policy, the Atlantic maritime strategy (European Commission, 2011), adopted in 2011 and updated with an Action Plan in 2020 (European Commission, 2020), aims at fully integrating the European Commission's political priorities for 2019-2024, notably the European Green Deal. The Action Plan focuses on four key thematic pillars: i) Atlantic ports as gateways and hubs for the blue economy, ii) promotion of blue skills of the future and ocean literacy, iii) Research, development and innovation, and the exploitation of marine renewable energy, iv) healthy and resilient coasts. There is thus strong political and economic interest in promoting ports role in the sustainable development of sectors such as coastal tourism, aquaculture, and shipbuilding, which are key to the transition to a carbon-free economy. Further, the Strategy's support for innovation in maritime sectors through innovation and technologies that reduce the carbon produced by vessels is also fully aligned with the EU Green Deal. In addition, as the leader in and testbed for the development of novel marine renewables, the EU Atlantic

[3] The 'Smart' region refers to fostering economic diversification to ensure viable jobs, and also developing innovative industries based on sustainable energy and tourism, circular economy and digitalization.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

area may play an essential role in offshore wind production and the transition to a climate-neutral economy. Finally, the Maritime Strategy also focuses attention on climate risk management and adaptation measures (see Sea Level Rise in Europe: adaptation measures and decision-making principles, section 4.1) to protect the coastal habitats and biodiversity and make the Atlantic coastal areas more resilient. Following this, circular economy, zero pollution, and energy efficiency could help develop more sustainable practices that benefit local economic sectors and employment rates (European Commission, 2020).

The **Arctic Ocean basin** has been rapidly transforming into a 'pole of instability' and a zone of militarized power politics, following decades of peaceful cooperation. Given the abundance of energy resources and potentially strategic position on global trade routes (Thangaraj and Chowdhury, 2022), the Arctic Ocean is emerging as a geopolitical hotspot (The Arctic Institute, 2022). The basin is increasingly the site of global competition for natural gas extraction, and profitable trade routes (Gross, 2020). With the increasing permafrost melting and erosion of shorelines, there is likely to be competition over land claims (Gross, 2020) of oil and gas reserves, natural minerals, hydrocarbon, and rare-earth elements useful to modern technology. Indeed, recent years have seen the increasing presence of international actors in the basin, such as China, regarding interests in ownership of critical infrastructure, the installation of sea cables, and global shipping (The EU's geopolitical awakening in the Arctic).

For the EU, the basin is of great strategic importance for the future of European security. The EU's full engagement in Arctic is a geopolitical necessity given the interest in resources and transport routes of the region (European Commission, 2021b). For EU policy, the EU's updated Arctic policy of 2021 focuses on three main points, namely (i) maintaining peaceful cooperation in the region and developing strategic foresight on emerging security challenges, (ii) addressing climate change-related challenges and making the Arctic more resilient with concerted action on black carbon and permafrost thaw, and (iii) supporting the sustainable development of the region with a focus on vulnerable groups such as Indigenous peoples, women, and future generations. Another EU policy priority in the Arctic is promoting a precautionary and science-based approach to fisheries in the Arctic. Indeed, the EU is a party to the Agreement to prevent unregulated High Seas Fisheries in the central Arctic Ocean that entered into force in 2021 (European Commission, 2021b) and that has financed several scientific initiatives in the region. Finally, the EU intends to keep strengthening the Arctic's Ocean governance, further developing relationships with partners in the region to ensure clean and sustainably managed seas (European Commission, 2021b).

5.2.2 Economic context in European Sea Basins

In 2021, EU gross domestic product was valued at €14.4 trillion, with Germany, France, and Italy as the largest economies. The EU economy significantly relies on services sectors, which accounted for more than 70% of the value added to the economy in 2020. The EU imports about two thirds of its energy, especially natural gas and crude oil, with high dependence on Russian energy imports being drastically reduced following the outbreak of conflict with Ukraine (Eurostat, 2022). In 2020, the total weight of goods transported to/from ports in the EU by short sea shipping was 1.7 billion tonnes. The EU's busiest 20 shipping ports accounted for slightly more than 50% of the total (Davos 2023: What you need to know about geopolitics) with Rotterdam being the busiest port

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

(195 million tonnes; 11.6 % of the EU total), followed by (100 million tonnes) and Amsterdam and Marseille (46 million tonnes each) (Eurostat, 2022).

EU policy relevant for coastal and marine areas is guided by the European Commission's Sustainable Blue Economy Agenda proposed in 2021 that aims to achieve the objectives of the European Green Deal. The policy stipulates that activities such as fisheries, coastal tourism and maritime transport reduce their environmental and climate impacts, tackle biodiversity loss and create alternatives to fossil fuels. Investment in new technologies is also a priority, with special attention to wave and tidal energies, development of innovative fishing gear and restoration of marine ecosystems, each of which may also create green jobs and business. Policy priorities relevant for coastal and marine areas includes i) developing offshore renewable energy, decarbonising maritime transport and greening ports; ii) switching to a circular economy and reducing pollution and plastic waste; iii) preserving biodiversity and investing in nature to enhance climate resilience; iv) supporting climate adaptation and coastal resilience through developing green infrastructure in coastal areas; v) ensure sustainable food production towards a new marketing standard for seafood; and vi) improving marine area management stimulating cooperative exchanges between offshore operators, stakeholders and scientists for the sustainable use of the marine environment (Eurostat, 2022).

Table 1 describes, for each sea basin, the currently significant economic sectors in coastal and marine areas, as well as developments in emerging sectors relevant for the EU Sustainable Blue Economy approach. For currently significant sectors, tourism, aquaculture and fisheries, ports and transport, and the related oil and gas export sectors cover the relevant sectors for coastal and marine areas across all sea basins. In terms of emerging sectors, offshore energy either for wind or green hydrogen are significant in several basins. In those basins without offshore energy developments, i.e. Black and Atlantic Oceans, ocean energy is being developed.

Sea Basin	**Current economic sectors**	**Emerging sectors**
Mediterranean Sea	***Coastal and maritime tourism:*** the world's leading tourism area with 35% of all international tourist arrivals. It accounts for 13% of Mediterranean countries' exports. In 2018, 2.3 million businesses employed 12.3 million individuals in tourism-related sectors. ***Fishing and aquaculture*** 1 million of workforce and employment. The total revenue from marine capture fisheries for the Mediterranean area was estimated at USD 2.7 billion, while the total employment on board fishing vessels was 166.000 in 2020. $12 billion is the estimated combined output of fisheries and aquaculture, and 112% is the increase in aquaculture production in the EU Mediterranean countries expected in 2030 in comparison to 2010.	***Desalination:*** a Blue Economy emerging sector with more than 2300 operational desalination plants in the EU producing about 9.2 million cubic meters per day. ***Floating offshore wind:*** a viable option for deep waters, possibly opening new markets, as the highest resource potential for ocean energy can have further exploitable potential in this sea. ***Offshore green energy development:*** Italy, Spain and Albania have signed a Memorandum of Understanding for the development of 5 green hydrogen projects in the Mediterranean basin (3 in Italy, 1 in Albania and 1 in Morocco). In Spain, Naturgy and Energas have announced plan for green hydrogen project off the coast of Asturias.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

STATE OF THE PLANET Discussions

Black Sea	***Fishing:*** the total revenue from marine capture fisheries was estimated at USD 241 million in 2020, with a total employment on board fishing vessels of 28 000. ***Aquaculture*** production has grown from over 500,000 tons of farmed seafood in 2017 to over 700,000 tons in 2019, helping to boost food security and providing jobs and incomes for many communities. ***Oil and gas:*** the region accounts for more than 34% of natural gas and oil imports to the EU, but its exploration is still incomplete, as for 2017, 20 wells were in place.	***Ocean energy*** the potential for wave energy and floating offshore wind may open new markets in this basin, fostering EU competitiveness.
Baltic Sea	***Shipping and port activities*** accounts for 15% of the world's cargo traffic in 2017. ***Fishing:*** in 2018, the fleets numbered 290 vessels, and employed 4265 full-time equivalent workers. The revenue generated amounted to €215 million, 74% of which came from Poland, Sweden, Finland, and Denmark.	***Offshore wind energy*** currently only 2.8 GW of total capacity is installed, and its 8 border countries are committed to increase that to 19.6 GW by 2030. Offshore energy is projected to multiply five-fold by 2030 and 30-fold by 2050 on an EU-wide level. ***Wave energy*** is a renewable source with localized exploitable potential. ***Offshore green hydrogen*** development has an important source through the wind energy of the sea.
North Sea	***Shipping and port activities:*** one of the world busiest shipping grounds with over 7.600 ships passing through hotspot areas of this sea basin. ***Oil and gas*** the western Europe's most important oil and gas production area that yields high-quality crude oil with a low-Sulphur content. ***Fishing*** one of the world's most important fishing grounds, with around 6600 active fishing vessels.	***Wave energy, wind energy, and floating solar photovoltaic energy*** regarding the potential of floating PV, the Dutch government aims to develop pilot projects in the North Sea in the period 2021-2026 to monitor efficiency and environmental impact of such installation. ***Offshore wind energy*** Germany, France, Belgium, and The Netherlands intend to jointly build 150 GW of offshore wind energy by 2050. The States also plan to collaborate on joint offshore wind projects, energy islands and offshore grid infrastructure, as well as strengthening renewable hydrogen production.
North-East Atlantic Ocean	***Coastal and maritime tourism*** this area offers high-quality tourism, and in 2019, Lisbon was the most visited port of call for cruise ships along the Atlantic coast of Europe with 310 port calls. ***Shipping and ports*** shipping activities increased by 34% since 2019, including in 73% of Marine	***Ocean Energy*** at the European level, the Atlantic coast has the highest resource potential notably for wave, and tidal energies, which is expected to be further developed up to 2030 with new EU resources and projects such as the EnergyMare, and the improvement of technologies. Deep-

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

	Protected Areas, and Western Scotland experienced the largest increase in vessel density. ***EU Blue Economy*** the largest sea basin in terms of Gross Value Added, representing 36% of the EU blue economy Gross Value Added. In 2017, the Blue Economy in the Atlantic Ocean employed 1.20 million people.	sea mining, environmental monitoring, desalination, and offshore wind are also relevant sectors for the future.
Arctic Ocean	***Oil and natural gas:*** important resources of minerals, notably hydrocarbons, and two of the world's major producing areas for oil and natural gas lie in the Arctic, namely North-western Siberia and the North Slope of Alaska. The region is composed of unique marine and terrestrial ecosystems and abiotic natural resources, such as minerals and oil, that provide a range of services to both local and global populations. ***Fishing, shipping and manufacturing:*** strong industries in these sectors at the macroeconomic level. In 2016, the Arctic provided about $281 billion per year in terms of food, mineral extraction, oil production, tourism, hunting, existence values and climate regulation.	***Fiber cables and data centers*** this sea is strategically located for global connectivity, and the melting Arctic ice creates new opportunities for the tech industry. Technologies in general can benefit from the cold climate and abundant hydropower in the Arctic, and some of the largest data centers are scheduled to be built in the region. ***Raw materials underground:*** a warmer climate will enable mining in previous inaccessible zones of the Arctic. The region is rich of raw materials that are keen for green technologies, used in batteries for electric cars and wind turbines.

Table 1: Key economic sectors and developments in coastal and marine areas in European sea basins.

