

## **4. DENMARK**

This country fiche provides a comprehensive overview and assessment of climate change adaptation in Denmark. After detailing the vulnerability of Denmark's coastal zones, the responsibility and financing for coastal protection is explained. Next, the fiche presents the relevant research activities, the coastal defence, risk reduction and adaptation plans available in Denmark as well as the current and future protection and adaptation expenditure. The persons contacted and sources of information used are listed at the end.

### **4.1. VULNERABILITY OF DENMARK'S COASTAL ZONES TO CLIMATE CHANGE**

The Danish coastline measures 4 605 km, bordering the Baltic Sea in the east and the North Sea in the west. Along the western coast, the country consists of a large peninsula, Jutland. The country is known for its many islands as Zealand and Lolland as well as its hundreds of minor islands often referred to as the Danish Archipelago.

The following paragraphs discuss the main climate change risks for the coastal zones of Denmark. Overall, the country's vulnerability to coastal flooding and erosion is rather limited. The main threat is likely to come from increased rainfall and flash storms. Also, the loss of eco-systems or wetlands due to climate change deserves attention.

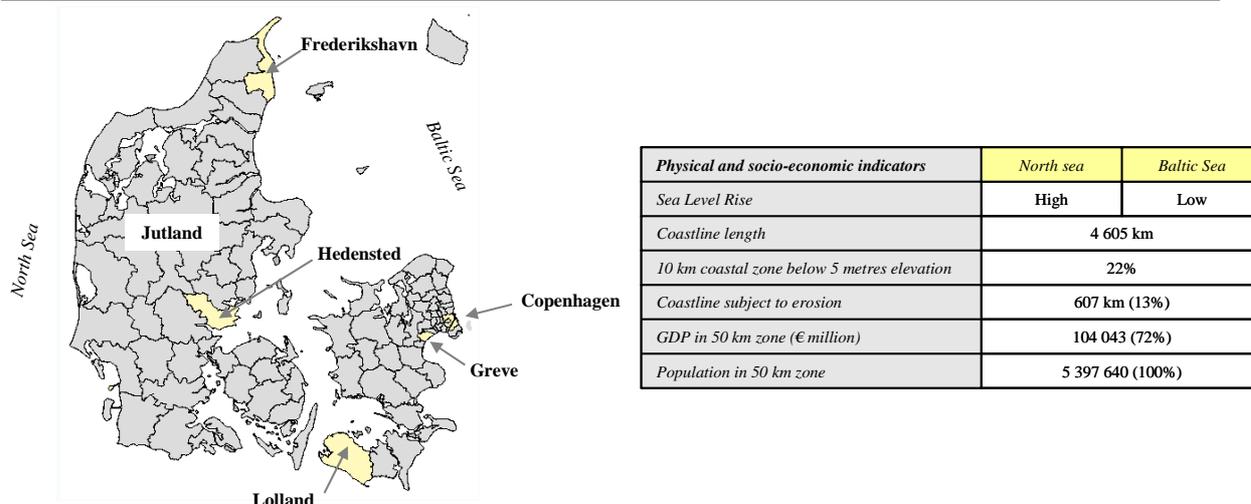
#### ***a/ Flooding and erosion***

Denmark's vulnerability to coastal flooding and erosion is rather limited. Although the Danish North Sea coast is more exposed to SLR and storm surges than the eastern part of the country, flooding and erosion are not considered to pose a real threat as low-lying coastal areas are often farmland or land with few inhabitants.

A few exceptions are the municipalities of Lolland and Greve situated along the Baltic Sea as well as the west coast of Jutland which is exposed to the North Sea. Also Copenhagen, as a low-lying city, is potentially vulnerable to coastal flooding. *Figure 4-1* provides an overview of the municipalities of

Denmark at highest risk or most advanced in terms of adaptation to climate change together with an overview of the main physical and socio-economic indicators of the Danish coastal zones. The municipalities are detailed in the remainder of the text.

**Figure 4-1: Municipalities of Denmark and the main physical and socio-economic indicators of the coastal zones**



Source: Policy Research based on EEA, 2006, *The changing faces of Europe's coastal areas (for Sea Level Rise and 10 km coastal zone below 5 metres elevation)*; European Commission (EuroSION study), 2004, *Living with coastal erosion in Europe: Sediment and space for sustainability (for coastline length and coastline subject to erosion)*; Eurostat 2004 (for GDP and population in 50 km zone)

The municipality of Lolland, represents, with an area of 1,243 km<sup>2</sup> and a population of close to 48 000 inhabitants, the fourth largest island of Denmark. Together with Greve, located in the southern part of Greater Copenhagen, the municipality is considered one of the most flood-prone areas of Denmark. The west coast of Jutland on the other hand is most exposed to the North Sea waves and vulnerable to coastal erosion. Along the coast, natural beach erosion averages 2 m/year.

