OSPAR COMMISSION

Assessment of climate change mitigation and adaptation

Monitoring and Assessment Series

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OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998.
La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l'Espagne.

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Photo cover page: Giant waves on the seafront at Seaham (Durham, UK) in 2008. Free Pictures - FreeFoto.Com

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Executive Summary

The effects of climate change are already becoming apparent in the North-East Atlantic. This adds urgency to OSPAR's work to meet current objectives for the protection of the marine environment and reduce existing human pressures and so increase the ecosystem's capacity to cope with the consequences of climate change.

In its future work, OSPAR will need to adapt its current policies and objectives to respond to an altering marine environment, increasing vulnerability of marine ecosystems and changing pressures from human activities on land and sea. OSPAR will have an important role in monitoring and assessing climate change and ocean acidification and their impacts on the North-East Atlantic.

OSPAR provides a framework to manage increasing uses of the sea to mitigate climate change

OSPAR countries are committed under global and European instruments to drastically reduce greenhouse gas emissions to slow-down climate change and ocean acidification and to lessen their impacts. Meeting the set targets will require to fully exploit all available options. This includes energy generation from marine renewable resources, and the capture of carbon dioxide at emission source and its permanent and environmentally safe storage in geological sub-seabed formations. To date, most existing and planned offshore renewable energy projects are wind farms concentrated in Regions II and III but demand for offshore wind, wave and tidal power are increasing.

OSPAR provides a framework for the coordinated management and regulation of increasing demands for the uses of the sea and for ensuring that these activities do not adversely impact the marine environment.

OSPAR needs to improve knowledge of climate change impacts and risks for the North-East Atlantic

Climate change and ocean acidification are expected to further alter the physical, chemical and biological components of the marine environment with substantial impacts on ecosystem functioning and ultimately ecosystem services. The nature, rate and impacts of climate change and ocean acidification, and the vulnerability of marine and coastal ecosystems and societies will differ considerably between and within OSPAR Regions. This implies a need for a better understanding of potential climate change impacts (scenarios) and associated risks at regional and local levels to inform formulating adaptation strategies.

OSPAR should actively work with partner organisations (*e.g.* ICES, IOC) to put in place appropriate systems for evaluating climate change, including both scenarios of potential impacts and indicators to assess progression of climate change impacts, particularly at the regional scale. Methods for monitoring ocean acidification and its effects are a priority.

OSPAR needs to integrate climate change into all its work areas

Whatever level of climate change mitigation can be achieved, some impacts will arise which require society to adapt. This will involve change in human behaviour and in the use of natural resources on land and at sea. This will alter the distribution and intensity of human pressures on the marine environment. Fewer tools will be available at sea than on land to adapt to climate change. Adaptation will depend on best available understanding of the vulnerability of ecosystems.

OSPAR will need to make additional efforts to enhance knowledge about the vulnerability of species, habitats and ecological processes and the interaction of these with pressures from human activities on the sea. OSPAR will need to integrate climate change issues into all its work areas and should continue to work on marine spatial planning and integrated coastal zone management as integrative and adaptive tools for the management of human uses of the sea. OSPAR should actively work with partner organisations (*e.g.* NEAFC, IMO) to promote integration of climate change issues and changed vulnerability of marine ecosystems into work areas relevant for the environmental protection of the North-East Atlantic.

OSPAR needs to respond to the imminent increase of coastal defence activities

Rising sea levels, increased storminess and higher and more forceful waves can be expected to increase the risk of coastal areas to flooding, erosion and loss of coastal ecosystems. Low-lying areas, such as those in the southern North Sea, will be particularly vulnerable. This requires an early response. Some adaptation of coastal defence is already taking place.

OSPAR should facilitate the need for enhanced cooperation and sharing of economic burden between Contracting Parties for example for research and planning of coastal adaptation, especially where larger coastal areas stretching across national boundaries are affected.

Récapitulatif

Les effets du changement climatique commencent à apparaître dans l'Atlantique du Nord-est. Il est donc d'autant plus urgent que les travaux d'OSPAR parviennent aux objectifs actuels dans le domaine de la protection du milieu marin et permettent ainsi d'augmenter l'aptitude des écosystèmes à faire face aux conséquences du changement climatique.

Au cours de ses travaux futurs, OSPAR devra adapter ses politiques et ses objectifs actuels afin de répondre aux changements dans le milieu marin, à la vulnérabilité croissante des écosystèmes marins et aux nouvelles pressions qu'exercent les activités humaines sur la terre et la mer. OSPAR jouera un rôle important en matière de surveillance et d'évaluation du changement climatique ainsi que de l'acidification des océans et leurs effets sur l'Atlantique du Nord-est.

OSPAR offre un cadre de travail qui permet de faire face à l'intensification de l'usage de la mer et d'atténuer le changement climatique

Dans le cadre d'instruments internationaux et européens, les pays OSPAR sont tenus de réduire considérablement les gaz à effet de serre afin de ralentir le changement climatique et l'acidification des océans et d'en réduire leurs impacts. Il faudra exploiter pleinement les options disponibles afin de parvenir aux objectifs que l'on a fixés. Ceci inclut la production d'énergie à partir de ressources marines renouvelables, le captage de dioxide de carbone à la source d'émission et son stockage permanent et en toute sécurité pour l'environnement dans les formations géologiques du sous sol marin. A ce jour, la plupart des projets dans le domaine de l'énergie renouvelable offshore – existants et prévus – sont les parcs d'éoliennes concentrés dans les Régions II et III mais la demande pour l'énergie éolienne et marémotrice est en hausse.

OSPAR offre un cadre afin de coordonner gestion et réglementation de la demande en hausse dans le domaine de l'usage de la mer et pour s'assurer que ces activités n'aient pas d'effets préjudiciables sur le milieu marin.

Il est nécessaire qu'OSPAR améliore ses connaissances des impacts du changement climatique et des risques pour l'Atlantique du Nord-est

Dans l'avenir, il est envisable que le changement climatique et l'acidification des océans transformeront encore plus les aspects physiques, chimiques et biologiques du milieu marin, avec des effets importants sur le fonctionnement des écosystèmes et par conséquent sur les services des écosystèmes. La nature, le taux et les impacts du changement climatique et de l'acidification des océans, et la vulnérabilité des populations et des écosystèmes marins et côtiers vont varier d'une manière considérable d'une région OSPAR à l'autre et au sein de chaque région. Il est donc nécessaire de mieux comprendre les effets potentiels du changement climatique (scénarios) et leurs risques spécifiques, au niveau régional et local, afin d'aider à formuler des stratégies d'adaptation.

OSPAR devra s'efforcer activement de travailler en collaboration avec des organisations partenaires (par exemple le CIEM et la COI) afin de mettre en place des systèmes pertinents qui permettent d'évaluer le changement climatique, notamment des scénarios d'impacts et d'indicateurs potentiels afin d'évaluer la progression des effets du changement climatique, en particulier au niveau régional. Les méthodes permettant de surveiller l'acidification des océans et ses effets sont une priorité.

Il est nécessaire qu'OSPAR intègre le changement climatique dans tous ses domaines de travail

Quel que soit le niveau de mitigation du changement climatique auquel on peut parvenir, certains de ses effets exigeront une adaptation de la société. Ceci impliquera un changement de comportement humain et l'utilisation des ressources naturelles sur terre et en mer. Cela modifiera également la distribution et l'intensité des pressions humaines sur le milieu marin. Il y aura moins d'outils en mer qu'à terre pour s'adapter au changement climatique. L'adaptation dépendra du degré de compréhension au sujet de la vulnérabilité des écosystèmes.

OSPAR devra faire des efforts supplémentaires afin d'améliorer ses connaissances sur la vulnérabilité des espèces, des habitats et des processus écologiques et l'interaction de ces derniers et des pressions exercées par les activités humaines sur le milieu marin. OSPAR devra intégrer les questions de changement climatique dans tous ses domaines de travail et poursuivre ses travaux sur la planification spatiale marine et sur la gestion intégrée de la zone côtière à titre d'outils intégrants et adaptatifs pour la gestion de l'exploitation humaine de la mer. OSPAR devrait s'efforcer activement de travailler en collaboration avec des organisations partenaires (par exemple la NEAFC, l'OMI) afin de promouvoir l'intégration des questions de changement climatique et de modification de la vulnérabilité des écosystèmes marins dans les domaines de travail pertinents à la protection de l'environnement dans l'Atlantique du Nord-est.

Il est nécessaire qu'OSPAR réponde à l'augmentation imminente des activités de défense côtière

Il est à prévoir que la montée du niveau de la mer, l'augmentation des tempêtes et de vagues plus hautes et plus fortes, augmenteront le risque d'inondation, d'érosion et de disparition d'écosystèmes dans les zones côtières. Les zones de faible altitude, telles que la mer du Nord méridionale, sont particulièrement vulnérables. Ceci exige une intervention rapide. La défense côtière est actuellement en cours d'adaptation.

OSPAR devrait faciliter la nécessité d'une meilleure coopération et d'un partage du fardeau économique entre les Parties contractantes, par exemple dans le domaine de la recherche et la planification de l'adaptation côtière, en particulier lorsqu'il s'agit de grandes zones côtières se trouvant à cheval sur des frontières nationales.

1. Introduction

The earth's climate is changing at unprecedented rate. Global emissions of greenhouse gases are recognised to have contributed substantially to the rise in globally-averaged atmospheric temperatures since the mid-20th century and to ocean acidification. These impacts are already becoming apparent in the North-East Atlantic.

Climate changes in the OSPAR maritime area are seen either directly (increasing sea temperature and decreasing sea ice extent) or indirectly as impacts on biodiversity (changing distribution and abundance of species).

With increasing atmospheric CO_2 dissolving in the sea, the acidity of the ocean is rising at accelerated pace. Ocean acidification is a key future threat. Significant ecosystem-wide effects may happen through the water column in parts of the Arctic as early as 2016 in winter and 2026 throughout the year.

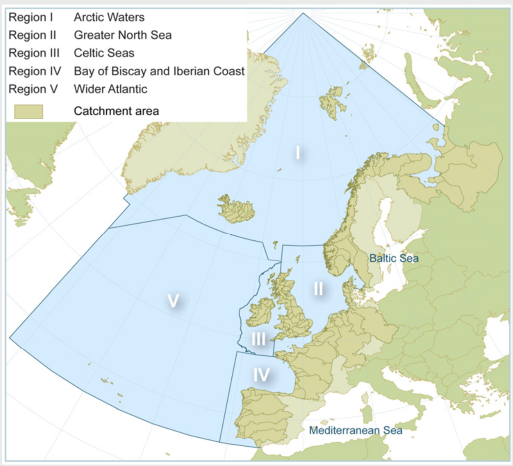
Although there can be no certainty about the precise nature and rate of future climate change and ocean acidification, even the more moderate of the predicted scenarios is expected to alter the marine environment and affect our societies.

This report addresses the need for OSPAR to rise to the challenge of climate change and ocean acidification impacts in the OSPAR area. The report provides an overview of the main challenges for OSPAR to adapt current policies and objectives for the protection of the marine environment (Section 2). It assesses the needs and options to mitigate climate change (Section 3) relevant for OSPAR's work and to adapt to the consequences of climate change (Section 4) and how this will influence OSPAR's future work. Section 5 sets out conclusions and recommendations for OSPAR to respond to the challenges of climate change and ocean acidification.

This assessment builds on the results of the OSPAR assessment of impacts of climate change (OSPAR, 2009a) and, together with that assessment, provides the evidence base for, and an important contribution to, the Quality Status Report 2010. The report focuses on issues relevant for shaping OSPAR's responses to climate change and ocean acidification and refers to detailed assessments of specific impacts and activities undertaken by OSPAR under its Joint Assessment and Monitoring Programme which are associated with certain mitigation and adapation activities (Box 1).