Finally, another key aspect of the socio-economic context in Europe is the demographic transition that has been occurring over the last 50 years, as life expectancy has considerably increased, while a continued trend of birth rate decrease has been consolidated. Due to these trends, despite the positive net migration, the EU's population and labour force has gradually declined over the past decades, a trend that is likely to continue (European Commission, 2023). The European population is estimated to have reached 451 million people in 2023, with a proportion of children and young people (0 to 19 years) of about 20%, while working-aged people (20 to 64 years) represent 59%, and both are projected to decrease to 18% and 50% by 2100 respectively. Long life expectancies, low death, and birth rates, in contrast, make older age groups (65 or more) projected to increase from 21% to 32% by the end of the century. There is a development towards a shrinking and ageing society, with a decrease in the shares of children and young people below 20 and those at working age, and with a relatively stable pyramid until around 85 years old (Eurostat, 2023). Sudden events such as Brexit, the Covid-19 pandemic and the Russia and Ukraine conflict may impact birth rates and profoundly change migration flows into the EU. Currently, Europe starts to face new challenges related to an ageing population, such as the pressure on labour markets and welfare states, the increase of the old-age dependency ratio, and the raise of the per-capita burden of public debt. Hence, sustaining economic growth will require an increase in the working-age population, as well as labour force participation and productivity – which can be improved through technological advances and skills development (European Commission, 2023). Table 2 describes the key demographic trends and future developments for each European Sea basin. The table thus highlights further potential governance challenges emerging in coastal and marine areas in Europe.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

Sea Basin	Current situation	Future perspectives
Mediterranean Sea Countries: Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, Syria, Tunisia, and Turkey.	529 million people living in 21 countries. Northern Mediterranean (205 million) and southern and eastern Mediterranean (324 million) are experiencing increasing urbanization. Sharp decline in fertility and an increase in life expectancy over the last decade, leading to a fertility rate below the replacement level, an acceleration of population ageing and a natural growth rate close to zero, with a forecast 4.3% drop in its current population by 2050. Shift of the demographic epicenter from the northwest to the southeast of Mediterranean shores: a significant generation imbalance between African (47%) and Asian (42%) shores with a young population (under 25 years old) compared to the European shore (25%).	Large-scale migration to Europe that will require coordinated action among bordering countries to accommodate new inhabitants. For Greece and Italy, the old-age dependency ratio is projected to exceed 60 % by 2050.
Black Sea Countries: Bulgaria, Romania, Ukraine, Georgia, Turkey, and Russia	17.5 million inhabitants live in the sea region, and it has 6 bordering countries. East region has a greater population density with 74.9 inhabitants/km, while the west has 62.9 inhabitants/km.	The population in this region is expected to decline. Countries such as Bulgaria and Ukraine present the largest projections of relative reductions in population size between 2022 and 2050, with losses of 20 per cent or more.
Baltic Sea Countries: Finland, Russia, Estonia, Latvia, Lithuania, Poland, Germany, Denmark, Sweden	85 million inhabitants in the area, and 9 countries. Slight population increases and increasing urbanization over the past two decades. Rural areas have experienced population declines, moderated by positive net migration flows in countries such as Germany and Sweden. Recent population declines are concentrated in the north-eastern Baltic Sea basin. Southern areas of Nordic countries and Poland have the highest rates of population increase mainly due to regional and north-eastern countries migration.	Structural changes in the population age are expected by 2030 due to increases in people entering retirement age, and younger people's emigration in, e.g. Latvia and Lithuania.
North Sea Countries: Norway, UK, Germany, France, Netherlands, Belgium, and Denmark.	80 million inhabitants and 7 countries, with high rates of urbanisation. Population density varies widely around the basin, being highest along the southern coast and lowest along the eastern one. The Netherlands and Belgium have the highest population density with maxima exceeding 1000 inhabitants km2 while the coasts of Norway and Scotland have the lowest densities with less than 50 inhabitants km2.	Demographic trends in the basin differ from the overall picture for Europe partly due to net positive immigration and fertility trends. To 2035, the population share of children is projected to narrowly increase in Germany and Denmark, with only small contractions in other countries, e.g. the Netherlands. While France is projected to have the 2nd

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

		highest young-age dependency ratio (26.2%) in the EU by 2100.
North-East Atlantic Ocean Countries: Ireland, France, Spain, Portugal	130 million inhabitants in 4 countries. One of the most heavily populated and intensely managed Europe coastlines, with almost a third of EU population living in its coastal zones. Population density is higher on the coasts than inland. Coastal resort towns in the basin experience high seasonal variation in population.	Parts of the basin are projected to experience significant population declines, e.g. 10-20 %, declines projected for Portugal, as well as declines in working age population, e.g. in Spain declines of 12.3pp are both projected to 2100. In other parts of the basin, changes will be increasing urbanisation, and expansion of urban areas to suburbs, e.g. in Ireland.
Arctic Ocean Countries: Canada, Greenland, Iceland, Norway, Sweden, Finland, Russia, and the United States.	4 million inhabitants live in Arctic region, and it has 8 bordering countries. 10% of the population are indigenous peoples. Increasing rates of urbanization particularly in capital cities have been experienced. Most of the countries are already experiencing low birth and death rates. After decades of growth, the population has stabilized, or even declined in some areas.	Increased population concentrations in capital cities is expected to continue due to employment opportunities, creating challenges for sparsely populated areas. There are potential emerging interethnic and social tensions between indigenous traditional economic activities and rural lifestyles, and urban settlements mainly consisting of new migrants' oil and gas extractive industry.

Table 2: Key demographic trends and future developments in European sea basins.

5.3 Coastal governance

5.3.1 Overview

Having introduced the geopolitical and socio-economic contexts in each European Sea Basin relevant to governance of coastal and marine areas, we now turn to an analysis of the key policy frameworks through which governance of adaptation to sea-level rise (SLR) are addressed within the basins. Generally, policy frameworks relevant to SLR governance at the basin level are in place at two levels: the regional level through multilateral agreements between states, and the national level. The latter remains the key level for coastal and marine area management because national policy-makers maintain decision-making authority for planning as well as design, implementation and financing of measures in coastal and marine areas in Europe. A further key dimension of governance is the financing of coastal adaptation and approaches to public finance of coastal adaptation, which are also reviewed below.

5.3.2 Key multilateral policy frameworks governing coastal adaptation

The policy and governance frameworks currently in place to tackle the impacts of climate change on coastal areas include diverse and cross-cutting instruments. At the international level, these mainly include the United Nations Convention on the Law of the Sea (UNCLOS), other Regional Seas Conventions (RSC), and the Integrated Coastal Zone Management (ICZM) process. At the European level, directives such as the Maritime

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

Spatial Planning Directive (Anon, 2014), the Floods Directive (Anon, n.d.), and the Marine Strategy Framework Directive (Anon, 2008) are relevant policies about climate resilience in coastal zones. Furthermore, aiming to make the adaptation process more systemic, the 2021 EU Strategy on Adaptation to Climate Change recognises the importance of addressing climate impacts and resilience in all sectors and areas, including coastal zones.

UNCLOS is the international agreement which sets forth the legal framework for all activities on the oceans and seas. UNCLOS defines the rights and responsibilities of States with respect to their use of the oceans and establishes principles of protection of the marine environment, including the ecosystem-based approach, the precautionary principle and sustainable development. UNCLOS provisions approaches the limits of maritime zones and the rights of passage and navigation through them, establishing principles on how States should determine the breadth of the maritime zones.

It also institutes mechanisms for achieving and maintaining peace and security of oceans and seas, for undertaking the conservation and management of marine living resources, for protecting and preserving the marine environment, for undertaking marine scientific research and for settling disputes regarding activities on the oceans. Regarding climate change and SLR, this legal framework is mainly relevant due to legal implications of sea level rise on baselines from which the outer limits and boundaries of maritime zones are determined (e.g., some parts of the world may witness a substantial shift in the configuration of the coasts, which can consequently affect base points and baselines). UNCLOS is one of the most widely ratified treaties under the international law framework and is currently a legally binding instrument for 168 signatories, including the EU.

The Regional Seas Conventions (RSC) are cooperation structures set up to bring together States and neighbouring countries that share marine waters to protect the marine environment of a specific region. These instruments are part of the United Nations Environment Programme (UNEP) Regional Seas Programme, and they provide inter-governmental frameworks to address the ecological degradation of the oceans and seas at a regional level. While in an initial phase they focused on sea pollution, they currently have been embracing the ecosystems approach to managing marine resources. There are also different protocols annexed to these treaties, including those on integrated coastal zone management (ICZM) through which one can address disaster reduction and climate change adaptation issues. Table 3 summarizes the existing global, European, and regional conventions and treaties that are directly or indirectly related to SLR and climate change management. Note that "soft law" refers to non-binding norms, principles, standards, or guidelines that are used in international law and international relations.

	Type of Instrument			**Objective**		
Instrument	**International or regional?**	**Sea Basin**	**Legally binding or soft law instrument?**	**Main objectives**	**Specific measures on coastal adaptation?**	**Specific information on SLR**
UN Convention on the Law of the Sea (UNCLOS - 1982)	International	All	Legally binding	Defines the rights and responsibilities of States in their use of the seas and oceans.	No	· SLR could have legal implications on baselines from which the outer limits and boundaries of maritime zones are determined

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

Agreement under the UNCLOS on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (i.e., High Seas Treaty)- Draft agreed on 4 March 2023, to be adopted	International	All	Legally binding	Conserving and ensuring sustainable use of biodiversity of the ocean areas beyond national jurisdiction (ABNJ)	No	N.a.
OSPAR Convention (1992)	Regional (Regional Sea Convention - RSC)	North-East Atlantic Ocean	Legally binding	Cooperation for the protection of the marine environment Addressing biodiversity loss, pollution, and climate change	No	N.a
Helsinki Convention (HELCOM - 1992)	Regional (Regional Sea Convention – RSC)	Baltic Sea	Legally binding	Protect the Baltic Sea from all sources of pollution, preserve biological diversity, and promote the sustainable use of marine resources	No	N.a
Barcelona Convention (1995)	Regional (Regional Sea Convention – RSC)	Mediterranean Sea	Legally binding	Ensure sustainable management of marine and coastal natural resources; prevention and reduction of pollution	Partially (Integrated Coastal Zone Management Protocol - ICZM)	N.a.
Bucharest Convention (1992)	Regional (Regional Sea Convention – RSC)	Black Sea	Legally binding	Cooperation to protect the coastal and marine environment in the Black Sea; prevent, reduce and control the pollution	No	N.a.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

EU Strategy for the Baltic Sea Region (2009)	Regional	Baltic Sea	Soft law	Improve sea basin governance; ensure a good environmental and ecological status of the marine and coastal areas	No	N.a.
EU Strategy for the Adriatic and Ionian Sea Region (EUSAIR – 2014)	Regional	Mediterranean Sea (Adriatic and Ionian Seas)	Soft law	Improve sea basins governance; ensure a good environmental and ecological status of the marine and coastal areas	No	N.a.
Black Sea Synergy Initiative (2007)	Regional	Black Sea	Soft law	Strengthen cooperation on good governance, environment, maritime policy and fisheries	No	N.a.
Atlantic Maritime Strategy (2014)	Regional	North-East Atlantic Ocean	Soft law	Unlock the potential of blue economy while preserving marine ecosystems and addressing climate change. Protect, secure, and enhance the marine and coastal environment; to create a socially inclusive and sustainable model of regional development	No	N.a.
Trilateral Wadden Sea Cooperation (1978)	Regional	North Sea	Soft law	Protect and conserve the Wadden Sea as an ecological entity through common policies and management. Monitor and assess the	Despite SLR is recognized as a major challenge, no specific adaptation measures are addressed in its regard	N.a.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

				quality of the Wadden Sea ecosystem in collaboration with national and regional authorities		
Marine Strategy Framework Directive (MSFD – 2008/56/EC)	Regional		Legally binding	Requires each coastal MS to develop a strategy to prevent and restore damaged ecosystems to Good Environmental Status (GES)	No	N.a.
Marine Spatial Planning European Directive (2014/89/EU)	Regional		Legally binding	Makes Maritime Spatial Planning (MPS) mandatory for all coastal MS. Promotes the sustainable growth of maritime economies and areas	No	N.a
Bologna Charter (2012)	Regional	Mediterranean Sea	Soft law	Promotion of a common framework for strategic actions aimed at the protection and sustainable development of Mediterranean coastal areas	Yes A Joint Action Plan (BC -JAP) issued in the framework of MED capitalization program (COASTGAP) proposing a strategy for assisting adaptation in the Mediterranean coastal region	· the Joint action Plan includes: supporting the design of structural works for coastal protection and adaptation to climate change, fostering adaptive management solutions and structural works for enhance the resilience of coastal systems, the individuation, access and efficient use of funding frameworks from the European to national and regional scale.
EU Strategy on Adaptation	Regional		Soft Law	Reinforce the adaptive	Yes	It states that "slow onset sea level rise

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

to Climate Change (2021)				capacity of the EU and minimise vulnerability to the impacts of climate change Stepping up adaptation planning and climate risk assessments	(It recognizes the importance of closing the gap on climate impacts in all sectors, including coastal areas) · Promotion of blue-green nature-based solutions for coastal adaptation	is an increasing worry for coastal areas, which produce ~ 40% of the EU GDP and are home to ~40% of its population. Losses are distributed unevenly, harming regions that may already face challenges like low growth or high youth unemployment."

Table 3: Key coastal Policy Frameworks: main objectives and relevance for SLR

From a legal standpoint, the International Law Commission of the United Nations General Assembly A/CN.4/761 (Anon, 2023) signals some relevant upcoming challenges related to sea level rise, such as the legal stability regarding baselines and maritime zones delimitation, effects of the situation whereby an agreed land boundary terminus ends up being located out at sea, and the consequences of when overlapping areas of the exclusive economic zones of opposite coastal States, delimited by bilateral agreements, no longer overlap. The exercise of sovereign rights and jurisdictions of coastal states is also of note, since historic waters, titles and rights and the permanent sovereignty over natural resources can be impacted by sea level rise with possible loss or gain of benefits by third States. Within statehood issues, sea level rise stresses concern on the practice on the requirements for the configuration of a State as a subject of international law and for the continuance of its existence, as is the case of the status of submerged islands, for instance. Regarding the protection of individuals, impacts of sea level rise point out to issues of nationality, international security, forced migration and human rights violations. In this sense, the regulation of displacement and statelessness, as well as the international cooperation on humanitarian assistance are concerns which will require further elaboration under international law.

