Mapping climate change

- barriers and opportunities for action

background report

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1. Introduction

Climate change will have an impact on a number of areas in Danish society. Although uncertainty still remains as to the magnitude and timing of future climate change, climate change adaptation should be an intrinsic part of ongoing and long-term planning.

The Danish government has decided to launch a series of initiatives to underpin general climate change adaptation efforts that can help prepare Denmark for the impacts of future climate change.

In its government programme, *Et Danmark, der står sammen* (A United Denmark), the government has identified the following tasks:

- Establish a task force which is to prepare an action plan for climate change adaptation and ensure rapid implementation of the EU Floods Directive.
- Ensure that all municipalities prepare action plans for climate change adaptation within two years.
- Modernise the legislation on watercourses and water supply.
- Examine whether water utility companies have adequate opportunities to finance climate change adaptation initiatives, and whether the need for adaptations, other than initiatives aimed at sewerage, make it appropriate to adjust the the division of responsibilities between the municipalities, water utility companies and other authorities.

This report was prepared by a cross-ministerial committee of government officials that was set up in conjunction with the overall Task Force on Climate Change Adaptation.

This report was completed as the first of two phases. The objective of this report was to map the impacts of climate change in Denmark, as well as the opportunities, and to highlight the areas in which Denmark is faced with the greatest challenges from future climate change.

The second phase will include the preparation of a national action plan for future climate change adaptation efforts in Denmark. This action plan will contain proposals for initiatives to help ensure that Denmark adapts to future climate change, for example through amending relevant legislation.

2. Summary and conclusions

The significance of climate change up to 2050
The Danish climate will change gradually in the future. In the years up to 2050, and in particular in the longer term, the climate will present a number of challenges. As a common starting point for climate change adaptation efforts in Denmark, since 2010 the recommended climate scenario has been the A1B scenario from the Intergovernmental Panel on Climate Change (IPCC). Detailed data from the Danish Meteorological Institute are available for this scenario via the Danish Portal for Climate Change Adaptation (www.klimatilpasning.dk). The annual average temperature in Denmark is expected to increase by about 1.2^{o} C up to 2050. Annual average precipitation is expected to increase by about 7% up to 2050, with the highest increase during winter. Denmark will be located on the border between two zones: with more summer precipitation in northern Scandinavia and less in central and southern Europe. Danish waters will become warmer, less salty and with higher sea levels. Weather extremes will generally be more likely and this will mean more intense and more frequent heatwaves, storms and rainfall, as well as longer periods of drought. For example, new calculations indicate that, in 2050, a 50-year storm in Denmark will be 10% more intense.

The more precise magnitude of climate change 50-100 years from now depends on future greenhouse gas emissions for example, and projections are associated with great uncertainty, as is the magnitude of the impacts of climate change for Denmark. Climate simulations, and our understanding of the uncertainties linked to them, are improving all the time. Moreover, local and regional effects of climate change may differ. Decision-making on climate change adaptation initiatives will therefore be subject to some uncertainty and this constitutes a challenge in itself for municipalities, enterprises and individuals when prioritising efforts, including the scope of these. Consequently, adaptation initiatives risk being either over- or under-dimensioned relative to what is economically ideal. It is therefore important that climate change adaptation initiatives allow for later adjustments and that the knowledge base is updated on a regular basis.

A review of the significance of climate change up to 2050 for the individual sectors and industries shows that Danish society may experience both positive and negative impacts.

The positive impacts will relate primarily to the higher temperatures which will result e.g. in a longer growing season and increased productivity for forestry and agriculture. Milder winters will moreover reduce energy consumption and construction costs, as well as the costs of winter weather preparedness and road salt.

The negative impacts of climate change will relate primarily to more frequent extreme rainfall, elevated sea levels and more powerful storms which can lead to flooding and damage to infrastructure and buildings as well as erosion along coasts.

Division of responsibilities
The municipalities and citizens will, for the most part, be responsible for addressing and adapting to climate change. Owners of buildings will have to decide whether they want to adapt homes and other buildings. The municipalities, which are responsible for a large number of areas such as wastewater treatment and a large part of the road infrastructure, decide themselves how they want to tackle the challenge from more intense precipitation, for example. The state plays a role in terms of adapting state-owned buildings, land and state-owned infrastructure to climate change.

From a central-government perspective, a major part of climate change adaptation is about ensuring that the right framework conditions are in place to enable the relevant players to address climate change in a cost-effective manner. The central government must establish good framework conditions e.g. by ensuring that the legislative framework facilitates appropriate solutions. Moreover, the government must contribute to knowledge-building and to the dissemination of knowledge to municipalities, enterprises and citizens.

The use of socio-economic analyses

Socio-economic analyses can contribute to informed decision-making about specific climate change adaptation initiatives by calculating whether and when a measure will be socio-economically appropriate. Socio-economic analyses are especially relevant in connection with large investments in infrastructure and other construction. Socio-economic feasibility is very much influenced by local conditions, the investment horizons of initiatives and whether ongoing adaptation is possible. There is a need for guidance in the application of socio-economic analyses.

Impacts, barriers and opportunities in individual sectors and industries

Construction and housing

Climate change may involve large costs for the construction and housing sector, but there are also good opportunities for addressing the impacts of climate change, and climate change may also offer benefits. For *new building*, ongoing adaptation of the building regulations is assessed to be sufficient to safeguard new buildings against climate change. Future changes in the climate are already widely being taken into account in connection with new construction. For the *existing building stock*, the individual owner is responsible for adapting the building to climate change on a regular basis, e.g. in connection with other renovation. A way to improve the feasibility of investments could be to incorporate climate change adaptation initiatives with e.g. energy-saving measures. Public information and development of instruments etc. by the Danish Portal for Climate Change Adaptation, www.klimatilpasning.dk and by public bodies for social housing and public construction may be useful in this context.

Coasts and ports

Changes in sea levels and wind patterns may influence the risk of flooding and coastal erosion. Erosion and flooding are well known phenomena, which land owners are already dealing with today. Individual coastal stretches are predicted to be affected by climate change to varying degrees, however the additional strain on Danish coasts up to 2050 is expected to be relatively modest. Developments are being monitored continuously in order to assess whether future climate scenarios call for the establishment of coastal models for different extremes in order to identify the implications climate change will have on coasts. On the basis of the Ministry of Transport's climate change adaptation strategy, the Danish Coastal Authority will prepare an action plan for climate change adaptation with targets and a milestone plan, as well as a "declaration of services" concerning the availability of the transport infrastructure. The Danish Coastal Authority has ongoing dialogue with the municipalities, and provides guidance for them. In connection with the implementation of the EU Floods Directive, in spring 2012 the Danish Coastal Authority visited relevant municipalities.

Transport

The transport sector is undergoing preparations to tackle climate change. Increases in precipitation and temperature and changes in wind patterns are likely to affect the road network at different

magnitudes. The Danish Road Directorate is working on managing climate change impacts on the basis of performance requirements. This involves preparing an action plan for climate change adaptation on the basis of the Ministry of Transport's climate change adaptation strategy which contains targets and a milestone plan as well as a "declaration of services" concerning the availability of the transport infrastructure. The Danish Road Directorate is maintaining an ongoing dialogue with the municipalities on road regulatory work. The most recent knowledge, which the Danish Road Directorate has either developed itself or procured from external providers, will be included in this work and will therefore benefit the municipalities as well as the Directorate. The Directorate and the municipalities are also cooperating via SAMKOM, a cooperation forum for public technical administrations, which involves benchmarking and knowledge-sharing activities. *Rail Net Denmark* is analysing road-related incidents, establishing warning systems and analysing the need to incorporate climate change adaptation in planning new rail installations. Furthermore, for the entire area under the Ministry of Transport, work is being carried out to manage climate change impacts on the basis of performance requirements. This involves preparing an action plan for climate change adaptation on the basis of the Ministry of Transport's climate change adaptation strategy.

Water

For *wastewater*, regulations aimed at minimising the negative effects of flooding are being developed. As a general rule, the water utility companies can finance the necessary investments and maintenance for the sewerage system via wastewater charges. It would be relevant to assess whether the water utility companies have the required tools and incentives to adapt to climate change through e.g. investments in maintenance and expansion of the sewerage system. Amongst other things, this should be seen in light of the relationship between depreciation periods and loan repayment periods. Finally, it would be relevant to assess whether alternatives exist outside the area financed through charges to enhance the capacity for diverting surface and wastewater cost-effectively, including letting private citizens manage the water on their own land. The current rules on financing through charges provide only limited possibilities for financing such initiatives through wastewater treatment charges. This is to ensure that water consumers only pay for the costs that relate to wastewater management. At the same time, pursuant to the 2011 government programme, municipalities are obliged to prepare municipal climate change adaptation plans within two years.

For *groundwater*, increased groundwater recharge will change the conditions for future water supply in the form of increased groundwater resources and in the form of e.g. increased groundwater recharge in the uppermost soil layers which leads to enhanced risk of groundwater flooding, and longer periods of drought which may require changing the catchment area. With regard to groundwater protection, efforts have been launched regarding protection zones around wells, and the need for climate change adaptation has also been incorporated in these efforts. A number of legislative acts and schemes contribute to protecting groundwater resources. In this area, there is a need to incorporate climate change adaptation as a consideration in public administration and in any amendments to the legislative basis. Existing groundwater models and other tools are deemed adequate to monitor the challenges arising from climate change, as long as data on the future climate are available.

Agriculture

Increases in temperature may lead to increases in productivity for agriculture if the adaptation of agriculture that is already ongoing continues. In this context it might be relevant to consider adjusting the regulations on the use of pesticides in agriculture, as the increases in temperature may

encourage plant diseases and, in particular, pests. More extreme precipitation may promote more run-off of nutrients, which might make it relevant to consider making adjustments in the regulation of the use of fertilizer in agriculture. More extreme weather events with flooding or drought are a challenge for agriculture, which will be amplified by the implementation of the Water Framework Directive. Farming of vulnerable, low-lying land will become unprofitable and alternative uses of the land may be considered. Several initiatives are under way which will enhance knowledge about the challenges and opportunities facing agriculture as a consequence of climate change, and it would be relevant to focus more on how agriculture can exploit climate change and avoid the negative effects.

Forestry
An important measure to ensure the resilience of Danish forests against climate change is to ensure that they are able to regenerate on their own. Several different tree species suited to the local environment must be present in the forest. Close-to-nature forest management is one way of achieving this. Danish state-owned forests are now being managed according to the principles of close-to-nature forest management. The transition to close-to-nature practices in private forests can be promoted by using different instruments, such as advisory services.

Fisheries
Rising sea temperatures, in particular, have already affected the fisheries industry, and the impacts on this industry are expected to increase in future. The spread and the size of populations of different fish species will come under pressure. New species and population combinations will require ongoing adaptation of fishing vessels as well as the industry itself. With new species, it may be necessary to monitor developments to provide the required scientific foundation for adapting and developing the fisheries management system. In order to improve the knowledge base, tools may have to be developed to quantify and qualify the significance of climate change for the marine food chains, ecosystems, fish stocks and sustainable use of these.

Energy
In practice, climate change will not have any considerable effect on Danish energy supply. The most important impact is assessed to be reduced energy consumption due to milder winters. Existing energy-producing facilities will be able to cope with the predicted climate change in their remaining life span, and it is estimated there will be no need for special initiatives aimed at energy-producing facilities. It is likely that the energy-supply-related climate change adaptation efforts will be directed primarily at limiting energy consumption for cooling.

Tourism
The potential for tourism in Denmark may increase as a consequence of higher average temperatures. It is assessed there will be no need for special initiatives. Adaptation efforts will be managed by the industry itself and by the relevant authorities in connection with routine tasks. Adaptation efforts will take place mainly through adjustments to strategies for tourism as well as through investment in new facilities and adaptation of existing facilities to cope with changes in rainfall, coastal landscapes etc.

Nature
Climate change will affect the Danish *aquatic environment* in a number of areas. However, knowledge is still insufficient as to what impacts climate change will have on the targets and efforts set out for the aquatic environment pursuant to the Water Framework Directive. The next

generation of national water plans is to be submitted by the end of 2015. New knowledge will be able to underpin the implementation of climate change adaptation in water planning.

For *nature on land* there has been no complete mapping of the possibilities to adapt to climate change. It should be assessed whether existing regulation in this area is adequate to support climate change adaptation. In this connection, it would be relevant to apply, and possibly to amend, a number of acts, including the nature protection act, the environmental targets act and the planning act. As the need for knowledge is being gradually met, it would be relevant to disseminate new knowledge to various nature administrators such as land owners, municipalities and authorities at state level. It is essential to remember that nature can be used in general climate change adaptation efforts to cushion the effects of climate change, e.g. to serve as a buffer in situations involving heavy rainfall or to prevent nutrient run-off.

Health
In terms of human health, climate change adaptation is primarily about collecting knowledge and providing consultancy about risks to authorities, health-care staff and individuals. The Danish Health and Medicines Authority is preparing information material and providing consultancy on an ongoing basis about the possible negative effects of climate change, e.g. about mould, how to include extreme weather in public health emergency response plans, and about precautionary measures during warm spells and heatwaves. The forward-looking efforts will mostly be a continuation of initiatives that have already been launched. Finally, it may be relevant to make greater use of health impact assessments of potential alternative approaches in climate change adaptation in order to improve decision-making.

Emergency preparedness
The government's report on emergency preparedness (May 2010) points out that in future the Danish fire and rescue service must be prepared to mitigate the follow-on effects of several climate-related events such as hurricanes/storms, heavy precipitation, cloudbursts, storm surges, and extreme water levels. On the basis of experience from climate-related events since 2007, it is likely that equipment to tackle such events will continue to be in demand in the future. The size of the investments required depends e.g. on whether there are enough preventive measures in other sectors, as well as on future organisation and coordination of the rescue preparedness services at local and central-government levels. The closer the collaboration and coordination of equipment procurement and resource use across local and central-government levels, the better and more cost-effectively the effects of climate change can be managed.

Insurance
So far, insurance companies have been able to recover greater indemnification costs due to climate events via increases in premiums and reinsurance schemes. Insurance companies are widely equipped with the necessary tools to prepare for climate change by adjusting coverage and premiums. Furthermore, the insurance industry has already launched initiatives to exchange data with public authorities so that the insurance companies will be able to adapt coverage and premiums to risks, and so that the municipalities and individual citizens can reduce their exposure to climate change. However, it is important to monitor the insurance industry in terms of citizens and enterprises that in future will not be able to take out insurance against water damage.

Spatial planning
Spatial planning is an effective instrument of control which can contribute to reducing or eliminating negative effects, as well as exploiting positive effects, of climate change in a number of

sectors and industries. A legislative bill was submitted on 29 March 2012 which will allow municipalities to incorporate climate considerations in local development plans, and guidelines on local development plans incorporating climate change will be prepared in connection with the 2013 municipal planning process. The revision of *Fingerplanen 2012* (a plan for the development of the Copenhagen metropolitan area) will clarify the opportunities for exploiting the green wedges for climate change adaptation purposes.

Summary

Our climate will change gradually in the future. This review of the significance of climate change for Denmark shows that, up to 2050, there will be a number of opportunities for adapting to climate change in a number of areas. Furthermore, initiatives have been undertaken at central-government level in the form of direct adaptation of works and infrastructure for climate change, ongoing adaptation of relevant regulation, and dissemination of the newest knowledge, tools and consultancy to municipalities, enterprise and citizens.

However, as mentioned above climate change will also entail challenges up to 2050.

The central government must ensure that the legislative framework facilitates the most appropriate solutions. This mapping of climate change indicates that legislative barriers may exist. This applies for water, in particular. In this area a number of barriers have been identified that prevent municipalities and utility companies from addressing challenges appropriately and there may be opportunities for creating better framework conditions for climate adaptation locally, e.g. by creating incentives for alternative diversion of surface water.

In this context, focus could also be on initiatives which can help point out new financing models, develop new technologies and solutions that create synergies inside and across sectors and municipalities. This would also help boost exports of technological solutions for water.

The central government must also contribute to knowledge-building and to the dissemination of knowledge to municipalities, enterprises and citizens. In several sectors and industries there are opportunities for further consultancy and for new tools, including guidance in the use of socio-economic analyses. A number of the consultancy initiatives that have already been launched are aimed at municipalities. Opportunities for initiatives aimed at citizens and enterprises will be assessed on a regular basis.

3. A common starting point for climate change adaptation efforts

With focus on 2050, the Danish Meteorological Institute has described the projected future climate changes in Denmark based on the most recent Danish and European scenario simulations.The assessment of future climate change is based on the same scenarios that are used by the UN Intergovernmental Panel on Climate Change (IPCC). Changes are expected to increase towards 2100.

As a common starting point for climate change adaptation in Denmark, since 2010 the recommended climate scenario has been the A1B scenario from the Intergovernmental Panel on Climate Change (IPCC) for the period up to 2050, as there are only minor differences between the different climate scenarios over this relatively short time span. For the period up to 2100, the climate model projections are much more reliant on the emissions scenario applied. On the basis of the Danish strategy for adaptation to a changing climate from 2008, in addition to results for A1B (an average scenario), descriptions for two of the IPCC's other SRES scenarios: B2 (an average-low scenario) and A2 (an average-high scenario), are included here in order to illustrate the range. The Danish Meteorological Institute has moreover performed calculations for a scenario which assumes global anthropogenic increases in temperature of no more than 2ºC relative to the pre-industrial level. This scenario is called 2C.

Climate simulations and our understanding of the uncertainties linked to them are improving all the time. The Danish Meteorological Institute has calculated the figures in the tables presented in the following and these figures are the most recent figures, based on EU studies in which a number of climate simulations were run with several regional climate models[1]. Thus the assessments of future climate change will be much more robust than if the figures had been based on only a single climate model. The tables give the mean value of the model as best estimate, and the uncertainty range indicates the standard deviation from the mean value of the results from the different models. This means that, with the assumptions underlying the model simulations, there is a 68% probability that a given future value will fall within the range.

Future global sea level rises depend on the melting of snow and ice as well as on increases in ocean temperature. Projections of ice melt are associated with great uncertainty, and estimates for sea level rises for the 21st century are therefore rarely linked to a well-specified climate scenario. The sea level rises described in the following are best estimates by the Danish Meteorological Institute and the Geological Survey of Greenland and Denmark on the basis of existing studies, and the uncertainty range corresponds to a standard deviation.

When planning, assessing and performing risk analyses in connection with climate change adaptation, it is important to think carefully about whether to include the whole spectrum of values (as given by the uncertainty range) or to include only the indicated best estimate.

3.1 IPCC projections of future changes in climate

In its fourth and most recent report (Fourth Assessment Report (AR4) from 2007), the Intergovernmental Panel on Climate Change (IPCC) concluded that there is a more than 90% probability that most of the observed global warming since the middle of the 20th century can be attributed to anthropogenic greenhouse gases. It is moreover very likely that continued emissions, at

[1]An ensemble of 14 model runs is included for the year 2050 and an ensemble of 8 for the year 2100.

the same or at a greater level than today, will result in additional global warming and lead to several changes in the global climate system of a greater magnitude than we saw in the 20th century. The basic estimate from the IPCC is a global temperature increase of between 1.8ºC and 4.0ºC by the last decade of the 21st century, relative to the period 1980-1999, or 2.3ºC to 4.5ºC relative to the period 1850-1899, corresponding to the pre-industrial level.

A number of international assessments of current national pledges for greenhouse gas emission reductions up to 2050 suggest that, with these current pledges, we will see global warming of about 3.5ºC up by the end of the 21st century, relative to the pre-industrial level.

The shrinking of sea ice and the melting of large ice sheets and glaciers will very likely continue and possibly at a greater pace. Increase ice melt from ice sheets and warming of the oceans will contribute to increasing sea levels. The occurrence of weather and climate extremes is likely to increase dramatically, which will probably mean e.g. more intense and more frequent warm spells and heatwaves, more heavy precipitation and longer periods of drought.