Box 1
Electronic navigator to complementary QSR assessments

- ➥ Impacts of climate change (OSPAR, 2009a)
- ➥ Offshore wind farms (OSPAR, 2008a)
- ➥ Placement of structures (OSPAR, 2008b)
- ➥ Placement of power cables (OSPAR, 2009b)
- ➥ Coastal defence (OSPAR, 2009c)
- ➥ Land reclamation (OSPAR, 2008c)



Map: OSPAR maritime area and its Regions

2. The challenges of climate change in the OSPAR area

Climate change is a global issue – its specific environmental and societal impacts, however, will ultimately be felt at local level and affect all people’s daily life. Climate change and its impacts need therefore to be addressed at all levels: global, regional – including OSPAR and the European Union – national, and local.

OSPAR’s detailed assessment of impacts of climate change shows that a wide range of predicted changes to the marine environment (Table 2.1) and marine biological systems (Table 2.2) is already taking place in the OSPAR maritime area (OSPAR, 2009a). Observed impacts which can be clearly linked to climate change include an increase in sea temperature, decrease in sea ice, northward movement of fish and plankton, and an increase in ocean acidity and associated effects on the development of shell-bearing larvae.

More changes can be expected on the physical, chemical and biological aspects of the marine environment with adverse effects on ecosystem functions, although predictions depend on the scenario used and many factors, including synergistic and trade-off effects and feedback mechanisms. The nature, rate and impacts of climate change and the vulnerability of marine and coastal ecosystems and societies will differ considerably between and within OSPAR Regions. This implies a need for a better understanding of potential climate change impacts (scenarios) and associated risks at regional and local levels.

Many of the coastal and marine ecosystems in the OSPAR maritime area are already under pressure from various human activities resulting in pollution, overfishing, and damage and loss of habitats. Cumulative effects and interactions of climate change with other pressures and impacts render marine ecosystems and biodiversity more vulnerable. This will have direct implications for OSPAR’s work and strategic objectives to protect the marine environment:

- protection and conservation of biodiversity and ecosystems: ocean acidification, coastal erosion and impacts on biological aspects of the marine environment are expected to result in loss of habitats. This and the predicted increasing invasion and establishment of non-indigenous species due to rising sea temperature will add additional pressures on threatened and declining marine species, making their recovery more difficult. Sea temperature rise is expected to change the distribution, abundance and seasonality of plankton and fish and add to pressures from fisheries on commercial fish species and impacts on the marine foodweb (predator-prey relationships);
- eutrophication: rise in sea temperature, change in salinity, increased freshwater input, increased storms, and ocean acidification are expected to change phytoplankton composition, increase phytoplankton biomass and events of harmful algae blooms, and nutrient enrichment from run-off, storm overflows and remobilisation from sediments. This will add to pressures from human-induced eutrophication and associated adverse effects on marine ecosystems;
- chemical pollution: increased freshwater inputs, reduced sea ice, increased storms are expected to lead to an increase of inputs of contaminants to the sea and affect marine life already under pressure from chemical pollution.

The severity of the impacts will depend on the extent to which mankind will be able to mitigate climate change. Irrespective of the level of mitigation achieved, there will be unavoidable consequences of climate change requiring adaptation. Both mitigation (Section 3) and adaptation to climate change (Section 4) will change human pressures on the sea.

OSPAR will need to adapt its current policies and objectives across all policy fields to account for those changing pressures and the increased vulnerability of marine ecosystems.

Table 2.1 *Predicted and observed climate change impacts on the physical and chemical environment. Source: OSPAR, 2009a*

Impact	What might happen	What has been observed
Increased sea temperatures	Warming in all OSPAR areas but with strongest warming in Region I	Regions I–IV have warmed since 1994 at a greater rate than the global mean Warming most evident in Region II
Reducing Sea Ice	Region I: sea ice may disappear in the summer in coming decades	Region I: extent of sea ice has decreased in recent decades
Increased Freshwater input	Region I: 10-30% increase in annual riverine input by 2100 with additional inputs from the melting of land-based ice Regional precipitation is difficult to project but Region IV and the southern part of Region V may experience decreases in precipitation	Region I: the supply of freshwater to the Arctic appears to have increased between the 1960s and the 1990s
Changed salinity	Region I and V: The Atlantic ocean north of 60° might freshen during the 21st Century	Freshening in the deep waters of Regions I and V over the last 4 decades of the 20th century
Slowed Atlantic overturning circulation	Slowdown of circulation in 21st Century is very likely	Monitoring is now in place that will be able to observe long term change in the Atlantic Overturning Circulation
Shelf sea stratification	Regions II and III: Shelf seas may thermally stratify for longer, and more strongly but in the same locations	Regions II and III: some evidence for earlier stratification in recent years and onset of the associated bloom
Increased storms	Projections of storms in future climate are of very low confidence	Regions I - V: severe winds and mean wave heights increased over the past 50 years, but similar strength winds were also present in earlier decades
Increased sea level	Between 0.18 and 0.59m by 2100 mostly through thermal expansion and noting high uncertainty at the upper range due to ice sheet processes. A rise of 2m in a century cannot be discounted as a possibility based upon past change	Global sea level rose on average at 1.7mm/yr through the 20th Century. A faster rate of sea-level rise was evident in the 1990s
Reduced uptake of CO_2	Dependent on water temperature, stratification and circulation	North Atlantic: reduced flux of CO_2 into surface waters in 2002-2005 compared with 1994-1995
Acidification	During the 21st Century ocean acidity could reach levels unprecedented in the last few million years with potentially severe effects on calcareous organisms	Global: average decrease in pH of 0.1 units since the start of the industrial revolution
Coastal erosion	Predictions are very uncertain and highly location specific	In many areas the combined effects of coastal erosion, infrastructure and sea defence development have lead to a narrow coastal zone
Nutrient enrichment	Predictions are linked to a number of factors	Regions I – IV: Drier summers may already be contributing to a decrease in nutrient inputs. Higher nutrients input in wet years have caused harmful algal blooms

***Table 2.2** Predicted and observed climate change impacts on the biological environment. In all cases predictions are limited by uncertainties in ocean climate projections and species and community responses. Source: OSPAR, 2009a*

IMPACT	What might happen	What has been observed
Plankton	Northwards shifts in species in shelf and open ocean Region I: Increased productivity with loss of sea ice	1000 km northward shift of many plankton species over the last 50 years Changes in timing of seasonal plankton blooms
Harmful algal blooms	Potentially increasing incidence as a result of changes in sea temperature, salinity and stratification	Anomalous phytoplankton blooms (often harmful) in specific habitats affected by lower salinities (*e.g.* Norwegian trench) or higher temperatures (German Bight).
Fish	Northward shifts in population but lack of knowledge of the underlying mechanisms make projections uncertain. Increased temperature could increase the incidence of disease for farmed species of fish and shellfish	Northwards shifts of both bottom dwelling and pelagic fish species, most pronounced in Regions I and II
Marine mammals	Loss of habitat for mammals dependent on sea ice Changes in availability of prey species are likely especially in Region I due to mismatches in production	Data on distribution, abundance and condition of marine mammals is limited. Ringed seals and polar bear may already be affected by loss of sea ice
Seabirds	Impacts on seabirds are likely to be more important through changes in their food supply than through the losses of nests due to changed weather	Seabird breeding failure in the North Sea has been linked to variations in food availability as a result of increased sea temperatures
Non-indigenous species	Increased invasions and establishment may be facilitated by climate change and pose a high risk to existing ecosystems	Establishment of pacific oyster *Crassotrea gigas* and the barnacle *Elminius dodestus* has been linked to climate change
Intertidal communities	Continues extension and retraction of the ranges of different intertidal species	Some warm water invertebrates and algae have increased in abundance and extend ranges around the UK over last 20 years
Benthic ecology	Benthic sessile organisms are largely tolerant to moderate environmental changes over reasonable adaptive time scales but are very vulnerable to abrupt and extreme events	Anomalous cold winter conditions have seen outbreaks of cold water species and die-offs of warm water species. Species composition changes have occurred but not major shifts or changes in gross productivity

3. Mitigation of climate change and ocean acidification

Mitigation refers to actions addressing anthropogenic causes of climate change and ocean acidification. Mitigation aims to slow down changes through reducing emissions and enhancing sinks of CO_2 and other greenhouse gases. A wide array of options is available both on land and at sea.

Mitigation options with immediate impact on the North-East Atlantic include electricity generation from offshore renewable sources and carbon dioxide sequestration into geological sub-seabed formations. Ocean fertilization to enhance uptake of CO_2 by the sea has received increasing interest but is currently considered not to be a relevant option in the OSPAR maritime area.

Mitigation options used onshore may have benefits or adverse effects on the marine environment. One example is that reduced use of coal will not only reduce CO_2 emissions but also other types of pollution of the oceans. Another example is that changes in agriculture practises may increase or decrease the run-off of pollutants to the sea. These effects are quite complex and are considered outside the scope of this report.

3.1 Policy and legislative drivers for mitigation actions

A wide range of international and regional instruments drive and facilitate domestic climate change mitigation (Table 3.1).

The United Nations Framework Convention on Climate Change leads the work at the global level with the aim of *"stabilisation of greenhouse gas concentrations in the atmosphere at a level that prevents dangerous anthropogenic interference with the climate system"*. In this context, the Kyoto Protocol has committed many industrialised nations to legally binding reductions in greenhouse gas emissions for 2008 – 2012. A post-2012 framework is being negotiated and expected to be completed at the Copenhagen Conference of the Parties in December 2009.

The Intergovernmental Panel on Climate Change (IPCC) has confirmed in its latest assessment that unless we cut greenhouse gas emissions worldwide – especially carbon dioxide (CO_2) – by 50% to 80% by 2050, the impact of global warming will be severe (IPCC, 2007). Such reductions will be most challenging given the expected doubling of the world's energy demand by that date and the increase in population.

The European Union (EU) has agreed a strategic objective to limit the global average temperature increase to not more than 2° C above pre-industrial levels; the non-EU OSPAR countries Icleand, Norway and Switzerland have set similar aims. To achieve this aim, the developed world would need to reduce emissions by 30% by 2020 and 60 – 80% by 2050. The EU is committed to a binding target to cut the EU's greenhouse gas emissions by at least 20% in 2020 compared to 1990 levels and is prepared to reduce emissions by as much as 30% under a new post-2012 global climate change agreement provided that other industrialised nations, including the United States, commit themselves to comparable emission reductions and that advanced developing countries (*i.e.* China and India) contribute to these efforts.

The latest Kyoto progress report of the European Environment Agency (EEA, 2009) found that more than 5000 million tonnes CO_2 equivalent of greenhouse gases were emitted in Europe in 2007. This is 9.3% less than in 1990. Emissions are dominated by EU-15 Member States (more than 4000 million tonnes CO_2 equivalent of greenhouse gases), in particular Germany, the United Kingdom, France, Italy, and Spain (in decreasing order). 80% of greenhouse gas emissions are energy related – that is, related to the production of electricity and heat, road transport etc. Greenhouse gas emissions are decreasing and are expected to continue to decrease until 2020 but further emission reduction will be needed to meet the 20% reduction target.

While the EU's 20% reduction target is considered technically feasible and the benefits are expected to outweigh the costs, there is a need for speedy action, using a portfolio of solutions, as no single solution will be capable of reducing CO_2 emissions on the massive scale required*.* These options include reductions in industrial CO_2 emitting production, transfer from traditionally fossil fuels to renewable energies, improved energy efficiency and CO_2 capture and storage. The EU has agreed a package on climate action and renewable energy[1] that is under implementation. The package includes a binding target to raise the EU's share of renewables to 20% by 2020, aiming towards building a low-carbon economy with support for using carbon capture and storage and the development of a European Strategic Energy Technology Plan to focus research and development efforts on low-carbon technologies.