Furthermore, sea level rise has the potential to significantly impact the spatial extent of national claims to maritime jurisdiction and change to low-water line along the coast. This physical shift poses legal fundamental questions of how to deal with the jurisdictions of territories losing their lands and the pushback of the limits of the maritime zones, how to react if the current baseline moves inland as a consequence of sea level rise, if water previously under national jurisdiction could become part of the high seas, and finally if the changes to the baselines should impact maritime boundaries between States with oppose or adjacent coasts. No single agreed solution to address these issues has been achieved so far. However, tools such as the further development of customary international law, protocols for the United Nations Framework Convention on Climate Change (UNFCCC), amendments of the provisions of UNCLOS, interpretations of the new Treaty of the High Seas, namely the Marine Biodiversity of Areas Beyond National Jurisdiction (BBNJ), adopted in

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

2023, and the Advisory proceedings on climate change may guide international legal responses to rising sea levels in the future.

Box 1: Emerging challenges of sea level rise for international law

5.3.3 Key national policy frameworks governing coastal adaptation[i]

Climate adaptation has become a policy theme for national governments in the last decades. In Europe, already in 2013, the European Commission's Adaptation Strategy moved adaptation up the policy agenda for member states. Although non-binding, the Strategy prompted Member States to develop their own adaptation policies, and to date, all Member States have approved a national adaptation strategy, a national adaptation plan, or both.

Yet, while there are concrete policy outputs at the national level for climate adaptation in general in all European members states, assessing the state of coastal adaptation in particular in the 22 maritime Member States[4] remains challenging. The approaches that countries take to coastal adaptation policy differ between countries according to their institutional arrangements and specific geographical and social circumstances. For example, coastal adaptation may be embedded in general climate adaptation policies or strategies as well as in sectoral or location specific (i.e. sub-national) policies, strategies and plans.

In order to assess progress at the national level on coastal adaptation, we therefore focused on two reporting mechanisms for climate adaptation and planning in marine areas that make available comparable information on coastal adaptation governance across different countries at the national level. These mechanisms are, first, the EU governance monitoring framework, which makes available county progress on climate adaptation policies through the climate-ADAPT platform. Second, the Maritime Spatial Planning platform, which reports on country progress of Member States in implementing the Maritime Spatial Planning Directive (Anon, 2014) that explicitly calls for planning to consider the impacts from climate change and to design interventions that are "resilient" to its effects.

Table 4 shows the results of this analysis reporting on the observations and future projections of SLR hazards in each country, the status of its coastal adaptation policy, and the status and context with respect to SLR of its MSP policies. Generally, the information reported by the countries shows that sea level rise already affects and is expected to impact almost all EU coastal countries. Indeed, many Member States identified sea level rise and coastal erosion as major hazard currently and in the future, with only Bulgaria and Cyprus not reporting future hazards associated with SLR. Despite this, not all coastal adaptation plans nor MSPs include measures to adapt to sea level rise. Indeed, only 5 countries include specific measures to adapt to SLR in their coastal adaptation policies. Slightly more, 10 out of 22 countries, include SLR adaptation measures in their MSPs, indicating the significance of MSPs as a coastal adaptation policy instrument, however this remains relevant low (less than half of countries) in terms of overall inclusion of SLR adaptation measures. 9 out of 22 countries do not yet include SLR adaptation measures at all in coastal adaptation policies and MSPs. Table 4 thus shows an observed lag

[4] We consider the 27 EU Member States, with the exclusion of Austria, Czech Republic, Hungary, Luxemburg and Slovakia.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

between recognizing the risk of SLR and taking adaptation action at the national level. These results are consistent with recent analysis of OECD countries' coastal adaptation policies, which found that states often first adopt an information provision strategy regarding coastal risks, while policies that allocate funds for protection and SLR risk reduction are slower to emerge (OECD, 2019).

Country	Sea Basin	Reported chronic hazards		Coastal Adaptation Policy			Maritime Spatial Planning	
		Observed	Future	Strategy adopted?	Is there a list of measures?	Measure addressing SLR?	Is enforced?	Does it address SLR?
Belgium	North Sea and Arctic	SLR Coastal erosion	SLR	YES	YES	NO	YES	YES
Bulgaria	Black Sea	Coastal Erosion	-	YES	YES	NO	NO	n.a.
Croatia	Mediterranean Sea	SLR	SLR	YES	NO	NO	NO	n.a.
Cyprus	Mediterranean Sea	Coastal erosion	-	YES	NO	NO	NO	n.a.
Denmark	North Sea and Arctic & Baltic Sea	SLR Coastal erosion	SLR Coastal erosion	YES	NO	NO	YES	NO
Estonia	Baltic Sea	SLR Coastal erosion	SLR Coastal erosion	YES	YES	YES	YES	YES
Finland	Baltic Sea	SLR	SLR	YES	YES	NO	YES	NO
France	Atlantic Coast and Mediterranean Sea	SLR Coastal erosion	SLR Coastal erosion	YES	YES	NO	YES	YES
Germany	North Sea and Arctic & Baltic Sea	SLR Coastal erosion	SLR Coastal erosion	YES	YES	YES	YES	NO
Greece	Mediterranean Sea	Coastal erosion	SLR Coastal erosion	YES	NO	NO	NO	n.a.
Ireland	Atlantic Coast	SLR	SLR	YES	YES	YES	YES	YES

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

			Coastal erosion	Coastal erosion					
Italy		Mediterranean Sea	SLR Coastal erosion	SLR Coastal erosion	YES	NO	NO	NO	n.a.
Latvia		Baltic Sea	SLR Coastal erosion	SLR Coastal erosion	YES	YES	NO	YES	YES
Lithuania		Baltic Sea	SLR Coastal erosion	SLR Coastal erosion	YES	YES	NO	YES	YES
Malta		Mediterranean Sea	SLR Coastal erosion	SLR Coastal erosion	YES	NO	NO	YES	YES
Netherlands		North Sea and Arctic	SLR Coastal erosion	SLR	YES	NO	NO	YES	YES
Poland		Baltic Sea	SLR Coastal erosion	SLR Coastal erosion	YES	NO	NO	YES	YES
Portugal		Atlantic Coast	SLR Coastal erosion	SLR Coastal erosion	YES	YES	YES	YES	NO
Romania		Black Sea	SLR Coastal erosion	SLR Coastal erosion	YES	NO	NO	NO	n.a.
Slovenia		Mediterranean Sea	SLR	SLR	YES	NO	NO	YES	NO
Spain		Atlantic Coast & Mediterranean Sea	SLR Coastal erosion	SLR Coastal erosion	YES	YES	YES	YES	YES
Sweden		Baltic Sea	Coastal erosion	SLR Coastal	YES	NO	NO	YES	NO

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

				erosion					

Table 4: Assessment of national policies for coastal adaptation and Maritime Spatial Planning policies in Europe.

Source: table developed by the authors based on climate-ADAPT and European MSP Platform[ii].

Beyond the overview presented in Table 4, more granular content analysis of the national coastal adaptation and MSP policies in EU member states provides the following further insights on progress in coastal adaptation policy frameworks at the national level.

First, although many Member States have initiated coastal adaptation actions, most measures address **consolidate knowledge and reduce uncertainty**, as well as measures for improving the governance and institutional capacity, a good example is provided by the National Adaptation Plan of Spain highlighting the necessity of improving the regulatory framework to facilitate adaptation on coasts and at sea (see Sea Level Rise in Europe: adaptation measures and decision-making principles, section 4.1). There are however some examples of member states already implementing concrete SLR adaptation measures. For example, Belgium issued a Royal Decree establishing the marine spatial planning for the period 2020 to 2026 in the Belgian sea-areas. The decree stipulates that an entire island is dedicated to testing innovative solutions for coastal defense, such as seawalls to contain future rising sea levels (Belgian Government, 2020).

Second, concerning the **coastal adaptation governance modes** in place for coastal adaptation, Member States differs substantially in governance modes according to their different institutional architectures. Coastal adaptation requires coordination, both vertically between central governments and sub-national bodies such as regions or municipalities, and horizontally between adjacent regions and central authorities with specific sectoral competences, and this plays out differently according to the institutional arrangements in member states. **Vertical coordination modes** occur in a number of member states. In Belgium, for example, the federal government delegates the three regions to draw up specific local adaptation plans. Denmark also adopts a form of vertical coordination, but with a direct relationship between the state and municipalities. The 2012 Danish national adaptation plan does not include direct action to address sea level rise, but it stipulates that municipalities develop a local adaptation plan that requires coastal municipalities to manage SLR risks. The central government provides supports in terms of information such as the web portal Klimatilpasning.dk and the yearly State of the Environment Report (CMCC, 2021)(Miljøtilstand.nu) by the Danish Environmental Protection Agency, which includes a chapter on climate change and SLR. Italy provides another example of vertical coordination between central state and regions for coastal adaptation. The Italian Constitution recognizes the legally binding competences of Italian regions regarding spatial and territorial management. However, the Italian National Adaptation Strategy (Ministry of Environment and Energy Security, n.d.) does not prescribe specific actions for the regions, and thus there remain some lack of clarity regarding adaptation competencies between different levels of government. The National Adaptation Plan (Ministry of Environment and Energy Security, 2023) aims to set out these responsibilities, however it is not yet approved. Despite these barriers, the constitutional legal structure has provided a sufficient basis for fruitful cooperation between the central state and the regions in coastal erosion management (see Box 4). Further, a set of regional coastal adaptation plans have been developed both as part of this collaboration and under the Integrated Coastal Zone Management protocol adopted by the Barcelona Convention (CMCC, 2021).

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

For **horizontal coordination modes,** The Netherlands provides an example of horizontal coordination. The Dutch climate adaptation action is based on two pillars, the 2016 National Adaptation Strategy (The Netherlands, 2016) and the Delta Programme (Alphen, 2015). Important for horizontal coordination, the Delta Programme, which focuses on flood risk management and adapting the Netherlands to SLR over the long term, has mainstreamed adaptation to SLR into all its decision-making process and measures. For instance, in 2019, the Dutch Government launched the Sea Level Rise Knowledge Programme as part of the Delta Programme, which is an extensive research and development agenda on SLR seeking both to improve forecasting capacity and identify adaptation solutions thus involving coordination across multiple sectors of society. In France, instead, although the National Adaptation Plan does not prescribe specific SLR adaptation measures, the National Strategy includes three recommendations (n. 39-40-41) for adaptation in coastal areas. These recommendations are addressed to a central public authority in charge of coastal management: the national institute for the protection of the coast (Conservatoire du littoral). Finally, Sweden provides an example of **hybrid horizontal and vertical coordination modes**. Collaboration among the county administrative boards (CABs) of Skåne and Halland, the Swedish Geotechnical Institute (SGI) and the Geological Survey of Sweden (SGU) involves four public bodies working together with the different coastal municipalities in the counties of Skåne and Halland to address the problems of coastal erosion and rising sea levels in these areas.

Governance structures play a key role in coping short-and long-term effects of climate change and guaranteeing population's safety. However, in a climate changing scenario, fragmented institutional power, and lack of communication across different levels of the management framework hinder the adoption of cross-cutting and coordinated preventive measures ultimately reducing the adaptive capacity of societies. Moreover, to scale up defenses in a planned manner and mobilizing resources towards climate resilient territories, institutions and governmental infrastructures should align with the most up-to-date scientific knowledge on climate change. In turn, calibrating governance instruments could significantly influence a country's ability to manage climate challenges, which reveals that political-institutional structures may interfere in the level of vulnerability of society (see section 5.3.3).

In summary, national governments are crucial in supporting coastal adaptation to SLR notably by ensuring the relevant actors have the correct incentives and tools to adapt, besides removing potential distortions. Governments should take a proactive approach to improve the co-ordination, efficiency and effectiveness of actions implemented at lower levels of governance. Key areas for improving coastal adaptation involve enhancing the access to information and guidance, ensuring that regulations and economic instruments are coherent, considering climate risks in funding decisions, and monitoring effectiveness of policy interventions (OECD, 2019).[5]

In Italy, the management of coastal areas is a shared competence between all levels of government (national, regional and local) and different sectors of the public administration, resulting in fragmentation and poor coordination in coastal management (Buono et al., 2015). Further, coastal erosion is salient issue with a recent

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

study of Italian coasts exposed to sea level rise found that expected damage from erosion without adaptation to be €219 million per year, with beach loss of ca. 500,000 m^2/year. With relevant adaptation costs estimated as €37.9 million per year, €7.9 million of which for nourishment interventions, resulting in a reduction of expected damage to less than €7 million per year, for each million euro invested in adaptation, about 5 million could be saved through avoided damages (MATTM-Regioni and ISPRA, 2018).