3.2 New IPCC climate scenarios in 2013/2014

A set of new representative emissions scenarios, so-called RCPs (Representative Concentration Pathways), have been defined prior to the IPCC's fifth assessment report to be released during 2013 and 2014 to replace the SRES standard scenarios used so far. In contrast to the SRES scenarios, these new scenarios have been specified specifically as stabilisation scenarios which means they include the effects of climate policy decisions. The objective of the new scenarios is to better meet the demands of decision-makers to be able to assess the implications of projected climate change under different degrees of global warming and to be able, on the basis of this, to assess which adaptation and reduction initiatives are most appropriate. A vast range of comparative model studies are being performed at present, based on the new scenarios with the most recent climate models. These calculations will form the basis for e.g. the forthcoming IPCC assessment report, and they will therefore constitute the reference for climate change projections globally and regionally in the years to come.

3.3 Denmark’s future climate

Denmark will be seeing a warmer and generally wetter climate in future with more extreme weather events. There will be more rain in particular during winter, and summer will most likely bring both longer periods of drought and heavier rainfall. It will generally be warmer; winters in particular will be warmer and this will mean that the growing season for crops and plants will be prolonged. Summers will also be warmer and there may be more and longer warm spells and heatwaves. It is likely we will see an increase in the strength of storms, especially over the North Sea. The future changes in wind patterns in Denmark are generally not as well determined as the changes in temperature and precipitation. Finally, a general increase in water levels is expected for the seas around Denmark.

The climate trend observed in Denmark so far, especially since the mid-20th century, is well in keeping with predicted future changes. Thus, the temperature in Denmark has increased by about 1.5ºC since 1870. Similarly, annual national precipitation has increased by about 100mm over the last 150 years, while there have been an increase in the number and intensity of heavy precipitation events.

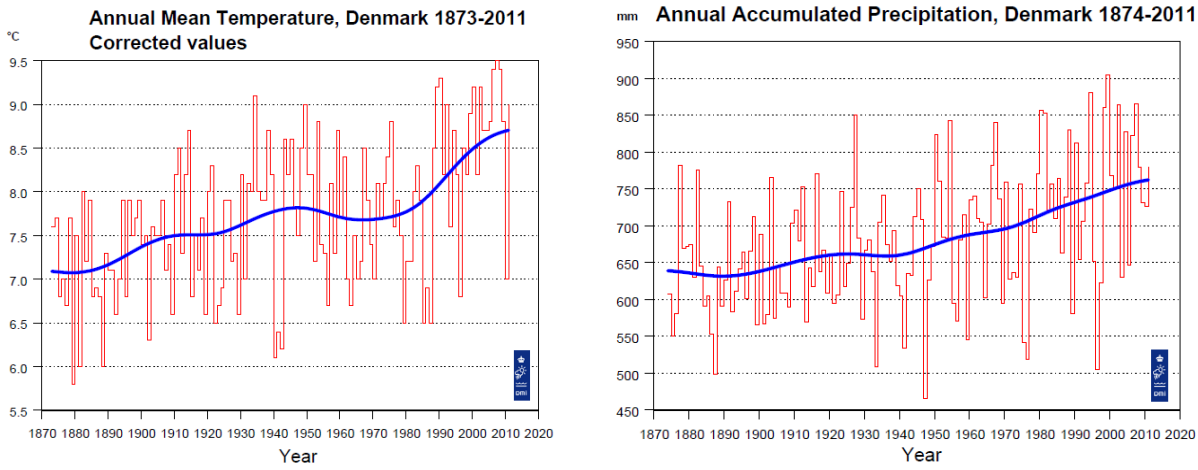


Figure 1. Denmark's annual mean temperature since 1873 (left) and annual precipitation since 1874 (right). The values are calculated as a national mean of observations from a number of selected weather stations. The blue curve represents the mean over nine years. (Source: Danish Meteorological Institute)

The Danish Meteorological Institute performs new calculations of future climate change in Denmark on a regular basis. Most recently, the Institute updated the figures on www.klimatilpasning.dk, the Danish Portal for Climate Change Adaptation, for temperatures and precipitation in 2011 on the basis of new and more robust calculations based on an ensemble of climate models. A dedicated study on future changes in wind patterns in Denmark will moreover be available at the end of 2012. All of the below changes are relative to the climate normal period 1961-1990, which has been defined by the World Meteorological Organisation, WMO.

3.3.1 Temperature

Future global warming will also cause warming in Denmark in line with developments already observed. The expected temperature increase by 2050 will be about 0.9ºC in summer and 1.5ºC in winter relative to the period 1961-1990, see table 1. By the end of the 21st century, the projected increases in temperature relative to the reference period will be 1.5ºC-2.6ºC in summer and 2.3ºC-3.8ºC in winter, depending on the emission scenario. Mean temperatures will generally increase the most during winter and the least during summer.

	2050	**2100**			
	A1B	**A1B**	**A2**	**B2**	**2C**
Season	**Temperature**	**Temperature**	**Temperature**	**Temperature**	**Temperature**
Annual mean	1.2 ºC (± 0.2 ºC)	2.9 ºC (± 0.3 ºC)	3.2 ºC (± 0.3 ºC)	2.5 ºC (± 0.2 ºC)	1.9 ºC (± 0.2 ºC)
Spring	1.1 ºC (± 0.2 ºC)	2.7 ºC (± 0.3 ºC)	2.9 ºC (± 0.3 ºC)	2.3 ºC (± 0.3 ºC)	1.8 ºC (± 0.2 ºC)
Summer	0.9 ºC (± 0.1 ºC)	2.2 ºC (± 0.2 ºC)	2.6 ºC (± 0.2 ºC)	2.0 ºC (± 0.2 ºC)	1.5 ºC (± 0.1 ºC)
Autumn	1.4 ºC (± 0.1 ºC)	3.1 ºC (± 0.3 ºC)	3.4 ºC (± 0.3 ºC)	2.7 ºC (± 0.2 ºC)	2.1 ºC (± 0.2 ºC)

Winter	1.5 ºC (± 0.2 ºC)	3.5 ºC (± 0.3 ºC)	3.8 ºC (± 0.3 ºC)	3.0 ºC (± 0.3 ºC)	2.3 ºC (± 0.2 ºC)

Table 1. Temperature changes for Denmark.
The figures indicate temperature changes in degrees Celsius relative to the reference period 1961-1990. The 2050 projection is an average for the period 2021-2050, and the 2100 projections are averages for the period 2071-2100. The figures for 2050 are for the A1B scenario, while the figures for 2100 are indicated for each of the four scenarios A1B, A2, B2 and 2C. The figures in brackets show the uncertainty (standard deviation) for the ensemble mean value which is derived by averaging the ensemble of 14 climate model runs for 2050 and 8 climate model runs for 2100.

3.3.2 Precipitation

Global warming increases the content of water vapour in the atmosphere, which leads to an increase in global precipitation. In Denmark, too, the climate models suggest that global warming will cause a change in patterns of precipitation both in terms of amount and intensity.

Up to the end of the 21st century, model studies show a general trend toward more precipitation in the most northern parts of Europe, including in Denmark, where the greatest increase will be during winter, see table 2. The predicted increase in winter precipitation will probably take effect as early as within the next half century. An increasing trend in precipitation is seen both during spring and autumn, most significantly towards the end of the 21st century. However, the results of calculations differ for changes in precipitation during summer. The model experiments suggest that in the future Denmark will be located on the border between two zones: with generally more summer precipitation in northern Scandinavia and less precipitation in central, eastern and southern Europe. This is evident from the values in the table below, in which the range in the model results is generally relatively large for precipitation, especially during summer.

	2050	**2100**			
	A1B	**A1B**	**A2**	**B2**	**2C**
Season	**Precipitation**	**Precipitation**	**Precipitation**	**Precipitation**	**Precipitation**
Annual mean	+ 7 % (± 3 %)	+ 14 % (± 6 %)	+ 15 % (± 7 %)	+ 11 % (± 6 %)	+ 9 % (± 4 %)
Spring	+ 4 % (± 3 %)	+ 14 % (± 6 %)	+ 16 % (± 7 %)	+ 12 % (± 5 %)	+ 9 % (± 4 %)
Summer	+ 4 % (± 4 %)	+ 5 % (± 8 %)	+ 5 % (± 9 %)	+ 3 % (± 7 %)	+ 2 % (± 5 %)
Autumn	+ 7 % (± 3 %)	+ 9 % (± 5 %)	+ 10 % (± 6 %)	+ 8 % (± 5 %)	+ 7 % (± 4 %)
Winter	+ 11 % (± 3 %)	+ 25 % (± 6 %)	+ 27 % (± 7 %)	+ 21 % (± 5 %)	+ 17 % (± 4 %)

Table 2. Precipitation changes for Denmark.
The changes in precipitation are indicated as percentage changes relative to the reference period 1961-1990. The 2050 projection is an average for the period 2021-2050, and the 2100 projections are mean values for the period 2071-2100. The figures for 2050 are for the A1B scenario, while the figures for 2100 are indicated for each of the four scenarios A1B, A2, B2 and 2C. The figures in brackets show the uncertainty (standard deviation) for the ensemble average value in percentage

points which is derived by averaging the ensemble of 14 climate model runs for 2050 and 8 climate model runs for 2100.

3.3.3 Wind

The predicted changes to average wind over Denmark are associated with greater uncertainty than temperature and precipitation and changes are generally much less significant.

However, the predicted change in strong winds (storms) is more pronounced than the changes in average wind conditions. The strength, but not the occurrence, of the strongest storms over Denmark is expected to increase during the next century.

3.3.4 Sea level

The sea level around the coasts of Denmark, except for around northern Jutland, is already rising and the trend is expected to increase in the next 100-200 years as a consequence of climate change. By 2050, the sea level around Denmark is expected to increase by 0.3m ± 0.2m compared with today. The rate at which the sea level will rise is linked to much uncertainty, especially due to the uncertainty about contributions from melting glaciers and ice sheets. Up to the year 2100, the sea level around Denmark is expected to increase by 0.8m ± 0.6m and no more than 1.5m compared with today. This rise is compensated partially by isostatic uplift, especially in northern regions, and there are minor differences in sea level changes between different parts of Denmark. Changes in sea level in combination with changes in wind patterns will lead to higher storm-surge levels, in particular in the Wadden Sea.

Expected sea level rise	**2050**	**2100**
Mean water level rise	0.3 ± 0.2m	0.8 ± 0.2m
Local conditions		
Isostatic uplift (most pronounced in northern Jutland)	-(0.0-0.10)m	-(0.0-0.20)m
Wind contribution, storm surge, coastal waters	0m	0m
Wind contribution, storm surge, west coast of Jutland	0.10m	0.3m
Estimate for storm surge, in total, Wadden Sea	0.4 ± 0.2m	1.1 ± 0.6m
Estimate for storm surge, in total, west coast of northern Jutland	0.3 ± 0.2m	0.9 ± 0.6m
Estimate for storm surge, in total, coastal waters	0.25 ± 0.25m	0.7 ± 0.7m

The greatest contribution to changes in storm-surge heights will probably come from the general change in sea level and the effect on the coastline from changes in wind patterns. Furthermore, it is estimated that the storm-surge heights along the west coast of Jutland may increase by 0.3m up to 2100 as a consequence of changes to wind patterns, while an increase in amplitude is not predicted for the Danish coastal waters. The increased sea level is of great importance for how often a given threshold value will be exceeded. Today, a 400-year-event around Copenhagen would come at 1.7m. If the average sea level increases by 0.8m, the contribution from the storm surge will have to be 0.9m to achieve the same sea level. Statistically, such an event would occur approximately every 1-2 years. Today, a 400-year-event around Esbjerg would come at 4.35m. If the mean sea level increases by 0.8m, and we see a further water level increase of 0.3m off the west coast of Jutland

from increased wind conditions, the contribution from the storm surge will have to be 3.25m to achieve the same sea level. Statistically, such an event would occur approximately every 7-10 years.

Apart from sea level rises, climate change will mean that Danish waters will become warmer and less salty.

3.3.5 Extremes and specific climate parameters

Climate model calculations show that an increased greenhouse effect leads to changes in the frequency, intensity and duration of extreme weather events. Denmark will see more and longer heatwaves, especially at regional level. Precipitation patterns will change, with summers dominated by longer dry spells and more heavy precipitation events, and winters will generally be dominated by increased precipitation. The number of frosty days will fall dramatically, while the growing season will be prolonged. Changes in sea level in combination with changes in wind patterns will lead to higher storm-surge levels, in particular in the Wadden Sea.

The same tendencies apply globally, as is evident from the IPCC's special report on extremes: the world will experience higher temperatures, more and more intense heatwaves, more heavy precipitation events, more droughts, and increasing sea levels.

In Denmark, we can expect more heavy precipitation events during summer, even though the summer season will probably become drier in large parts of the European continent. Furthermore, we can expect the most intense precipitation events to become even more intense, and the most extreme events will increase the most. This can be illustrated by an initial analysis based on annual maximum precipitation from 13 regional climate models. This analysis shows that an event, which in the climate corresponding to the 1961-1990 period would occur on average every ten years, will occur with a frequency of every 6.7 years in the climate corresponding to the 2021-2050 period, and with a frequency of every 5.7 years in the climate corresponding to the 2071-2100 period. Similarly, a present-day 100-year event will occur every 49 years in the 2021-2050 climate, and every 41 years in the 2071-2100 climate. These figures are subject to uncertainty, but they nonetheless serve to illustrate the general conclusions: The greatest changes will occur for the most dramatic and rare events, and the changes will grow in step with anthropogenic climate change.

The data in table 3 are for all of Denmark. It should be noted that extreme values based on grid point models will generally be smaller than observed extremes, which are normally based on point measurements. At any given time, the model knows only the mean values over the 25km x 25km that make up the grid box. This tendency is particularly evident for heavy precipitation which has great spatial variability. More detailed data are available in short form via the Danish Portal for Climate Change Adaptation at www.klimatilpasning.dk. It should also be noted that the model-based changes in climate parameters will have lower uncertainty than what appears from the period values in table 3. This is because a model that is e.g. warmer than the average today, will normally also be warmer in the future.

The most conspicuous changes in the table are seen for indices that are defined in terms of exceeding certain threshold values such as number of frosty days and precipitation events above 20mm. The geographical location of Denmark, with average temperatures below 0 in only a single month of the year, makes the number of frosty days very sensitive to a warming climate. This is further reflected in a dramatic reduction in the number of times the temperature will drop below freezing point, which is of relevance for e.g. salt application to roads, and in the average snow cover during winter, which will also be drastically reduced towards the end of the century.

As can be seen from table 1 above, the general warming of the climate in Denmark is greatest during winter but is not fundamentally different from the warming during summer. This can be illustrated by the considerable changes in the occurrence of heatwaves. The limit value of 28ºC is only rarely exceeded in the present climate, however the predicted warming of a few degrees Celsius will increase this number drastically.

For wind conditions, the changes in strong winds (storms) are expected to be more pronounced than the changes in average wind conditions. The strength, but not the occurrence, of the strongest storms over Denmark is predicted to increase during the next century.

New calculations indicate a significant change in the strength of a 50-year storm in Denmark by more than 10% as early as by 2050. This result will be even more pronounced around 2100, when it will apply for the entire North Sea. Swedish calculations show a similar picture, with changes of more than 10% for a 50-year event. In these calculations, however, the changes are not statistically significant until toward the end of this century.

	1990	**2050**	**2100**
Frosty days	85 d/y (± 8 d/y)	61 d/y (± 7 d/y)	29 d/y (± 5.3 d/y)
Growing season	230 d/y (± 11 d/y)	270 d/y (± 12 d/y)	300 d/y (± 11 d/y)
Hot summer nights	8 d/y (± 4 d/y)	13 d/y (± 4 d/y)	44 d/y (± 13 d/y)
Precipitation events > 10mm	19 d/y (± 2 d/y)	22 d/y (± 2 d/y)	26 d/y (± 3 d/y)
Precipitation events > 20mm	2 d/y (± 0.3 d/y)	3 d/y (± 0.5 d/y)	5 d/y (± 0.7 d/y)
Annual highest day total	70mm (± 8mm)	75mm (± 8mm)	81mm (± 10mm)
Annual highest five-day total	94mm (± 6mm)	100mm (± 5mm)	108mm (± 7mm)
Mean intensity, precipitation	5.0mm/d (± 0.2mm/d)	5.2mm/d (± 0.2mm/d)	5.6mm/d (± 0.2mm/d)
Heatwave days	1.5d/y (± 0.6d/y)	2.8d/y (± 1.0d/y)	5.0d/y (± 2.6d/y)
Longest heatwave	3.2d (± 0.7d)	4.2d (± 0.9d)	5.6d (± 1.9d)
Warm spell days	5.8d (± 1.4d)	8.7d (± 2.2d)	13.9 (± 4.7d)
Longest warm spell	6.9d/y (± 1.1d/y)	8.2d/y (± 1.4d/y)	10.1d/y (± 3.3d/y)

Table 3. Climate parameters for Denmark.
A number of climate parameters are indicated for 1990, 2050 and 2100. The figures in the three columns represent mean values for the periods: 1961-1990, 2021-2050 and 2071-2100. All figures are from model runs with a 25km x 25km resolution grid, and the calculated extreme values will therefore generally be smaller than observed extremes, which are normally based on point measurements. The A1B scenario has been used for projections. The uncertainty indicates the ensemble-based standard deviation for the ensemble average value of 14 climate model runs for 1990 and 2050 and 8 climate model runs for 2100. Note that the figures do not take into account the fact that the 1990 values may be slightly different depending on whether they are based on the 8 runs or the 14 runs. The definitions for the individual climate parameters are described in the following.

Frosty days
The number of days in a year with temperatures below freezing point.

Growing season
The length of the growing season constitutes the number of days from the first six consecutive days with daily average temperatures above 5°C to the last six consecutive days with daily average temperatures above 5°C.

Hot summer nights
The number of summer nights in a year with night temperatures above 20°C.

Precipitation events > 10mm
The number of days in a year with more than 10mm of precipitation.

Precipitation events > 20mm
The number of days in a year with more than 20mm of precipitation.

Annual highest day total
The total volume of precipitation during the day in a year that has the most precipitation in the grid point where the value is greatest.

Annual highest five-day total
The total volume of precipitation during the five consecutive days in a year that have the most precipitation averaged across Denmark.

Mean intensity, precipitation
The average precipitation for all days with more than 1mm of daily precipitation.

Heatwave days
The number of annual national heatwave days. The definition of a heatwave is when the highest recorded temperatures observed over three consecutive days on average exceed 28°C. A national heatwave is when at least half of Denmark is experiencing a heatwave.

Longest heatwave
The length of the longest heatwave averaged over a 30-year period.

Warm spell days
The number of annual national warm spell days. The definition of a warm spell is when the highest recorded temperatures observed over three consecutive days on average exceed 25°C. A national warm spell is when at least half of Denmark is experiencing a warm spell.

Longest warm spell
The length of the longest warm spell averaged over a 30-year period.

3.4 Regular updating of data sets for use in climate-change adaptation efforts

The current data presented above, which informs climate change adaptation efforts, are based on the IPCC's SRES scenarios. There is need for continuous updating of these data sets that underpin local

climate change adaptation initiatives and upcoming action plans. Without such updating, Danish climate change decisions would soon have to be based on outdated data.

A number of model experiments with the new RCP scenarios are being performed at present, leading up to the IPCC's fifth assessment report with global climate models. Extensive global-scale model data will therefore be available soon with the new scenarios, and the data sets informing Danish climate change adaptation efforts should therefore be updated regularly to reflect the most recent knowledge.