To achieve the objectives set, all mitigation options must be enhanced, among them possible mitigation options in the OSPAR maritime area such as offshore generation of electricity from renewable sources (*e.g.* wind, tides and wave), and carbon capture and storage in geological sub-seabed formations. Since 1991, the European Climate Change Programme explores the most environmentally-efficient and cost-efficient options to reduce greenhouse gas emissions at European level.

OSPAR should promote that the potential impact of ocean acidification should be considered when developing mitigation strategies and setting international objectives to limit future atmospheric CO_2 levels.

Table 3.1 *Overview of selected main international and regional instruments driving and facilitating climate change mitigation*

International instrument	What they regulate
UN FCCC – Kyoto Protocol	▪ At least 5% reduction of greenhouse gas emissions by 2012 in developed countries (8% in the EU) from 1990 levels ▪ Emission trading ▪ Clean development mechanism
IMO London Convention	▪ Offshore CO_2 capture and sequestration
OSPAR Decisions 2007/1 and 2007/2	▪ Ban on storage of CO_2 in the water column ▪ Framework for environmentally safe offshore CO_2 capture and sequestration in geological formation of the sub-seabed
European Climate Change Programme	▪ Main sectors (energy supply, energy demand, transport, carbon capture and storage) ▪ Emission trading schemes ▪ Taxation of energy products ▪ Adaptation
EC Directive 2009/28	▪ 20% of energy from renewable sources by 2020
EC Directive 2009/31	▪ Legal framework for environmentally safe storage of CO_2

[1] http://ec.europa.eu/environment/climat/campaign/index_en.html

3.2 Offshore renewable energy

In the OSPAR area, wind is the main renewable energy source used offshore. There is also research and some pilot projects for other renewable energy sources such as wave power, tidal power and facilities based on salinity gradients. Although the theoretical potential of these other options is large, they are currently less developed with 0.3 GW installed capacity in total by the end of 2008 (REN21, 2009) - and there is little knowledge available about them.

Offshore wind provides a huge potential source of renewable energy

By end of 2008, almost 98% of the production from wind farms in Europe (EU-15) was installed onshore with a total capacity of about 64 GW (EWEA, 2009). In 2009, the OSPAR windfarm database listed 13 operational wind farms with a total of 623 turbines and a capacity of 1.5 GW. The offshore wind farms are located in Denmark, Ireland, the Netherlands and the United Kingdom. All but one of the offshore wind farms in operation and all the new authorised plants have undergone environmental impact assessment (EIA). So far only standing structures have been installed. Research and development projects are trialling floating structures for energy generation from wind and operational experience is limited (Figure 3.1).

Figure 3.1 *Technologies for floating wind turbines are expected to enable wind power generation far offshore at sites with greater water depths. At a test site off Karmøy (southwest Norway) a 2.3 MW wind turbine is attached to the top of a floating concrete buoy construction, which is moored to the seabed, using three anchor points, a system also applied in the offshore oil and gas industry.*

The number of offshore wind farms in the OSPAR area has increased substantially over the past 10 years and it is expected that this development will continue beyond 2010. In 2007, 31 offshore wind farms representing a capacity of 9 GW have been authorised and there were applications for 47, partly large scale offshore wind farms with a total capacity of 16 GW (OSPAR, 2008a). If all the farms authorised and applied for in 2007 are developed, the number of offshore turbines will increase ten-fold, and more applications are expected. Authorised and planned wind farm projects concentrate in the North Sea (Region II) with some projects in the Arctic Waters (Region I) and the Celtic Seas (Region III) (Figure 3.2).

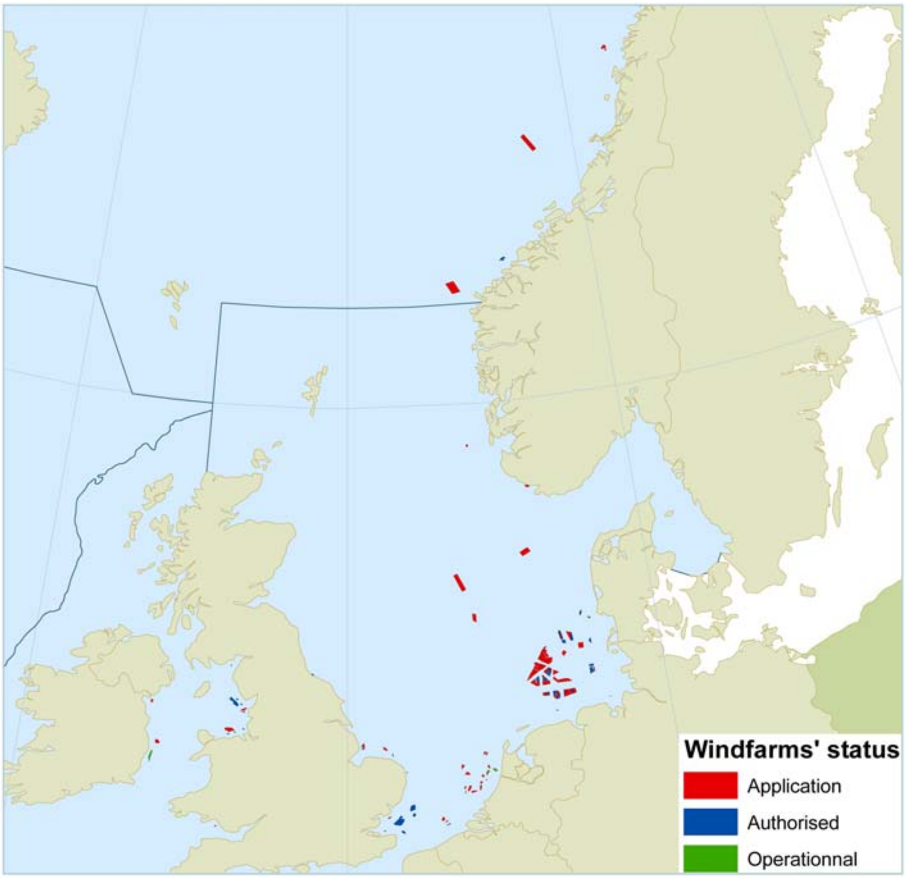


Figure 3.2 *Overview of location of operational, authorised and planned wind-farms in the OSPAR maritime area. Source: OSPAR, 2008a*

It can be expected that in the short term the development of offshore wind farms will experience capacity constrains *e.g.* related to availability of installation vessels and access to the electricity grid. It can therefore be assumed that there will be a moderate further development of offshore wind-farms up to 2010 and that it is unlikely for the number of turbines installed per year to exceed 800. This estimate is consistent with recent updated predictions of the European Wind Energy Association that 3.5 GW of offshore wind capacity could be installed within Europe by 2010 (EWEA, 2008).

Interest in energy from waves, tides and salinity is increasing

Ocean energy includes various technologies for generation of electricity from wave, tides and salinity gradients which operate both close to the coast and offshore, and include hard structures (*e.g.* dams), devices which float or are installed on the seabed and which operate underwater or above surface. (Figure 3.3). Their demand for space, potential conflicts with other uses and environmental impacts will clearly differ. So far, experience of commercial scale developments is limited. A first commercial scale wave farm development was inaugurated in 2008 off Portugal with a capacity of 2.25 megawatt (MW) per year and is expected to be operational soon; there were initial plans to extend the farm to 21 MW in the future. There are however a number of test sites that have been operating for several years, for example off Ireland and Scotland with a total capacity of 0.3 GW. Some countries have established targets for tidal stream and wave energy production.

Figure 3.3 *Examples of technologies for generating electricity from waves and tides*

Prototype tidal mill tethered to the seabed, installed since 2003 in Kval-sundet, Norway. There are plans to install mills worth 1 MW in Scottish waters.

1:3 scale test platform in Oslo fjord. Bridging boats underneath a floating platform (real size: 36 m wide; 18 m high) pass on wave movement to a hydraulic system to generate energy (1.5 MW per platform).

140 m long foating tubes convert constant motion of the sea into electricity off Aguçadoura, Portugal. Farm output planned: 2.25 MW

The 1.2 MW tidal turbine in Strangford Lough, Northern Ireland, works like an underwater mill but with rotors driven by tidal currents. It has taken up com-mercial produc-tion in 2008.

Scotland for example plans to install 1.3 GW of capacity by 2020, and leasing of sites for commercial development is in progress. Effective cooperation between developers and the policy, regulatory and science arms of Marine Scotland is leading to improvements to the environmental assessment and consenting processes with a view to simplifying and unifying the regulatory system while maintaining appropriate levels of environmental protection. Collaboration between the industry and scientists is targeting seabed survey work to meet Scottish Governmental needs for a system of marine spatial planning, and clarify the development potential of resource-rich areas.

In Norway the world's first prototype of a salinity power station will become operational in late 2009. The potential for salinity power is big *e.g.* the total potential in Norway is estimated to be 12 terrawatt hours (TWh). It is expected that such power stations can be build under ground or on land and avoid spatial conflicts at sea.

Environmental impacts of offshore renewable energy

OSPAR's assessment of impacts of offshore wind farms identifies physical impacts on habitats and seabed through the introduction of hard substrate. Impacts on birds (collision and displacement), and potential impacts of underwater noise and electro-magnetic fields are still being researched (OSPAR, 2008a).

Other ocean energy installations will have some impacts on the waves and currents. Impacts can relate to the placement of offshore structures, cables and construction and operational noise. Emissions are considered to be minor although there can be some emissions from antifouling etc. Fish stocks are generally expected to benefit as long as fishing is prohibited or restricted in areas developed for renewable energy, acting in a similar way to harvest refugia.

The most important consequences of renewable energy for the marine environment are expected to relate to physical impacts and competition for limited space. Generally, for well planned and carefully selected sites only minor effects on the environment are expected, although there are notable gaps in our knowledge. There are important exceptions and the likelihood of the more significant effects is very dependent on the particular characteristics of the projects being developed (effective use of mitigation measures), in combination with the locations where they are being deployed.

The choice of the site for offshore renewable energy generation will be key to minimise impacts. This includes interference with other uses of the sea *e.g.* fisheries, shipping, mariculture etc. and associated added pressure on marine life or risk of accident and pollution.

Development of offshore renewable energy needs to be kept under review

For offshore wind farms, OSPAR measures guiding good environmental practice in site location, licensing, environmental impact assessment, monitoring, construction, operation and removal/decommissioning of offshore wind-farms have been adequate leading up to 2010. The OSPAR assessment of impacts of offshore wind farms recommended that this conclusion should be regularly revisited after 2010 as the scale and rate of offshore wind farm development within the OSPAR area increases. The ongoing data collection on offshore wind farms provides a tool for monitoring the scale of development in the coming years.

Currently, no specific measures apply for other offshore renewable projects but integrated coastal zone management and marine spatial planning provide tools for their management.

OSPAR should keep the development of wind farms, wave, saline and tidal power under review, assess their impacts on the marine environment, and consider the need for requirements for management measures (*e.g.* environmental impact assessments, guidelines for Best Environmental Practice or Best Available Techniques) to manage and minimise their impacts on the marine environment.

3.3 Carbon dioxide capture and storage

Carbon sequestration relates to techniques which allow to capture carbon dioxide at point sources, compress it and store it permanently away from the atmosphere. Suitable geological formations for storage can be found on land and at sea. Offshore reservoirs include depleted oil and gas wells, mainly in the North Sea (Region II) and the Norwegian Sea (Region I).

Carbon dioxide capture and storage could contribute to reduce atmospheric greenhouse gas

Carbon capture and storage (CCS) technologies could make a relevant contribution to climate change mitigation on century-long time scales.