The main climate change threat for Denmark appears to be increased rainfall and flash storms. The current sewage systems are not able to cope with large amounts of water as was demonstrated during the storms of 2002 and 2007. In the municipality of Greve, evacuation was needed to protect the citizens as the whole area was flooded. Despite this, Danish sewage systems have until now been planned without taking a climate induced SLR into account.

***b/ Freshwater shortage***

In 2006, calculations performed by the Geological Survey of Denmark and Greenland<sup>1</sup> revealed that available water resources will probably increase in west Jutland. In river valleys and low-lying areas on the other hand, freshwater shortage could become a problem. Furthermore, a changed precipitation distribution, with a moderate rise in winter precipitation and a minor decrease in summer precipitation, could influence the ground water formation and the need for catchment areas. Saltwater intrusion into freshwater aquifers<sup>2</sup> is only a problem in a few areas, e.g. smaller islands and along low-lying coasts, but for the moment this does not threaten freshwater availability.

The recently published Danish Strategy for Adaptation to Climate change<sup>3</sup> stated that ad-hoc adaptation measures, e.g. the repositioning of catchment areas to areas where water resources are more plenty or where the influence on streams and wetlands is smaller, might be needed. Concrete measures are only expected to be taken after 2009 when the plans for the EU Water Framework Directive must be drawn up.

***c/ Loss of coastal eco-systems***

Salt marshes and dunes are commonly found along the Danish coastline, especially along the west coast of Jutland. The areas constitute important natural habitats for a large number of plant and animal species. To safeguard their ecological as well as flood-protective characteristics, actions, as the designation of such areas as nature reserve, are undertaken by the national government of Denmark.

## **4.2. RESPONSIBILITY AND FINANCING FOR COASTAL PROTECTION AND CLIMATE ADAPTATION**

The overall principle regarding the implementation and financing of coastal protection in Denmark is that the *persons who profit* bear the responsibility. Hence, measures need to be initiated, financed and implemented by landowners or arranged for within the municipalities.

At national level coastal defence falls under the responsibility of the *Danish Coastal Authority* (DCA), a division of the Danish Ministry of Transport. The DCA's actions are mainly focused on policy and strategic issues such as:

- Supervising the compliance to coastal defence laws;
- Providing advice with regard to coastal defence;
- Approving regional and private plans for coastal protection works;

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<sup>1</sup> GEUS, 2007, *Annual report 2006 – Research for a society in change*.

<sup>2</sup> Underground layers of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt or clay) from which groundwater can be usefully extracted.

<sup>3</sup> Danish Government, 2008, *Danish strategy for adaptation to a changing climate*.

- Monitoring coastline changes;
- Issuing warnings with regard to storm tide.

When private landowners feel the need to protect their coastal property, they can submit a project proposal to the DCA. Permission will usually be granted when:

- There is concrete evidence that the landowner will be threatened by violence of the sea within the next 20 to 25 years;
- The project does not harm any nearby Nature 2000 sites<sup>4</sup>;
- The project complies with the coastal planning regulations.

Although most initiatives come from private landowners, municipalities can also initiate coastal protection projects for which the same procedures need to be followed. In this case, projects are financed with local taxes or through public-private partnerships.

#### **4.3. RESEARCH INTO DENMARK'S VULNERABILITY TO CLIMATE CHANGE AND CLIMATE CHANGE SCENARIOS**

In Denmark, research into climate change and the development of climate change scenarios is mainly undertaken by different departments of the *Danish Meteorological Institute* (DMI)<sup>5</sup>, a public institution set up under the Ministry of Climate and Energy.

The Forecasting Services Department monitors the weather, sea level, waves, currents and various other parameters such as sea-ice. The Danish Climate Centre Department on the other hand studies the future climate and the consequences of climate change. The goal is to make projections of the climate into the 21st century and to contribute to the understanding of the climate's influence on the development of the Danish society.

Additionally, the Danish Coastal Authority carries out some research into climate change with the aim of providing better advice to the municipalities and enable better decision-making concerning the coastal protection projects they propose.

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<sup>4</sup> When the area of the project is situated next to a Nature 2000 area, the DCA can ask the local landowners to investigate the effects of the project on the Nature 2000 site.