However, future Danish climate change adaptation efforts should continue to be based also on regional models, including the Danish HIRHAM model, which has been verified and tested meticulously for Danish conditions. Global models do not provide the necessary resolution and quality of data for the Danish region.

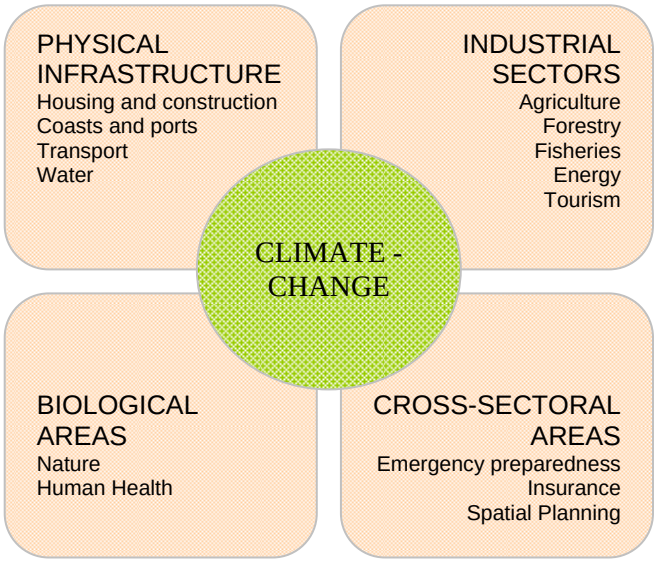
Similarly, it will be necessary to update the data sets for the impacts of climate change on the water cycle. With a new information basis in terms of climate models and RCPs, as well as continuous improvements to the national water resources model (the DK Model), it will be possible to reduce the uncertainties linked to predicting the climate impacts on groundwater recharge and groundwater level as well as on surface water, including flooding.

No doubt we will be able to achieve an ever better understanding of the data needed in local and sector-specific climate change adaptation efforts, as well as how to provide further data to meet these needs.

4. Climate change impacts, and barriers and opportunities for climate change adaptation

This chapter is about the most important impacts of climate change on relevant areas of Danish society as well as barriers and opportunities for adapting to climate change. The chapter also includes examples of climate change adaptation initiatives completed or in progress.

A total of 14 areas have been identified which require special attention. These areas differ significantly in nature but can be divided into the following four main areas to provide a quick overview:



Physical infrastructure

- *Construction and housing*
- *Coasts and ports*
- *Transport*
- *Water - sewerage and water supply*

These four main areas represent society's physical installations, which are characterised by large investments and which for the most part have long life spans. This means that it will be relevant to include climate change early on in ordinary investment plans in these sectors and industries. These main areas are moreover areas in which the potential costs of damage will be very high if adequate adaptation is not carried out.

Climate change gives rise almost exclusively to costs in these areas, in which the potential benefits are few. Furthermore, the costs are typically caused by extreme weather events.

Industrial sectors

- *Agriculture*

- *Forestry*
- *Fisheries*
- *Energy*
- *Tourism*

The industrial sectors, apart from tourism, are characterised by production directly dependent on the climate and therefore extremely vulnerable to climate change. Higher temperatures will generally provide for better growing conditions, which these sectors may exploit in their production, whereas more extreme events such as storms and heavy precipitation may harm production. Increased temperatures in Denmark in combination with more intense heatwaves in southern Europe will open up for tourism opportunities in Denmark.

Biological areas

- *Nature*
- *Human health*

In the biological areas, both humans and nature will respond and attempt to adapt to the changed climate. There will be both negative and positive impacts. For example, higher temperatures will provide for improved growing conditions for many species, however they may also lead to the spread of new types of disease.

Cross-sectoral areas

- *Emergency preparedness*
- *Insurance*
- *Spatial planning*

There will be direct physical climate change impacts in the cross-sectoral areas in the same way as in the other areas identified. The cross-sectoral areas, however, are characterised by providing services to the other areas where they are especially vulnerable to changes in climate.

Spatial planning is about land use, which is extremely reliant on physical and climatic conditions, and, as such, spatial planning is vital in cross-sectoral preventive efforts within climate change adaptation.

Emergency preparedness is about reducing the extent of the damage from extreme weather events, while the *insurance industry* provides compensation to those who have suffered damage. Both of these cross-sectoral areas are vital in mitigating the negative impacts of extreme weather events in the other sectors and industries.

Below is an outline by area of the positive as well as the negative impacts of climate change, and the barriers and opportunities in climate change adaptation efforts.

4.1 Physical infrastructure

4.1.1 Construction and housing

The climate affects our buildings and the way in which we build them. With global warming we can expect wetter, warmer and more extreme weather. Climate change may therefore pose new challenges for both existing and new buildings.

Buildings stand for up to 100 years or more in Denmark and it is therefore important that the framework conditions for new buildings are improved continuously to prepare for the future so that buildings will remain resilient and at as little risk of damage as possible. The long life span means that there is a large age spread in the existing building stock, and less than 1% of the building stock is replaced annually, which means existing buildings also need to be given attention.

Important effects of climate change
Climate change will have both positive and negative impacts for buildings. These include primarily

- *More extreme rainfall events will lead to more flooding:*
  The most important challenge will probably come from increased precipitation. Heavy rainfall may lead to more basements being flooded by intruding rainwater and sewage water. Houses and buildings with entrances at terrain level may also be exposed. A gradually rising sea level and more frequent storm surge events in combination with heavy precipitation may put low-lying and coastal urban areas at risk, *see the section on water.*

- *Greater air humidity and less frequent temperature movements across the freezing point are significance for the wear on buildings.*
  Milder winters with greater humidity may affect buildings and reduce the life span of individual building components. This can be mitigated though greater focus on management and maintenance. However, less frequent temperature movements across the freezing point may help reduce the wear and tear on buildings.

- *More powerful storms and changes in snowfall may damage buildings:*
  Powerful storms may pose a risk of damage to buildings, including damage to roof constructions from storms and greater snow load. The latter will often be manageable through roof snow removal. In addition to this, there will probably be a need for increased maintenance and, in some situations, reinforcement of the building.

- *Less demand for heating during winter, but risk of poorer indoor climate:*
  Milder winters may in general entail a reduced demand for heating. At the same time more humid winters may result in a more humid indoor climate providing better conditions for house dust mites and increasing the risk of mould, *see the section on human health.* A more humid climate may also result in greater demand for maintenance of building envelopes.

- *Greater risk of overheating:*
  Large window sections facing south, and longer periods with warm weather in summertime may pose a risk of overheating in buildings, which will have to be addressed when designing highly insulated buildings. The problem has already been addressed in the

building regulations' provisions on energy efficiency classes 2015 and 2050, which stipulate requirements on maximum indoor temperature.

- *Changes in productivity in the construction industry:*
  A more humid climate, in particular during winter, may mean longer drying times and may pose the risk of damage to building materials all of which may affect parts of the construction industry. However, the industry can prepare for this by using and further developing methods and materials which reduce the significance of the climate during the construction phase. Climate change could also result in fewer bad-weather days due to milder winters (fewer frosty days). This will help enhance productivity in the industry.

The most fundamental challenges for the existing building stock are likely to relate to increased precipitation and risk of damp in buildings. However, for a typical building, the damage scenario will be limited to a greater need for maintenance. Moreover, there will be less serious damage. Finally, there may be water damage resulting from powerful cloudbursts. Extensive damage, affecting the building's stability, will primarily be a risk for large constructions involving large spans from wall to wall, such as sports halls, and not for ordinary homes and similar more traditional buildings.

Division of responsibilities between the authorities and private citizens
Requirements for building construction are set out in the Danish Building Act under the auspices of the Danish Energy Agency (Ministry of Climate, Energy and Building). The Building Act and the Danish building regulations stipulate requirements for construction of all types of buildings. The primary objective of the Building Act is to ensure that buildings are constructed and designed with appropriate levels of fire, construction and health safety.

As a rule, the Building Act applies only to new buildings unless the construction project involves larger conversions or changes in use of existing buildings. This means that any given building under construction or conversion is covered by the provisions in force at the time of the construction.

The owner of the building, whether a public body or an individual, is responsible for ensuring that a building is legal An owner of a building has a duty to maintain the building so that it does not present a danger to people. This applies to all buildings irrespective of when they were constructed.

Central government can help building owners adapt to climate change through providing consultancy and tools and through imposing requirements on the parts of the construction and housing sectors subject to special regulation. This includes the social housing sector, for which the *Social Housing etc. Act*[2] includes regulation with relevance for climate change adaptation, and this applies to public construction too, *see the Public Construction Act.*

Possibilities for adaptation
Because of the long life spans of buildings, owners of buildings have to invest relatively large sums on regular maintenance and improvement, including of the building envelope and technical installations. Recent years have seen a greater focus on the need to reduce the energy consumption of existing buildings. With a view to improving the profitability of investments, it would be appropriate to incorporate climate change adaptation initiatives with other renovation activities, including investments in energy-saving measures.

[2]Social Housing etc. Act (*Lov om almene boliger mv.).*

Owners of buildings could also benefit from taking account of surface water diversion and drainage in the design and planning of buildings and the areas around these, e.g. by ensuring good ground levelling and suitable opportunities for infiltration.

Owners of buildings can adapt existing buildings to climate change on an ongoing basis. This includes e.g. initiatives aimed at draining away surface water and removing snow and slush along house walls and from roofs to avoid damage. Owners of buildings can adapt their buildings to climate change in connection with ordinary maintenance activities and minor renovation work.

Initiatives completed and in progress
The 2010 Building Regulations introduced provisions aimed at addressing climate change. These provisions include:

- tightened requirements for surface water management on private land;
- requirements on maximum indoor temperature for energy efficiency classes 2015 and 2020.

So as to be able to adjust building-regulation requirements in future, with a view to adapting new buildings to the weather of the future, it is crucial that the necessary knowledge and data exist. A number of studies have been commenced in order to assess whether the current building-regulation requirements are suitable.

- The current calculation rules for snow load are being re-evaluated on the basis of experience from recent years. Similarly, in 2012, the current rules applying to wind load and foundations are being assessed in order to ensure that these suffice against predicted climate change. The foundations of buildings are affected e.g. by rising groundwater levels.
- A qualitative analysis has been launched of the need for more knowledge about the significance of climate change for Danish buildings in terms of the building regulations. Release of the report is planned for spring 2012.
- A project has been launched to ensure the preparation of a new reference year with key weather parameters for a normal year, which takes climate trends in to account.

Owners of buildings are also offered information via the Danish Portal for Climate Change Adaptation at www.klimatilpasning.dk, which presents information about e.g. climate change impacts on houses and other buildings, including mould in buildings, cooling of buildings, surface water diversion, storm protection, and snow and slush. Furthermore, a number of leaflets have been produced on subjects such as roof inspection and protection, and snow removal.

The housing area
A new interactive tool, the *BoligWizard* (the Resilient House), launched in spring 2012, will help home-owners familiarise themselves with how to tackle issues related to climate change. Current legislation provides certain opportunities for providing owners of buildings with incentives to improve and maintain their residential buildings. Funding is available under the Urban Renewal Act, within a certain annual expenditure framework, for renovation of old private residential buildings and for improvement of privately owned recreational areas. Funding is provided to privately owned rented housing as well as to owner-occupied and shared-ownership housing. Moreover, funding is provided to urban renewal projects at local-government level. Climate change measures can be carried out as a part of urban renewal projects, and to some extent this is taking place in practice.

Urban renewal and climate change adaptation

In some situations, climate change adaptation affects more than just the individual building. In such situations concerted efforts may be difficult to coordinate, e.g. in housing areas with many different owners and/or many smaller properties/detached houses. Here, by application of the Urban Renewal Act, the municipality can play the role of initiator and coordinator:

Urban renewal of *Kulturringen*, an urban area in Høje-Taastrup Municipality near Copenhagen, has received funding under the Urban Renewal Act. The project is a public-private partnership managed by the municipality and with participation from property owners, enterprises, cultural institutions, schools and housing associations in the area. The overall project includes a sub-project which stems from a need for climate change adaptation. In order to prevent future flooding, the area's retention basin had to be extended. The project chose to establish a "blue park"; a recreational area which also serves as a connection between two parts of the city.

The legislative framework for the social housing sector includes extensive requirements for systematic property management of social housing, including requirements for long-term operational and maintenance planning. Most recently, requirements have been introduced for the digitisation of property management and maintenance based on a newly developed administrative classification system. The municipalities and the social housing organisations are responsible for realising at local level the requirements that have been stipulated at central level. If they deem it relevant, the municipalities and the social housing organisations could include climate change adaptation as an integral part of their management dialogue.

The Danish Building Defects Fund for social housing, which has performed inspections of buildings classified as social housing since 1986, has collected considerable knowledge about the problems relating to building design and building materials. The Fund makes its experience available to others, including experience related to climate change vulnerability and adaptation; experience which could be relevant for players in other housing sectors. The area covered by the Danish Building Defects Fund was expanded in 2011 to include large renovation projects in the existing social housing stock.

Digital records on buildings, topography and climate are plentiful. The Ministry of Housing, Urban and Rural Affairs has launched work to link climate data with data on public rental properties in registers such as the Danish Building and Housing Register and the Ministry's own social and public housing registers. Topographic data from the Danish Elevation Model are linked to information in the Danish Building and Housing Register about the location of buildings. Furthermore, the proportion of social housing with basements in the individual municipalities has been mapped. The aim is to enable the use of climate data digitally in connection with management and renovation of properties and planning new building etc. The greater focus on digitisation of property management, see the above, will very likely be able to support this.

In recent years the Ministry of Housing, Urban and Rural Affairs has developed economic models for use when contemplating renovation projects with long life spans, e.g. energy savings or climate change adaptation in social housing, including building new low-energy housing. These models can relatively easily be adapted for use when investing in existing buildings, also outside the social housing sector.

Public construction and public buildings

The Public Construction Act, which is administrated by the Danish Building and Property Agency, provides for the possibility to stipulate rules for public construction works. The purpose of the rules is to ensure e.g. that the construction of state-owned buildings includes considerations on how best to organise work so that the construction, operation and maintenance phases are approached from a holistic point of view, and so that economic calculations and use of digitisation are included. These initiatives are currently spreading to regional- and local-government levels (i.e. Danish regions and municipalities).

The Public Construction Act allows for the instigation of pilot projects to develop and test new building materials and techniques which reduce the negative effects of climate change. Experience gained will also benefit other parts of the sector.

Danish state-owned office and university buildings are under the Danish Building and Property Agency. The Agency carries out systematic registration of damage to buildings that can be related to climate change with a view to identifying where it will be most cost-effective to minimise the risk of new damage and to work on risk management to prevent future damage related to climate change. From the flooding event in the summer of 2007, the Danish Building and Property Agency gained valuable experience that may be used in future efforts to prevent water intrusion into buildings.

In 2001, the Danish Building and Property Agency launched pilot projects to implement a broader approach to risk management in new-building projects, e.g. with the objective of enhancing focus on future risk aspects, including an assessment stricter requirements for the building envelope. The Agency is also contemplating the possibilities for more external collaboration with e.g. municipalities, tenants and other stakeholders, and is exploring the possibilities for identifying and initiating future protective measures.

The Danish Building and Property Agency will be incorporating climate change adaptation in future construction work by looking at:

- the possibilities for locating buildings in areas where the risk of damage is smallest;
- rainwater management (e.g. establishing green roofs and rainwater collection);
- studies of the relationship between paved areas and their drainage systems, as well as of grass areas on properties;
- topographic/geothechnical studies of building sites in terms of groundwater and risk of flooding of low-lying areas, and areas with gravitational water;
- ensuring protection against water intrusion when establishing basements and technical installations below ground level.

Climate change adaptation considerations will be incorporated in work on the existing building stock through:

- limitations on basement use, in particular for IT installations, electrical installations, and other technical installations and storage;
- improvements and protection of basements against water intrusion;
- diversion of surface water on the property;
- considerations concerning relocating clients that are located in low-lying or particularly damaged properties that will be sold.

Barriers and opportunities for future action

Knowledge and consulting services

Whether building owners decide to carry out climate change adaptation initiatives is likely to depend on e.g. the financial incentives for doing so and whether the initiative can enhance the building's market price and the buildings' value, or prevent loss of value. It is a prerequisite that the building owner possesses knowledge about the need for climate change adaptation and is familiar with the best solutions and that the owner has the financial means, and is able to assess the risk and overall economic aspects of climate change adaptation measures.

The possibilities are deemed to be good for supporting and stimulating further knowledge-building about climate change vulnerability and climate change adaptation among building owners through disseminating information and developing new tools. The demand is assessed to be particularly great among owners of smaller buildings.

Regulation

The legislation allows for ongoing adaptation of the building regulations which realise the Building Act. This means the building regulations can be adapted to ensure that new buildings are resilient to climate change. The building regulations are revised on a regular basis and future changes in the climate are already widely being taken into account. Enhanced requirements in the area of climate change adaptation may however make building activities more expensive. Before new requirements are introduced, their additional cost will have to be compared against their possible effects. The revision of the building regulations will always include a balancing of whether new requirements impose unnecessary costs. If the building regulations are tightened, buildings activities may become more expensive as a consequence.

The Danish Energy Agency and the Danish Building and Property Agency will assess, regularly, whether experience from state-owned buildings and public construction activity should lead to an amendment of the building regulations. The two agencies will also assess whether experience gained can be made available on the Danish Portal for Climate Change Adaptation, (www.klimatilpasning.dk). Similarly, jointly with the Danish Energy Agency, the Ministry of Housing, Urban and Rural Affairs will contemplate whether experience from the social housing area can be made available to the Danish Energy Agency for use when assessing the need to amend the building regulations, as well as for use on the Danish Portal for Climate Change Adaptation.

The house inspection scheme, with its requirement for home inspection reports in connection with property sales, maps the physical building defects and categorises them according to seriousness. The Ministry of Housing, Urban and Rural Affairs will look into whether it is possible to raise the focus on climate change vulnerability in the owner-occupied property sector via the house inspection scheme, including through imposing requirements for the content of home inspection reports.

Within the social housing sector, it is possible, in principle, to stipulate requirements for mapping climate change vulnerability, the need for climate change adaptation, and, in continuation hereof, requirements for the preparation of climate action plans for the individual building. However, one should keep in mind that such requirements could result in higher housing costs.

Summary
The construction and housing sector is characterised by the fact that climate change may involve large costs for the sector, but that also good opportunities exist for addressing the impacts of climate change.

For *new building*, ongoing adaptation of the building regulations is assessed to be sufficient to safeguard new buildings against climate change, supplemented by the required information dissemination. Further adjustments to the building regulations, in addition to what has been implemented so far, will take into account any price-raising effects for the sector.

For the *existing building stock*, the individual owner is responsible for adapting the building to climate change on a regular basis, e.g. in connection with other renovation. Public information and development of instruments etc. by the Danish Portal for Climate Change Adaptation, www.klimatilpasning.dk and by public bodies for social housing and public construction may be useful in this context.

4.1.2 Coasts and ports

Rising sea levels and more powerful storms are expected to lead to higher storm-surge water levels. Coastal areas will obviously be more at risk. This problem to some extent will become evident before 2050, however, according to future climate projections, it will not be a major problem until towards the end of the century. Due to the nature of Danish coasts, it will be possible to prevent the effects of climate change to a significant extent by making the required precautions in the long-term planning of coastal protection and protection in form of dykes.

Nature, land development, and infrastructure, including dykes along the coasts, will be affected by climate change. Low-lying land areas along the coast and Danish ports pose particular challenges.

Erosion and flooding are well known phenomena, which land owners are already dealing with today. Individual coastal stretches are predicted to be affected by climate change to varying degrees, however the additional strain on Danish coasts up to 2050 is expected to be relatively modest. Some parts of the coastline are protected against erosion via beach nourishment. It is assessed that climate-related erosion can be addressed by increasing the sand volume in beach nourishment by one-fifth.