So far three CCS projects exist in the OSPAR area as part of the operation of offshore gas installations. At the Sleipner field in the North Sea approximately 10 million tonnes CO_2 in a supercritical state[2] have been injected into the geological formation Utsira by 2008. The project has been in operation for twelve years and so far no leakage or release of CO_2 to the marine environment have been observed (see case study at Annex 1). In April 2008 a new full scale CCS project went into operation at the Snøvit field outside Melkøya in the Northern part of Norway. When in full operation this project will inject 0.7 tonnes CO_2 into the geological formation Tubåen. The CCS demonstration project (CRUST) at the K12-B gas field 100 km offshore the Netherlands injects CO_2 into a part of the gas reservoir no longer under production; pilot test injection is restricted to 20 000 tonnes of CO_2 a year; at a later stage the injection amount can rise to 480 000 tonnes a year.

Those projects capture CO_2 contained in the produced natural gas at the offshore production site. The use of CCS in future is intended to captured CO_2 from the flue gas of installations (*e.g.* from fossil

[2] “Supercritical carbon dioxide” refers to carbon dioxide that is in a fluid state with both temperature and pressure being above its critical point, resulting in CO_2 behaving like liquid.

power stations) on land and transported by pipelines or ships offshore to platforms over injection wells through which CO_2 is injected into geological sub-seabed formations.

To enable the use of the geological carbon capture and storage, two challenges must be overcome. The first is to manage the environmental risks of the technology, in order to ensure that CO_2 captured and stored remains isolated from the atmosphere and biosphere, and so it is environmentally secure and effective as a climate change mitigation option. The second is to address the present commercial barriers to the deployment of CCS. If left to the market, investments in CCS technology development may be insufficient compared to the aims of the EU climate and energy policy, at least in the first period.

Storage of carbon dioxide in geological formations on land or at sea could help achieve emission reduction targets. Recent research shows that carbon dioxide can be safely stored in natural systems for millions of years (Gilfillan *et al.*, 2009), even when accounting for continuing, low level leakage. Concerns over leakage can however cast a shadow over plans for artificially created storage sites. Besides posing local safety hazards, leakage could reduce the overall effectiveness of CCS as a climate change mitigation strategy in the long term.

Researchers, funded under the EU TranSust.Scan project[3], used a computer model called DEMETER to understand the extent to which CCS' contribution to climate change mitigation efforts would be compromised by various leakage scenarios. They found that as long as sites are carefully selected, CCS will be effective. However, leakage rates must stay below 1 per cent a year. According to the researchers, CCS can only help to achieve climate stabilisation by the year 2100 if half of all energy needs are supplied from renewable sources. In employing the model, the researchers assume that governments introduce taxes on carbon emissions and other policies that help to stimulate the use of CCS as well as reducing reliance on fossil fuels. (Van der Zwaan and Gerlagh, 2009)

A number of environmental risks are associated with offshore carbon capture and storage

The potential hazards of CCS to the environment and human health include a global risk of re-emitting stored CO_2 to the atmosphere, and local risks of possible releases of CO_2 and other substances in the CO_2-stream for the environment, human health and safety.

The potential hazards are connected with the different phases in the CO_2 storage project: construction, injection, closure, and the long-term post-closure storage. For well selected and managed storage sites the possibilities for leakage is expected to be reduced over time due to the various trapping mechanisms in the storage formation.

The *global risk* can be connected to both accidental releases and fugitive emissions and will depend on the likelihood of leakages to occur and of the amount of CO_2 released. It is considered that the primary potential leakage route will be via the wells rather than via some geological route. Apart from accidental releases of CO_2 fugitive emissions may occur along the entire CCS activity chain, in particular in compressor stations and from the injection plant. Greenhouse gas emissions from CCS operations will occur not only as fugitive emissions or accidental releases, but also as a consequence of the increased fossil fuel combustion needed for the capture process – the energy penalty. The supply and transport of this additional fuel will result in emissions of greenhouse gases in the upstream phase of a CCS scheme.

The *local risks* connected to human health and safety depends on the likelihood of leakages and the amount of CO_2 released and on the density of the human population potentially being affected by the release. Offshore releases are not expected to impose any risks on members of the public, but there

[3] TranSust.Scan (Scanning Policy Scenarios for the Transition to Sustainable Economic Structures) was supported by the European Commission under the Sixth Framework Programme. www.transust.org/transust.scan.htm

might be people working on the injection installation. There will be risks to personnel working on the riser platform and injection plant, but it is assumed that these will be managed under existing health and safety legislation.

During the *construction of the CO_2 injection facilities*, significant quantities of wastes and effluents may be produced as a by-product of well drilling. This will include drilling muds and cuttings. Quantities will depend on many factors, including the geology of the drilled area, drilling depth and method and their impact will depend on the particular disposal location and method. Well drilling is well-established technology in the oil and gas industry, and there are control measures for the management of wastes from these sectors which can be applied here to minimise impacts.

In the event of loss of containment of underground reservoirs geological and hydro-geological impacts could result from CO_2 storage. These risks will be highly site-specific and cannot be assessed without detailed modelling. The geological and hydro-geological setting of storage sites will therefore need to be carefully evaluated at the feasibility stage on a case-by-case basis to ensure that cumulative and instantaneous releases of CO_2 to the environment would not compromise the effectiveness of the storage. Upon the start of injection, appropriate survey methods will need to be used at regular intervals to monitor the movement of the injected CO_2 plume within the reservoir to ensure that plume behaviour is as expected and if not to plan remediation options. It is assumed that effective site selection and good regulatory control of operational practices will ensure that the risk is acceptable.

Biodiversity may be affected significantly by the development of new pipelines, both permanently where routes cross sensitive areas and temporarily when construction activities lead to dust, noise and other disturbance. The toxic effect of CO_2 accidentally released during pipeline operation can adversely impact species and ecosystems in adjacent areas. Leaking CO_2 is likely to cause localised acidification with adverse effects on local benthic organisms. Field and laboratory studies have shown that CO_2 released on the seabed affects local small benthic organisms, reduces fertilisation success and has an impact on larvae, especially those of molluscs and echinoderms with calcareous shells or skeletons. Accidental and fugitive releases could also impact on biodiversity at injection and storage facilities in the same way as releases from transport. The installation of pipelines may also provide a hard substratum in an area of soft substrata and attract rock-growing organisms to settle on them. While this can increase local biodiversity it may also displace indigenous soft-bottom species.

Measures are in place to ensure environmentally safe storage

Site selection and licensing of operations will be essential to manage the risks of CCS and to minimise impacts. OSPAR has amended its Convention to facilitate the commercial storage of CO_2 in geological sub-seabed formations and adopted a legally binding Decision 2007/2 and guidelines (agreement 2007-12) to manage the risks of CCS projects and to prevent adverse consequences for the marine environment, human health and other uses of the sea. All CCS projects should be authorised and national authorities are required to comply with a minimum set of authorisation requirements relating for example to the characteristics of the CO_2 streams to be stored, site selection for storage, risk assessment and management, monitoring and reporting, and site closure plans. Decision 2007/1 prohibits the storage of CO_2 in the water column or on the seabed. OSPAR Decisions and Recommendations are also in place to regulate drilling activities and disposal of wastes such as cutting piles from offshore oil and gas industry which could help minimising impacts associated with the CCS, *e.g.* the drilling of injection wells.

OSPAR measures are supported by several EU directives, including Directive 2009/31/EC providing a legal framework for environmentally safe storage of CO_2. The EU measures contain requirements for national authorities and operators similar to those required by OSPAR.

OSPAR should keep development of CCS activities and their impacts on the marine environment under review.

3.4 Ocean fertilisation

Ocean fertilisation is any activity undertaken by humans with the principal intention of stimulating primary productivity in the oceans, using micro-nutrients such as iron, and thereby enhancing sequestering of atmospheric CO_2.

There has been a growing interest of research in ocean fertilisation as potential means for removing CO_2 from the atmosphere and increasing commercial interests in the development of large scale projects. However, ocean iron fertilisation remains largely speculative as effective mitigation strategy, and many of the environmental side effects have yet to be assessed (IPCC, 2007). Recent evidence suggests that natural iron fertilisation in the Southern Ocean enhances carbon export to the deep sea (Pollard *et al.,* 2009). Experiments have so far concentrated on the Southern Ocean and the North-East Pacific. Current state of knowledge suggests that ocean fertilisation may not be a relevant mitigation option in the OSPAR area, as there is no evidence that iron is a limiting factor to phytoplankton growth in the area.

The recent interest in ocean fertilisation has raised environmental concerns in several conventions. The Conference of Parties (COP) to the Convention on Biological Diversity in May 2008 requested Parties and urged other Governments, in accordance with the precautionary approach, to ensure that – with the exception of small scale scientific research studies within coastal waters – ocean fertilisation activities do not take place until there is an adequate scientific basis on which to justify such activities, including assessing associated risks, and until a global, transparent and effective control and regulatory mechanism is in place for these activities.

The Meeting of Contracting Parties to the London Protocol in 2008 agreed to consider a potential legally binding resolution or an amendment to the London Protocol at its next session in 2009. Given the present state of knowledge, ocean fertilisation activities other than legitimate scientific research should currently not be allowed. Scientific research proposals should be assessed on a case-by-case basis using an assessment framework to be developed by the Scientific Groups under the London Convention and Protocol. Until specific guidance is available, Contracting Parties were urged to use utmost caution and the best available guidance to ensure protection of the marine environment.

4. Adapting to climate change

Adaptation recognises that some impacts will arise from climate change on natural and human systems irrespective of mitigation achievements. Adaptation refers to actions dealing with the unavoidable consequences of climate change through enhancing the resilience of natural and human systems, *i.e.* their capacity to cope with those consequences.

4.1 The challenges of adaptation

Climate change and ocean acidification will affect natural systems and water quality (cf. Tables 2.1 and 2.2) and increase vulnerability of marine and coastal systems.

Climate change will also, directly and indirectly, affect all society and numerous sectors, including water resources, energy, urban planning, infrastructure, food production, soil management etc. Impacts on the coasts and maritime activities include the following examples:

- sea level rise, risks of storms and floods and coastal erosion will affect coastal communities, infrastructure and tourism;
- relevant marine and coastal ecosystems services, affecting for example fisheries, may be lost as result of ocean acidification and sea level rise, with coastal wetlands disappearing and sensitive marine habitats such as coral reefs declining;
- sea level rise and coastal erosion will lead to loss of coastal systems such as salt marshes and dunes and their important functions as habitats, natural flood barriers and to dissipate the force of waves during storm surges.

Effects of climate change on natural systems can also provide new opportunities for human activities for example:

- retreat of the ice shield in the Arctic and longer ice free seasons could mean more oil extraction, shipping and tourism in Region I;
- changes in species reproduction and distribution could mean change in fisheries and their geographic distribution across the OSPAR area;
- rising sea temperature and establishment of non-indigenous species could give opportunity to different aquaculture practices.

This means that business, society and legislation will have to adapt to the new circumstances. This situation has both negative and positive aspects. Changes give new opportunities but may add new pressures on ecosystems. Adaptation activities both on land and sea will change the distribution and intensity of human pressures on the marine environment.

4.2 Developing strategies for adaptation

Working with nature's capacity to absorb or control impact can be a more efficient way of adapting than simply focusing on physical infrastructure. With the exception of the coastal area, physical actions may be less feasible in the marine environment. Adaptation strategies related to the marine environment will be different and more challenging than on land as fewer tools will be available. First national adaptation strategies at policy level have been adopted in OSPAR countries. These focus mainly on adaptation on land and of infrastructure for coastal defence.

4.2.1 Marine adaptation

Rise of sea temperature and ocean acidification are important driving forces for changes in the marine environment which will affect species, habitats, ecosystem processes and ultimately ecosystem functioning and associated services. Adaptation will need to take place both at local and at regional level.

Vulnerability of marine ecosystems in the OSPAR area

Impacts of climate change are expected to differ widely between OSPAR Regions. The increase in sea temperature and acidification, for example, will be higher in the northern part (Region I) than in the southern part (Regions IV and V). There will be generally (further) northward movement of species, *e.g.* Atlantic species moving to more northern seas such as the Arctic, Barents Sea and the Nordic Seas (Region I), and subtropical species moving northward to temperate regions such as the Iberian upwelling margin (Region IV) and the Celtic Seas (Region III).