<sup>5</sup> DMI has developed, together with the Max Planck Institute in Hamburg, a climate model, called HIRHAM, to simulate regional climate variability and change and to interpret the changes in extreme events such as heavy precipitation and strong storms.

#### **4.4. COASTAL DEFENCE, RISK REDUCTION AND ADAPTATION PLANS IN RELATION TO CLIMATE CHANGE**

The Danish government considers changes in climate still too uncertain to pro-actively invest in adaptation measures, as confirmed in the 2008 high-level national strategy for adaptation to a changing climate. For coastal zones, a spatial planning regulation is the main instrument offered at national level to protect people, infrastructure and nature against the violence of the sea. In addition, a national storm flood fund has been established to compensate flood damage. Coastal defence measures to protect against flooding, erosion and extreme weather events are only undertaken when there is a concrete need for it.

##### *a/ Strategy and legislation at national level*

At present, coastal defence in Denmark is generally not driven by adaptation to climate change. Currently, the general tendency in the coastal protection policy of national authorities is “wait and see”. The Danish tradition of rather strict spatial planning regulations limits the impact of flooding along the coastline and in case of flooding in uninhabited areas, land is given back to the sea. When flood protection measures are a must, the Danish Coastal Authority mainly opts for beach nourishments or other soft defences.

Three acts of the Danish legislation are important to mention when considering coastal adaptation measures:

- *Coastal Protection Act*: the municipalities have the right to undertake coastal protection projects when necessary, financed with the money from the local landowners gathered through taxes;
- *Nature Protection Act*: in the first 300 m zone from the coast no new constructions may be build;
- *Planning Act*: in the first 3 km from the coast planning for new activities is restricted.

Besides these planning restrictions, climate discussions in Denmark focused mainly on mitigation until recently. Though, in March 2008, the Danish government published a general strategy with regard to climate change adaptation. The main purpose is to support coordination and informed decisions about autonomous measures. The policy document sets the strategic agenda and does not contain any specific analysis or actions yet. Coastal zones are mentioned only briefly:

- Climate adaptation may become a necessity due to SLR and more intense storms;
- Enforcement of the protection structures may be needed based on risk-analyses;
- An integrated flood warning system could be useful in the future.

In addition, the Local Government Denmark (LGDK), an interest group of Danish municipalities, has set up a discussion forum on climate change, offering municipalities the possibility to share good practices in the field of coastal protection and stimulate cooperation between them. Municipalities can also rely on the LGDK for individual consultancy services.

In response to several flood events in Denmark, national authorities established a flood insurance scheme dedicated to coastal flooding in 1990. Compensation is paid to landowners, companies or farms that have suffered flood damage due to severe storm events. Since 2000, the fund has also been covering compensation payments for forest damages. Means for compensation are collected by an annual tax payment charged through all private fire insurance policies. Whenever a coastal flood takes place, the Danish Storm Council represented by Danish ministries, insurance companies and the Local Government Denmark, amongst others, decide whether or not and to whom compensations will be paid out.

***b/ Protection and adaptation measures at sub-national level***

At the sub-national level, adaptation actions are making their way up on the agendas of the Danish municipalities. In recent years, and especially following the storm surges in 2006, the DCA has experienced an increase in the number of applications for coastal protection<sup>6</sup>.

As case in point coastal protection and climate change adaptation measures taken at the west coast of Jutland, the municipalities of Frederikshavn, Lolland, Greve and Hedensted and the city of Copenhagen are illustrated in the following paragraphs.

***West coast of Jutland***

The protection of the Jutland west coast is carried out in 5-year timeframes. In each period the allowed rate of erosion and the appropriate measures are decided upon. Some stretches along the coastline are usually allowed to erode by 0.2-2 m/year (compared to natural erosion rates of 1-8 m/year along the entire stretch of the coast) while in other stretches measures are taken to prevent or reduce erosion.

The measures carried out, mainly sand nourishments, but also dune protection and revetments, are co-financed by the national government. It has to be noted that for historical reasons this is the only part of the coast that receives financial support from the national government.

***Frederikshavn municipality***

Frederikshavn municipality is located on the northeast coast of the Jutland peninsula in northern Denmark. The municipality does not have a general adaptation plan or strategy but ad-hoc measures are undertaken to protect the municipality against flooding and erosion.

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<sup>6</sup> The number of applications has increased from about 100 per year prior to 2006, to 300 in 2007 and approximately +200 in 2008.