Important effects of climate change
Based on future projections of climate change, see section 3, key consequences for Danish coasts and ports will include

- *Higher storm-surge water levels will increase erosion and coastal recession:*
  This is the implication of the general increase in sea level and the fact that the coasts are being impacted by higher waves during more frequent and more powerful storms, which will lead to increased erosion and recession of the coastline relative to today. The flatter the coastal part of the seabed, the greater the erosion. Erosion will be most pronounced for the west coast of Jutland and less for other Danish coasts. Built-up areas in low-lying coastal areas will be at threat from higher storm-surge water levels and more frequent flooding. Furthermore, houses and other buildings near the coast will be at threat from erosion.

- *More frequent flooding of low-lying coastal areas:*
  Low-lying land not protected by dykes will be exposed to more frequent flooding. At the same time, the risk of water breaching existing dykes will increase. Cities developed by the mouth of rivers, e.g. in fjords, may come under double pressure: from a rising sea level as well as from increased precipitation and run-off from the catchment area.

- *More powerful storm surges will make activity at ports more difficult:*
  With more powerful storm surges, key areas will be flooded more frequently and this means interruption in port activities and also poses a greater risk of damage to buildings. The same applies to ferry landings. At the same time, more intense storms will pose a greater risk of ships breaking their moorings and causing damage to cranes and other equipment at the port.

- *More powerful storm surges put port infrastructure under pressure:*
  The port protection that protects the basin itself will be affected to an increasing extent by the waves and protection will be less effective during high storm surges. In ports where

fairways and/or port basins are dredged the need for dredging will often grow because higher waves will lead to greater sanding.

Increased erosion and enhanced risk of flooding from more powerful storm surges are the most important impacts that climate change will have for Danish coasts. The full consequences of these effects will not be seen until after 2050. Even though there are signs already today of accelerated erosion, the increase in erosion from climate change is relatively modest, as can be seen from the figure below.

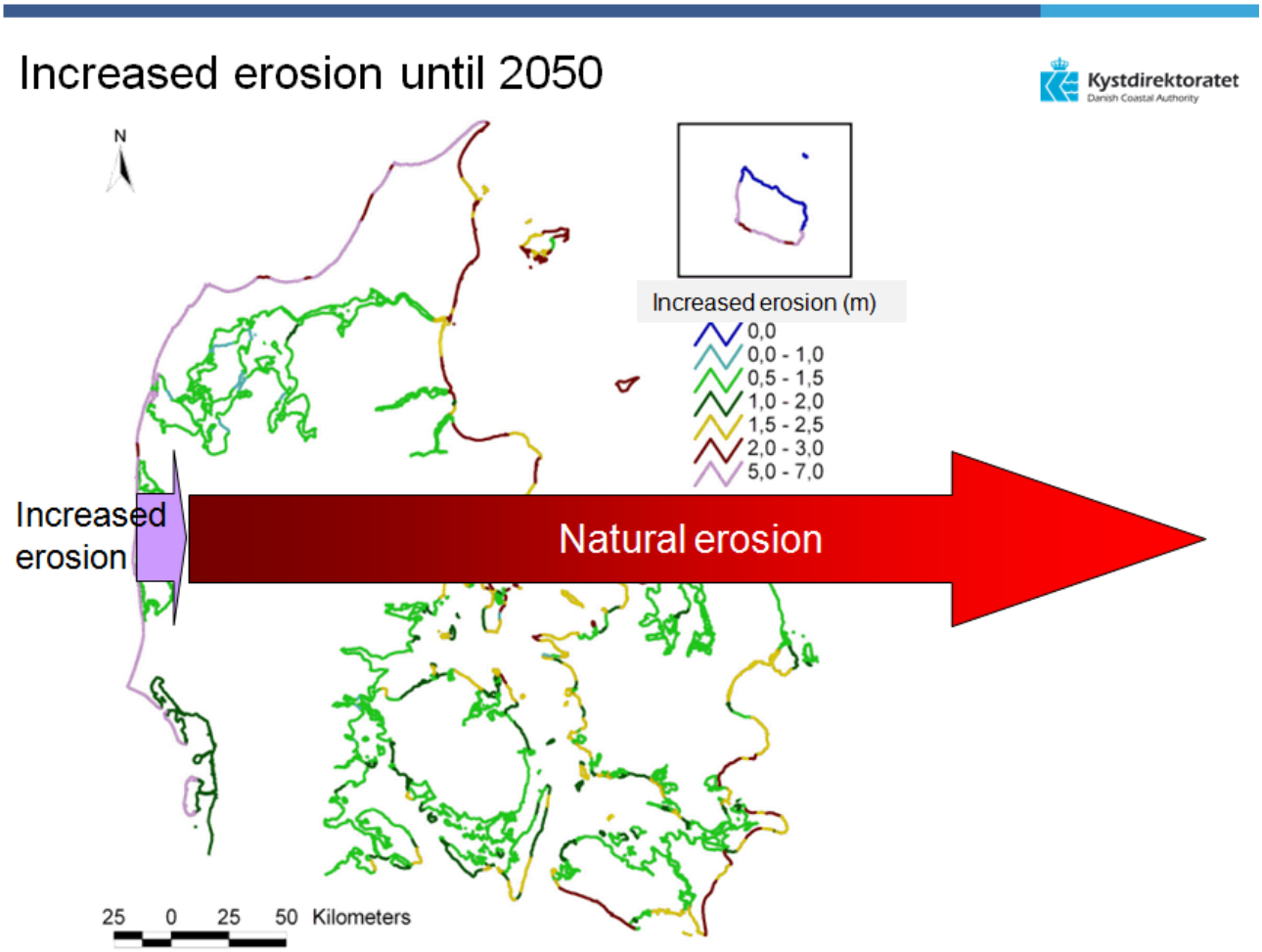


Figure 2: Up to 2050, the impact of climate change on Danish coasts is expected to vary considerably. In general climate change represents a modest additional load on the coasts and this load can be managed through existing measures.

Division of responsibilities between the authorities and private citizens
Today, climate change adaptation in Danish coastal areas is being managed by several parties. These parties can contribute in different ways, however the municipalities play a key role. As a general rule, the individual land owner is responsible for ensuring and financing coastal protection.

The Danish Coastal Authority authorises coastal protection and is therefore a key actor. The Danish Nature Agency and the Danish Coastal Authority play an important role in the implementation of

the EU Floods Directive[3], which sets out requirements e.g. for mapping of flooding risks and preparation of risk management plans for flood-prone areas.

Due to the special physical conditions that characterise the west coast of Jutland, coastal protection is here maintained by state and municipal authorities.

As a general rule, the establishment and operation of ports and fairways are the responsibility of the individual port. A few ports are partially or fully state-owned. The state is also responsible for maintaining the minimum depth of main fairways and the entrances to some ports.

Possibilities for adaptation
Coastal protection of the central part of the west coast of Jutland takes place chiefly by compensating for erosion through beach nourishment. In order to curb the effects of climate change and also maintain the current, political ambition to keep the coastal development in check, beach nourishment efforts may be gradually increased. For other coasts, the significance of erosion should be assessed for the individual area. The increase in erosion due to climate change is currently progressing slowly. There is no immediate need for response, however, in the long run, it may be relevant to look at coastal protection and land-use change. In other words, there are opportunities for ongoing adaptation.

For those parts of Denmark where dykes and/or dunes protect human lives, the appropriate response to the climate-change induced deterioration of dyke protection would be to fortify the dykes and dunes to maintain the current level of protection. This would naturally include regular updating of the emergency and storm surge response plan in place.

In connection with future maintenance work on port protection, it should be assessed whether the individual construction can withstand increasing loads. Furthermore, emergency preparedness in the event of storm alert should be adjusted regularly to prevent storm damage. Ferry landings should be modified regularly and fairways should be dredged more frequently as required.

Initiatives completed and in progress
In 2010 the Ministry of Transport published a climate change adaptation strategy. Following the publication, performance requirements for climate change adaptation were introduced in the 2012 performance contracts of all major institutions under the Ministry. These performance requirements entail preparing an action plan for climate change adaptation with targets and a milestone plan, as well as a "declaration of services" concerning the availability of the transport infrastructure.

In 2011, the Danish Coastal Authority published a national coastal protection strategy for the climate proofing of Danish coasts that is required in order to ensure sustainable use of the coasts in future. The coastal protection strategy aims at ensuring that coastal protection is approached holistically, taking into account the many stakeholders involved, as well as including coastal protection in a long-term perspective.

In 2011, the Danish Coastal Authority held a coastal conference at which focus was on the future coastal landscape, the national coastal protection strategy and implementation of the EU Floods

[3]The Danish Coastal Authority is responsible for implementing those parts of the EU Floods Directive that relate to coasts and fjords, while the Danish Nature Agency is responsible for implementing the parts that relate to watercourses and lakes.

Directive. The coastal conference will be held every two years and climate change has also been a theme at previous conferences.

Coastal protection in Dalby Bay

Dalby Bay (*Dalbybugten*) on northern Funen is a natural beach meadow built up with holiday homes. The Danish Coastal Authority has carried out a risk analysis for the area. This risk analysis included calculations of the size of the damage from different types of flooding and the likelihood of their occurrence. This provided for a calculation of the risk of flooding.

Then the reduction in risk from establishing the dyke in 2008 was calculated.

The risk of flooding will increase with time due to the predicted sea level rise as a consequence of climate change. The risk of flooding can be calculated for a given future year. The need for any later fortification of the high-water protection works can be quantified, along with when such fortification should take place. These findings would be appropriate to include in the local development plan for the area.

The Sea Water on Land (*Havvand på Land*) screening tool was released at the Danish Portal for Climate Change Adaptation, www.klimatilpasning.dk in February 2012. This tool provides planners and other stakeholders with knowledge about the areas of Denmark that are at risk of being affected by a rise in the sea level.

The Coastal Planner (*Kystplanlæggeren)*, a tool for coastal development planning, was also released at www.klimatilpasning.dk. This tool shows current coastal conditions and future predicted climate-related developments. Consultants, planners and other stakeholders can use the tool to obtain knowledge about current and future high-water events, coastal types, coastal protection works, sediment transport, and more.

Barriers and opportunities for future action

Knowledge and consulting services

Timely, objective and holistic consulting services are key to climate change adaptation because climate change will happen over a long time period and projections are subject to considerable uncertainty. It seems that more knowledge is needed in particular about the regional differences between the Jutland west coast and Danish coastal waters.

The Danish Coastal Authority has ongoing dialogue with local governments. Municipal planning is in demand of consultancy on possible measures to mitigate climate change impacts and related planning efforts. Guidelines would be appropriate here, based on tools to model the coastal landscape during extreme impacts.

During spring 2012, the Danish Coastal Authority visited all Danish municipalities that have been identified as relevant in connection with the implementation of the EU Floods Directive. The purpose was to provide information about the Directive and start a dialogue about local coastal conditions in the risk-prone areas, in order to ensure the best basis for implementing the second phase of the Directive, the mapping of risks.

It will have to be assessed whether future climate scenarios call for the establishment of coastal models for different extremes in order to identify the different implications climate change will have on coasts. The model calculations may form the basis for planning future siting of new installations and buildings and for protecting existing ones.

The Department of Geography and Geology (University of Copenhagen) and the Danish Coastal Authority are currently working to provide the required data and to develop a screening tool for assessing erosion of Danish coasts. The Danish Coastal Authority has performed very general calculations of the increased erosion following from climate change.

The goal is that the screening tool will be able to provide knowledge about which areas will be or are already at threat of flooding, as well as the scope of the existing and potential erosion. This knowledge can be used as a basis for making decisions about how to adapt the Danish coastline to the climate of the future.

Regulation

The Coastal Protection Act, including the state's sovereignty over Danish territorial waters, and the recent amendment to the Planning Act (see the section on planning), provides for a legislative framework for timely adaptation of Danish coastal zones to the climate of the future.

Danish coasts are generally covered by a 300-meter-wide beach- and dune-protection zone (in holiday home areas the zone is only 100m) within which it is prohibited to make any changes pursuant to the Nature Protection Act. On some stretches this zone may be smaller or may have lapsed all together. The course of the zone is evident from the digital cadastral map. In situations with considerable coastal erosion or accretion, or to mitigate the risk of sand drift, the Minister for the Environment may revise the delineation of the beach- and dune-protection zones.

The coastal zone, which is generally a 3-meter-wide zone along the shoreline in rural zones or in holiday home areas, is defined in the Planning Act. Installations and buildings may only be sited in the coastal zone when special planning or functional needs call for this.
Danish municipalities are free to plan their climate change adaptation and pollution prevention at higher levels of the planning hierarchy. The municipal council can thus choose to exert their influence on the municipal development plans, so that these take climate change into account.

Summary

Changes in sea level and wind patterns may influence the risk of flooding and coastal erosion. Erosion and flooding are well known phenomena, which land owners are already dealing with today. Individual coastal stretches are predicted to be affected by climate change to varying degrees, however the additional strain on Danish coasts up to 2050 is expected to be relatively modest. Developments are being monitored continuously in order to assess whether future climate scenarios call for the establishment of coastal models for different extremes in order to identify the implications climate change will have on coasts. On the basis of the Ministry of Transport's climate change adaptation strategy, the Danish Coastal Authority will prepare an action plan for climate change adaptation with targets and a milestone plan, as well as a "declaration of services" concerning the availability of the transport infrastructure. The Danish Coastal Authority has ongoing dialogue with the municipalities, and provides guidance for them. In connection with the implementation of the EU Floods Directive, in spring 2012 the Danish Coastal Authority visited the relevant municipalities.

4.1.3 Transport

Roads, bridges, tunnels and railway lines will be vulnerable to increases in precipitation, groundwater level, temperature and windfall. Flooding following from increased precipitation is the most important challenge facing the road network, and may entail a safety risk for road users, lead to reduced passability and temporary close down roads. Future temperature increases may however also help enhance the life span of roads, reduce the construction costs of road surfaces and minimise the need for winter weather preparedness. The overhead wire system of the Danish rail network is vulnerable to higher wind speeds, which may lead to increased risks of windfall and ultimately to implications for finances and traffic.

The road network

Important effects of climate change
Based on future projections of climate change, see section 3, key consequences for the transport area in Denmark, in terms of the road network and permanent links, will be

- *Higher temperatures reduce construction costs:*
  Higher temperatures during winter will mean that periods with heavy frost will be shorter or will all together disappear. This will provide opportunity to reduce the thickness of the bottom-most layers of roadbeds, frost protection, and thus the amount of raw materials needed.

- *Higher temperatures reduce winter weather preparedness and salt application:*
  Higher temperatures allow for savings on winter weather preparedness and road salt, which provides both financial and environmental benefits.

- *Temperature increases can have both positive and negative impacts on the roadbed:*
  Fewer temperature movements across the freezing point may serve to improve the life span of the asphalt. Freezing point passages exert a wear on the road surface which results in loss of stone and cracks. However, asphalt surfacing becomes softer at higher temperatures and its carrying capacity and friction decreases. This problem may be managed by using alternative binding agents. For the underlying gravel and sand layers of the roadbed, the increases in temperature will have a limited but positive effect on the life span.

- *Greater water volumes are a challenge for the road network:*
  Increased precipitation and rising groundwater level, leading to more flooding events, will be a problem for traffic safety and passability. This will place greater demand on road drainage systems and monitoring of the road network. Flooding not only reduces the carrying capacity of roads, it also shortens their efficient life span. Similarly, increased precipitation amounts may cause road banks to become unstable thereby leading to risk of landslide.

- *Greater water volumes will challenge bridge design:*
  For bridges and tunnels, there is a greater risk of reduced carrying capacity of foundations, supporting walls and sheet piles due to higher groundwater levels, regardless of whether this is due to higher sea water levels or increased rainfall. For constructions founded on sand in particular this may become a problem.

- *More frequent storms will pose a challenge for road sign portals:*
  More powerful storms will expose road sign portals to greater force.

Permanent links:

- *Rising water levels and precipitation may affect Danish permanent links:*
  For the permanent links cross the Great Belt and the Sound an increase in precipitation will mean a greater amount of surface water which will have to be pumped up from surface drainage systems in tunnels and roads. This in turn means there may be a greater demand for pumping capacity. A rising water level and more powerful storms may combine to enhance the risk of flooding of tunnels and lead to longer periods of interruption. More powerful storms may also mean that bridges will have to be closed down temporarily more often.

Division of responsibilities between the authorities and private citizens
It is the responsibility of the individual road authority to dimension road drainage systems to meet the recommendations in Danish road regulations. In situations with flooding and damage to sewer lines, the responsibility rests with the individual owner of the line. This applies to all types of line. Section 102(4) of the Danish Public Roads Act stipulates an absolute ban on diverting wastewater onto road surfaces, including into trenches and road drainage systems.

In situations with extreme downpours, in which sewer lines are insufficient to manage the water amounts, the road authorities may make claims for compensation against the owners of the sewer line if they can substantiate that the owner has neglected to maintain his lines to a sufficient capacity.

With regard to surface water run-off from adjacent land at higher ground, the road authorities are however not protected under the Danish Public Roads Act.

Possibilities for adaptation
With warmer winters, the thickness of the sand and gravel layer (i.e. the anti-frost layer) may be reduced. The resulting reduced amount of raw materials required for the anti-frost layer means construction costs will be reduced. However, studies are still needed to determine the frost-free depth. Warmer winters also provide opportunity for using alternative road surfaces which e.g. reduce the risk of aquaplaning, mitigate the discharge of pollutants into the surroundings, and which have noise-reducing properties. Application of salt may however be difficult on certain types of alternative road surfaces, and the durability of these surfaces may be poorer than that of traditional materials.

When planning and constructing new roads, the road drainage system will be dimensioned so it can manage considerable amounts of surface water. This dimensioning of the capacity of the drainage system must, however, be performed on the basis of an assessment of the financial costs as well as the risk linked to the system's inability to cope with every conceivable situation. In socio-economic terms, it will not be cost-effective to dimension a road so that it can withstand every conceivable situation.

Opportunities also exist for testing alternative drainage methods. For example, the Kliplev-Sønderborg motorway in the southern part of Jutland has been fitted with linear drainage. If it turns

out that linear drainage is better suited for situations with much precipitation, it would be appropriate to use this method in future. If there are plans for a long-term conversion of drainage systems on Danish roads, this conversion should take place on a continuous basis over the course of several years. Trenches and trench basins for capacity relief for surface water and rainwater are also options. These methods may be used to increase the number of places of discharge and to reduce inappropriate accumulation and transport of water.

The use of linear drainage lines to transport surface water from roads requires transportation of surface water/rainwater across large distances. The effectiveness of road drainage systems and, in particular, retention basins, deteriorates with time, which leads to the systems not performing optimally during extreme weather events. The drainage systems can be cleared to restore them to full capacity but it is still uncertain how this will benefit water drainage. Moreover, it is very cost-intensive to clear up all retention basins along Danish roads to restore their full capacity.

The challenge from rising groundwater leading to parts of the road network being situated below the groundwater level (a situation which the carrying layers of the roads have not been designed to withstand) may be addressed by constructing roads on dams or by pumping the water off the roads. The latter solution can be extremely expensive but it is necessary on existing roads. More and more often, the longitudinal profile of the road is sunk/dug into the ground to reduce noise pollution. This design means that there is no physical slope to divert the water away from the road. Moreover, there may be low-lying areas which will often be difficult to drain.

Increasing maximum wind speeds entail that road sign portals have to have stronger foundations. Furthermore, consideration may be given to whether a greater number of road trees should be cut to prevent them from falling across lanes during storms.