There is a need for a better understanding of potential climate change impacts at regional and local level, of those ecosystems and species that are the most vulnerable to climate change, and of the thresholds to changes in different climate factors and how they work together, particularly where they determine 'tipping points' at which a change is no longer linear and reversible, but abrupt, large and potentially irreversible over timescales relevant for contemporary generations. Some species are sensitive to increased temperatures while others are sensitive to changes in acidity and salinity. It should be remembered that the realised niche of a species is a combination of all the environmental variables acting on that species. There is also a need to improve knowledge about the range extension of individual species and the influx of non-indigenous (*e.g.* southern) species that may colonise an area.

Monitoring and assessment of climate change and ocean acidification will therefore be essential for a better understanding of the vulnerability of marine ecosystems and interactions between climate change/acidification and other human pressures. According to the Global Climate Observing System (GCOS) standards, relevant parameters linking to climate change include:

- sea-surface temperature, sea-surface salinity, sea level, sea state, sea ice, current, ocean colour (for biological activity), carbon dioxide partial pressure in the surface domain; and
- temperature, salinity, current, nutrients, carbon, ocean tracers, and phytoplankton in the sub-surface domain.

OSPAR will have a key role in monitoring and assessing climate change and ocean acidification and their impacts on the marine environment. OSPAR should work with partner organisations (*e.g.* ICES, IOC) to put in place systems for assessing climate change. This should include scenarios of potential impacts and methods and indicators to monitor and assess the progression of climate change impacts particularly at regional scales. Methods for monitoring ocean acidification are a priority.

Options for marine adaptation

Marine adaptation may to a large extent have to rely on the development of existing and new regulations on the management of human resources and maritime activities to increase resilience of the natural system. Experience with marine adaptation is limited. Adaptation options could include:

- adaptation of operational quotas (*e.g.* fisheries catch quotas) to take into account the added pressures resulting from climate change;
- building climate change implications into work to protect and conserve marine biodiversity, *e.g.* by establishing protection for sites most likely to suffer adverse effects or by identifying species and habitats vulnerable to climate change as priority for protection;
- adaptation of environmental objectives;
- building climate change implications into sectoral planning and management of maritime activities and into tools to implement an ecosystem approach.

Initiatives and measures to adapt to climate change will depend on the best available understanding of the vulnerability of the marine ecosystem.

4.2.2 Coastal adaptation

Rising sea levels, increased storminess and higher and more forceful waves can be expected to increase the risk of coastal areas to flooding, erosion, loss of coastal ecosystems, and freshwater shortage. Coastal communities, infrastructure and economies will be under threat. Early (proactive) adaptation of current policies is imperative to minimise the potential risks, damages and residual costs of climate change (see case study at Annex 2 on cost-benefits of coastal adaptation).

Vulnerability of coastal systems in the OSPAR area

The vulnerability of coastal systems to sea level rise differs widely across OSPAR regions depending on their local physical characteristics and the rate and nature of the impact. In Region I, for example, the rate of sea level rise may be lower where land levels are still rising or responding to the loss of ice cover. In contrast, impacts of sea level rise will be most strongly felt in low-lying areas in the southern North Sea (Region II) (Figure 4.1).

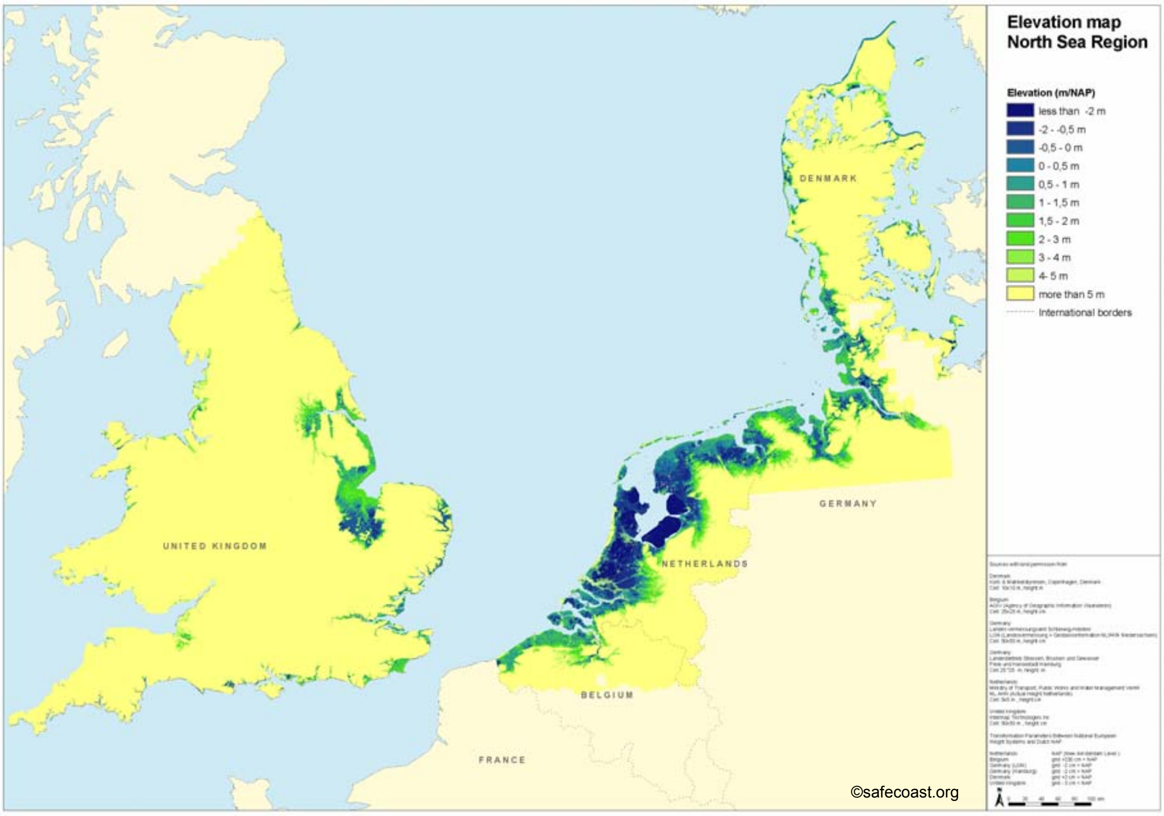


Figure 4.1 *Large coastal areas of the North Sea are low-lying and particularly affected by increased risks of flooding as sea level rises (source: www.safecoast.org). This includes densely populated and highly industrialized areas such as London, Hamburg and the so-called randstad in the Netherlands, and many areas of high ecological value included in the EU Natura 2000 network.*

The risk of direct impacts of rising sea levels will be lower along high and rocky coasts for example in Norway, Sweden, Iceland, Ireland, and some coasts in Spain and the UK. Increased storminess and higher and more forceful waves however may increase the rate of erosion of the coastlines in all OSPAR Regions. These impacts are expected to be highly location specific and responses would need to take place primarily at local level.

Options, practices and plans of coastal adaptation

A wide range of options is available to respond to sea level rise and increased risks of flooding and coastal erosion, examples of which are included in Table 4.1.

Table 4.1 *Examples of coastal adaptation options. Source: Policy Research Corporation, 2009*

Options	**Protect** = effort to continue use of vulnerable areas	**Accommodate** = effort to continue living in vulnerable areas by adjusting living and working habits	**Retreat** = effort to abandon vulnerable areas
"Hard"	Dykes, seawalls, groins, breakwaters, salt water intrusion barriers	Building on pilings, adapting drainage, emergency flood shelters	Relocation threatened buildings
"Soft"	Sand nourishment, dune building, wetland restoration or creation	New building codes, growing flood or salt tolerant corps, early warning and evacuation systems, risk-base hazard insurance	Land use restriction, set-back zones

A number of OSPAR countries have adopted first national plans and strategies to respond to sea level rise and coastal erosion (Table 4.2). National initiatives in the Netherlands (see case study at Annex 3) and Spain (see case study at Annex 4) at policy and operational level illustrate examples to develop strategic and coherent responses to the expected consequences of climate change on coastal areas.

Current strategies focus mainly on protective options building on existing measures and practices to minimize risk of floods and coastal erosion. There is a long history and experience especially in the North Sea with coastal dynamics and flood defence. Much of the coastline of the North Sea is protected against erosion by structures such as dykes, groyne fields and sea walls, and by beach nourishment schemes to replace sand lost from beaches with marine sediments. Current strategies give priority to reinforcing existing defence structures, construction of storm surge barriers and beach nourishment (Figure 4.1). This includes cooperation of countries on innovative technologies for flood defence as demonstrated by the Ellewoutsdijk project in the Netherlands. Only the UK has included strategic objectives to maximize the efficiency and sustainability of coastal systems through strategic planning (*e.g.* shoreline and estuarine management plans, including coastal realignment, spatial marine planning and environmental management plans).

Coordination of existing and planned adaptation activities is essential for successful adaptation. It can be expected that in the short-term the pressures on the marine environment from coastal defence structures and extraction of marine sediment will considerably increase especially in the southern North Sea. A more strategic approach should take into account the effects of adaptation measures on hydrodynamics and sediment budgets. Some countries like Germany and the Netherlands are already putting such approaches into practice.

***Table 4.2** Overview of current national coastal adaptation strategies in the OSPAR area. Emphasis in responses to sea level rise (in order of importance) and coastal erosion*

Contracting Party	National strategy	Adaptation measures	Comments
Belgium	Yes	• Beach nourishments • Primary defences	
Denmark	Yes	• Beach nourishments • Dike foreland management • Primary defences	Along the Western coast of Jutland beach nourishment is regularly adjusted to the actual changes of sea level and coastal erosion. Dike foreland is considered as coastal protection measure, however, at the moment, no measures are undertaken to adapt to climate change. Adaptation of the primary flood defences is usually considered a local affair.
France	In preparation	Flood risk mapping	A national strategy for the coastline and its adaptation is under way as result of “Le Grenelle de la mer”, a process to set a new integrated policy for the sea and the coastal zone (http://www.legrenelle-mer.gouv.fr). First consideration *e.g.* on risks and costs of coastal adaptation have already been undertaken.
Germany	Yes	• Primary defences • Beach nourishments • Dike foreland management • Secondary dike lines	Master plans coastal defence Lower Saxony and Schleswig-Holstein.
Greenland	In preparation		Has no national strategy at present, but is in the process of drafting a strategy that will also consider coastal zone issues.
Iceland	Yes	Primary defences	In areas prone to flooding by the sea the Icelandic Planning Act stipulates that coastal defence, building of harbours etc. have to take into account sea level rise in defining ground levels of the constructions/ buildings
Ireland	In preparation	Local authorities and State agencies involved in • flood hazard mapping • tidal defences • coastal zone management	Research on adaptation planning ongoing including issues like vulnerability and adaptation in the coastal zone.
Netherlands	Yes	• Large scale beach nourishment • dams, including novel techniques • storm surge barrier (re)design • land reclamation and coastal defence structure	
Norway	In preparation	• Coastal zone management planning • Wave awareness	Ongoing work on an adaptation strategy will include issues like vulnerability and adaptation in the coastal zone
Portugal	Regional strategy	• National Strategy for ICZM • Coastal Zone Management Plans.	National Strategy for ICZM covers vulnerability and risk evaluation for decision making; existing hard interventions (re)evaluation; monitoring
Spain	Yes	• Adaptation of infrastructure and coastal resources • Impact and vulnerability predictions • Integration of adaptation into ICZM	Assessment climate change impacts in coastal areas. The National Plan for the Adaptation to Climate Change (PNACC)
Sweden	In preparation	• Coastal zone management planning • Adaptation for sea level rise	Several types of protective measures are used to prevent damage from erosion and flooding.
UK	Yes	• Primary defences • Managed realignment • Dike foreland management • Conversion of farmland to salt marshes and grasslands	

Figure 4.1 *Examples of national approaches to adapting coastal defences*

Abbotts Hall Farm on the East coast of the UK is part of the coastal realignment project under the Essex Wildlife Trust which is converting over 85 ha of arable farmland into salt marshes and grassland to provide coastal defence in an ecologically important coastal area.