In this context, the Ministry of Environment and Energy Security has initiated coordinated management of coastal erosion risk, through the National Board on Coastal Erosion (MATTM-Regioni and ISPRA, 2018), involving the Italian coastal Regions. One output of the board is the Italian Guidelines for coastal protection from erosion and climate change impacts (MATTM-Regioni and ISPRA, 2018). The document offers an overview of all possible options for managing coastal erosion and provides recommendations for technicians and experts tasked to design interventions to combat erosion. The Guidelines consider previous similar initiatives at the European, national and local level, that represent good practices from the last decades, in line with the EU Directive 2007/60/EC on the assessment and management of flooding and submersion risks.

Box 2:Vertical collaboration scheme without legally binding policies for coastal adaptation: the case of Italy

5.3.4 Coastal adaptation financing arrangements

A major component of coastal adaptation governance is the financing of measures to address SLR. Coastal adaptation presents a major **coastal adaptation financing needs** in Europe. Current estimates of investments needed globally to raise current coastal protection up to standards of the most flood risk intolerant countries are up to US$4 trillion (Nicholls et al., 2019). Moreover, investment needs will increase with socio-economic development and sea level rise (SLR), and could lead to up to $70 billion in annual protection costs globally by 2100, a significant share of which will be in Europe (Hinkel et al., 2014). Further, investments needed to adapt to other sea level rise related risks, such as, salinity intrusion and coastal erosion, will increase these investment needs further.

Meeting these needs is largely a public funding challenge, as governments often have statutory requirements to provide coastal protection, and are otherwise either explicit or implicit insurers of last resort (Bisaro et al., 2020b). Meeting coastal adaptation funding needs is challenging because many coastal adaptation measures generally have high up-front investments costs with benefits from avoided damages materialising over the medium to long-term. Various fiscal instruments are available to fund such measures, including taxation, public debt instruments, e.g. 'green bonds'(Keenan, 2019), as well as cost sharing arrangements with the private sector, e.g. public-private partnerships (Bisaro and Hinkel, 2018).

Funding challenges necessarily involve multiple levels of government because coastal adaptation measures often span multiple scales and jurisdictions beyond the immediate physical location where flooding or other SLR impacts may occur (Woodruff et al., 2020). This can give rise to distributional conflicts across different levels of government, e.g. over who pays for a given measure (Storbjörk and Hedrén, 2011) and between jurisdictions, e.g. over who receives funding for measures (Osberghaus et al., 2010) that can hinder public investments. Barriers to coastal adaptation financing also arise at the local level, where social acceptance of new taxes or levies to fund protection or beach nourishment measures may be low (Mullin et al., 2018), low risk

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

awareness may hinder support for local government finance instruments (Merrill et al., 2018), and there may be a lack of capacity and misaligned performance incentives for local officials (Moser et al., 2019).

One potentially major source of funding for adaptation to SLR in Europe is the European Investment Bank through their Blue Sustainable Ocean Strategy ("Blue SOS"), which aims to improve the health of oceans, coastal environments and increase sustainable economic activity. Through the strategy, the EIB has committed to doubling lending to sustainable ocean projects to €2.5 billion over the period 2019-2023. Further, the EIB aims to mobilise at least €5 billion of investments that contribute to improving the health of oceans. In particular, the "Blue SOS" targets sustainable coastal development and protection and makes finance available through long-terms loans, and other instruments, for governments and the private sector. Further, the facility provides technical assistance to support project promoters in preparing and implementing their sustainable ocean projects.

An example of EIB funded coastal protection projects is the "Protection against coastal erosion - Phase II" project financed from the Cohesion Fund under the Large Infrastructure Operational Program (LIOP) 2014-2020. The project provides significant positive environmental impact and contributes to the protection of the Romanian Black Sea coast from coastal erosion and floods exacerbated by climate change (COASTAL EROSION PROTECTION (FL 2015-0548), 2023), enhancing compliance with EU Environmental Law, in particular the Water Framework Directive, the Floods Directive and the Marine Strategy Directive. The project aims to generate substantial economic benefits, the most important of which are: (i) environmental benefits from improved protection of marine habitats and species within Natura 2000 sites (wetlands) and of freshwater lakes against sea intrusion, (ii) benefits from improved recreational value of beaches, and (iii) avoided costs of damage to properties and infrastructure. In addition to the advisory support, favourable conditions of the EIB loan (i.e. longer maturity and below market interest rate) have a significant impact on the operation (COASTAL EROSION PROTECTION (FL 2015-0548), 2023).

Countries take different **public finance approaches to coastal adaptation**. These approaches can be characterized in multilevel governance regimes along different public planning and fiscal dimensions and their distribution between national (centralised) and local (decentralised levels (Hooghe et al., 2016). Key dimensions of characterising public finance approaches to coastal adaptation have been developed in Bisaro et al. (Bisaro et al., 2020a), and include the following dimensions:

- **Setting strategic goals**: Which levels of government (co-) determine the medium to long-term goal for coastal risk management? Authority for such goal setting may be implicit or explicitly defined, e.g. through establishment of a statutory body for goal setting. Typical goals are: protect, accommodate, retreat, avoid.
- **Set coastal flood safety rules:** Which levels of government (co-)determine rules for coastal flood safety? Typical types of rules are: flood safety norms, funding rules, planning regulations.
- **Designing coastal adaptation measures**: Which levels of government (co-) determine the design of individual measures? Project design may be carried out by national level implementing agencies, by designated local authorities, or by entities comprising several levels of government, often in consultation with citizens/stakeholders at the coast.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

- **Fiscal control**: Which levels of government (co-)determine the total budget for coastal adaptation, and dedicated tax revenues, i.e tax base and rates? General revenue taxes, and dedicated coastal flood risk reduction levies, may be set by national, regional or local governments depending on tax legislation.

Table 5 shows several examples of coastal public finance arrangements within Europe. Even within this sub-set of examples, there are a range of approaches to financing coastal adaptation from centralised approaches (e.g. NL, Spain (López-Dóriga et al., 2020) to more decentralised approaches (e.g UK). Further, there are hybrid approaches, such as in Germany, where along some parts of the coast a centralised approach is taken on at the Federal State level, e.g. in Schleswig-Holstein at the Baltic Sea, while for other parts of the coastal financing and decision-making is devolved to the local level.

Italy represents another interesting case of hybrid approach, which is somewhere between a centralized and federal system of government. The central State has devolved to the Regions the competence on territorial management including coastal areas and to the River Basin Authorities the competence on flood risk management. These competences are shared and sometimes overlapping, which can in some cases lead to fragmentation (see table 5).

		Set strategic goal	**Set coastal flood safety rules**	**Design measure**	**Fiscal control**	
					Set public investment budget	**Set tax base and rates**
Netherlands		National	National (regulate)	National	National	National
United Kingdom		National-Regional-Local	National (Incentivise)	Local	National-local	National-local
Germany	Schleswig-Holstein	Regional (state dikes)	Regional (regulate)	Regional	National-regional	Regional
Spain		National	National	National-local	National	National
Italy		Regional	Regional	Regional	Regional	National Regional
		Hybrid national-regional bodies (Basin authorities)	Hybrid National-Regional bodies (Basin Authorities)	Hybrid National-Regional bodies (Basin Authorities)	National	National

Table 5: Coastal adaptation decision-making and fiscal arrangements in multilevel governance systems in Europe

Beyond public finance arrangements for coastal protection and risk management in general, some countries have dedicated funds for addressing the increasing risks and associated costs of adaptation due to SLR. In France, the national government provided EUR 500 million to fund flood prevention measures, particularly in coastal areas, through the National Flood Plan ("plan submersions rapides"). The United Kingdom has established a GBP 2.6 billion six-year capital investment programme (2015-21) to reduce flood and coastal risk, which the 2nd National Adaptation Programme estimates will provide over GBP 30 billion in overall economic benefits (e.g. reduced damages) and benefit 300 000 households by 2021 (Defra, 2018). In Germany, a special instrument (Sonderrahmenplan) to accelerate implementation of coastal protection due to climate change risks was

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

established in 2009, which provides EUR 25 million for all coastal federal states annually until 2025 (EUR 550 million total) (OECD, 2019).

Finally, managed retreat as an adaptation strategy is also receiving increasing attention. To date, in Europe, public financing for retreat or relocation measures, e.g. though buy-outs or compensation of private property owners, has however been implemented only in fragmented way through small scale pilot projects, e.g., in the UK (Atoba, Kayode O. et al., 2021) or Germany (de la Vega-Leinert et al., 2018). While public finance for such strategies can be rationalised on the basis of reducing overall costs of coastal protection to the public purse, it is important to consider the distributional implications of housing availability and affordability, employment opportunities and facilitating collective relocation processes, when implementing managed retreat strategies (Braamskamp and Penning-Rowsell, 2018). Buyouts and managed retreat programs should be carefully designed to avoid creating or exacerbating existing socio-spatial inequalities, particularly by ensuring that retreat does not disproportionately affect already disadvantaged areas, both in terms of areas that retreated from, and areas that will receive inmigration from retreat initiatives. Additionally, providing practical and psychological support during the relocation process is essential in alleviating feelings of loss and addressing cultural and psychological impacts (Dannenbarg et al., 2019) (see section 5.3.3).

Finally, several observations can be made regarding the **outlook for coastal adaptation finance under future sea level rise**. SLR is likely to increase the costs of maintaining current protection levels and coastal adaptation costs more broadly. This has several implications for coastal adaptation public finance arrangements. First, centralised public finance arrangements that exhibit little overlap between coastal adaptation beneficiaries and funders are likely to come under increasing pressure from SLR. For example, centralised funding arrangements in Germany entail a significant re-distribution of federal funds to coastal Federal States for building and maintaining State Dikes. As SLR increases the significance of this re-distribution in the national economy, these arrangements may be reconsidered. Relatedly, hazard-based flood safety standards as currently used in Schleswig-Holstein, which maintains State Dikes that protect up to a 1-in-200-year flood hazard event, may also be reconsidered in favour of risk-based safety standards due to rising protection costs under SLR. Risk-based standards weigh the costs of protection against the value of protected assets and thus are more economically efficient. Second, under SLR, decentralised arrangements may lead coastal communities to be overwhelmed by the increasing financial burden from SLR due to budget and capacity constraints (Moser et al., 2019), and resistance from local vested interests to raising new funds (Beatley, 2012). Finally, across all decentralised arrangements, coastal adaptation measures other than protection (such as retreat) are likely to become more important, as the costs of protecting the coast will outweigh the benefits particularly in rural areas (Lincke, Daniel and Jochen Hinkel, 2018).

5.4 Complexity and challenges

Despite the similarity in coastal issues facing SLR, complexity in adaptation approaches derives from the great variety of the considered coastal setting, such as in physical (processes), socio-economic (development and activities) and administrative terms (governance), and from intrinsic uncertainties in sea level rise estimates.

A major source of uncertainty for long-term policies, in fact, is the assessment of SLR at the regional to local scale. Indeed, regional and local differences in changes in mean and extreme sea levels can be observed along the

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

European coasts due to different processes (see Sea Level Rise in Europe: observations and projections, section 4). Thus, despite IPCC being the most reported source of climate information in SLR planning in Europe (McEvoy et al., 2021), and recognising that global SLR information does contribute to advance in local agenda setting and awareness raising (Brian Blankespoor et al., 2023), global projections are not suitable for all basins/sub-basins. The reconstruction of coastal vertical movements and of the local sea level variability at the sub-basin scale (see, for instance, (Meli et al., 2023); (Oelsmann et al., 2023) is crucial for supporting local/regional hazard assessment and related mitigation/adaptation policies. Addressing these challenges relies on the development of adaptive planning approaches, integrated with monitoring activities able to capture signals that may suggest update or change in the plans and that allow to verify their effectiveness (see section 5.3.1). Cross-domain and cross-sectoral coordination is essential and should be based on the involvement of stakeholders and local communities in planning local adaptation, also through participative processes (see section 5.3.2). Furthermore, distributive and procedural justice challenges as well as vulnerability issues are also essential to address when designing and implementing the adaptation policy framework (see section 5.3.3).