The beaches on the east coast near Frederikshavn are nourished every year since 1982 to protect against flooding and erosion. Furthermore, in 2007, the harbour was extended to the east with 110 km<sup>2</sup> of land for industrial use. The outer constructions of this harbour were built 2 m above sea level to protect against flooding in the future. In addition, Frederikshavn plans to rebuild and extend the 25 breakwaters on the west coast to protect the village Gammel Skagen against erosion.

### ***Lolland municipality***

The Lolland municipality is located in the south-east of Denmark, close to mean sea level. At present, coastal protection measures against flooding, erosion and extreme weather events are rarely taken but a climate adaptation plan is under development.

In September 2008, the Lolland municipality organised a workshop with the participation of local, regional and state actors to discuss local issues in Lolland regarding climate change adaptation. As a result, a draft proposal on the elements to be addressed in a future climate adaptation plan for Lolland has been formulated. The proposal highlights that:

- Risk areas need to be indicated by the municipality;
- Existing spatial plans need to be re-examined;
- Cost-benefit analyses could be helpful;
- The Ministry of Environment should integrate climate change in its 4-yearly planning.

### ***Hedensted municipality***

The Hedensted municipality is situated on the eastern Jutland coast. The municipality has close to 46 000 inhabitants and predominantly consists of rural areas with large plains. Although the municipality has not experienced any severe weather events in the past, Hedensted is considered to be one of the forerunners in Denmark with regard to adaptation of coastal protection to climate change.

In 2008, the municipality published its first adaptation strategy. This strategy describes the vulnerability of Hedensted and states that coastal protection policy must be shaped on the basis of the IPCC scenarios (A2 scenario for urban areas, A1 scenario for open land areas). This strategy has mainly an effect on local government planning in which Sea Level Rise will be taken into account from 2009 onwards. Additionally it is a tool to trigger further investigations of climate change impacts and possible protection measures needed. Until now, ad-hoc protection measures along the coastal zone of Hedensted are owned and maintained by private landowners.

### ***Greve municipality***

Greve is located in the southern part of the Copenhagen region and it is situated at low elevation. The municipality has not yet experienced any severe coastal flooding, but is mainly exposed to flash storms.

In response to the severe flash floods of 2002 and 2007, the municipality of Greve started to investigate all major aspects of water flows in the city (e.g. flood plains, rivers, sewage-systems and storm water systems). The first measure put in place was a mapping of water flows, geological conditions and other determinants effecting the municipal water management. Secondly, the areas were identified that had the capacity to handle the water and to which water masses could be directed. These mapping exercises were complemented with a record of the most critical infrastructures to make a more solid scenario for how future flooding events could affect the municipality. As a result, first adaptations were made to the local sewage system.

### ***Copenhagen***

Copenhagen is located on the east side of the Danish island Zealand and partly upon the island of Amager. The city has a population of around 1.3 million inhabitants of which only a small part lives in areas with an elevation of less than one metre above sea level. Parts of the city are protected by dikes but generally the city harbour is protected by quays which are about 2 m above sea level.

A recent OECD study<sup>7</sup> states that currently most of Greater Copenhagen's 60 kilometres of coastline is well-protected, but highlights that the city itself is not equipped to handle extreme, temporary water increases of 1.5 meters or more. The report warns that the city should update the protection against flooding in key localities such as harbours and the historic centre of the city. The OECD estimates that under a 50 cm SLR scenario, the biggest storm likely in 120 years would bring waves that could cause €5 billion of flood damage in the city. In a first reaction, the Danish government stated that the report presents a good idea of the true cost of climate change but that it was based too heavily on uncertainties. Dikes and higher port docks may be needed, but national authorities prefer to consider first the water level increases in the construction of new buildings and roads situated in the exposed areas.

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<sup>7</sup> Hallegatte S., Patmore N., Mestre O., Dumas P., Corfee Morlot J., Herweijer C. and Muir Wood R., 2008, *Assessing climate change impacts, Sea Level Rise and storm surge risk in port cities: a case study on Copenhagen*.

#### **4.5. PAST, PRESENT AND FUTURE ADAPTATION EXPENDITURE**

As coastal protection works need to be financed by the persons who profit, measures will only be undertaken when it is necessary.

In 2008, the total national expenditure to protect the people, infrastructure and nature of the Danish coastal zones against flooding and erosion amounted to €12.7 million. About €10 million was spent on beach nourishments along the west coast of Jutland and €2.7 million to compensate for flood damages.