The Ellewoutsdijk in the Netherlands is one of 10 pilot projects of the EU-funded ComCoast project through which Belgium, Denmark, the Netherlands and the UK cooperate on innovative flood defence measures. The village harbour and the historic fort of Ellewoutsdijk form an integral part of the dyke enforcement design.

Many areas along the North Sea continental coast will mainly rely on beach nourishment and dune protection and revetment measures for flood protection. This will lead to an increase in pressures from dredging of marine sands. Denmark for example plans to increase beach nourishment by 9% up to 2025 and 18% in 2025-2050 for the central part of its West coast.

Next steps in coastal adaptation

Most current national plans and strategies do not exceed the 2020 horizon. Recent policy developments start aiming for long-term strategies, especially through emerging climate adaptation policies. Yet, the current state of knowledge about local effects of climate change is still limited and, where available, estimates differ widely and are too uncertain to inform decisions about optimal adaptation options in the long-term. A better understanding of changes in local risks is therefore essential for the development of operational adaptation strategies.

Risk assessments would need to take account not only of the impacts of climate change but also of spatial developments and changes in coastal protection levels. For example, an understanding of the rate of coastal erosion is important to avoid that flood defence relying on beach nourishment, dune building or wetland restoration is undermined.

Some project-based platforms are already available for countries to coordinate national approaches to coastal adaptation. Platforms like Ourcoast allow exchange of experiences and best practices in coastal planning and management (http://ec.europa.eu/environment/iczm/ourcoast.htm). For North Sea states Safecoast provides a framework to collaborate on coastal flood and erosion risk management (http://www.safecoast.org/).

An important strategic element for OSPAR is to underline the need for enhanced co-operation and sharing of economic burden between Contracting Parties for example for research and planning in coastal adaption. This is particularly important where sea level rise and coastal erosion affect larger coastal areas stretching across national borders.

4.3 Policy and legislative frameworks facilitating adaptation

Since the sea knows no frontiers, adaptation to climate impacts will require co-ordination on transboundary issues and a comprehensive and integrated approach to coastal and marine areas. Some instruments are already in place which can facilitate coastal and marine adaptation to climate change (Table 4.3).

In July 2009 the EU Environment Council adopted a White Paper on adapting to climate change: Towards a European framework for action. It sets out an initial framework to reduce the EU's vulnerability to the impact of climate change to complement action by EU Member States. The EU's framework adopts a phased approach. Phase 1 (2009-2012) will lay the ground work for preparing a comprehensive EU adaptation strategy and will focus on four pillars of action:

- building a solid knowledge base
- integrating adaptation into EU key policy areas
- employing a combination of policy instruments to ensure effective delivery of adaptation
- stepping up international cooperation on adaptation

Table 4.3 *Overview of main EU instruments facilitating marine and coastal adaptation*

EU instruments	What they regulate
EU White Paper on adapting to climate change	• Framework for adaptation measures and policies to reduce the EU's vulnerability to the impacts of climate change
Marine Strategy Framework Directive 2008/56/EC	• 'Good environmental status' of the marine environment
Water Framework Directive 2000/60/EC	• 'Good ecological status' of coastal and transitional waters
Floods Directive 2007/60/EC	• Assessment and management of flood risks
Integrated Coastal Zone Management	• Integrated planning and management of human uses of the coastal zone

The Marine Strategy Framework Directive and the Water Framework Directive provide frameworks which facilitate inclusion of climate change in required marine strategies to protect the marine environment and its resources and in river basin management plans, respectively. They provide mechanisms which allow to regularly adapt strategies and plans to new knowledge on impacts of climate change on ecosystems and human systems and the need for management responses. The EC Floods Directive provides already a framework for the assessment and management of risks of flooding which can take into account changes in flood risks as result of climate change. It requires Member States to take adequate and coordinated measures to reduce flood risks and adverse effects on the environment, human health, cultural heritage and economic activities.

Integrated Coastal Zone Management (ICZM) and marine spatial planning are tools promoted both in the OSPAR framework and the EU which allow integrating climate change issues in, and can provide flexible adaptive mechanisms for, planning and management of human uses and their interaction with environmental interests.

Next steps for OSPAR towards adapting to climate change impacts will need to include integrating climate change issues into all its work areas and active cooperation with partner organisations (*e.g.* NEAFC, IMO) to integrate climate change issues and changing vulnerability of marine ecosystems into their work (*e.g.* fisheries management) relevant for the environmental protection of the North-East Atlantic. To formulate adaptation strategies, enhanced knowledge is needed:

OSPAR should work with partner organisations (*e.g.* ICES, IOC) to monitor and assess climate change and ocean acidification. This should include scenarios of potential impacts and methods and indicators to monitor and assess the progression of climate change impacts, particularly at regional scales.

OSPAR needs also to enhance its knowledge about the vulnerability of species, habitats and ecological processes to climate change and the interaction of these with pressures from human activities on the sea.

OSPAR should continue work on marine spatial planning and integrated coastal zone management as integrative and adaptive tools for the management of human uses and provide a framework to facilitate cooperation on coastal adaptation, especially where this is of transboundary relevance.

5. Conclusions and recommendations

There is increasing evidence of impacts of climate change on the physical, chemical and biological aspects of the marine environment. Ocean acidification is a key future threat. The severity of predicted impacts will be influenced by the extent to which humankind can act to mitigate these changes.

Commitments and obligations of OSPAR Contracting Parties under global and EU policy and legal instruments are important driving forces for mitigation actions in the OSPAR area. This includes an increasing demand for uses of the sea for energy generation from renewable sources such as wind, waves, tide and salinity regimes and for the permanent and safe storage of CO_2 streams in geological sub-seabed formations. OSPAR offers a framework in which these increasing demands on the marine can be managed and regulated in a coordinated way.

There will be a need for society to adapt to climate change. This will involve change in human behaviour and use of natural resources on land and at sea which will alter the human pressures on the marine environment. There is need for a better understanding of potential impacts of climate change at local and regional level (scenarios) and of the risks for natural and human systems to inform the development of strategies to adapt to climate change and its consequences. Some EU instruments are already in place to facilitate marine and coastal adaptation.

Climate change therefore adds urgency to OSPAR’s work to meet its current objectives for protecting the marine environment to increase resilience of ecosystems already under pressure from pollution and various human activities. In its future work OSPAR will need to adapt its policies and objectives for the protection of the marine environment in all fields of work. In this context, OSPAR should:

- increase monitoring of climate change, ocean acidification, and related impacts on marine ecosystems;
- assess and understand observed changes using *inter alia* scenarios and models;
- take properly account of changing pressures and increased vulnerability of marine ecosystems;
- adjust current policies and objectives to support work on mitigation of greenhouse gas emissions;
- focus on the management and regulation of new activities at sea such as marine renewables and to ensure that these activities do not have negative impacts on the marine environment;
- focus also on new tools such as marine spatial planning and integrated coastal zone management;
- enhance cooperation with other organisations dealing with mitigation of and adaptation to climate change and ocean acidification.

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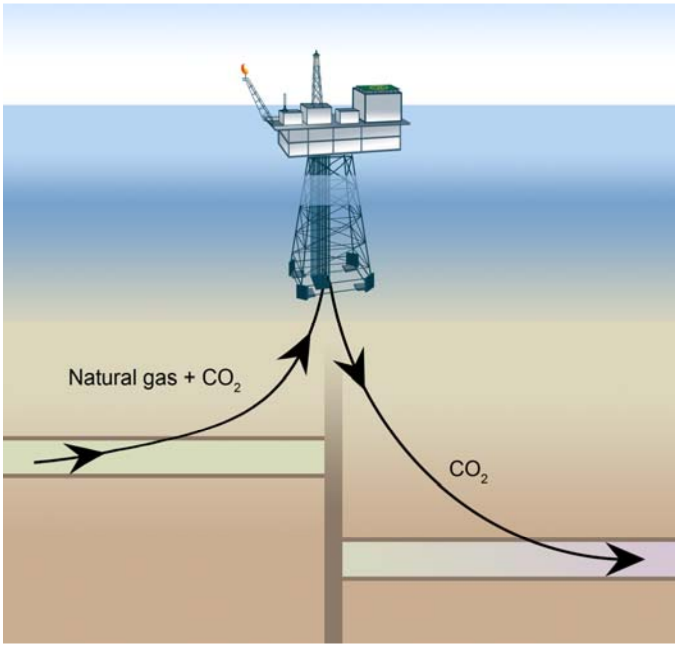
7. Abbreviations

CO_2	Carbon dioxide
COP	Conference of the Parties
EEA	European Environment Agency
EU	European Union
GW	Gigawatt
ICES	International Council for the Exploration of the Sea
ICZG	Integrated Coastal Zone Management
IMO	International Maritime Organisation
IOC	Intergovernmental Oceanographic Commission
IPCC	International Panel for Climate Change
MW	Megawatt
NEAFC	North-East Atlantic Fisheries Commission
TWh	Terrawatt hours

Annex 1: CO2 capture and storage at the Sleipner Vest gas-condensate field in the North Sea (case study)

The Sleipner CO_2-injection project is the first industrial-scale CO_2-injection project in the world and has been in operation since 1996. By January 2008, 9.7 million tonnes CO_2 had been injected. The recent amendment of the OSPAR Convention and the adoption of a package of OSPAR measures enable future environmentally safe storage of carbon dioxide streams, captured at sources on land, in geological sub-seabed formations subject to agreed standards for risk assessment and management of the activity.

The natural gas at the Sleipner Vest gas-condensate field, offshore Norway, contains about 9 per cent CO_2. The CO_2 content has to be reduced to about 2.5 per cent before it can be transported to the consumers onshore. The CO_2 to be removed amounts to about 1 million tonnes per year.



Strategies to reduce greenhouse gas emissions formed part of the original planning considerations for the development of the Sleipner Vest gas-condensate field. The considerations were influenced by the Norwegian tax on CO_2-emissons (introduced in 1991 and extended in 1996). It was therefore decided that excess CO_2 from the field would be injected for permanent storage into a geological reservoir.

The selection of an appropriate reservoir and injection location were essential for the success of this strategy. In their search for a suitable reservoir the companies were looking for a saline aquifer with reasonably high porosity and a capture rock above to prevent leakage. Furthermore the CO_2 should be stored under high pressure - preferably more than 800 meters below the surface. Under these conditions CO_2 is buoyant, and less likely to move upwards than CO_2 in gaseous form. A formation in the Utsira aquifer, located 800 – 1000 m below sea level, was chosen for its suitable size, depth and geological characteristics. The chosen formation has excellent porosity and permeability (which is well suited for high injectivity). The formation is overlain by a widespread thick layer of shales, which act as an effective barrier to CO_2 leakage.

Seismic surveys and information from core drillings provided relevant information on the reservoir's characteristics. The injection well and the storage site has been located in such a way that the injected CO_2 could not migrate back to the Sleipner A platform and the production wells. This will both prevent corrosion problems in the production wells and minimise the risk of CO_2 leakage via the production wells. The injection point is located 2.5 km east of the Sleipner A platform. Migration evaluations have been developed, expecting that CO_2 will migrate vertically to the sealing shales and horizontally along the saddle point of the structure. Migration will take the CO_2 away from other wells drilled from the Sleipner platform.