5.4.1 Time horizon and uncertainty

The rate, timing and amount of sea level rise over longer time horizons (roughly, beyond 2050) create deep uncertainty for decision makers in coastal areas (van den Hurk et al., 2022). Traditional planning time frames and tools (e.g. economic assessments to compare alternative actions) and conventional political systems are typically not well suited to address long-term and uncertain risks, when balancing clear, near-term policy objectives. Public support also tends to prioritize current needs while undervaluing long-term risks. For example, developing coastlines is an attractive proposition in many parts of Europe, where demand for housing in coastal areas is high. However, further development of vulnerable coastlines creates a lock-in to protect assets against increasing risks from sea level rise in the future. This challenge is illustrated in the case of nuclear reactors planned on the French coast.

Long time horizons and uncertainties in the timing of sea level rise on local coastlines are especially relevant for long-lived infrastructure, such as new generation nuclear plants. France is planning to add new nuclear reactors in two coastal plants: Penly, in Normandy, and Gravelines, close to the Belgian border. The expected lifetime of these nuclear reactors is at least 60 years, not including construction and dismantling. Hence, these plants will still be in place in 2100, when scenarios well above 1 m of sea level rise cannot be excluded if a collapse of marine ice sheets in Antarctica is initiated. While the decision to implement these two reactors was announced by the national government in February 2022, the following year, the national chamber of accounts raised the issue that flood risks induced by sea level rise will be different in the two locations: in Penly, the nuclear reactors are located 11 m above sea levels on the toe of a chalk cliff, whereas in Gravelines the plant is located in a polder area, largely below sea levels at high tide. In Gravelines, flood damage may not directly affect the plant itself, but could compromise access through road damage, posing challenges to safe operation. There is currently no evidence that high-end scenarios involving ice sheet collapse are considered in territorial adaptation plans in the area of Gravelines, nor signals that the plans in Gravelines may be canceled or amended due to consideration of high-end sea level rise. If the decision is confirmed, it will result in a long-term legacy that could lock-in investments for coastal protections in the Gravelines area for several generations. However, a positive decision would also create immediate and near-term

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

economic benefits for the territory via the construction and operation of the new reactors, and support France's current energy and climate policy objectives.

Box 3: Case 1 nuclear reactors: Lock-in & balancing near-term benefits & long-term risks

Strategies for addressing uncertainty in long time horizons, such as dynamic adaptive policy pathways link near-term actions with keeping long-term options open, to avoid mal-adaptation or lock-in under future climate or socio-economic conditions. The Dutch Delta Program (Alphen, 2015) and the Thames Estuary 2100 (Ranger et al., 2013) are two well documented cases of adaptation pathways in practice. A challenge in implementing adaptive planning methods is establishing and operationalizing a mechanism to monitor for locally relevant signals that indicate when it is time to consider a new action (Haasnoot et al., 2018). Existing governance and institutional structures are typically designed for 'predict-and-act' planning and are less suited to adaptive planning, which requires trusted knowledge holders, a monitoring program, a relatively stable political environment that respects established processes, and often, the integration of different agencies (e.g. coastal authorities, spatial planning, environmental protection) (Hermans et al., 2017). The Dutch Delta Program and the Thames Estuary have both implemented long-term, comprehensive monitoring programs in their adaptive planning strategies.

The Dutch Delta Programme takes an adaptive approach that makes use of scenarios, adaptive strategies, and a 6-year review period. The programme also relies on a Signals Group of independent, multi-disciplinary experts who advise the Delta Commissioner annually on external scientific and societal trends and knowledge relevant for the programme. This *anticipatory* monitoring should signal when a change to the (adaptive) strategy may be needed. A separate, *retrospective* Monitoring Group monitors the implementation and effectiveness of the plan.
In line with knowledge at the time, in 2014 the Delta Commissioner proposed adaptation to prepare for SLR of 0.3–1.0 m in 2100 (relative to 1990). In 2017, the Signal Group advised exploring the accelerated SLR scenarios and the implications for the Dutch Delta. This triggered a 2017 study on the topic, followed by an inventory of strategies to deal with accelerated SLR, in 2019. These strategies are currently elaborated in a dedicated SLR Knowledge Programme.

Box 4: Dutch Delta: Monitoring for signals in adaptive planning

Accounting for potential long-term risks while making near-term decisions and keeping future options open is critical to avoiding lock-in and maladaptation. This can be achieved in different adaptation strategies. For example, protective measures, such sea walls can be built with a larger foundation than needed for the current protection height to allow the walls to be raised easily under higher amounts of sea level rise. By contrast, preventative actions, like restricting development of coastal zones, land buyouts and short-term land-use arrangements can avoid lock-in (see Sea Level Rise in Europe: adaptation measures and decision making principles, Box 1).

Most countries in Europe use 2100 as the long-term horizon for sea level rise planning (McEvoy et al., 2021). However, time to plan and implement adaptation strategies often takes decades (Haasnoot et al., 2020). The MoSE barrier timeline illustrates that it took over 50 years from an initiating event to a fully operational system, in 2020 (IPCC AR6, WG2 Ch13). Recent studies suggest that under high emission scenarios, closures of

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

the barrier for more than 2 months per year are virtually certain by the 2080s and closures of 6 months per year are likely by the end of the century (Lionello et al., 2021).

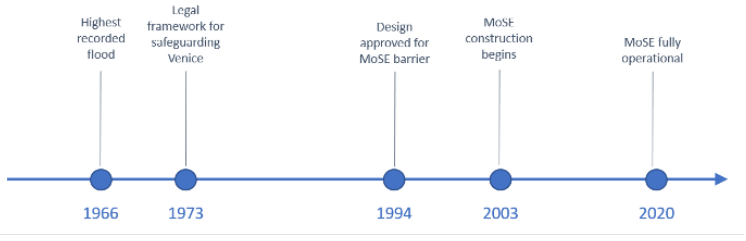

Figure 1: The timeline of milestones in the lead, design, construction and operationalization of the MoSE barrier, in Venice, illustrates the significant time to implement large scale adaptation to sea level rise.

The long lead times required by especially large-scale adaptation may require taking decisions before there are clear signals. Accelerated sea level rise could further reduce the window to act (Haasnoot et al., 2020). In cases where retreat is a plausible future adaptation strategy, decision makers often face the need to take preparatory action or decide whether to continue investment in the area, long before public opinion may recognize the need for retreat. However, early action can allow more equitable and managed retreat in the long run (Haasnoot et al., 2021).

At the European level, preparedness and disparities in adaptation planning for SLR vary significantly across countries. Despite having significant populations living in low-lying coastal areas many EU countries are either not planning for SLR (e.g., Bosnia and Herzegovina, Latvia, Malta, Montenegro, Romania, Slovenia, Ukraine) or are considering relatively low projections (i.e., less than 0.65m by 2100, including countries like France, Italy and Spain). Most countries are adopting a low-regret approach and considering SLR estimates that occur in all projections independent of climate and emission scenarios - i.e., between 0.15 and 0.35m by 2050, including Albania, Croatia, Cyprus, Denmark, France, the Netherlands, Norway, Portugal, Spain, Ukraine.

5.4.2 Cross-scale and cross-domain coordination

Both vertical (national to regional-local) and horizontal (inter-sectorial, cross-regional and interdisciplinary) coordination mechanisms are the base for integrating adaptation into sectorial policies and for shared management of responsibilities at multiple administrative levels. As indicated in section 5.2.2, at the European level some Member States have established national coordination bodies dealing with intersectoral policy coherence, or regulatory mainstreaming of adaptation into sectoral policies (EEA, 2022). These coordination processes play an essential role in supporting local governments to develop and implement local adaptation strategies and action plans. Nonetheless, extensive effort is still required by local authorities to initiate, support, foster knowledge transfer and exchange of information within the area through consultations including academic institutions and stakeholders. Co-development processes are essential in these contexts. An example of local adaptation plan developed in collaboration with the research community is the case of Ravenna Municipality (see Box 7). To be effective, such plans require a strong commitment to co-creation processes with the wider community of stakeholders at the coast.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

In line with the EU initiatives "Covenant of Mayors" and "Mayors Adapt", aimed at promoting environmental policies for the mitigation of climate change impacts towards sustainable and resilient territories, a local adaptation plan has been developed by the Ravenna Municipality in the recent action plan PAESC (Comune di Ravenna, 2020). An effort was made to integrate different competencies and points of view (urbanistic, naturalistic, etc), and to consider the different challenges involved in the coastal sector, such as natural areas and ecosystems, agricultural and touristic activities.

The timeline of the strategic scenario for the proposed adaptation strategies and for the realization of a first "transition stage" is fixed to 2050 (Fig. box.1). The adaptation strategies included aim at enhancing the resilience potential of the territory and, besides the protection of coastal settlements, include: the re-naturalization and reinforcement of the dune and paleo-dune systems, the improvement of the hydraulic network in the internal area and the creation of a "buffer" zone for flooding and salinization processes. This mid-term scenario should allow the identification of main challenges and specific barriers to face and overcome at longer terms.

Fig. box.1: strategic scenario at 2050 of the Ravenna Municipality territory (vertical exaggeration: 10x) (The original source of this figure is Lobosco and Mencarini: Landscape and climate change: a resilient strategy for the adaptation plan of the Ravenna area in Italy. Vol. 13 no. 26, 2023. Available at https://doi.org/10.53681/c1514225187514391s.26.39, last access on January 8th, 2024).

The SebD (*Scenarios' Evaluation by Design*) method has been applied to evaluate the suitability of future adaptation strategies, through the reconstruction of landscape transformation scenarios at 2100 by considering the high-end IPCC RCP8.5 scenario for SLR. In the plan, possible adaptation options are proposed for two particularly critical, low-lying coastal areas of the Ravenna territory, the most potentially exposed ones to marine ingression and local sea level rise. The two areas have high naturalistic-environmental value (both include natural reserve areas) and are located in the southern and in the northern coastal sectors of the Ravenna Municipality. The effects of two different possible approaches have been tested, one more rigid-conservative using pre-existing structures, and the other more dynamic and evolutive. This enabled the evaluation of more suitable mid- to long- term adaptation strategies and related impacts. In the first case, the present setting and location of the territory is intended to be maintained in the future configuration, with a general stiffening of the present coastal defense structures (see, for instance, Fig. box.2a). In the second approach, the geomorphological characteristics of the natural systems should guide an adaptive planning for future coastal land use and ecosystem management. In this case, managed retreat of the coastline (apart from coastal settlements), shift of transitional habitats and the partial

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

transformation in land use (to wetland, marsh and forest areas) is foreseen (Fig. box.2b). This plan should support coastal adaptation decisions, and the future selection of the most suitable adaptive strategies and related territorial transformative processes. Decisions and changes in planning will be also based on integrated, multidisciplinary monitoring activities on the territory, to be scheduled in the next stage of the PAESC with the involvement of academic institutions (University of Bologna).

Fig. box.2: computer-generated images of possible configuration at 2100 (considering the IPCC RCP8.5 projections for SLR) in the southern coastal area of the Ravenna Municipality (Lido di Classe-Lido di Dante), according to: a) a rigid-conservative approach, with maintenance of the coastal defense structures and the coastline position, with a prevalent agricultural destination in internal areas; b) a dynamic and evolutive approach, considering managed retreat of the coastline, the construction of a new dune line and the partial environmental transformation of the territory.

Box 5: Ravenna Municipality Visions at 2100 (The original source of these figures is Lobosco and Mencarini: Landscape and climate change: a resilient strategy for the adaptation plan of the Ravenna area in Italy. Vol. 13 no. 26 (2020). Available at https://doi.org/10.53681/c1514225187514391s.26.39, last access on January 8th, 2024).

Cross-cutting challenges are also arise with respect to the involvement of stakeholders and local communities in the processes of planning local adaptation. Challenges include a lack of communication from local authorities to communities leading to a lack of knowledge and understanding, and related negative perceptions of adaptation plans (Buono et al., 2015). Participatory methods (see also Sea Level Rise in Europe: adaptation measures and decision making principles, section 4.2.3) based on the involvement of stakeholders (citizens, local communities, public administration and companies, private companies, working activities, coastal users, local associations and

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

NGO's) can enhance communication and facilitate collaboration and consensus-building (Carbonnel, P. and Richard, A., 2010). Communication, consultation and outreach are thus fundamental steps in the process of developing and implement local coastal adaptation. The case of Texel (Box 8) provides an example of the need for effective communication and co-development processes involving both coastal management experts and local communities.

Another aspect of cross-level and cross-domain challenges in coastal adaptation governance is the governance of critical infrastructure, such as ports, which play a key role in the economic activity beyond the coast. Ports play a crucial role in a nation's economy by serving as vital gateways for international trade, facilitating the movement of goods and fostering economic growth (international shipping transports more than 80% of the global trade all over the world, according to the International Maritime Organization (IMO). Due to their location on the coast, **ports are particularly vulnerable to climate change,** including rising sea levels combined with changes in the waves and wind regime, or the frequency and intensity of storms. These changes may turn into an increased average time of operations disruption, potential damage to infrastructures and higher maintenance costs, impacting trade flows and the overall economy. Increase in the size of ships over the last years may aggravate these effects as greater draughts and construction of new and more exposed infrastructures are required.