Initiatives completed and in progress
On the basis of the Ministry of Transport's climate change adaptation strategy, performance requirements for climate change adaptation were introduced in the 2012 performance contracts of all major institutions under the Ministry. These performance requirements entail preparing an action plan for climate change adaptation with targets and a milestone plan, as well as a "declaration of services" concerning the availability of the transport infrastructure.

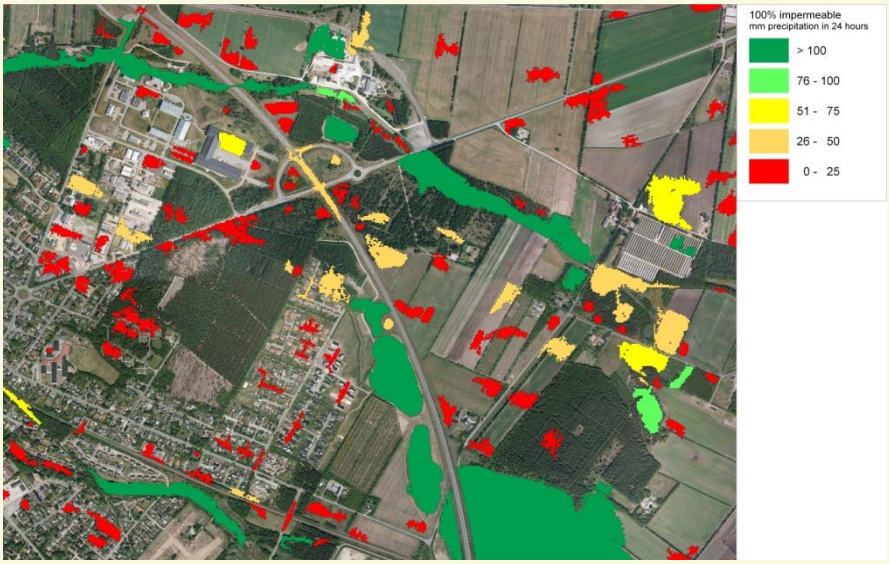
In connection with major flooding events, detailed subsequent analysis of these events is performed. This has resulted in comprehensive emergency response plans for relevant areas, e.g. *Lyngbyvejen*, a major approach road to Copenhagen, in order to ensure the best response in future.

Risk analysis of underpass of expressway

The Danish Road Directorate has performed a "blue-spot analysis" on an expressway near the city of Brande in Jutland. The blue-spot analysis is a tool to identify the most flood-prone areas on national roads, including where the consequences of flooding are greatest. Using GIS the vulnerable stretches can be identified digitally.
The method behind the identification of e.g. the most risky underpasses has been divided into three levels.

Level 1 identifies all underpasses where there is a risk of water pooling (i.e. blue spots) on the roadway or within few meters of the road.
Level 2 analyses how vulnerable the blue spots identified in level 1 are to precipitation.
Level 3 is a hydrological model calculation of the most vulnerable blue spots.

This process included e.g. identification of an underpass (near the city of Brande) in which water will pool up on the roadway in the event of 51-75mm of precipitation within a 24-hour period and if the drainage system is not operating.
The specific place in question will subsequently have to be studied to address questions such as: Has water been observed on the roadway? What is the state of the road drainage system? Will it be able to withstand increased loads? What are the consequences of possible flooding and what emergency preparedness is needed?



Results of a level-2 analysis

Barriers and opportunities for future action

Knowledge and consulting services
The Danish Road Directorate is constantly building on its knowledge base, and new areas in which knowledge is required are identified regularly. This is because of changed conditions. Climate change and the ongoing development of new materials and methods create a need for continuous development.

The Danish Road Directorate provides external consulting services within all areas of activity. The consultancy may be relevant in relation to climate change adaptation. The future will probably see an increase in the demand for this type of consultancy. Today, much consultancy takes place as road regulation. The Danish Road Directorate has ongoing dialogue with the municipalities through a road regulation council. The most recent knowledge which the Danish Road Directorate has either developed itself or procured from external providers will be included in this work, and will therefore benefit the municipalities as well as the Directorate. The Directorate and the municipalities are also cooperating via SAMKOM, a cooperation forum for public technical administrations, which involves benchmarking and knowledge-sharing activities. This work will continue to be important for the Danish road sector.

The *blue-spot method* involves a screening of the entire road network for stretches that are vulnerable to flooding. The places identified can then be risk-assessed, guidelines can be established for management and maintenance of the drainage systems, or, as a last resort, the road

may be realigned. The Danish Road Directorate has developed a method which, using GIS, can identify the places in the national road network most at risk of flooding. This method ensures that the Danish Road Directorate can concentrate efforts aimed at flooding on the spots where the risk and the consequences are greatest, thus providing the most climate change adaptation for the money. The project has already been commenced and will be covering the entire national road network in a couple of years.

By using intelligent transport systems (ITS) and intelligent speed adaptation (ISA), road speed limits can be adjusted according to the intensity of rainfall. In combination with a road radar, this can allow for targeted traffic reports. However, developing such systems is cost-intensive. Warning systems using road radars etc. could be financed jointly with other authorities.

Regulation

The Public Roads Act
The current Public Roads Act[4] holds no provisions or notes directly addressing climate change adaptation. It may be relevant to examine when revising the Public Roads Act whether the act should provide authorisation to incorporate areas for use in climate-related preventive measures.

More stringent discharge requirements from the authorities
The road authorities can place requirements on the design and dimensioning of installations in contract documents in connection with construction projects. The authorities stipulate e.g. strict requirements on the discharge of surface water from retention basins. This may lead to surface water accumulating in basins so that they become full and are unable to hold additional rainfall. Consequently, it may take too long to empty the basins and this might exacerbate a possible flooding event unnecessarily. Unproblematic discharges should not be subject to more stringent discharge requirements; here, requirements should perhaps even be made more lenient, e.g. relative to the number of overflow events in places that were/are otherwise unproblematic.

Insufficient watercourse maintenance
Insufficient maintenance of watercourses by land owners and the municipalities makes surface water drainage and diversion even more problematic, and problems that arise may be due not to road drainage but to a lack of possibilities for drainage and insufficient watercourse maintenance.

Summary
Increases in precipitation, increases in temperature and changes in wind patterns are likely to affect the road network at different magnitudes. The Danish Road Directorate is working on managing climate change impacts on the basis of performance requirements. This involves preparing an action plan for climate change adaptation on the basis of the Ministry of Transport's climate change adaptation strategy which contains targets and a milestone plan as well as a "declaration of services" concerning the availability of the transport infrastructure. The Danish Road Directorate is maintaining an ongoing dialogue with the municipalities on road regulatory work. The most recent knowledge which the Danish Road Directorate has either developed itself or procured from external providers will be included in this work, and will therefore benefit the municipalities as well as the Directorate. The Directorate and the municipalities are also cooperating via SAMKOM, a cooperation forum for public technical administrations, which involves benchmarking and knowledge-sharing activities.

[4] Public Roads Act (*Lov om offentlige veje)*

The rail network

Important effects of climate change
Based on future projections of climate change, see section 3, key consequences for the national rail network will include

- *Increased water amounts will enhance the risk of flooding and landslides:*
  Flooding events and rises in groundwater level will enhance the risk of landslides and embankment failures. A rise in mean sea level could pose a problem for rail services where embankment and slope drainage systems divert the water into nearby watercourses that are affected by the rise in sea level. Damming up of water in the watercourse could affect the water level in trenches.

- *More powerful storms could lead to breakdowns of overhead wires and fallen trees:*
  On electrified railway lines, powerful storms and greater wind speeds may lead to greater frequency of breakdowns of overhead wires and to more incidents with trees falling across the tracks. This may result in interrupted train services with consequences for traffic and for the economy.

The most prominent impacts on the rail network from future climate change are assessed to be an increased risk of landslides and embankment failures, enhanced risk of flooding of railway terrains and more frequent events with overhead wires falling down and trees being knocked over by storms.

Division of responsibilities between the authorities and private citizens
The division of responsibilities between the authorities and private citizens with regard to climate change adaptation in the railway area is relatively clear-cut today. Rail Net Denmark is responsible for its own activity in terms of climate change adaptation, which involves climate-proofing an efficient and operational railway.

Possibilities for adaptation
Rail Net Denmark, which manages the major part of the national railway infrastructure, is already in the process of preparing for the predicted increase in precipitation, higher groundwater level, stronger winds and higher temperatures. Climate change preparations include analyses of road-related events, such as embankment failures (of which there were two in 2010 and 2011, respectively); establishing warning systems which ensure a high level of security for the railway; revising existing technical railway standards; and by analysing the need to incorporate climate change adaptation in planning of new rail installations.

Initiatives completed and in progress
On the basis of the Ministry of Transport's climate change adaptation strategy, performance requirements for climate change adaptation were introduced in the 2012 performance contracts of all major institutions under the Ministry. These performance requirements entail preparing an action plan for climate change adaptation with targets and a milestone plan, as well as a "declaration of services" concerning the availability of the transport infrastructure.

To prevent accidents on the railway following heavy downpours, Rail Net Denmark has introduced a new early warning procedure which can shut down the train service in the event of problems. Rail Net Denmark has implemented routines for intensified inspection and control of problematic

embankments in the event of long periods with intensive rain, and is also securing well-functioning drainage systems for a large number of trenches along the railway. Furthermore, Rail Net Denmark is looking at drainage systems at stations where drainage problems have already been observed, and efforts to prevent trees from falling across the tracks have been boosted.

In connection with planning of new rail stretches, Rail Net Denmark is carrying out analyses on a routine basis of the need to incorporate climate change adaptation into projects. This is important as the climate is expected to change over the course of some years leading to problems for rail installations that have life spans of up to 100 years.

Up-to-date climate-proofing of the upcoming new rail link between Copenhagen and Ringsted

As a consequence of the most recent knowledge about climate change, in terms of precipitation, groundwater and sea levels, assumptions underlying the original environmental impact assessment have changed. Therefore, an updating of the climate change impact assessment was launched as part of the detailed planning phase, so as to ensure that the new rail link between Copenhagen and Ringsted can withstand future climate change. Below are some examples of areas in which the assessment gives rise to amendments that need to be clarified and ultimately included in the project.

- A screening (blue-spot analysis) of the topography along the railway identifies local spots at risk of flooding in the event of extreme precipitation.
- Flooding of the railway terrain due to precipitation: A "critical spot height" is defined, and the frequency of flooding, as well as its implications for the design of drainage systems, including pumping stations on tunnel stretches, are examined for particularly critical stretches (tunnels and troughs).
- Technical installations must be located taking into account the critical spot height and the likelihood of flooding.
- In several locations, the vertical alignment of the railway has been sunken relative to the programme phase, which gives a higher number of potential trouble spots along the railway track. Any increase in the groundwater level will therefore be critical. Mitigating initiatives will be assessed specifically for the individual location.

With the implementation of climate change adaptation measures, it will be possible to prevent the climate change predicted over the next 120 years from damaging the infrastructure or operations on the new Copenhagen-Ringsted rail link.

Barriers and opportunities for future action

<u>Knowledge and consulting services</u>
The impact of climate change adaptation initiatives carried out today is associated with the uncertainties linked to current projections of climate change. One of many issues related to long-term planning is that current projections run up to the year 2100, while bridges, tunnels and underpasses according to Rail Net Denmark's standards must be constructed with life spans of at least 120 years.

Climate change adaptation is carried out with assistance from large engineering firms, which are also widely used by local governments and other authorities. As the same mindset has been applied in risk perceptions, methods and solutions, collaborative efforts with municipalities and other players have been good. However, long-term planning of climate change poses special challenges which only few municipalities relate to in practice in their work on climate change adaptation.

Recent years have seen a huge increase in the availability of tools due especially to work taking place within the framework of the Danish Ministry of the Environment's portal on climate change adaptation at www.klimatilpasning.dk. With regard to long-term planning, an especially useful tool, Sea Water on Land (*Havvand på Land*), makes it possible to plan for any surprises relative to current climate forecasts.

The blue-spot analysis is another interesting tool developed by the Danish Road Directorate.

Regulation

Planning by Rail Net Denmark is generally based on a series of standards. In future years, Rail Net Denmark will carry out a revision of the drainage standard which determines the dimensioning of drainage systems for surface water etc.

Summary

Greater rainfall amounts and more powerful storms may have different effects on the rail network. Rail Net Denmark is preparing to cope with increased precipitation and stronger winds by analysing road-related events, establishing warning systems, revising existing technical railway standards, and by analysing the need to incorporate climate change adaptation in the planning of new rail installations. Finally, Rail Net Denmark is also working on managing climate change impacts on the basis of performance requirements. This involves preparing an action plan for climate change adaptation on the basis of the Ministry of Transport's climate change adaptation strategy. This action plan is to contain targets and a milestone plan as well as a "declaration of services" concerning the availability of the railway infrastructure.

4.1.4 Water

Water plays an important role with regard to climate change impacts in Denmark. The knock-on effect of more extreme precipitation events, sea level rise and longer periods of drought will pose a challenge to water management. More frequent and more intense events with extreme precipitation and storm surges will exacerbate the demand for managing large amounts of water, while periods of drought may put the water supply under pressure, even though, in overall terms, increases in groundwater recharge are predicted.

Water has been divided into two main areas in the following: wastewater and flooding, and groundwater and water supply. This division is due to the fact that impacts and possible actions differ substantially between these areas.

Wastewater and flooding

Important effects of climate change
The key consequences for wastewater and flooding include

- *More precipitation will increase the pressure on the sewerage system:*
  More frequent events with extreme precipitation could mean that the capacity of sewers is exceeded more often leading to greater risk of overflow events and subsequent flooding of terrain, buildings and basements, which, in turn, poses a risk to human health. More overflow events will also lead to greater strain on vulnerable aquatic areas from pollution. Furthermore, an increased seal level will deteriorate the drainage capacity of drains close to the coast, as reduced water flow in the sewerage system may lead to local flooding events.

- *More precipitation means that vulnerable areas will be at higher risk of flooding:*
  Increased precipitation will affect watercourses and low-lying land, resulting in a higher risk of local flooding events. At the same time, the increase in groundwater recharge could also mean more frequent flooding from groundwater.

These consequences are important in climate change adaptation. Extreme precipitation events could lead to greater pressure on the sewerage system and to overflow of the system and flooding of vulnerable areas.

Division of responsibilities between the authorities and private citizens
The water utility companies are responsible for an appropriate dimensioning of their drainage systems. The Minister for the Environment is authorised to set out binding guidelines for the dimensioning and design of drainage systems. However, so far, this option has not been utilised. The Water Division under the Ministry of Business and Growth is responsible for setting the price caps for the water utility companies and approving supplements for investment and expenses for environmental and service goals.

A "non-profit" principle applies in the water sector. This means that water utility companies are required to ensure a balance between their expenses and profits over a number of years. This principle involves full user financing. In other words, the water utility company's expenses for establishing, operating, maintaining, managing and paying interest on loans must be fully covered by contributions from the users.

Possibilities for adaptation

Traditionally, the immediate response to managing extreme rainfall has been to install larger sewer pipes and to build retention basins, or to manage surface water locally. In many situations, an expansion of the existing drainage systems could take place in connection with ongoing renovation work. Locally, it will be possible to climate-proof against water damming up e.g. in critically sited basements, or initiatives could be launched to divert the water to where it does least damage. In practice, an expansion of the sewer system will not always be the most socio-economically appropriate solution.

Today, some municipalities already partially compensate property owners for the connection charge (a lump sum) if the owner installs a dry well on his ground to divert rainwater, or another local rainwater bypass solution. The Danish Nature Agency has analysed the different models that can provide incentive to reduce the drainage of rainwater into the central sewers. The opportunity for establishing local infiltration solutions depends on e.g. local soil conditions, and this option is therefore not present on all locations. Another solution could be to retain and store the rainwater in basins on the individual property. However, this type of solution may be associated with large costs for the individual property owner.

Initiatives completed and in progress

Strategic climate change adaptation in Greve Municipality

Due to a greater number of intense flooding events, Greve Municipality has decided the city's surface and wastewater management system is to be able to cope with 30% more water. The required adaptation of the system is being carried out at a total of 42 urban districts addressing the most critical areas first.

This climate change adaptation initiative includes both existing and future run-off and drainage systems, and the entire surface water management system and local watercourses are being included in the scale-up, which is expected to be completed by 2020. The adaptation initiative is being implemented using a strategy model that is based on a combined landscape and surroundings model, as well as a hydraulic model, which calculates how water flows in the drainage systems and in watercourses.

The municipality has also been working on emergency response plans to ensure the municipality will be able to execute a timely response in the event of extreme rainfall and/or elevated water levels, thus reducing the extent of damage.

With the enhanced capacity of watercourses and surface water and drainage systems, and the emergency response planning, the municipality is expected to be able to prevent more negative impacts from extreme rainfall in future.

Key stakeholders have identified a number of legislative obstacles for financing and incorporating climate change adaptation efforts in surface water and wastewater planning. A process has therefore been initiated in order to solve the current problems and to ensure the proper legislative framework is in place for carrying out the socio-economically best solutions.

The *Danish Water Sector Reform Act* introduced a price cap which entails that additional expenses may only be added to charges under special circumstances, e.g. operational expenses for environmental and service goals. Regulation in the area is however unclear and this has kept many of the water utility companies from seeking approval of a supplement to the price cap.

A proposal for an amendment of the Danish Water Sector Reform Act has therefore been prepared. The proposed bill was presented to the Danish Parliament (the Folketing) on 29 March 2012. As follow-up to the bill, a statutory order will be prepared which will clarify the rules.

Climate change partnerships - developing and procuring new solutions

The Business Innovation Fund is to assist small and medium-sized enterprises, in particular, in exploiting the global challenges in the environment and climate area as a springboard for new business opportunities. The Fund received DKK 760 million in funding for the period 2010 to 2012.

In spring 2012, the Fund entered into a partnership with a number of municipalities and utility companies that are facing huge challenges and investments in surface water and wastewater management. The goal of the partnership is that the municipalities and utility companies facing the same challenges join forces in the demand for new commercial and innovative solutions through specific tenders that combine development and final delivery under a single contract.

The objective of the partnership is to help solve specific local-government challenges in the area of surface water and wastewater, as well as to harvest the future large commercial potential of investments by municipalities in climate change adaptation. The demand for innovative solutions which effectively meet upcoming challenges within the municipality's legislative framework therefore also create a huge commercial potential for Danish enterprises that should be utilised as a driver for growth, employment and exports.

Through the partnership, it is the goal to bring municipalities and utility companies together with enterprises at an early stage of solution development. This will allow municipalities and utility companies to achieve greater insight into the market and possible solutions, and enterprises will gain greater knowledge about the challenges and needs of municipalities. This will better equip enterprises to develop competitive solutions.

The Business Innovation Fund has earmarked DKK 30 million to the development phase.

Barriers and opportunities for future action

Knowledge and consulting services

There may be large regional differences in rainfall. Greater knowledge about local precipitation series is therefore desirable. Moreover, since the sewers have a life span of up to 100 years, it is difficult to dimension exactly how much sewers should be expanded in future.

An option could be to require that wastewater companies complete a risk analysis for important drainage systems with a view to identifying any hydraulic bottlenecks in the systems as well as the most flood-prone locations. This risk analysis can be used for mapping and price-setting adaptation measures.

Several different model tools may be used to identify the sewer system's ability to cope with extreme rainfall. A hydraulic model combines drainage systems with flows on surfaces (terrain level), as well as water levels and water flows in water courses and the sea. It will then be possible to identify the spots where flooding events are likely to occur and how extensive these events are likely to be. This model thus provides a satisfactory basis for assessing the costs of damage from various events and knowledge about how to alleviate the problem efficiently. This also provides a tool that can be used to identify the most beneficial initiatives.