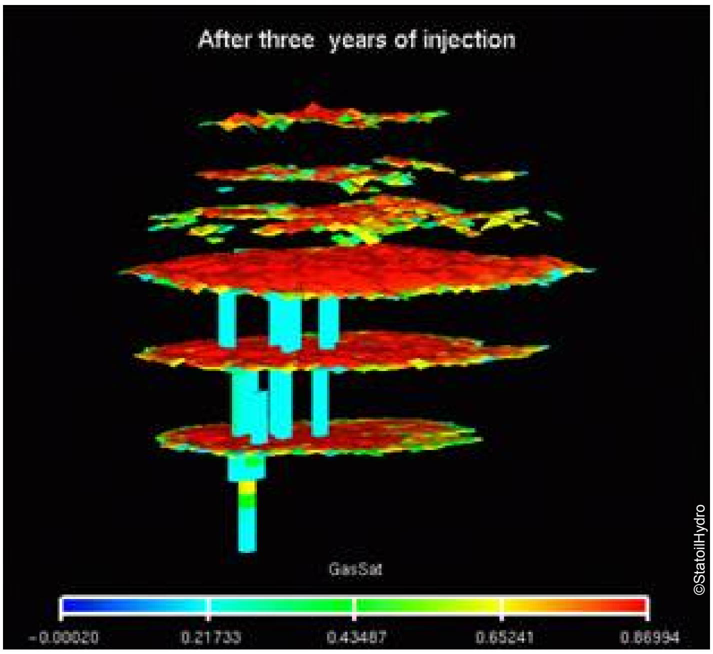
In Norway, storage projects like Sleipner have to apply for a permit under the Pollution Control Act. The storage of CO_2 is included in the emission license for the Sleipner Vest field. According to the license, the operating company StatoilHydrois obliged to monitor the CO_2-storage and to report the amount of CO_2 emitted and the amount injected every year to the Norwegian Pollution Control Authority. The stored CO_2 has been monitored using time lapse seismic to confirm its behaviour and evaluate

- whether any of it has leaked into the overburden seal, the ocean or the atmosphere, or
- whether any of it has migrated towards the Sleipner installations, potentially leading to corrosion problems for well casing.

So far the monitoring has shown that the injected CO_2 is kept in place without leaking out. In case that unexpected CO_2 movements will take place beyond the capture rock, monitoring techniques will be able to register this.

The time-lapse seismic data clearly image the CO_2 within the reservoir. The data also resolve a vertical CO_2 chimney, which is regarded the primary feeder of CO_2 in the upper part of the bubble. Simulation models, which match the 4D seismic data reasonably well, have been used to predict the CO_2 behaviour, (see figure below). The time-lapse seismic images clearly show the development of the CO_2 plume, and also have been used to calculate the amount of CO_2 in the reservoir. The volume calculated from the observed reflectivity and velocity pushdown is consistent with the injected volume.

StatoilHydro is also applying other monitoring methods for the injected CO_2, including gravimetric monitoring, pressure measurements and well monitoring.



Flow simulation of CO_2 showing gas saturation of the aquifer

The spread of carbon dioxide through the aquifer is recorded by seismic surveys. This together with other monitoring has shown that the injected CO_2 has remained in place without leaking.

Annex 2: The economics of climate change adaptation in EU coastal areas (case study)

The recent study "The economics of climate change adaptation in EU coastal areas" presented by the European Commission investigates the costs and benefits of coastal adaptation (Policy Research Corporation, 2009). This case study presents the key findings of the EU study for two marine basins: the North Sea (relating to OSPAR Region II) and the Atlantic Ocean (relating to OSPAR Regions III and IV). The text of the case study is a compilation of text extracted from the EU study report (Policy Research Corporation, 2009):

Climate change adaptation has come to the agenda in almost all EU member states, yet, is at different stages. Most cost-benefit assessments tend more towards a cost-assessment: measuring which actions are optimal from a technical and financial point of view to ensure the safety of the area at risk. Nevertheless, most experts highlight the benefits of early (proactive) adaptation to climate change to minimise the potential risks, damages and residual costs.

The total coastal protection expenditure of the EU countries related to the Atlantic Ocean (relating to OSPAR Regions III and IV) and the North Sea (relating to OSPAR Region II) amounts to € 8.8 billion over the period 1998 – 2015. The Netherlands, Germany, United Kingdom and Spain account for the majority of total expenditure. In average the expenditure has increased from 1998 to 2008, while in the near future (2009 – 2015) the annual normal expenditure is expected to slightly decrease.

The size and scope of coastal area risks and efforts to overcome these risks vary largely between EU Member States, depending on the physical situation. From the empirical analysis, it can be observed that *current scientific research results with respect to the more local effects of climate change are too uncertain* for policy development. Both the scientific and empirical analysis indicate that (national) coordination is a prerequisite for the success of climate adaptation in coastal zones.

Albeit the uncertainties linked to the potential effects of climate change, *long-term strategic questions are put on the political agenda, for example in relation to spatial development*. Nonetheless, in the majority of EU Member States, additional efforts are needed to turn strategic thinking into comprehensive adaptation policies and operational actions.

Conclusions per marine basin

The colours used in each little table represent the safety level when comparing the *real* expenditure with *theoretically estimated* investment that is needed to protect the human use of the coast. Figures have to be interpreted against the background of the underlying differences between the PESETA[4] estimates and the actual coastal protection and climate change adaptation expenditure. Countries which are indicated with a '*' are located within more than one marine basin, therefore their expenditures have been split between the different basins.

[4] PESETA – Project of Economic impacts of climate change in Sectors of the European Union based on boTtom-up Analysis – is a mulit-estoral assessment of impacts of climate change in Europe for the 2011-2040 and 2071-2100 time horizon which is coodinated by the Joint Research Centre of the European Community and involves several research institutes. Cf. http://peseta.jrc.ec.europa.eu/docs/Coastalareas.html

North Sea

	*Scientific cost of adaptation per annum in € million* *ECHAM4B2 (1995-2020)*		*Actual average cost of adaptation per annum in € million* *(1998-2015)*
	Low SLR (22.6 cm)	*High SLR (50.8 cm)*	*Annual normal and hot-spot related expenditure*
Belgium	2.0	2.5	23.3
Denmark*	39.8	71.0	15.5
France*	8.8	16.6	1.7
Germany*	38.4	77.6	107.1
the Netherlands	54.3	88.1	190.1
UK*	64.4	112.8	61.6 *(83)*[109]
Total	*207.7*	*368.8*	***399.3 (420.7)***

Source: Policy Research Corporation, 2009. Red indicates that real expenditure is below the theoretic minimum; orange indicates that real expenditure is above the theoretic minimum and below the theoretic maximum; green indicates that real expenditure is well above the theoretic maximum. SLR means Sea Level Rise. ECHAM – European Centre Hamburg Model – is the climate model on which the low and high sea level scenarios are based. Countries annotated with (*) are located within more than one marine basin and their expenditures have therefore been split between the different basins.

Significant sea level rise expectations, storm surges, many low-lying areas (more than 85% in Belgium and the Netherlands) and high economic and population concentrations make flood risks a major concern for the North Sea countries.

The North Sea countries will have spent in total € 7.6 billion to coastal protection over the period 1998-2015; the Netherlands, Germany and the UK account for the majority of total expenditure.

Along the North Sea coast, the actual annual coastal protection and climate change adaptation expenditure for the countries concerned – excluding the expenditure for the Thames barrier – over the period 1998 – 2015 amounts to € 399 million (€ 420 million including expenses for the Thames barrier) which is slightly above the cumulative theoretical estimate of € 369 million under a high sea level rise scenario. Under a low sea level rise scenario the theoretical estimate is around € 208 million.

The actual UK expenditure is close to the scientific estimate under a low sea level rise scenario when also considering the additional hot-spot investment of the UK (London Thames Barrier). The Belgian, Dutch and German expenditures are much higher than the scientific estimated investment needed to protect the human use of the coast under a high sea level rise scenario but these countries defend their coasts since decades and are more advanced and risk-averse when it comes to the protection against increased flood risk.

The Netherlands and the UK are very active in climate change adaptation both at strategic and operational level. The Netherlands follows an integrated national approach to climate change adaptation. In the UK main strategic actions are undertaken by the four devolved administrations. At operational level, German states and UK administrations integrate climate scenarios into Master Plans and Shoreline Management Plans respectively. Hamburg (Germany) has accounted for climate change in their latest regional development project 'Hafencity Hamburg'. Belgium accounts for climate change in its forthcoming Master Plan for coastal protection as well as in current hot-spot activities (Ostend, Zwin).

North Sea countries use primarily hard and soft 'protective' measures (beach nourishments, heightening of dikes) which corresponds to the measures taken into account in the theoretical estimate of Richards and Nicholls (2009)[6].

[5] The total amount of € 83 million includes the yearly expenditure made to the Thames Barrier (UK), but this has not been taken into account in the PESETA estimates.

Atlantic Ocean

	*Scientific cost of adaptation per annum in € million* ECHAM4B2 (1995-2020)		*Actual average cost of adaptation per annum in € million* (1998-2015)
	Low SLR (22.6 cm)	*High SLR (50.8 cm)*	*Annual normal and hot-spot related expenditure*
France*	1.7	3.2	0.3
Ireland	26.7	45.8	5.3
Portugal	10.6	21.8	7.3
Spain*	8.3	16.3	20.8
UK*	35.1	61.4	33.4
Total	*82.3*	*148.5*	***67.1***

Source: Policy Research Corporation, 2009. Red indicates that real expenditure is below the theoretic minimum; orange indicates that real expenditure is above the theoretic minimum and below the theoretic maximum; green indicates that real expenditure is well above the theoretic maximum. SLR means Sea Level Rise. ECHAM – European Centre Hamburg Model – is the climate model on which the low and high sea level scenarios are based. Countries annotated with (*) are located within more than one marine basin and their expenditures have therefore been split between the different basins.

In the Atlantic marine basin (which relates to OSPAR Regions III and IV), the main climate risk is flooding due to sea level rise and changes in both the direction and the power of waves. Southern countries could become more exposed to freshwater shortage in the future due to prolonged and more intense periods of drought.

The total coastal protection expenditure of the Atlantic Ocean countries amounts to € 1.2 billion over the period 1998 – 2015. The UK and Spain account for the majority of the total expenditure.

In the Atlantic Ocean marine basin, the actual annual coastal protection and climate change adaptation expenditure over the period 1998 – 2015 for the countries concerned amounts to € 67 million whereas the cumulative theoretical estimates under a high and low sea level rise scenario amount to € 82 million and € 148 million respectively.

France and Ireland spend less than the scientific estimation; the gap might relate to the fact that both countries do not take a sea level rise scenarios into account in current coastal protection operations. Ireland moreover tends to use accommodate and retreat actions in the future, which have not been accounted for by Richards and Nicholls (2009)[7]. Portugal spends slightly less than the scientific estimation under a low sea level rise scenario but, to date, a sea level rise scenario is taken into account in only 2-3 regional plans.

Spain spends slightly more than the scientific estimate and is in general more advanced in climate adaptation than the other Atlantic Ocean countries.