Potential impacts of rising sea levels on port operations include the frequent interruption of coastal low-lying road and rail due to storm surges and flooding of terminal areas, more frequent flooding and potential damage of infrastructure in low lying areas, erosion of infrastructure support and changes in harbour facilities to accommodate higher tides and surges (UNCTAD, 2022). Further, changes in the tide and higher water level fluctuations are expected to cause periods of extreme low water levels on key inland waterways such as the Rhine in Europe or the Yangtze in China, with a negative effect on vessels loading and navigation planning.

It is therefore essential to **enhance ports resilience** and minimize the adverse effects of climate change on their economic contributions. Individual risk analysis and adaptation measures must be considered for each port dependent on its oceanographic, meteorological and environmental conditions, coastal topography, relevant activities and proximity to urban areas and other natural ecosystems. On the other hand, **ports governance systems are complex** and vary around the world, from ports publicly owned and operated by government entities, allowing for direct control and coordination of port activities, to landlord models, where the government or port authority owns the land and infrastructure but contracts out operations to private companies, or fully privatized ports where private companies own and manage all aspects of port operations. There are therefore scientific, technical, socioeconomic and governance challenges, some of them shared with other economic sectors, and others specific of the port activity, yielding to adaptation strategies that may differ significantly from one country to another. The effort made by Spain is a good example of such complexity and related cross-domain impacts of SLR.

To maintain the coast, to protect land from flooding by the sea, and to build infrastructure that provides the desired living environment now and in the future, Dutch coastal management has traditionally involved collaboration between different social actors and decision-makers (Avoyan and Meijerink, 2021; Lodder and Slinger, 2022). Indeed, decision-making along the coast has faced challenges in embracing local knowledge and moving towards innovative or potentially equitable solutions (Slinger et al., 2022). Given that inputs of professional experts are

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

necessary in designing coastal solutions to fit the social, ecological and technical requirements of the local environment along the Dutch coast, the question of how to balance stakeholder perspectives with scientific information when seeking effective solutions becomes salient.

In two case studies on Texel, the westernmost island in the Wadden Sea, ongoing coastal management practice was not using locally crafted solutions – although local and regional authorities frequently organise participatory processes and multiple scientific research projects have been running and are ongoing on the island (Vos et al., 2010). Both studies revealed the deep competence of local people, the knowledge that can be harvested to broaden and enrich the design space for coastal solutions, as well as a willingness on the part of the stakeholders to become involved in crafting such local solutions.

The first study was an innovative co-design process on Texel, in which local stakeholders and coastal experts were tasked with seeking an effective solution for the beach erosion problem on south-west Texel. The co-design collaborative process was configured according to theoretically founded principles for participatory design processes (D'Hont, 2020), and consisted of three main workshops between 2016-2017, involving local stakeholders and disciplinary experts (including engineers, geomorphologists, ecologists, coastal managers and governance specialists), to check the feasibility of the visions (cf. (Cunningham et al., 2014; Slinger et al., 2014; Klaassen et al., 2021; Slinger and Kothuis, 2022).

While participants in the co-design process initially proposed innovations in the bio-geophysical system (e.g., nourishment programmes, dredging, re-location of the beach pavilion), later iterations increasingly considered potential adaptations in actor networks and institutions (e.g., renumeration schemes, coalition building). Overall, the co-design process facilitated an appreciation of the social-ecological system complexity inherent to flood defence on the island of Texel and revealed the potential to generate new types of solutions by bringing local knowledge to the foreground in the process.

These findings are consistent with a second case study, in which the role of system understanding in supporting integrated management of a small estuary was explored: the Slufter on Texel. The area includes a sand dike which forms a component of the primary flood defence of Texel, protecting the hinterland from flooding from the North Sea. The results of this study (D'Hont et al., 2014; D'Hont and Slinger, 2022) underline the close knit and well-informed nature of the island community of Texel. For example, citizens know how to access and alert relevant authorities, and local citizens are well-organised and are vocal in stakeholder groups, such as village committees (D'Hont, 2020).

Overall, the need to create environments in which technical experts can engage local knowledge in developing better solutions through co-design was identified. Such environments support the search for environmentally just decisions in the coastal context, enhancing the distribution of benefits while employing inclusive decision-making practices.

Box 6: The Slufter on Texel North Sea: Balancing stakeholder values with scientific information in seeking effective solutions for Texel's coastal problems

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

In Europe, the vast majority of port managing bodies in 2022 are publicly owned (ESPO, 2022). As an example, in Spain the Ministry of Transports defines the port policy and development strategy of the state-owned port system. This is composed of 46 general interest ports administered by 28 Port Authorities (PA), organically dependent on this Ministry through the state public agency Ports of Spain.

In October 2022, a **new Spanish Ports Strategic Plan** was approved, including the development of a climate change adaptation plan for the Ports, aiming to ensure the operability of the physical elements and critical assets, and to anticipate and react efficiently in case of downtime, disruption or operational delays. The plan identifies two goals, aligned with the second Spanish National Climate Change Adaptation (2021-2030): i) the Spanish Port System adaptation plans defined by 2025, with implementation completed by 2030; and ii) a Port Climate Change Observatory including the monitoring of impacts implemented in 2025.
This ambitious plan requires the coordinated effort of Ports of Spain and the 28 Port Authorities, both to implement the new measures and to continue those already initiated. As an example of accommodation adaptation measure, Ports of Spain has successfully implemented an advanced early warning system of essential climate variables in the last decades. This system is composed of one of the most complete observational networks in the country, measuring sea level, waves, currents and other oceano-meteorological variables, with 30 years of data in some cases, and more than 70 operational models forecasting sea level, waves, circulation and wind at regional, coastal and harbour scales. All these data are integrated in the Portus visualization tool and Cuadro de Mando Ambiental: **Environmental Management Dashboard** (CMA) which integrates **additional tools and downstream services to support harbour decision makers and operators.** This activity will be continued and even enhanced, with possible densification of the observational network as required for the climate change observatory at each port. In addition, high resolution models will be a key element for the development of climate projections at the scale required by the ports in the framework of the CC adaptation strategy. This system will contribute to the risk analysis and feed the climate component of the future Port Climate Change Observatory, which will link the oceano-meteorological data with the record of impacts in the ports.

The **future roadmap** builds on experiences of ports in Spain. In 2016 Ports of Spain published, in collaboration with the Spanish Meteorological Agency and other institutions, a vulnerability assessment of Spanish ports to climate change (Gomis and Álvarez-Fanjul, 2016), analysing past trends and future projections of oceano-meteorological variables. Campos et al., 2019 proposed a downscaling modelling methodology for addressing local effects at port scale, which was applied to the Port of Gijón, in the North of Spain. Several lessons have also been learnt from the INTERREG-SUDOE Project ECCLIPSE (ECCPLISPE project, n.d.), led by Valencia Port Foundation with the participation of Ports of Spain, based on the World Association for Waterborne Transport Infrastructure (PIANC) methodology for ports climate change adaptation (PIANC, 2020), applied to the ports of Valencia (Spain), Aveiro (Portugal) and Bordeaux (France). In 2022, the Port Authority of Balearic Islands developed a first climate change adaptation plan for the ports of the Balearic Islands, with scientists and coastal engineers of the University of Catalonia (Sierra et al., 2022).

In the **new roadmap to achieve the Spanish ports strategic goals,** Ports of Spain will include the provision of relevant climate information, ensuring the use of common data and models, the link with the scientific community through the establishment of a group of experts and participation in research projects, and the development of a

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

common methodology and best practices for implementation of the high-resolution risk analysis and adaptation plans at the port level. The final adaptation measures, including the economic, social and environmental impact, will be approved and adopted by each individual Port Authority, relying on the risk analysis and the vulnerability assessment of an inventory of physical assets and port activities. A port community including public and private bodies will be established at each port, for recording climate change impacts at the required spatial resolution, with a user-friendly application that should facilitate reporting to individual port actors. The record of damage to assets or impacts on operations can be sensitive information as it may negatively affect the interests of the affected party (ranging from economic to reputational interests). This element of the **Port Climate Change Observatory** will have to reconcile the principles of transparency and confidentiality of information, providing aggregated analysis that can inform decision-making, while limiting the publication of individualized data, establishing restricted access based on the type of data, or keeping information management within the scope of the Port Authority.

Box 7: Ports climate change impacts and adaptation: status and challenges for the Spanish Ports system

5.4.3 Equity and social vulnerability

The EU adaptation strategy introduced the concept of 'just resilience' to acknowledge that the impacts of climate change are not evenly distributed across society and that benefits from climate adaptation need to be fairly distributed (European Commission, 2021b). This change builds on the rationale of 'leaving no one behind' in the climate mitigation and adaptation agendas. Achieving equal adaptation requires dealing with diverse levels and forms of social vulnerability throughout the adaptation process, ensuring both effective protection of communities and individuals from the adverse effects of climate impacts while avoiding disproportionate consequences of adaptation measures (Brisley et al., 2012; Reckien et al., 2018).

Justice has been emerging as a key criterion for designing and implementing climate adaptation policies that recognize and address existing social vulnerabilities. Environmental justice is widely acknowledged to encompass two main dimensions: distributive and procedural justice (cf.(Schlosberg, 2007):

i. *Distributive justice* focuses on the equitable allocation of burdens, disadvantages, and benefits arising from climate impacts and adaptation efforts among individuals, places, and generations.
ii. *Procedural justice* relates to the fairness of political procedures and decision-making processes related to adaptation, encompassing aspects such as representativeness, inclusion, openness, transparency, and capacity to influence.

Further concepts have also been introduced in adaptation policies, namely recognition and restorative justices. While *recognition justice* focuses on recognising social differences, *restorative justice* highlights the need to identify and respond to those damages that already occurred or where mitigation actions are not anymore possible nor effective (Forsyth et al., 2021). Recently, the concept of *just resilience* in all its dimensions has been addressed by EEA in the report 'Towards 'just resilience': leaving no one behind when adapting to climate change (EEA, 2022).

Given the ever-increasing importance of justice issues for policy and decision making, this section focuses on the challenges posed by ensuring distributive and procedural justice approaches when addressing sea level rise impacts, defining adaptation measures, and designing decision-making processes. These aspects are discussed in-depth below and table 6 presents a summary of how adaptation responses and measures interact with

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

vulnerability factors (re)producing unequitable outcomes. Despite the relevance of justice issues, there is a significant gap both for research and concrete examples at the European level. For this reason, the section is somewhat lacking in regional differentiating and examples. Nonetheless the addressed concepts remain valid for all the European Sea Basins.

Type of adaptation response	Response description and examples	Justice implication	Vulnerability factors	References
Protect/ advance	Building hard (e.g., seawalls) and soft (e.g., beach nourishment and dune rehabilitation) protective structures to hold or advance the shoreline	• Coastal protection prioritizes high-density areas, leading to property devaluation and limited land use options in low-density and underprivileged areas (distributive justice) • Powerful stakeholders having economic interests at risk dominate decision-making, favoring options aligning with their interests (procedural justice)	• Income • Source of livelihood • Absence of access to services and infrastructures	MCGinlay et al. (2021) Hinkel et al. (2018)
Accommodate	Implementing technological, architectural, and urban planning solutions, such as elevating buildings and infrastructures, adapting drainage systems, strengthening monitoring and early warning solutions and insurance schemes to promote safer behavior	• Affordability challenges regarding insurance and proofing measures arise for low-income households, rented households, and non-homeowners (distributive justice) • Elderly individuals and those with lower education levels face challenges in accessing information on coastal risks (procedural justice)	• Income • Home property • Age • Education • Digital literacy	Hudson et al. (2019) Tesselaar et al. (2020)
Retreat	Relocation of infrastructures, exposed houses, neighborhoods, or entire cities	• Relocation disproportionately affects low-income and rural communities, resulting in loss of social ties, negative mental health impacts, and housing challenges (distributive justice) • Lack of psychological and social support exacerbates the sense of loss in managed retreat/relocation (distributive justice) • Decision-making often disregards local priorities, place-specific cultures, and livelihoods, leading to vertically imposed decisions (procedural justice)	• Physical isolation • Physical and mental health • Source of livelihood • Income	Kind et al. (2019) Ciullo et al. (2020) Siders et al. (2021) de la Vega-Leinert et al. (2017) Dannenbarg et al. (2019) Sayers et al. (2022)

Table 6: Box - Interaction of Adaptation Responses and Vulnerability Factors in (Re)producing Inequitable Outcomes

- *Distributive aspects of coastal SLR impacts*

Faced with sea level rise, communities and infrastructures located in coastal areas are expected to face increasing damage and losses due to increased erosion, flooding, and storms (IPCC, 2022). The gradual rise in sea levels and associated impacts from the intensification of extreme weather events will manifest in the form of property devaluation and damage to material assets such as buildings, transport, and energy infrastructures (Lager et al., 2023). Further, natural and infrastructural assets related to tourism, fishery, agriculture, and cultural heritage will also be affected as well as intangible aspects such as place-based knowledge, memories, values, and traditions (Breil et al., 2021).