According to the government programme from 2011, Danish municipalities are to prepare municipal climate change adaptation plans over the next two years. Today, accessible and relevant tools already exist at the Danish Portal for Climate Change Adaptation (www.klimatilpasning.dk), such as the Sea Water on Land (*Havvand på Land*) tool, an interactive screening tool that shows the areas of Denmark that will be affected by an increase in the sea level. Another tool is Coast Planner (*Kystplanlæggeren*), a screening tool that shows areas that are potentially vulnerable to high-water events.

Regulation

The water sector is regulated on the basis of the non-profit principle and it is subject to a price cap. As a general rule, the water utility companies are able to finance the necessary investments and maintenance work on the sewerage system via wastewater charges through an investment supplement to the price cap. However, with the current regulation, the water utility companies may experience liquidity problems in future. An amendment to the Statutory Order for the price cap aiming at solving this problem is currently under consultation. In addition, there may be a general need to look more closely at whether the utility companies have the necessary incentives to make the investment required in maintenance and expanding the sewerage system, amongst other things because, for the majority of the installations, the period of depreciation for investments in the water sector is significantly longer than the term for municipal loan guarantees.

Finally, there may be assessments of whether there are alternatives outside the charges-financed area which could increase the drainage capacity of wastewater utilities cost-effectively and in a way that ensures that any amendments to the regulations are not over-exploited. The current charges-financing rules limit possibilities for financing such initiatives through the wastewater charge in order to ensure that water consumers only pay for the costs that actually relate to wastewater management. Cost-effective alternatives can also include water management by private consumers on their own property.

Summary

On the basis of the consequences of extreme downpours, regulations aimed at minimising the negative effects of flooding are being developed. As a general rule, water utility companies are able to finance the necessary investments and maintenance work on the sewerage system via wastewater charges. It would be relevant to assess whether the water utility companies have the required tools and incentives to adapt to climate change through e.g. investments in maintenance and expansion of the sewerage system. This should be seen in light of the relationship between depreciation periods and repayment periods, etc. Finally, it would be relevant to assess whether alternatives exist outside the charges-financed area to enhance the capacity for draining surface and wastewater cost-effectively, including by letting individual citizens manage water on their own land. The current charges-financing rules limit possibilities for financing such initiatives through the wastewater charge in order to ensure that water consumers only pay for the costs that actually relate to wastewater management. At the same time, pursuant to the 2011 government programme, municipalities are obliged to prepare municipal climate change adaptation plans within two years.

Groundwater and water supply

Important effects of climate change

The most important effects for the groundwater and water supply are as follows

- *More precipitation means higher annual groundwater recharge:*
  The increase in annual precipitation will increase groundwater recharge, and this will increase the size of the groundwater resource available for water recovery. However, seasonal variations mean that this will primarily be in the winter and there are regional variations between east and west Denmark. In the summer there will be less flow into lakes and rivers. Increased groundwater recharge in the upper strata could give more local flooding problems.

- *Long periods of drought may bring water supply under pressure:*
  Ever longer periods of drought are expected in the summer periods and these will put more pressure on the water supply, especially in areas which are already affected by water catchment for larger cities and to irrigate fields. Therefore, in exposed areas it is likely that groundwater extraction will be adjusted to maintain water flow in watercourses.

- *Higher temperatures mean more bacteria in drinking water:*
  Higher temperatures may mean a slightly higher content of bacteria and amoeba in drinking water compared with current levels. Today it can already be difficult for some waterworks to comply with the recommended requirements for the temperature of drinking water of max. 12°C at the tap.

- *Higher sea levels may add saltwater to the groundwater:*
  Higher sea levels will move the current freshwater boundaries further inland. Locally, this could cause problems with saltwater infiltration into coastal extraction wells and create a need for new wells. The problem is especially serious for smaller islands.

The most important effect of climate change on the groundwater is the likely increased groundwater recharge, although with significant regional differences. There may also be a higher risk locally of periods of drought as well as risks of bacteria and saltwater in the groundwater.

The increased groundwater recharge in the upper strata could give more flooding problems. The effects of this have been described in the section above on wastewater and flooding.

Division of responsibilities between the authorities and private citizens
The Ministry of the Environment is responsible for surveying, planning and monitoring the groundwater. *The municipal council* is responsible for planning water supply to households and industry in the municipality. The municipality also works to protect the groundwater through action plans and plans deriving from the government water plans.

Danish water supply is exclusively based on extraction of groundwater, and there is a decentralised supply structure. There are about 2,600 public water utilities. In addition there are about 700 smaller installations and about 50,000 private wells supplying individual properties. Finally there are almost 1,300 larger extraction installations for industrial use etc.

The municipal council is responsible for water supply and notification of licences.
As a rule, extraction or diversion of the groundwater can only be with a licence.

Possibilities for adaptation
The environmental requirements for watercourses and wetlands have been set in the water plans drawn up under the Water Framework Directive. A reduction in summer flows in water courses etc.

may make it more difficult to meet these objectives, particularly on Zealand, where both reductions in summer flows and water extraction are expected to be greatest.

Licences for water extraction are for limited periods and are currently granted for a maximum of 30 years (waterworks) or 15 years (field irrigation). This means that the water resource authority will regularly be able to reassess licences. Therefore, there could be ongoing adaptation of water catchment and of the objectives for watercourses and wetlands. Agricultural water requirements and protection of watercourses and wetlands will be balanced.

If it is not possible to satisfy both consideration of watercourses and wetlands and consideration of the water supply, it may be necessary to move water catchment to areas with a more plentiful water resource, or to areas with less impact on watercourses and wetlands.

A requirement for moving water catchment to new locations will be to set precise objectives for the quality/water flow in watercourses and wetlands so that it is possible to determine 1) the amount of water involved, and 2) the areas to which it will be possible to move the water catchment area.

Initiatives completed and in progress
In response to the objectives in the government programme regarding protection of drinking water, and more specifically to establish protection zones around wells (BNBO) for public water utilities, an annual DKK 20 million in 2012 and 2013 has been allocated in the 2012 Finance Act to a subsidy pool and a task force to advise municipalities.

The subsidy pool is available for municipalities to help finance protection-zone (BNBO) surveys. The task force is responsible for administration of the subsidy scheme. In addition, the task force will offer advice and guidance to municipalities looking to establish protection zones and it will advise about protecting the groundwater in general. Special issues regarding the impacts of climate change for drinking water supply will be included in the advice from the task force as required.

There are a number of climate change adaptation tools with regard to groundwater, especially modelling tools to calculate quantitative aspects (groundwater flow/lowering). A nationwide water-resource model has been developed by the Geological Survey of Greenland and Denmark; the DK-model: http://vandmodel.dk/vm/index.html

Therefore there are integrated groundwater models which can broadly describe the water cycle and, for example, analyse the relationship between groundwater levels and impacts from the surface water (e.g. watercourses and lakes).

Furthermore, there are a number of tools to calculate groundwater chemistry, e.g. nitrate run-off, which is relevant in a climate context.

Barriers and opportunities for future action

Knowledge and consulting services
With the incorporation of the need for water for watercourses and wetland nature, the government water plans for the second period (22 December 2015 to 22 December 2021) will contain more accurate statements of the size of the groundwater resource available for water extraction. In this

context it will be relevant to account for the effects of climate change on the groundwater resource now and in the future.

The knowledge and data basis is extremely well developed, with statutory reporting to central public databases of:

- Groundwater-technical data
- Quantitative data of extracted (pumped-up) amounts.
- Geological data in the form of samples, geological information etc.
- Well data, model data and administrative data.

Notifications of data will regularly show the impacts of climate change and with the right follow-up, it may go on to be used in work on adapting groundwater protection and extraction licences to climate change.

Advice in the groundwater area is traditionally based on regulatory work. There is no overview of the scope of advice on climate change adaptation in respect of the groundwater, but the task force mentioned above has been set up to enhance the government's advice and consulting services for the municipalities.

Regulation

The impacts of climate change on water supply must be regularly incorporated in administration of the legislative framework as well as in connection with amendments to the legislation. This is primarily relevant for the Water Supply Act[5] and associated Statutory Orders as well as provisions in the Environmental Protection Act[6] relating to discharges and additions of pollutants to the groundwater.

Moreover there is groundwater protection in, amongst other things:

- The Action Plans for the Aquatic Environment
- The certification scheme for pesticides
- The pesticides agreements, including agreements to stop using pesticides on public areas
- The Soil Contamination Act

Summary

In general, increased groundwater recharge will change the conditions for future water supply. Partly this will be through increased groundwater resources and partly through certain challenges. Increased groundwater recharge in the uppermost soil layers will mean higher risks of flooding.

A reduction in summer flows in water courses may make it difficult to realise the targets in the Water Framework Directive and therefore it may be relevant to move water extraction locally.

With regard to groundwater protection, efforts have been launched regarding protection zones around wells, including a subsidy scheme and an advisory task force, and the need for climate change adaptation has also been incorporated in these efforts. A number of legislative acts and schemes contribute to protecting groundwater resources. In this area, there is a need to incorporate

[5]Consolidating Act no. 635 of 7 June 2010 on water supply etc. (*Lovbekendtgørelse nr. 635 07/06/2010 om vandforsyning m.v.)*

[6]Statutory Order no. 1757 of 22 December 2006 on environmental protection (*Lovbekendtgørelse nr. 1757af 22. december 2006 om miljøbeskyttelse)*

climate change adaptation as a consideration in public administration and in any amendments to the legislative basis.

Existing groundwater models and other tools seem adequate to monitor the challenges arising from climate change.

4.2 Business sectors

4.2.1 Agriculture

Climate change has a very direct impact on Danish agriculture. The total agricultural area of Denmark amounts to about 62% of the total land area. Overall, agricultural exports account for around 12% of Danish exports. Therefore, climate change may have an impact on land use by agriculture and commercial activity, including employment and exports.

Important effects of climate change
The most important effects of climate change for agriculture are as follows

- *Increases in temperature will be favourable for many crops:*
  Crops such as grass, sugar beet and maize will benefit from increases in temperature as the length of the growing season determines the yield. Even now there is a change in Denmark towards growing more maize. A longer growing season for grass fields may also mean longer grazing periods.

- *More CO_2 means increased yields:*
  More CO_2 in the atmosphere will increase yields. If the CO_2 concentration doubles, the yield is likely to increase by around 20% for most crops.

- *Higher temperatures extend the production season for vegetables and fruit:*
  For field vegetables and fruit, higher temperatures, especially in the spring and autumn, will mean an extended production season with a clear market advantage. There will also be possibilities for new crops, for example more Danish wine may be produced.

- *Higher overall yields for agriculture may give more nitrogen and phosphorus run-off:*
  Increasing yields involve a greater need for fertilizers. Furthermore, higher temperatures and winter precipitation will increase the risk of nitrogen and phosphorus leaching and run-off into the aquatic environment.

- *Rising temperatures mean lower yields for annual crops:*
  Temperature increase will reduce the length of the active growing period for annual crops such as cereal and rape and thereby reduce the yield as the crops will mature earlier. Increases in temperature may also lead to significant variations in yields.

- *Increased winter precipitation and increasing water levels mean poorer agricultural exploitation:*
  Increased winter precipitation and rising water levels in some areas will lead to flooding or to groundwater levels which are so high that security of cultivation will be difficult to maintain. This may be particularly relevant along a number of fjords and watercourses, but there may also be problems for other drained areas with poor drops to watercourses in case of greater precipitation intensity.

- *Longer periods of drought increase the need for irrigation and watering:*

Longer periods of drought during the summer mean a greater need to water crops artificially, especially on sandy soil. Higher temperatures also increase evaporation, but much of this effect is countered by less evaporation from plants due to higher concentrations of CO_2 in the atmosphere. Changing crop types to more maize will also increase the need for irrigation and artificial watering. More artificial watering may have an effect on summer flows in water courses.

- *Higher temperatures strengthen some species of weed:*
  Some weed species will benefit from a warmer climate, e.g. cockspur and green bristle grass, both of which are relatively new species in Denmark. These species are considered some of the most aggressive globally, but so far they have not been a serious problem in Denmark.

- *Higher temperatures could result in more disease:*
  It is very hard to give a clear-cut description of the developments in plant diseases, but the overall assessment is that higher temperatures in the future will be more favourable for a number of plant diseases, which therefore will become more widespread.

- *Rising temperatures change conditions for exotic diseases in animals:*
  Rising temperatures could change conditions for the incidence of animal diseases which are currently regarded as 'exotic' in Denmark. Vector-borne diseases are an example of this, as small changes in temperatures and humidity can enable ticks and mosquitoes to establish themselves in new locations. The vector-borne disease known as blue-tongue was considered an exotic disease some years ago. In just a few years it has spread to most EU countries with consequent comprehensive vaccination programmes.

In general, Danish agriculture will benefit from the effects of the expected climate changes on production potentials. However, there remains considerable uncertainty about the impacts of larger climate variations and climate extremes, which in some places could reduce cultivation potentials and profitability for agricultural production.

With regard to livestock production, climate change and greater global mobility for people, animals and goods, will contribute to new spread-patterns for diseases and infections.

Division of responsibilities between the authorities and private citizens
The agricultural sector itself will be responsible for the composition of crops and livestock production.

The municipalities will be responsible for practical implementation of the instruments in the Water Framework Directive regarding changed water-course maintenance and higher groundwater levels, including issuing watering licences and monitoring changes in circulars on watercourses.

The Ministry of Food, Agriculture and Fisheries is the Danish representative in EU negotiations leading up to a revision of the Common Agricultural Policy (CAP) in 2014. The EU's theme is ”Greening the CAP”, and therefore various initiatives have been proposed to abandon use of sensitive agricultural land and other initiatives in relation to adapting to climate change.

The Ministry of the Environment is working with the *Ministry of Food, Agriculture and Fisheries* on implementing the initiatives in the Water Framework Directive regarding run-off of nitrogen and phosphorus into the aquatic environment as well as initiatives on sustainable use of pesticides. Both

aspects are influenced by climate change and have been dealt with in more detail under the section on nature.

The Ministry of Food, Agriculture and Fisheries is focusing on diseases in livestock, including diseases arising due to climate change, for example because this group of animals may pose a risk for food-borne diseases in people.

Consulting services within the agricultural and livestock sectors is the responsibility of *the Knowledge Centre for Agriculture*, which each year completes a large number of cultivation trials with agricultural crops, including trials of new crops, varieties and cultivation techniques. This new knowledge is disseminated to farmers through an effective consultancy system supported by continuous dialogue with universities. Moreover, the Knowledge Centre for Agriculture collects similar knowledge from vets, trials hosts and researchers and this new knowledge within livestock production is also disseminated to farmers.

Possibilities for adaptation

Exploitation of the potential for increased yields resulting from climate change requires adaptation in farmers' cultivation practices, and there will be considerable regional differences. Short-term adaptation aims at optimising production under the given conditions (e.g. choice of species, choice of variety, sowing time, fertilising and use of pesticides. For example, the area of Denmark planted with maize has increased from 560 ha. in 1965 to 172,000 ha. in 2010.

Management of agriculture will be important, particularly within the interaction with the environmental impact of agriculture. Conditions regarding regulation of draining low-lying areas, watering, fertilisers and plant protection are particularly influenced by climate change. Model calculations show that cultivating catch crops could limit the risk of increased nitrogen run-off. The risk of losing phosphorus to the aquatic environment could probably be mitigated through new, environmentally friendly technologies.

The problem of managing increased amounts of water on low-lying areas could be solved through expanding drainage capabilities, building dykes and pumping away the water, or by giving up using the land for agriculture completely. It may be necessary to map the scope of the problem and chart the time horizon.

Damage as a result of more extreme weather conditions could be reduced through greater use of perennial crops which are better able to resist climate extremes.

Increased needs to water fields may create a need for more watering licences. At the same time, watering can have an impact on summer flows in water courses, and this may make it necessary to adjust existing water-extraction licences. Further mapping of the scope of the problem may also be necessary.

Initiatives completed and in progress

The establishment of the Nature and Agriculture Commission in 2012 has brought renewed focus on the complex interaction between nature, the environment and agriculture. The challenges regarding the impacts of climate change are part of the terms of reference of the Nature and Agriculture Commission.

Adaptation to climate change covers a very broad spectrum of possible research fields and focus areas, from managing changes in temperatures and precipitation, to cultivating new crops and managing new pests and/or plant and livestock diseases. These are conditions which to differing degrees are sub-elements in several projects to promote sustainable production within the food industry, but which are relatively seldom independent objectives. This also applies for the Ministry of Food, Agriculture and Fisheries, whose independent research programmes have been transferred to the new Green Development and Demonstration Programme (GUDP). The GUDP currently has ten projects with adaptation to climate change as part of the objectives.

The Advisory Committee for Animal Health has set up a working group which, in addition to looking at new infectious diseases which may spread to Denmark, is also looking at initiatives which could be implemented to increase the focus of vets, physicians and animal owners on these diseases in pets in order to minimise the risk of introducing and spreading diseases significant to the health of both human beings and animals - including diseases caused by climate change.

Research into use of pesticides

A recently completed research project (PRECIOUS) has developed scenarios for pesticide use in a future climate corresponding to projected climate changes in 2050. The calculations show an increase in the treatment index of 10%-20% as a result of climate change. Despite this, run-off of strongly bound herbicides, insecticides and fungicides will not increase in the future climate. On the other hand increased run-off of sulphonylurea herbicides, and to a lesser extent other herbicides, is likely. On clay soil the direct climate effects, e.g. heavy downpours, will cause increased pesticide run-off by a factor of about 100-10,000, because the majority of the flow through the upper strata will be through macro pores. In sandy soil the changes in precipitation intensity, evaporation and temperature will be less significant.

Barriers and opportunities

Knowledge and consulting services

Knowledge about the impact of climate change on agricultural crop production and on related environmental impacts has been considerably enhanced in recent years, particularly due to national and international research projects which, in collaboration with other European researchers, have compared models and data bases and then applied these in the latest scenarios for climate change.

In order to enhance the data foundation, in the current CRES project under the Danish Council for Strategic Research, uncertainty studies have been completed of the interaction between climate scenarios, scenarios for land use, and models for crops and substance transport on the possible consequences for water supply, cultivation suitability and nitrogen pollution in the catchment area for Odense Å. The research has shown that climate extremes will have a significant effect in the future and that the existing knowledge and effect models are inadequate for this purpose. Therefore, this will be the primary focus in future research projects which can apply for funding from the EU and in connection with the EU JPI-FACCE initiative.

The draft animal-health strategy from the European Commission provides a basis for tackling the new challenges for animal health, and there is a possibility to incorporate climate change into realisation of the strategy. Furthermore, in recent years the EU has increased its focus on diseases significant for both human beings and animals under the ”One Health” concept.

The increased risk of losses of nitrogen and phosphorus from agricultural land under climate change may make it relevant to assess the need to convert some of the current area with crops in rotation to permanent vegetation (e.g. grass or willow) in order to reduce environmental impacts. However, there is a complex relationship between the climate and discharges of nitrogen and phosphorus into the aquatic environment, and further research in this area is necessary before these effects can be quantified and assessed.

Part of the problem with increased use of pesticides is that it may make it difficult to meet the targets in the Pesticides Action Plan. Much of this problem could probably be solved through new technology such as resistant crops or more targeted use of pesticides. However, there is a lack of knowledge about the relationship between climate change, the need for plant protection and preventive efforts against weeds, diseases and pests.

There are a large number of internet-based tools providing advice about, for example, fertilising, watering, plant protection and livestock. These tools are maintained and offered by the Knowledge Centre for Agriculture. To varying degrees, these tools take account of variations in weather conditions, while many of them will probably have to be extended and adjusted to be able to cope with larger climate changes. There is also a need to expand the range of consultancy tools, especially with regard to risks of flooding and possibilities/needs to change field drainage.