Reference:

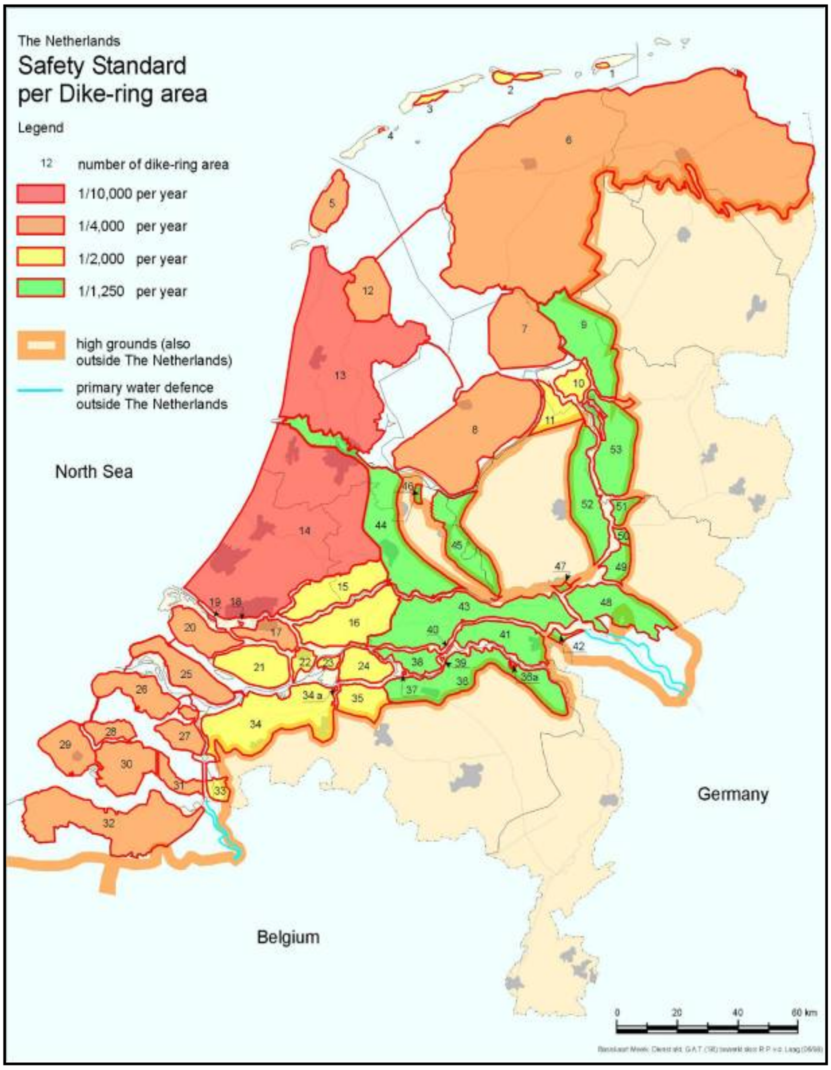
Policy Research Corporation, 2009. European Commission study. The economics of climate change adaptation in EU coastal areas. European Communities, Luxembourg, 2009. http://ec.europa.eu/maritimeaffairs/climate_change_en.html.

[6] Studies performed by Richards and Nicholls in the framework of the wider PESETA (2009) study. See http://peseta.jrc.ec.europa.eu/docs/Coastalareas.html

Annex 3: Coastal adaptation in the Netherlands (case study)

This case study provides a short overview of coastal climate change adaptation in the Netherlands. It describes the vulnerability of the Dutch coastal zone, the relevant policies, the coastal defence and adaptation measures and plans in the Netherlands, and expected impacts of the adaptation measures on the marine ecosystem. It is based on the Fact Sheet for the Netherlands compiled by the Policy Research Cooperation.[7]

With half of the Netherlands' territory located below sea level, the North Sea coast, the estuaries of the Rhine, Meuse, Scheldt and Ems, and the low-lying areas inland are highly vulnerable to flooding. The sea level is currently rising at a rate of 2 mm per year. Coastal protection measures leave 134 km (11%) of the coastline (1275 km in total) subject to erosion (Policy Research Corporation, 2009; EEA, 2006 and EU, 2004).



Reliable flood protection structures are essential for the safety in the Netherlands (figure left). Failure of flood defences can have serious consequences for humans and the economy as shown by the damage caused during the North Sea flood of 1953. A combination of high spring tide and severe windstorm resulted in local water levels to rise to more than 5.6 metres above sea level. Officially 1835 people died as a consequence of the 1953 flooding, almost 200 000 hectares of land was inundated and 3000 homes and 300 farms were destroyed.

Sea level rise, the increased likelihood of severe storm surges in the tidal North Sea region, and considerable structural erosion along the sandy coast are expected to increase the flood risk in the future.

Several national coastal defence and climate change adaptation initiatives are ongoing in the Netherlands both at policy and operational level.

[7] http://www.europa.eu/maritimeaffairs/climate_change/netherlands_en.pdf.

At policy level, initiatives are centred upon increasing risks of flooding. National studies and commission advices on vulnerability and adaptation to increased flood-risks stemming from these initiatives serve as a starting point for the first National Water Plan to be adopted by end of 2009 and the first Adaptation Agenda scheduled to be published in 2009. Contributing initiatives include:

- studies on the probability and consequences of flooding. “Flood-risk and safety in the Netherlands” and “Water Safety 21" provide risk and impact assessment for 16 selected dike rings and investigate the adequacy and economic viability of current protection levels.
- the “Poelman Commission”, initiated by the Ministry of Transport, Public Works and Water Management in 2006, has examined flood prone areas outside the primary coastal protection systems and has advised to formulate specific safety levels for these areas. Possible measures to protect the outer dike areas are still under examination.
- “Watervision 2007” sets out policy objectives to keep the Netherlands climate-proof. This is supported by the “Delta Commission” established in 2007 to examine how the Netherlands can handle the consequences of climate change up to 2100 – 2200. One of the main outcomes of the Delta Commission’s analysis is that a sea level rise of 0.65 – 1.3 m by 2100 and 2 – 4 m by 2200 should be taken into account in further planning. The most important recommendations of the Commission are that the Netherlands should (1) continue nourishing its beaches with the aim of allowing beaches to expand in the future, and that locations for sand mining should be held in reserve; (2) prolong the lifespan of the storm surge barrier of the ‘Oosterschelde’ possibly up to a rise in sea level of 1 m.

At operational level various projects already address flood protection:

- the establishment of the Delta Plan dates back to 1937 and has been regularly updated. It’s implementation is supported by advice from the Delta Commission, founded in 1953, which also oversaw the organization of dam constructions under the 1959 Delta Law. The building of the 'Deltaworks' was an enormous project that was finished in 1997.
- since 2001, the High Water Protection Programme, managed by the Ministry of Transport, Public Works and Water Management, works to support the strengthening of primary coastal protection that do not live up to the required safety standards.
- the Sand Nourishment Programme, managed by the Ministry of Transport, Public Works and Water Management, provides the framework for annual beach nourishment in order to preserve the coastline relative to its conditions in 1990.

Additional operational actions are foreseen to respond to predicted increasing flood-risks as result of climate change, taking into account the need to reduce impacts on the coastal and marine environment. These include

- the protection of 13 coastal cities using flood and erosion scenarios and new developed methodologies to assess tailor-made protection standards which do not increase developments of seaward coastal defences. In the future and depending on the need, these protection standards may be maintained with sand nourishments near these coastal towns.
- increased sand extraction in the North Sea, mostly in areas of more than 20 meters depth (below mean sea level) to limit impacts on ecosystems.
- weak links in the sandy coastline are defended through various interventions which are constructed in such a manner not to cause harm to the environment or are compensated for in order to mitigate for their impacts.
- compensation of the erosion of intertidal areas in the Eastern Scheldt.

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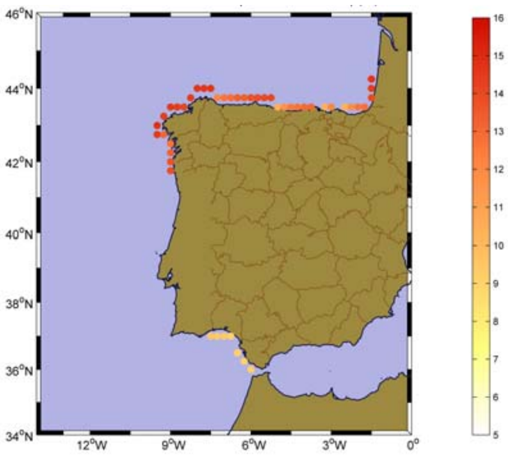
Annex 4: Coastal adaptation in Spain (case study)

Spain's economy is strongly dependent on its coastal areas, with a total of 7500 km coastline including the peninsular mainland, archipelagos and islets. A high percentage of Spain's population is concentrated in coastal areas. Tourism, fishing, industrial and farming activities and other services linked to the coastal resources are the basis for their living. When considering the country's key areas of vulnerability to climate change, Spain dedicated special efforts to identifying the threats to its coastal areas.

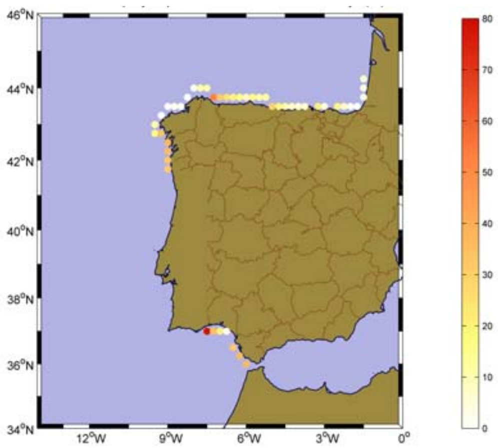
Since 2004 Spain has taken major steps towards the definition of a coherent set of public policies to deal with climate change. One of two first reports that summarise and integrate these studies and also addresse climate change impacts on the Spanish coasts was published in 2005: *A Preliminary Assessment of the Impacts in Spain due to the Effects of Climate Change*. A more comprehensive study, *Impacts in Spanish coast due to climate change effects,* was developed by the University of Cantabria and considers sea level rise and other key factors relating to climate change with impacts on the coastal areas. These include changes in wind patterns and wave direction, and force and frequency of wind and waves. Some results are showed in following figures:

Estimation of shoreline retreat of Spanish beaches as a result of sea level rise by 2050.



OSPAR area	*Approximate retreat*
Coast of Galicia and Cantabria	15 metres
Cádiz Gulf	10 metres

Estimation of shoreline retreat on Spanish beaches due to swell turn by 2050.



OSPAR area	*Approximate retreat*
Northern Galicia	10 metres
Cádiz Gulf	20 metres

The main problems in coastal regions are related to the foreseeable changes in the coastal dynamics and the increase of the mean sea level rise. In this context the most significant likely impacts are:

- The increase of mean sea level will mainly affect deltas and confined beaches, while coastal cliff areas do not seem to face particular risks.
- With maximum projected increases of 0.5 m, the most threatened low-lying coastal areas are located in the Cádiz Gulf and Doñana (Andalucía).
- The Eastern Cantabria region is another area which could be affected, with 40% of its beaches under risk of flooding.

One of the cornerstones of the institutional response to climate change is the Spanish National Climate Change Adaptation Plan (PNACC). This Plan was adopted in October 2006 with the main aim to mainstream adaptation to climate change into the planning processes and policies of all relevant socio-economic sectors and ecological systems. The PNACC is the reference framework for the coordination of Public Administrations' efforts dealing with the assessment of impacts, vulnerability, and the adaptation to climate change in the Spanish sectors acknowledged as potentially affected (water resources, agriculture, forests, biodiversity, coasts, health, tourism, etc.).

PNACC is developed through Programmes of Work. The First Programme of Work, adopted together with the PNACC in 2006, tackles four sectors, including the coastal areas. The work underway is a mainstreaming exercise of climate change adaptation into a national 'Sustainability Strategy for the Spanish Coastal Areas' that is carried out by the General Directorate of Coast and Sea Sustainability of the Ministry of the Environment and Rural and Marine Affairs (MARM). It aims at developing an Integrated Coastal Zone Management system. Following the results and methodology to provide detailed models of the likely impacts of climate change in coastal areas mentioned above, a preliminary and detailed projection of the impacts and vulnerability has been carried out along several hundreds of small coastal units defined by a mix of socio-economic and natural features. This will be the starting point to face and review coastal planning in a participatory process, together with all the relevant administrations and the social and economic actors.

In this regard, another study related to the Spanish coast called *Climate Change in Spanish Coastal Areas* (C3E) has recently been launched by the University of Cantabria, within the framework of the National Plan of Research and Development for the period 2008-2011 and the future Second Programme of Work of the PNACC. C3E has as a general objective to further improve data, methodologies and tools for the assessment of climate change impacts in coastal areas taking into account a more refined spatial resolution and a special focus on costs and benefits of adaptation measures and their practical application in the tourism sector.

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