Communities reliant on coastal resources and infrastructure for their livelihoods, such as coastal tourism-based or agriculture-based communities, may bear the brunt of the consequences of SLR, experiencing not only economic losses due to environmental change (e.g., reduction and changes in use of available land, disruption of

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

coastal ecosystem functioning, soil and aquifer salinization) but also adverse effects on mental well-being due to environmental stress and anxiety related to e.g., loss of income (IPCC, 2022; Foudi et al., 2017).

The distribution and severity of these impacts will not only be influenced by the level of hazard exposure but also by personal and social factors of vulnerability. The housing market often drives lower-income groups towards areas more susceptible to flooding, as these regions offer more affordable housing options (EEA, 2022). In the United Kingdom, coastal communities are frequently characterized by higher levels of deprivation, consisting of low-income groups and elderly populations who may experience declining income, property values, and health because of increased risk (Buser, 2020).

- *Distributive aspects of adaptation measures*

Regarding distributive aspects of SLR adaptation, areas with lower population and asset density are often deemed unsuitable for costly private and public investments in protective infrastructure such as coastal defenses, consequently increasing property devaluation, and insurance pricing while decreasing land use options in already fragile areas (Landry et al., 2003; Hinkel et al., 2018; Paul Sayers et al., 2022).

In this context, coastal defenses are often perceived as socially inequitable, as they tend to prioritize the interests of coastal residents living in high-value areas over spatially distant groups regardless of their socio-economic differences (Cooper and Mckenna, 2008). There are notable disparities in the groups affected by SLR, and the loss of homes or decline in property values will vary among second-home owners and long-term residents. Impacts of declining property values also extend to the loss of social and family ties, negative effects on mental health, and challenges in accessing suitable alternative housing options (Hardy et al., 2017).

Despite adaptation options are increasingly shifting from hazard protection to increasing coastal resilience (van den Hurk et al., 2022), this shift often leans toward a risk-based approach, favoring managed retreat and accommodate options that tend to more negatively affect low-income or marginalized groups (Dannenbarg et al., 2019). Without adequate compensation or support programs, low-income households may face challenges in affording quality flood insurance or implementing flood-proofing measures (Hudson et al., 2019). Moreover, these measures and associated support tend to be available primarily to homeowners and not to those residing in rented or social housing, which often includes the most vulnerable groups in many EU countries (cf. (Tesselaar et al., 2020). Notably, only Belgium, France, Romania, and Spain have implemented public sector initiatives that cover flood risk through an equitable solidarity-based system (EEA, 2022). In addition, some areas at higher risk of flooding are inhabited by populations either unable or unwilling to move to safer locations (EEA, 2020; Filčák, 2012).

Among the factors leading to the unequitable distribution of *adaptation benefits*, scholars raise substantial criticism regarding the narrow use of cost-benefit analysis (CBA), e.g. focusing on the metric of money, as a decision-making tool for adaptation planning. Indeed, CBA is often legally prescribed to determine coastal adaptation options, and when applied narrowly, it can often result in favoring engineered solutions and prioritizing areas with high population and asset density, while disadvantaging poorer and rural areas with lower exposed values, which are often the key focus of managed retreat programs (Kind et al., 2020; Ciullo et al., 2020; Siders et al., 2021). Further, CBA, when narrowly applied, may fail to acknowledge interests and values that are challenging to monetize, neglecting the ecological, socio-cultural, and psychological impacts, such as mental stress from relocation, loss of social ties, place identity, or cultural heritage (Tubridy, et al., 2022; Maldonado,

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

2014). Moreover, managed retreat, nature-based solutions and ecosystem-based adaptation solutions may not fare well in CBA, particularly when high discount rates are applied, due to the initial high costs associated with the latter despite their potential long-term benefits (Bongarts Lebbe et al., 2021).

- *Procedural aspects of adaptation*

Assessing and selecting adaptation measures can involve substantial conflict as adaptation can intensify inequalities and concentrate wealth in certain groups or hurt vulnerable members of society (Sovacool et al., 2015).

Failure to adequately acknowledge and involve vulnerable groups and diverse knowledge systems and interests poses a risk of excluding or not prioritizing options that could benefit the less powerful segments of society. Often options benefitting less powerful segments of society do not reach the agenda, whilst more powerful groups might dominate the discussion and decision and prioritize options that align with their interests and minimize their expenses and losses (Breil et al., 2021).

Therefore, if a 'participatory parity' in decision-making is to be achieved, marginalised groups should be meaningfully engaged in these processes. This involves including and supporting the most disadvantaged individuals in understanding the issues at hand and contributing their knowledge to assess and identify solutions, enabling all groups to have a voice and influence in the assessment, design, and implementation of measures while considering and addressing diverse capacities and power dynamics (Lager et al., 2023). This can be addressed through decision-making approaches that rely on joint fact-finding and co-creation processes to accommodate societal preferences, raise awareness and greater learning, and gain support (Bongarts Lebbe et al., 2021). Such approaches can enable greater consideration in decision-making of often neglected social factors such as local priorities, place-specific cultures, and livelihoods. Such inclusive decision-making aims to balance more technocratic approaches that can perpetuate procedural injustice and may lead to conflicts (Rocle et al., 2020; Tubridy, et al., 2022)

Another challenge for inclusive coastal management and adaptation ensuring that community involvement is initiated at the outset of coastal decision-making processes. Often co-production process are limited to agenda setting and evaluation (Mees et al., 2018). While community consultations may solicit input only on pre-selected options, informed by coastal management professionals and experts' decisions about problem definition or solution finding(Few et al., 2007; Blunkell, 2017). Limiting stakeholder involvement, for example by inviting stakeholders only to select from pre-defined solutions rather than to contribute to scenario building, can risk reinforcing or recreating existing inequalities within new institutional frameworks (Schuerch et al., 2022).

Experiences on the German Baltic Sea coast show that managed retreat can be successfully negotiated to bring benefits to all major parties when conducted with inclusive participation. Stakeholders are prepared to trade some losses for individual and collective gains. In contrast, when such projects are implemented in a top-down manner without involving the affected parties, local opposition can arise (de la Vega-Leinert et al., 2018).

With increasing risks, the burden on public budgets and insurers to absorb impacts will rise drastically over the medium and long term (Ocean & Climate Platform., 2022a). According to the Commission Staff Working Document, the existing insurance systems risks being inadequate in facilitating financial recovery and, at the same time, it may inadvertently encourage the continuation of high-risk developments in vulnerable areas (European

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

Commission, 2018). However, the expertise of the insurance industry in risk assessment and quantification can play a pivotal role in advancing the principles of 'build back better' or even 'build forward better'. Insurers can contribute to strengthen risk information through assessment, communication, and price signaling (European Commission, 2021a). Moreover, insurance systems covering risks separately tend to be less cost-effective compared to single insurance products that address multiple risks, which is crucial given that many cities face compound risks (Ocean & Climate Platform., 2022a). However, not all risks are fully insurable by private or compensated by national funds, as is the case of the Fund for the Prevention of Major Natural Hazard in France that does not count erosion as eligible.

When private insurers can partially or cannot cover relevant risks, governments can consider public-private partnerships, as illustrated by the Storm Council in Denmark (Paleari, S., 2019). Insurance and compensation systems that rely on collective solidarity, such as those based on shared responsibility in France and the Netherlands, or universal flood coverage in the United Kingdom, offer extensive coverage and distribute risks more evenly (European Commission Directorate-General for Climate Action, 2018). Finally, governments can also act by providing tax incentives or subsidies. In this regard, the provision of subsidies and technical support to redevelopment can be planned through community-driven approaches to assess vulnerability and needs (e.g., community profiling at the village or neighbourhood level) to identify vulnerable subjects, sites for redevelopment, and oversight redevelopment in a bottom-up process (Breil et al., 2018).

Box 8: Addressing distributive justice in insurance scheme

Climate change litigation is an emerging field that raises legal or factual issues relating to climate change before adjudicatory bodies (Sabin Center for Climate Change Law and Columbia Law School, n.d.). These cases have spiked in recent years, and currently there are about 300 climate cases in around half of European countries, making European courtrooms increasingly relevant to address climate change (United Nations Environment Programme, 2020).[6] Sea level rise has figured indirectly in European litigation yet, but disruptive scientific predictions for the future and the ever-growing robustness of attribution science[7] (IPCC, 2022; Ekwurzel, B., et al., 2017) make litigation targeting sea level rise both causes and consequences likely to increase. To date, European climate litigation approaches to sea level rise include the violation of human rights, the breaching of (mainly) mitigation obligations by granting new licenses for fossil fuels activities, and liability of damage to investments in flood prone areas.

Human rights to life, health, territory, and culture are highly threatened by the sea level rise. A prominent vulnerable group in this climate litigation are children, youth, and future generations since they will bear the burden of sea level rise-related harms far more and longer than adults, and have limited participation in political decisions. In the case *Sacchi, et al. v. Argentina, et al.* (Anon, 2019), 16 children discussed whether the respondent countries violated children's rights under international law by insufficiently cutting greenhouse gas emissions and failing to protect them from carbon pollution by the world's major emitters. The case has a strong transnational feature since

[6] Regarding the European Union, the countries with the largest number of cases are Germany, France and Spain. Outside the EU but still in Europe, the United Kingdom is also of note.
[7] As for the attribution science, the causal chain for slow-onset events such as sea level rise is scientifically clear in a condition-sine-qua-non formula and contributory causation. Climate science can trace back sea level rise with the Carbon Majors emission, and already knows that 26-32% of sea level rise is attributable to historical emissions, while 11-14% is related to recent ones.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

it involves European Union members - France, Germany, and Sweden - as well as a Sea Basin perspective, encompassing Mediterranean bordering countries of Tunisia and Turkey. Sea level rise is only indirectly claimed as one of the climate-related events that violate human rights. However, the United Nations Committee on the Rights of the Child acknowledged extraterritorial responsibilities for transboundary harms. In this sense, not only the State where the event occurred or where the emissions where generated can be hold accountable for the damage, but also a State whose jurisdiction controlled the emissions if there is a causal link between the events. This understanding can lead to transnational liability for countries or companies with headquarter in Europe, even when their activities are carried out abroad.

In cases challenging environmental licenses that grant permits for new fossil fuel projects, sea level rise is usually indirectly approached as a consequence of climate change potentiated by the fossil fuel activities. The *Greenpeace v. North Sea Transition Authority* case discussed the approval for an oil and gas field in the North Sea, and the *Greenpeace Ltd v (1) Secretary of State for Business, Energy and Industrial Strategy and (2) the Oil and Gas Authority; and Uplift v (1) SSBEIS and (2) the OGA (North Sea oil and gas licensing)* challenged the North Sea Transition Authority for granting the 33rd Offshore Oil and Gas Licensing Round. Some cases combine both human rights and fossil fuel permit arguments. The *Greenpeace Nordic and Others v. Norway* challenged the license to develop deep-sea oil and gas extraction in the Barents Sea. Pending before the European Court of Human Rights (ECtHR) and discussing whether Norway has violated fundamental rights, this is a potential 'impact case', since it may impact the effectiveness of the European Convention system and national legal systems as well. Despite the transversal role of sea level rise, this case raises the issue of ECtHR possibly requiring countries to reconsider their oil and gas policies and strengthen their due diligence obligations to avoid climate harm (Setzer and Higham, 2022). Sea level rise appears as an associated climate impact in other cases around Europe[8] – most of them combining human rights claims as well. Although many lawsuits are filed against governments, one may observe that they can have indirect effects on financial institutions as they may result in stronger regulation for mitigation and adaptation, changes in licensing for specific sectors, which affects portfolio investments and involve financial costs to comply (Sarra Janis and DeMarco Elisabeth, 2021).

Moreover, sea level rise may appear as a *climate damage* in transnational lawsuits against the private sector. As for an example, in *Asmania et al. vs Holcim*, 2022 (Justice of the Peace of the Canton of Zug, 2022) inhabitants of an Indonesian island sued the Swiss company Holcim requesting compensation for climate-change-related damages, such as flooding, reduction of carbon dioxide emissions, and financial contributions to adaptation measures. The plaintiffs argue that sea level rise is destroying their livelihoods, and the defendant bears a significant amount of responsibility due to its tremendously high emissions. This is a groundbreaking claim which engages the private sector on a transnational level dispute. It may also highlight the insufficiency of monetary compensation in scenarios involving non-economic losses such as culture, traditional knowledge, and displacement. The possibility of going beyond the remedies for ex post harms and asking for injunctive relief is also a relevant argument arising from this case.