Regulation

Climate change can increase cultivation problems for certain land areas which may become unprofitable and possibly have to be abandoned as agricultural land; a process which will be reinforced by implementation of the Water Framework Directive. Similarly, the spread of certain vector-borne diseases will make grazing on some land areas impossible. Whether land in exposed areas can or should be used for other purposes will probably depend on the local situation. Impacts on biodiversity, the environment and on food and biomass needs as well as considerations for nature also play a role. This may require a large degree of land-use planning in Denmark.

Increasing discharges of phosphorus and nitrogen into the aquatic environment may lead to a need for further initiatives with regard to the proposed water plans to follow up the Water Framework Directive, which will ensure good quality groundwater, watercourses, inlets and coastal waters. In order to reduce possible future phosphorus losses, in the future there may be a need to consider whether it is necessary to regulate additions of phosphorus to Danish agricultural land.

The most important source of financing for climate change adaptation initiatives in agriculture will be the EU CAP. The current CAP agreement runs up to 2013, and according to the proposal from the European Commission, a number of reforms can be expected which will affect production conditions for agriculture and thus also the interplay with climate change. These reforms primarily aim at providing opportunities for regional and local measures which can reduce the environmental impacts of agriculture and also reduce the vulnerability of agriculture to climate change.
It may be relevant to secure financing for larger structural changes such as support to abandon use of soil from especially threatened areas.

Summary

Increases in temperature may lead to increases in productivity for agriculture if the adaptation of agriculture that is already ongoing continues. In this context it is relevant to consider adjusting regulation of agricultural run-off of nitrogen and phosphorus as well as use of pesticides.

More extreme weather events with flooding or drought are a challenge for agriculture which will be amplified by the implementation of the Water Framework Directive. Farming of vulnerable, low-lying land will become unprofitable and alternative uses of the land may be considered.

Several initiatives are under way which will enhance knowledge about the challenges and opportunities facing agriculture as a consequence of climate change, and it would be relevant to shed more light on how agriculture can exploit climate change and avoid the negative effects.

4.2.2 Forestry

Forests are the natural type of vegetation more or less throughout Denmark, and therefore they have a particular significance in climate-proofing biodiversity. Forests cover about 14% of the land area of Denmark. In addition to annual felling of about 2 million m^3 (approx. 30% of Danish wood consumption), the forests contribute with significant landscape, natural and recreational values.

In general, trees have a high adaptation capacity for climate change. Many tree species will therefore benefit from rising temperatures, while longer periods of drought in the growing season will weaken most trees. Conifers in particular may suffer from changed temperatures and precipitation as well as greater risks of storms. Because of the long production time for forests (about 50-80 years for conifers and 80-150 years for deciduous trees), it is important to adapt to climate change now, amongst other things by changing selection of species and types of cultivation.

Important effects of climate change
The most important impacts for forestry are as follows

- *Rising temperatures mean longer growing seasons and larger biomass production:*
  Higher temperatures and higher CO_2 content in the atmosphere may cause greater plant growth and thus greater inland biomass production. Because of the warmer climate, the growing season for trees will also be lengthened.

- *Increased storm intensity affects wood production and biodiversity:*
  Increased storm intensity (5-10%) as well as increased storm risk, may lead to more trees being blown down (especially conifers which comprise about one-half of the Danish forest area) and more frequent forest storm damage. This can affect wood production and cause a loss in biodiversity in forests, if forest storm damage occurs in large, cohesive areas.

- *Drought stress and storms affect forest trees:*
  Forest trees are vulnerable to climate change (drought stress and storms). This also increases their vulnerability to harmful diseases and pests. Pests and diseases can attack trees more easily, weakening the wood and rotting or drying it out.

- *Higher summer temperatures increase the risk of more forest fires:*
  As a result of the warmer climate, there is a risk of more forest fires, which are already widespread in southern Europe.

- *Rising temperatures change the species composition of forests.*
  Tree species have different ways of dealing with climate change. The Norway spruce, which covers about 17% of Danish forest land, is threatened by temperature increases as the species cannot cope very well with mild winters and summer droughts (other, non-indigenous conifer species such as the Sitka spruce will cope with increases in temperature better). In contrast, deciduous forests will have better conditions as a result of rising temperatures.

The most important climate change impacts are poorer growth conditions, primarily for some conifer species, but also better growth conditions for other trees. Forest challenges come primarily from the combination of stronger storms and higher temperatures and precipitation. The immediate

effects are likely to concentrate on some conifer species, but other tree species may have new problems from diseases and pests. Forestry operations based on same-age trees and monocultures will be especially vulnerable.

Division of responsibilities between the authorities and private citizens
Forests are regulated under the Forest Act and the Nature Protection Act, both of which are the responsibility of the Minister for the Environment. The Forest Act stipulates regulations for use of the existing forests and authorises subsidies for activities in existing forests and for afforestation. The Nature Protection Act regulates protection of a number of natural habitat types and includes rules for public access.
Furthermore, under the Ministry of Business and Growth there are acts dealing with storm surge and windfall which allow for subsidies for replanting after windfalls.

Ownership of forests in Denmark
About 70% of the forests in Denmark are privately owned. The remaining 30% are publicly owned, of which 75% by the state. Privately owned forests are on about 25,000 different properties. About 85% of forests are listed, i.e. the area must be used for forestry purposes into eternity.

Possibilities for adaptation
Because of the long production times for forests, early intervention is necessary to deal with the future climate change. An important tool is to ensure the correct choice of tree species as early as possible so that a greater proportion of forests become more robust towards climate change. In this context it is vital that forests are a mixture of many different tree species so that the forest can withstand possible losses of individual tree species. The type of cultivation can be adapted so that forests are less exposed. By establishing greater variation in species and structures, overall the forest will be better able to withstand climate change. Close-to-nature forest management, by which forests are operated with large variations in species and structures, is therefore one method of cultivation which could adapt forests to a changed climate.

Initiatives completed and in progress
After the storms in 1999/2000 and 2005, subsidies have been paid to convert about 16,000 ha. of forest to more robust forest such that deciduous trees now comprise about 66%, whereas before the storm they only accounted for about 10%.

As determined in the 2002 national forest programme, state forests are being converted to close-to-nature forestry.

As part of the improvements in Danish private forests, up to 2009 the Ministry of the Environment had granted subsidies for forest planning, with focus on converting to sustainable forest management. The afforestation scheme supports planting deciduous forest, and since 2001 around 18,000 ha. of deciduous forest have been approved.

Similarly, up to 2009 the Ministry of the Environment had granted subsidies to the rejuvenation scheme to improve Danish private forests, with the subsidies going to converting from conifers to deciduous trees and requirements to mix several species and to include indigenous deciduous trees.

New forests adapted to future climate

Climate change has been taken into consideration in two afforestation projects west of Hillerød, in North Zealand, aimed at protecting and optimising groundwater resources. In future the forests Skævinge Skov and Gørløse Skov will cover about 1000 ha. of new climate-adapted forest area.

The primary aim of the project is to protect existing groundwater sources and provide potential for new ones. Purchasing agricultural land and planting forests instead ensures that pesticides and chemicals from fertilisers do not seep into the groundwater in the future. The purpose of the large forest areas is also to capture more CO_2, and thereby prevent it from escaping into the atmosphere, as well as to create a more varied landscape with a high degree of biodiversity.

The forests were planted with climate-robust species such as stable deciduous tree species, mixed with a little Scotch pine. On the other hand there is no spruce, as this species has been found to be very sensitive to climate change. This mix of species can withstand the major storms caused by climate change. Moreover a varied natural mix has been established, which is interesting to visit and is able to withstand climate change.

Barriers and opportunities for future action

Knowledge and consulting services

In practice there is only limited knowledge about the resistance and adaptation abilities of tree species. In this respect, windfalls, for example, have provided important information about the stability of tree species in storms under different conditions. However, knowledge is sparse about the long-term effects of changes in several different growth factors, e.g. wind, temperature, radiation, CO2 concentration, seasonal variation.
At the same time, there is also little knowledge about the potential pests which climate change may encourage.

Forests are continuously being monitored and on the basis of this, statistics are being drawn up for Danish forests. These will provide knowledge about forests and their condition in general. Forest research has provided knowledge about the origins of tree species and their theoretical genetic ability to adapt to climate change.

General advice for private forest owners about cultivation and management of forests, including conversion to close-to-nature forest management, is through several channels. The ”*Videntjenesten*” service from Forest & Landscape Denmark disseminates research results, magazine articles and membership of an association for many smaller forest owners/managers.

One barrier to converting private forests is the long time horizon in forestry and certain reluctance in the sector due to uncertainty about the financial aspects in converting to close-to-nature forest management.

More efforts can be made if private forestry in particular is to adapt forests to the predicted climate change. Development and communication of financial models including climate risks may help address this challenge.

Regulation

The Forest Act supports close-to-nature forest management. Consideration may be given to evaluating the Forest Act with regard to whether it provides an appropriate framework for adapting to a changing climate. For example, there could be requirements relating to cultivation methods and selection of species and source.

Summary

An important measure to ensure the resilience of Danish forests against climate change is to ensure that they are able to regenerate on their own. Several different tree species suited to the local environment must be present in the forest. Close-to-nature forest management is one way of achieving this.

Danish state-owned forests are now being managed according to the principles of close-to-nature forest management. By using different instruments, the transition to close-to-nature practices in private forests may be promoted.

4.2.3 Fisheries

Climate changes, in particular increasing water temperatures and increases in precipitation, have already affected the fishing sector and it is likely that impacts will become more severe in future. Impacts on the fishing sector are primarily due to climate-related changes to the marine environment, which will have direct and indirect impacts on fish and aquaculture resources. Furthermore, the increased frequency of extreme weather events with strong winds will influence the expansion of marine aquaculture.

Important effects of climate change
The most important effects for fisheries are as follows

- *Rising sea temperatures impact fish stocks:*
  Fish are generally adapted to a single temperature interval and rising temperatures will mean a general change in the composition of stocks in Danish waters and thereby the resource base for fishing. Stocks which have their southern limit in Danish waters will be affected negatively, while stocks preferring higher temperatures will generally be affected positively. Therefore it is likely that there will be an increase in species preferring warmer waters (e.g. sardine and brisling/sprats) and species preferring colder waters will retreat (e.g. cod in the North Sea).

- *Climate change affects species composition:*
  Rising sea temperatures and other climate-related changes will affect the species composition throughout the marine ecosystem and thus change food-chains, including the supply of food for fish and fish predators. It is currently unclear whether these changes will make fish populations and ecosystems more or less vulnerable to anthropogenic impacts on the ecosystem such as fishing and eutrophication, and therefore how the fisheries sector will be affected.

- *Rising sea temperatures and increased precipitation may cause oxygen depletion:*
  Rising sea temperatures, for example in the Baltic Sea and in coastal areas, could lead to more and more serious problems with oxygen depletion, which can cause poorer living conditions for cod, for example. Similarly, increased precipitation and run-off from watercourses could increase run-off of nutrient salts and the risk of oxygen depletion (hypoxia). These factors will also affect fishing.

- *Rising sea temperatures encourage disease-promoting bacteria:*
  Rising sea temperatures can underpin the incidence of new disease-promoting bacteria and toxic algae, which can threaten fish and shellfish stocks as well as food safety.

- *Rising sea temperatures can affect production conditions:*
  Rising sea temperatures could accelerate the occurrence of populations of invasive species which may lead to significant changes in ecosystems and thus affect production conditions and therefore fisheries for a number of fish and shellfish species. Similarly, trout production is very sensitive to increases in temperature, and marine rainbow trout farming may be threatened.

- *Rising sea temperatures enable alternative farming methods:*

Increases in winter temperatures in particular enable the application of alternative farming methods and farming of other species.

- *Increases in precipitation and run-off from watercourses lead to a drop in salt concentration in the Danish Belts and in the Baltic Sea:*
  Populations of a number of important fish species in Danish coastal waters are demonstrating local adaptation to the existing salt gradient from the Baltic Sea out to the North Sea. Changes in salt concentration may mean changes in the geographical and temporal distribution of the fisheries resources.

- *Strong winds and precipitation affect the development of marine aquaculture:*
  More frequent weather events with strong winds and precipitation may impact possibilities to develop marine aquaculture and may periodically obstruct shellfish harvests in coastal areas because of discharges of untreated wastewater and consequential problems for food safety.

- *Drops in pH impact production of a number of organisms:*
  Drops in pH levels (acidification) as a result of increasing carbon concentration can affect the production of a number of organisms, including fish and shellfish, because of reduced calcium formation.

- *Cumulative effects of climate change:*
  There may be cumulative effects from climate change in relation to other anthropogenic impacts. This means that even though the impact of climate change in relation to an organism or ecosystem may be small, the impact may become significant because of other pressures such as increased nutrient content in the aquatic environment or the impact of fishing.

Division of responsibilities between the authorities and private citizens
Climate change adaptation in the fisheries sector is divided between a large number of authorities and business players.

The Ministry of Food, Agriculture and Fisheries works to ensure that administration of the common fisheries policy progresses on the basis of securing sustainability via an ecosystem-based approach.

There will be a need to regularly quality-assure hygiene and toxicological preparedness in relation to the presence of new bacteria and toxins in the aquatic environment, and even the raw material itself, which is the join responsibility of *research institutions, the Ministry of Food, Agriculture and Fisheries* and the *processing sector*.

More frequent storms and compositions with new species and stocks will require adaptation of vessels and equipment for the new conditions and opportunities in fisheries. The *fisheries industry* itself, with support from *research institutions* is responsible for developing equipment.

The new compositions of species and stocks will mean that new machinery and technologies will have to be developed in the *processing industry*.

With regard to reducing run-off of nutrient salts from land and consequent eutrophication and oxygen depletion in the marine environment, the *Ministry of the Environment*, collaboratively with

the Ministry of Food, Agriculture and Fisheries, is working to implement the initiatives in the Water Framework Directive.

Possibilities for adaptation
Climate change is likely to bring changes throughout the food chain and therefore the entire biological system, including growth and survival of fish. This means that there will be a need for holistic adaptation of fisheries, equipment, vessels and management systems.

With new species, such as anchovies, red mullet, mullet, sardine and Pacific oyster in Danish waters, it will be necessary to monitor developments in stocks to provide the required scientific foundation for adapting and developing the fisheries management system.

For species at the edge of their spread, there is a need to clarify how these populations and their genetic composition can be conserved.

Within aquaculture, through e.g. selective breeding, it may be possible to breed subspecies which can better tolerate higher water temperatures, but these possibilities are relatively limited. Moving most of the installations affected to less exposed locations could be another adaptation possibility, provided good breeding conditions are present and that licences can be obtained (see the section on barriers and opportunities for future efforts). Breeding alternative species may be another possibility.

Initiatives completed and in progress
In order to improve the knowledge base, tools (models and databases) may have to be developed to quantify and qualify the significance of climate change for the marine food chains, ecosystems, fish stocks and sustainable use of these. There are already a number of research projects aiming at describing the direct, physical and biological climate change impacts on the aquatic ecosystems around Denmark. Relevant institutions and universities in Denmark and abroad are taking part in the projects.

Examples of climate-related research activities and projects:

A study has been initiated of the sensitivity of fish populations to climate variations and anthropogenic impacts, e.g. the zoo plankton - tobis interaction and Baltic Sea sprat and cod.

Trials are taking place to develop trawls with "windows", aiming at more selective and thus more sustainable Norwegian lobster fishing. The windows ensure that unintentional bi-catch of young cod while fishing for lobster is reduced as the fish can escape from the trawl.

Barriers and opportunities for future action

There are a number of barriers and opportunities to efforts for commercial fisheries.

- Ecological knowledge about climate change impacts on fish stocks and ecosystems is fragmented and has become only available at scales that are not relevant for fisheries management.

- There remains a great deal of uncertainty and fragmented knowledge about the ecological processes, even though they are significant for fisheries management, and therefore considerable safety limits have been incorporated in the models.

Knowledge and consulting services
Within aquaculture there may be a need to study the existing species with a view to determining their tolerance to increases in temperature, for example, as well as the possibilities to change production, including introducing alternative species to farms.

There may also be a need to develop new instruments and improve old ones.

Regulation
There may be a need to change the existing regulations for sea farming.

Summary
Rising sea temperatures, in particular, have already affected the fisheries industry, and the impacts on this industry are expected to increase in future. The spread and the size of populations of different fish species will come under pressure. New species and population combinations will require ongoing adaptation of fishing vessels as well as the industry itself. With new species, it will likely be necessary to monitor developments to provide the required scientific foundation for adapting and developing the fisheries management system. In order to improve the knowledge base, tools may have to be developed to quantify and qualify the significance of climate change for the marine food chains, ecosystems, fish stocks and sustainable use of these.

4.2.4 Energy

Climate change will affect the energy sector on several fronts, with both positive and negative consequences. Changed temperatures will mean changed energy requirements. Weather conditions such as more powerful storms will put demands on the dimensioning of installations etc.

To a great extent the energy sector is probably already well equipped to face the changed climate.

Important effects of climate change
Effects for the energy sector are primarily likely to be as follows

- *Milder winters mean less energy consumption:*
  With higher average temperature and milder winters, energy needs in the winter will drop. The difference in energy consumption between mild and cold winters is about 20%. However, warmer summers will also mean more needs for cooling, but the effect of this is expected to be less than the effect of milder winters.

- *Weather extremes may affect energy-producing facilities:*
  More extreme weather with more powerful storms may lead to a need to secure installations against changed weather conditions. The effects are limited, however, as wind turbines have been secured against high wind speeds and the vulnerable electricity supply grid will more or less be buried underground. In high winds, wind turbines are cut off which means electricity production will also stop.

- *More wind gives more output from wind turbines:*
  With stronger winds there is a potential for better exploitation of wind turbines for greater electricity generation. The expected increase in average speeds of 1-2%, however, will only lead to limited additional production with no significant effect on the economy.

- *Changed import/export patterns give lower electricity prices:*
  Changed precipitation patterns in Sweden and Norway will mean production of more hydropower. Higher temperatures in Norway and Sweden will also reduce electricity consumption for heating in these countries. Both these factors will reduce electricity prices in Denmark.

- *Possibility for more biomass production:*
  Higher temperatures and higher CO2 content in the atmosphere may cause greater plant growth and thus greater domestic biomass production. Biomass production can be incorporated in electricity and heating supply and can replace fossil fuels as well as increase security of supply.

In practice, climate change is insignificant to energy supply. There will always be autonomous adaptation and therefore there is no need for further regulation. The most important impact of climate change is therefore assessed to be reduced energy consumption due to milder winters.

Division of responsibilities between the authorities and private citizens
It has been assessed that there is no need for special initiatives as autonomous adaptation is most likely. Adaptation will be ongoing with regular establishment/shut-down as required. Responsibility lies with owners of installations, both private and public.

Possibilities for adaptation
The future choice of energy sources will be independent of the short-term climate changes, which will be relatively insignificant in relation to the utilisation of energy sources. Storm events within the next 20 years will not change to the extent that they will have any significant effects for wind turbine production. Otherwise, wind turbines are dimensioned according to wind loads, and as the expected lifetime of a wind turbine is 20 years, there will be no significant changes over the lifetime of turbines which require special initiatives.

Energy consumption for cooling can be optimised through district cooling. District cooling exploits the energy in district heating water to produce air conditioning. This means that surplus heat from electricity production at CHP plants in the summer can be exploited as an energy source to produce cooling as an alternative to air conditioning systems running on electricity.

Initiatives completed and in progress
In June 2008, the Danish Parliament (the Folketing) adopted an act on district cooling.[7] This has enabled municipal participation in district cooling projects which were previously restricted to private companies. Thus a barrier to municipal participation in district cooling projects has been removed. A concrete district cooling project has been initiated, *see the box below.*

Adaptation initiatives within the energy sector today

In 2010, Copenhagen Energy inaugurated a district cooling project for a number of customers around the Kongens Nytorv square in Copenhagen. The district cooling plant at Kongens Nytorv is the first of its kind in Copenhagen. Operational experience from this plant (and others being planned) will be able to provide valuable experience of the possibilities to minimise energy consumption for cooling.