At sub-national level ad-hoc measures are mainly undertaken in Jutland and Frederikshavn. In 2008, these municipalities spent respectively €1.5 million and €0.45 million on beach nourishments. For private spending, national or regional authorities could not provide an accurate estimate<sup>8</sup>.

The total of national and sub-national expenditure thus amounts to €41.65 million for the year 2008. Over the entire period considered (1998-2015) Denmark spends about €315 million to protect its coasts from flooding and erosion.

*Table 4-1* provides an overview of the past, present and future expenditure on the protection against flooding, erosion and extreme weather in Denmark for the period 1998-2015.

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<sup>8</sup> Annual coastal protection spending by private owners is not known publicly but expected to have a minor impact; the only reference to private spending in Denmark can be found in the Safecoast project: 'annual private coastal spending on 110 km of Danish west coast in 2004-2008 is expected to be below €5 million'; Safecoast, 2008, *Coastal flood risk and trends for the future in the North Sea region*.

**Table 4-1: Expenditure to protect against coastal flooding and erosion (in € million)**

Year	MAINTENANCE EXPENDITURE			CAPITAL EXPENDITURE		TOTAL
	Storm flood fund*	Jutland (mainly beach nourishments)**	Frederikshavn (beach nourishments)***	Frederikshavn (rebuild/extend 25 breakwaters)****	Copenhagen	
1998	2.7	16.00	0.45	0	n.a.	19.15
1999	2.7	15.40	0.45	0	n.a.	18.55
2000	2.7	15.40	0.45	0	n.a.	18.55
2001	2.7	15.40	0.45	0	n.a.	18.55
2002	2.7	15.40	0.45	0	n.a.	18.55
2003	2.7	15.40	0.45	0	n.a.	18.55
2004	2.7	11.50	0.45	0	n.a.	14.65
2005	2.7	11.50	0.45	0	n.a.	14.65
2006	2.7	11.50	0.45	0	n.a.	14.65
2007	2.7	11.50	0.45	0	n.a.	14.65
2008	2.7	11.50	0.45	0	n.a.	14.65
2009	2.7	15.00	0.80	0.8	n.a.	19.30
2010	2.7	15.00	0.80	0	n.a.	18.50
2011	2.7	15.00	0.80	0	n.a.	18.50
2012	2.7	15.00	0.80	0	n.a.	18.50
2013	2.7	15.00	0.80	0	n.a.	18.50
2014	2.7	15.00	0.80	0	n.a.	18.50
2015	2.7	15.00	0.80	0	n.a.	18.50
<b>TOTAL</b>	48.6	255.5	10.55	0.8	n.a.	<b>315.45</b>
		314.65		0.8		

\* Proxy provided by the DCA

\*\* Up to 90% is financed by the national government, forecast budgets are a proxy provided by the DCA

\*\*\* Proxy provided by Frederikshavn municipality, the yearly expenditure on these nourishments is expected to increase due to the fact that the nourishments will take place from a ship in the future instead of from the coast as has been the case till now

\*\*\*\* Expenditure provided by Frederikshavn municipality; the cost for this project will be shared between the local landowners and the municipality

#### **4.6. PERSONS CONTACTED AND SOURCES OF INFORMATION USED**

##### **4.6.1. PERSONS CONTACTED**

<i>Name</i>	<i>Organisation</i>
<i>Andersen, Mai M.</i>	Danish Meteorological Institute
<i>Brandt, Gyrite</i>	Local Government Denmark
<i>Dissing, Henrik</i>	Copenhagen municipality
<i>Munk-Nielsen, Carl-Christian</i>	Danish Coastal Authority
<i>Paludan, Birgit</i>	Greve municipality
<i>Pedersen, Leif Hald</i>	Frederikshavn municipality
<i>Rauff, Niels</i>	Hedensted municipality
<i>Sorensen, Carlo</i>	Danish Coastal Authority

##### **4.6.2. SOURCES OF INFORMATION USED**

- Danish Government, 2008, *Danish strategy for adaptation to a changing climate*
- Fenger J., 2000, *Implications of accelerated sea-level rise (ASLR) for Denmark*, proceedings of SURVAS expert workshop on European vulnerability and adaptation to impacts of accelerated Sea-Level Rise (ASLR), Hamburg, Germany, 19 -21 June 2000
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- Pickaver A., 2002, *Integrated coastal zone management in the Baltic states*
- The Copenhagen Post, 2008, *Higher dikes needed for Copenhagen*
- [www.kyst.dk](http://www.kyst.dk), Danish Coastal Authority
- [www.coastalguide.org/icm](http://www.coastalguide.org/icm)