Finally, sea level rise appears as an emerging concern for the private sector also due to the liability of damage to investments in flood prone areas. The insurance industry is facing an increasing risk associated with sea

[8] *Milieudefensie et al. v. Royal Dutch Shell plc; Armando Ferrão Carvalho and Others v. The European Parliament and the Council; Notre Affaire à Tous and Others v. France,* and the remarkable *Urgenda Foundation v. State of the Netherlands.*

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

level rise and climate litigation, both as an investor with shareholder obligations, and as an underwriter to claims against its policyholders. Insurers will have to deal with the uncertainty and reach of liability exposure for climate change-related claims, which can pose a threat to the industry itself. Besides, climate litigation cases have been increasingly targeting Carbon Majors (Heede, 2013) for their contribution to the crisis, which affects liability insurers with the duty to defend the policyholders challenged in these lawsuits. Since 2018, lawsuits have been strengthening the argument that Carbon Majors created a public nuisance and, as such, should be responsible for paying for the damage associated with climate change and for the costs of adaptation against, inter alia, rising sea levels (British Institute of International and Comparative Law, 2021).

At the governmental sphere, many industrialized countries have advocated insurance mechanisms as a principle and effective means to deal with climate-related damages (Vanhala & Hestbaek, 2016). This, in turn, raises for companies the questions on embedding the management of climate-related risks as part of core business risk management to reduce the litigation. The further development of this case in European litigation is yet to be seen.

This table synthetizes formal aspects of the aforementioned cases:

Case and status	Parties	Principal law	Year	Jurisdiction	Sea Basin
*Sacchi, et al. v. Argentina, et al.,*decided	Individuals and government	United Nations Framework Convention on Climate Change, Paris Agreement, The United Nations Convention on the Rights of the Child	2019	United Nations Committee on the Rights of the Child	Mediterranean Sea
Greenpeace v. North Sea Transition Authority, pending	NGOs and government	Regulation 16 of the Offshore Petroleum and Pipelines (Assessment of Environmental Effects)	2022	England and Wales High Court of Justice	North Sea
Greenpeace Ltd v (1) Secretary of State for Business, Energy and Industrial Strategy and (2) the Oil and Gas Authority; and Uplift v (1) SSBEIS and (2) the OGA (North	NGOs and government	Petroleum Act 1998, Environmental Assessment of Plans and Programs Regulations 2004	2022	England and Wales High Court of Justice	North Sea

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

Sea oil and gas licensing, pending					
Greenpeace Nordic and Others v. Norway, pending	NGOs, individuals, and government	European Convention on Human Rights	2021	European Court of Human Rights	Arctic Ocean
Greenpeace Nordic Ass'n v. Ministry of Petroleum and Energy (People v Arctic Oil), pending	NGOs and government	Norwegian Constitution, European Convention on Human Rights	2016	Norwegian Supreme Court	Arctic Ocean
Asmania et al. vs Holcim, pending	Individuals and private company	-	2022	The Justice of the Peace of the Canton of Zug, Switzerland	-

Table 7: Climate litigation cases

Box 9 - Sea level rise in the crosshairs of the courts: catching the eye for climate litigation

5.5 Summary: key developments per basin

Regarding *policy frameworks* relevant for coastal adaptation *(5.2.1),* the **Mediterranean Sea Basin** has three regional instruments in force, only one of which is legally-binding. Two of these instruments have statements on coastal adaptation, and only one – a soft law Charter – includes specific information on SLR. The **Black Sea**, **East-Atlantic Ocean,** and **Baltic Sea Basins** each have two different regional instruments, one soft law and the other legally-binding. However, for all three basins, none of the regional instruments address specific measures for coastal adaptation nor sea level rise**.** The **North Sea Basin** has one specific soft law instrument that, while recognizing SLR as a major challenge, does however not contain provisions or guidelines on coastal adaptation measures. No specific treaty was mapped concerning the **Arctic Ocean.** Further, there are international legally binding instruments that apply for all countries in Europe, however these also do not provide specific measures on coastal adaptation. Of the three EU policy instruments that apply to all European sea basins, only the soft law Strategy on Adaptation to Climate Change acknowledges the risks of SLR and provide measures for coastal adaptation. The two legal-binding Directives on Marine Strategy and Marine Spatial Planning do not make specific provisions for SLR or coastal adaptation measures.

Regarding the *State of Coastal adaptation at national level (5.2.2),* almost all countries in the **Mediterranean Sea Basin** have reported SLR as an already observed or future expected hazard with the exceptions of Cyprus, whose national policies do not mention SLR at all. All countries have adopted Adaptation Policy Strategies, but only France and Spain provide a list of adaptation measures, the latter specifically to address SLR. Only four

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

countries have enforced Maritime Spatial Plannings and three of these instruments address SLR. Further, countries are taking different approaches to funding coastal adaptation measures, with Spain having a centralized national funding approach, whereas in Italy funding for measures is distributed across multiple levels of government. In terms of addressing cross-domain governance challenges, progress of Ports in Spain in advancing climate change monitoring systems and adaptation measures illustrate the potential positive spillovers of coastal adaptation to sectors and economic activities beyond the coast.

All **North Sea Basin** countries have reported SLR both as an observed and a future chronic hazard. Adaptation Policy strategies have been adopted by the four countries, but only half of them have a list of measures, and Germany is the only providing specific measures to SLR. All countries Maritime Spatial Planning, but only Belgium and the Netherlands address SLR in theirs. Further, countries' approaches to funding coastal adaptation also differs substantially within the basin. The Netherlands funding is highly centralized and concentrated at the national level, whereas the UK has decentralized both coastal adaptation and decisions to local authorities. Germany has a hybrid of centralized funding for some portions of the coast, with decentralized funding responsibilities at other locations. The North Sea Basin also shows several examples of incorporating flexibility into governance processes and adaptation measures to address the challenges of uncertainty of long-term SLR. In the Netherlands, Dynamic Adaptation Pathways explicitly incorporate flexibility into the approach of the Delta Programme, while in Germany, dike reinforcement includes additional widening of dike crests in order to reduce future costs of increasing dike heights should high-end SLR materialise. Finally, progress is being made on co-development processes that engage local communities on equal footing with experts and coastal managers, as illustrated in the case of Texel in the Netherlands.

Of EU **Black Sea Basin** countries**,** only Romania reported SLR both as an observed and future chronic hazard. Both Romain and Bulgaria have adopted Adaptation Policy strategies, however only Bulgaria lists adaptation measures and none of them specifically addresses SLR. Neither country has Maritime Spatial Planning in force.

All **Baltic Sea Basin** countries have reported SLR as an observed and future chronic hazard, except for Sweden which reported it only as a future one. All having adopted Adaptation Policy strategies, five of them list measures but only Estonia and Germany address specifically SLR. Maritime Spatial Planning have been enforced by all, but Estonia, Latvia and Lithuania are the only ones addressing SLR in their MSPs.

SLR is an observed and future chronic hazard in all **Atlantic Ocean Basin** countries. All countries have adopted Adaptation Policy strategies with a list of measures, and only France does not include measures specifically addressing SLR. Maritime Spatial Planning is also enforced by all countries, and only Portugal does not specifically address SLR in their MSP document. In terms of addressing the challenges of uncertainty in SLR and risks associated with lock-in of coastal planning decisions with long time horizons, in France, there is little evidence that high-end scenarios are being considered in the siting and design of new nuclear power plants at the coast.

In the **Arctic Ocean Basin,** Norway is considering mid-range SLR scenario information in its planning approaches.

https://doi.org/10.5194/sp-2023-37
Preprint. Discussion started: 9 January 2024

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SB, GG, and EFB wrote the paper with text contributions from CR, SME, ES, FB, RD. JS, FdH, and GLC wrote the box of The Slufter on Texel, and BPG and AGZ wrote the box of the Spanish ports. All authors participated in the iterations and revisions of the paper. KL is the handling editor.

Competing interest

The contact author has declared that none of the authors has any competing interests.

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Preprint. Discussion started: 9 January 2024

Endnotes

[i] The following mechanisms were used to collect data for the analysis conducted in Section 5.3.3:
a) the Energy Union Governance monitoring framework (Regulation (EU) 2018/1999 and its implementing regulation) that requires Member States to report every two years information about the observed and future climate change impacts and the status of climate adaptation policies. The first round of reporting was carried out in 2021 and the information is available on climate-ADAPT country profiles; b) the framework of the Maritime Spatial Planning Directive (Directive 2014/89/EU) that explicitly calls for planning to consider the impacts from climate change and to design interventions that are "resilient" to its effects. The European Commission constantly monitors the implementation of the MSP Directive in Member States.

[ii] This table is a Summary of Adaptation and Maritime Spatial Planning policies in Europe with a focus on SLR related issues. Its sources are climate-ADAPT (https://climate-adapt.eea.europa.eu/#t-countries) and European MSP Platform (https://maritime-spatial-planning.ec.europa.eu/msp-practice/countries). The Maritime Spatial Planning platform is available at https://maritime-spatial-planning.ec.europa.eu/msp-practice/countries
As for the specific countries, please see:

Belgium (Belgian National climate Change Adaptation Strategy: https://www.cnc-nkc.be/sites/default/files/report/file/be_nas_2010_0.pdf and Belgian National Adaptation Plan 2017-2020: https://www.cnc-nkc.be/sites/default/files/report/file/nap_en.pdf);
Croatia (Climate Change Adaptation Strategy for the period to 2040 with a view to 2070: https://prilagodba-klimi.hr/);
Denmark (How to manage cloudburst and rain water – Action plan for a climate-proof Denmark: https://en.klimatilpasning.dk/media/590075/action_plan.pdf);
Estonia (Climate Change Adaptation Development Plan until 2030: https://envir.ee/media/912/download);
Finland (Finland's National Strategy for Adaptation to Climate Change: http://urn.fi/URN:ISBN:952-453-231-X and Finland's National Climate Change Adaptation Plan 2030: https://mmm.fi/paatokset/paatos?decisionId=0900908f807fc600);
France (Stratégie nationale d'adaptation au changement climatique: https://www.ecologie.gouv.fr/sites/default/files/ONERC_Rapport_2006_Strategie_Nationale_WEB.pdf and 2e Plan national d'adaptation au changement climatique (PNACC-2): https://www.ecologie.gouv.fr/sites/default/files/2018.12.20_PNACC2.pdf);
Germany (Deutsche Anpassungsstrategie an den Klimawandel: https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Klimaanpassung/das_gesamt_bf.pdf);
Greece (National Strategy for Adaptation to Climate Change: https://ypen.gov.gr/wp-content/uploads/legacy/Files/Klimatiki%20Allagi/Prosarmogi/20160406_ESPKA_teliko.pdf);
Ireland (National Adaptation Framework: https://www.gov.ie/en/publication/fbe331-national-adaptation-framework/);
Italy (National Adaptation Strategy to climate change: https://www.mase.gov.it/sites/default/files/archivio/allegati/clima/documento_SNAC.pdf);
Latvia (Latvian National Plan for Adaptation to Climate Change until 2030: https://www.varam.gov.lv/en/media/32915/download?attachment);
Lithuania (National Climate Change Management Agenda: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/219a2632a6b311ecaf79c2120caf5094?jfwid=-56ckr0gcc and National energy and climate plan: https://energy.ec.europa.eu/system/files/2022-08/lt_final_necp_main_en.pdf);
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Poland (Polish National Strategy for Adaptation to Climate Change by 2020 with the perspective by 2030: https://bip.mos.gov.pl/fileadmin/user_upload/bip/strategie_plany_programy/Strategiczny_plan_adaptacji_2020.pdf);

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Portugal (National Adaptation to Climate Change Strategy (ENAAC 2020): https://files.dre.pt/1s/2015/07/14700/0511405168.pdf and Action Plan for Adaptation to Climate Change (P-3AC): https://dre.pt/application/conteudo/123666112);
Romania (The National Climate Change and Low Carbon Green Growth Strategy: http://www.mmediu.ro/categorie/cadrul-national/408);
Spain (National Climate Change Adaptation Plan 2021-2030: https://www.miteco.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/pnacc-2021-2030-en_tcm30-530300.pdf and Climate Change Adaptation: Work Programme 2021-2025: https://www.miteco.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/pt1-pnacc_tcm30-535273.pdf);
and Sweden (Nationell strategi för klimatanpassning: https://www.regeringen.se/contentassets/8c1f4fe980ec4fcb8448251acde6bd08/171816300_webb.pdf)