Barriers and opportunities for future action
Energy-producing facilities have a typical investment horizon of 10-30 years. The capacity of plants is regularly changed and adapted as requirements change. The existing energy-producing facilities are relatively insensitive to the climate changes expected within the next 20-30 years. Therefore, it is unlikely that there will be a need for special climate change adaptation initiatives for energy-producing facilities (electricity and heat production plants, including CHP plants and wind turbines).

If climate change leads to changed requirements for energy-producing facilities (increased or reduced production), there will be an autonomous adaptation as production plants are renewed or renovated.

Therefore there are no immediate barriers to climate change adaptation for energy-producing facilities.

[7] Municipal District Cooling Act

An increase in summer temperatures could lead to more needs for cooling in the summer, and these are traditionally met with electrically powered air conditioning systems. Climate change adaptation efforts within energy supply are primarily expected to have to address minimising energy consumption and costs for cooling.

Initiatives should be directed towards more prevention of cooling needs and towards energy optimisation of the cooling required. Prevention of cooling needs could be through appropriate design of the building regulations for new building, *see construction and housing*, and to a lesser extent, renovation of existing buildings.

Summary
In practice, climate change will not have any considerable effect on Danish energy supply. The most important impact is assessed to be reduced energy consumption due to milder winters. Existing energy-producing facilities will be able to cope with the predicted climate change during their remaining life span, and it is estimated there will be no need for special initiatives aimed at energy-producing facilities. It is likely that energy-supply related climate change adaptation efforts will be directed primarily at limiting energy consumption for cooling.

4.2.5 Tourism

In 2010, tourism generated total revenues of DKK 74.6 billion in Denmark, of which foreign tourism accounted for DKK 30 billion, corresponding to 3.3% of total exports.

In the medium term, Danish tourism will face a number of challenges as a result of rising water levels and flooding, but in the longer term the scenario is more positive, with considerable growth and development potentials.

Important effects of climate change
The most important impacts for tourism are as follows

- *Denmark will be an attractive holiday destination for a larger part of the year:*
  At the moment, 75% of all tourists visit Denmark in the summer, i.e. June, July and August. With a warmer climate, it is likely that the Danish tourist season will extend towards the whole year, and Denmark will be even more attractive in the high season. An analysis by Deutsche Bank highlights Denmark, with its wide beaches, as the country in northern Europe with the best conditions to meet the future European demand for sun and sand.

- *The Mediterranean will be too hot, and this will make Denmark more attractive:*
  Although the Mediterranean is currently is the most popular region for tourists in Europe, with a very hot and dry climate, it is expected that, especially in high summer, the Mediterranean will attract fewer tourists. More days of heat waves will increase the probability that it will be so hot that tourists from primarily north-west Europe will seek alternative holiday destinations and as a replacement for Cyprus, Greece, Malta and Spain, Deutsche Bank[8] points to Denmark amongst others in the temperate zone as an attractive country for summer holidays.

- *The current coastal holiday areas will be less attractive because of higher sea levels:*
  In the medium term, sea level rises will make a number of current holiday areas along the coast, with holiday centres, holiday houses and camp sites, unusable or less attractive.

- *Larger investment in climate protection as a result of heavy downpours:*
  The heavy downpours expected in the summer will affect many outdoor activities and attractions tourists often demand in Denmark. These also include the large amusement parks such as Tivoli, Dyrehavsbakken, Bonbonland and Fårup Sommerland, which will have to invest in facilities to manage increased amounts of rain.

The most important impact is likely to be that the potentials for tourism will be significantly improved as a result of the warmer summers in Denmark and heat waves in southern Europe.

Division of responsibilities between the authorities and private citizens
Private players and municipalities are responsible for adapting to climate change, including the more intense rainfall. The municipalities are responsible for planning new areas which can be used by the tourist industry.

[8] "Climate change and tourism: Where will the journey lead ?"
http://www.dbresearch.com/PROD/DBR_INTERNET_EN-PROD/PROD0000000000222943.pdf

Possibilities for adaptation
Adaptation could be through regular revision of strategies for tourism in order to promote the potential for Danish tourism as much as possible. Where climate change affects existing facilities, investments can be made in, for example, rainwater management installations. Climate change could make some tourist areas less attractive and others more attractive, and therefore new areas can be planned if they are required by the industry.

Initiatives completed and in progress
There are no special initiatives planned for the tourist industry, as it is deemed that these will be managed by the industry itself and by the relevant authorities in connection with their ordinary tasks.

Barriers and opportunities for future action
When adapting strategies for tourism, it should be considered how the potential for Danish tourism can be promoted as much as possible. For example, in the medium term, investments in new tourist facilities could be considered, and facilities in the new coastal areas arising as a result of higher sea levels. These will primarily come without intervention.

There are no important barriers to efforts by the tourist industry.

Summary
The potential for tourism in Denmark may increase as a consequence of higher average temperatures. It is assessed there will be no need for special initiatives. Adaptation efforts will be managed by the industry itself and by the relevant authorities in connection with their ordinary responsibilities. Adaptation efforts will take place mainly through adjustments to strategies for tourism as well as through investment in new facilities and adaptation of existing facilities to cope with changes in rainfall, coastal landscapes etc.

4.3 Biological areas

4.3.1 Nature

Nature is part of the solution to adapting to climate change and at the same time climate change means that nature will come under further pressure.

Danish nature is already undergoing change as a result of a changed climate and the changes will intensify in line with more intensive climate change. In general the impacts will mean a number of natural habitat types and species are weakened or disappear because they do not have time or space to adapt. At the same time existing and new species will be encouraged and spread. This applies for nature on land and in the aquatic environment, and the rest of this section has been divided between the two.

The aquatic environment

In Denmark there are about 69,000 km of watercourses, about 120,000 lakes larger than 100 m^2 as well as about 43,500 km^2 coastline, of which inlets and closed coastal waters account for about 9,000 km^2. Climate change will expose the aquatic environment to increased pressure. However, a number of the instruments which are included in measures for the aquatic environment may be part of the solution to adapting to climate change.

Important effects of climate change
The most important impacts for the Danish aquatic environment are

- *More precipitation may increase the nutrient load on the aquatic environment:*
  Increases in precipitation and changed rainfall patterns are expected to cause more nutrient enrichment in the aquatic environment. In combination with rising temperatures, this will result in greater algae growth, poorer light conditions, more oxygen depletion and possibly consequential fish death.

- *More precipitation means increased hydraulic impact of watercourse:*
  Increases in precipitation will also mean greater water flow in watercourses and higher sea levels in coastal areas, which may have an impact on animal and plant life.

- *Warmer climate can change the species composition:*
  Rising temperatures can lead to changes in the biological structure in the aquatic environment - with generally changed species composition and more invasive species.

- *Warmer climate leads to increased substance conversion:*
  Increases in temperature also mean changed substance conversion in the aquatic environment in which the biological activity/conversion will increase because of increased temperature.

- *More CO_2 in the air causes acidification of the sea:*
  The content of CO_2 in water is in chemical balance with the content in the air. When the content of CO_2 in the air increases, so does the content in water and causes acidification with potentially large impacts on aquatic ecosystems.

The most important impacts for the aquatic environment are the possible increased nutrient loads in the marine environment as well as higher temperatures impacting substance conversion and species composition. As yet there is a lack of knowledge about what these impacts together will mean for the aquatic environment.

Division of responsibilities
Aquatic environment planning is managed on the basis of the Water Framework Directive which has been implemented in Denmark via the Environmental Targets Act. The overall objective of the Water Framework Directive is to achieve good ecological conditions in aquatic areas (watercourses, lakes and coastal waters) by preventing deterioration and protecting and improving the condition of aquatic areas.

The state is responsible for implementing the Water Framework Directive and preparing water plans. No later than one year after publication of the water plans, the municipalities have to draw up action plans describing how they will achieve the goals of the water plans. As required, the municipalities have to update their sector plans, for example the municipal wastewater plans. In general, the municipalities must administrate in accordance with the water plan and they have to prioritise their efforts. Furthermore, municipalities must specifically prioritise their initiatives to underpin efforts in connection with adapting to climate change.

Possibilities for adaptation
The opportunities for adaptation will be included as a central part of the upcoming collection of knowledge and research on the impacts of climate change on the aquatic environment.

Future climate efforts for water could, in line with recommendations from the EU, be based on:

- Implementing monitoring such that it can demonstrate climate change.
- Ensuring that the general choice of instruments and initiatives for the aquatic environment is robust with regard to climate change.
- Investigating how projections of climate change affect the assessment of the impact calculations and environmental impacts in the water plans.

Such climate efforts will be based on collection of research and knowledge with regard to how climate change affects the aquatic environment so that climate change can be incorporated in the next water plan to be issued at the end of 2015.

Initiatives completed and in progress
In order to reduce discharges of 9,000 tonnes of nitrogen and 190 tonnes of phosphorus into the aquatic environment as well as to improve conditions in up to 5,300 km watercourse, as a follow-up to the programmes in the water plans, a number of specific legislative initiatives have been implemented, including establishing buffer zones through the Buffer Zone Act[9] as well as establishing wetlands and changing maintenance practices for watercourses with amendments to the Statutory Order on Fertiliser [10] and the Nature Protection Act[11].

Since 2010, the Ministry of the Environment and municipalities have initiated establishment of almost 13,000 ha. nitrogen and phosphorus wetlands in order to reduce nitrogen and phosphorus

[9]Statutory Order no. 591 of 14 June 2011 *(Lovbekendtgørelse nr 591 af 14/06/2011 om randzoner*
[10]The amendments to the Statutory Order on fertilizer entered into force on 14 July 2011.
[11]Statutory Order no. 933 of 24 September 2009 on nature protection *(Lovbekendtgørelse nr 933 af 24/09/2009 om naturbeskyttelse)*

run-off to the aquatic environment. This initiative is very important for climate change adaptation of the Danish aquatic environment. However, there is a lack of knowledge about the scope to which these initiatives contribute positively to adapting to a changing climate.

Barriers and opportunities for future action

Knowledge and consulting services
Knowledge is insufficient as to what impacts climate change will have on the targets and efforts set out for the aquatic environment pursuant to the *Water Framework Directive*. New knowledge will be applicable in the development of new water plans as well as for consulting services to municipalities in their further work on the action plans.

Efforts to apply wetlands as buffer zones to retain water in connection with extreme rainfall events could also benefit from being coordinated with the establishment of wetlands in accordance with water plans.

Summary
Climate change will affect the Danish aquatic environment in a number of areas. Knowledge is however still insufficient as to what impacts climate change will have on the targets and efforts set out for the aquatic environment pursuant to the Water Framework Directive. The next generation of national water plans is to be submitted by the end of 2015. New knowledge will be able to underpin the implementation of climate change adaptation in water planning.

Nature on land

The effects of climate change on Danish land-based nature and landscape depend on the type of natural habitat in question, e.g. heaths, meadows or dune areas, as well as habitats for specific plants and animals. The growth and survival of each natural habitat type is affected in different ways by various climate factors (temperature, precipitation, wind conditions, etc.).

In step with changes in nature, ecosystems are likely to become ever more unstable and thus vulnerable to impacts. This increased vulnerability is a potential obstacle for meeting the targets set out for the quality of nature in Denmark.

Important effects of climate change
The most important impacts for Danish nature and landscapes are as follows

- *Higher temperatures and increases in the air's content of CO_2 will enhance biomass production:*
  Rising temperatures provide for a longer growing season. At the same time, increased contents of CO_2 in the atmosphere lead to more favourable growth conditions. In combination, these factors provide for enhanced biomass production in Danish nature.

- *Higher storm-surge water levels will probably lead to the loss of habitats along the coasts:*
  A higher sea level and more powerful storms could cause coastal erosion and recession, which will reduce and in other ways affect Danish coastal habitats. These problems, however, will be limited up until 2050.

- *More frequent and more intense rainfall will lead to more flooding of low-lying land areas:*

Not only along coasts but also in low-lying areas, such as river valleys and meadows, habitats and the biodiversity living there may come under pressure from more flooding events. There will also be pressure from the lack of opportunity to spread to other habitats and not enough time to adapt to new conditions.

- *A warmer climate will alter the species composition:*
  More non-native species will be able to exploit a warmer climate to expand their natural habitat to include Denmark, affecting the existing ecosystem and very likely supplanting current species. This applies to all types of ecosystems: terrestrial, freshwater as well as marine ecosystems.

The most important challenges from climate change will be an additional pressure on nature which is already under pressure today from areal reduction and fragmentation of habitats as well as from pollution from environmentally hazardous substances.

Division of responsibilities between the authorities and private citizens
The state has overall responsibility for regulating nature management efforts, while the municipalities are responsible for activities aimed at the public and for most of authority and enforcement activities, including enforcing section 3 of the Nature Protection Act, which protects lakes, watercourses, bogs, meadows, heaths, grasslands and coastal meadows. These habitats are present throughout Denmark and must not be changed.

In connection with the implementation of Natura 2000, public land owners are required themselves to carry out required efforts. The Ministry of Transport, which manages the state's sovereignty of Danish coastal waters up to 12 nautical miles from the coast, will be involved in Natura 2000 plans that concern these territorial waters. In the marine area, activities which involve land-based activities, and for which the municipality is the authority, are also the responsibility of the municipality, whereas the relevant ministries are responsible for efforts under their jurisdiction.

With regard to listings, both local and central governments, as well as the Danish Society for Conservation of Nature, can propose new listings. The municipality has final responsibility for the conservation of privately owned land and carry out inspection of all listed land, except for the land that belongs under the Minister for the Environment and which is inspected by the Danish Nature Agency. The Danish Nature Agency has final responsibility for its own land and performs inspection of its own land.

Possibilities for adaptation
Nature adapts naturally to climate change using the following general survival strategies when living conditions alter:

1. relocating - this requires the individual species' ability to spread allows it to reach the nearest other, suited habitat.
2. adapting - this requires the individual population of a species includes enough individuals that can survive the altered living conditions long enough to reproduce themselves.

Adaptation to climate change should underpin nature's ability to pursue these strategies of survival.

In order to preserve nature, including its functions and benefits, it may be necessary to commence planning ahead for climate change in the context of nature management, and to adjust the current practice and legislative bases in the sectors of society that have an impact on nature.

It is also important to remember the considerable potential for solutions to other climate-related challenges which also benefit nature. For example, the use of low-lying areas as buffers of surplus water or for the uptake of nutrients, or coastal areas for natural floods.

Species' ability to spread and adapt to climate change may be supported in nature management by reducing the pressure of other negotiation factors, by securing more habitat opportunities, as well as including greater quality of and interconnections between habitats.

In order to achieve this, acts, statutory orders and management practice as well as relevant planning efforts may have to be altered and should be underpinned by targeting a number of financial means of control, e.g. within agriculture policy, forestry and nature management.

Initiatives completed and in progress

As a rule, *the Nature Protection Act*[12] provides for dynamic protection of nature, including areas protected under section 3, such as lakes, watercourses, bogs, meadows, coastal meadows and grasslands exceeding a certain size.

Furthermore the *Watercourse Act*[13] and requirements for buffer zones along watercourses contribute to creating green corridors. In this context, initiatives should be considered in conjunction with climate change adaptation in agriculture.

The Natura 2000 plans, which have been pursuant to the *Environmental Targets Act*[14], aim to ensure vulnerable areas are included in the designated Natura 2000 sites. These efforts will help make habitats more resilient to climate change.

Nature restored in Egå River Valley

Near Aarhus is the Egå River Valley (*Egådalen*) the southern part of which constitutes a flood-prone heavily built-up area. The area was subject to drainage from the 1950s until recently. Today is has been partially restored as natural wetlands and the project is as an example of a successful climate change adaptation initiative which benefits several purposes. The costs of establishing Egå Meadow Lake in 2006 amounted to DKK 20 million, of which a large part was compensation given to land owners.

The new Egå Meadow Lake has reduced the risk of flooding in the densely built-up area of the lower part river valley and around the town of Egå. The lake now serves as a retention basin for rainwater in connection with intense or prolonged precipitation. The high water levels are reduced downstream but the period with slightly higher water levels is prolonged.

The new wetlands serve several purposes, e.g.:

[12]Statutory Order no. 933 of 24 September 2009 on nature protection *(Lovbekendtgørelse nr 933 af 24/09/2009 om naturbeskyttelse)*

[13]Statutory Order no. 927 of 24 September 2009 on watercourses *(Lovbekendtgørelse nr 927 af 24/09/2009 om vandløb)*

[14]Statutory Order no. 932 of 24 September 2009 on Environmental Targets etc. for water occurrences and international nature conservation sites *(Lovbekendtgørelse nr. 932 af 24/.09/.2009 om miljømål m.v. for vandforekomster og internationale naturbeskyttelsesområder)*

- Noticeable improvement in conditions for nature, such as nature- and environmentally friendly operation of the land.
- Reduced discharge of nutrients into the Bay of Aarhus.
- Fewer floods in the lower parts of the Egå watercourse system by securing more time and more space for the water.
- Improved recreational opportunities in and around Egå Meadow Lake.

With this project, the municipality has improved nature and provided more recreation for inhabitants, as well as ensured protection against flooding from changed precipitation patterns. The municipality is planning to continue the success by establishing another wetland area in the river valley.

Barriers and opportunities for future action

Knowledge and consulting services

Studies of how nature can adapt may be beneficial in ensuring the right knowledge and data to find holistic solutions. Furthermore, there is a lack of knowledge about certain natural habitat types and species that will be affected by increases in sea level. This knowledge could also provide information about the nature's potential to mitigate the impacts of climate change in built-up areas and other vulnerable areas.

Initiatives for knowledge-building are preferable in particular in these areas:

Coastal nature

Studies are relevant on how Danish coastal landscapes are likely to become affected by rises in sea level and more frequent intense storms, including possible preventive measures.

River valleys

It is relevant to assess the potential of large river values in minimising risks of flooding from extreme precipitation in villages located downstream in watercourse systems. Many straightened watercourses today unintentionally serve as "water express ways" that exacerbate the downstream problems from flooding. More knowledge may therefore be required as to how nature restoration could delay water flows in extreme events.

Low-lying areas

Larger low-lying areas with peat soil in e.g. forests which today are drained may be potential wetlands able to store and retain water and thus relieve the pressure on other flood-prone areas. In other words, low-lying areas, and their climate-related potential, may be assessed along with other parameters of significance for decisions about nature restoration projects.

The administrations responsible for managing Danish nature and landscapes should be provided consultancy about how management efforts may support nature's own ability to adapt. These include, in particular, land owners and government at local as well as central level, including the Danish Coastal Authority and the Danish Nature Agency.

Such consulting services could focus on the following:

1. The vulnerability of individual natural habitat types and their ability to adapt to climate change, as well as any instruments that support this ability.

2. How nature managers may apply existing legislation (the Environmental Targets Act, the Nature Protection Act and the Planning Act, etc.) to support nature's own adaptation efforts.
3. The cross-sectoral opportunities for synergies in climate change adaptation, which involve nature, e.g. interaction between nature and built-up areas in connection with flooding or the use of natural buffer zones to provide relief against the increased pressure on Danish coasts.

Regulation

As mentioned in the section on initiatives in progress, the Nature Protection Act, the Watercourse Act and the Environmental Targets Act are all relevant for climate change adaptation of Danish nature. Therefore, in future there will be need to assess whether these acts set out appropriate framework conditions for climate change adaptation and how these framework conditions are applied in the best possible way. For example, climate change impacts are expected to gain ever more importance for initiatives carried out in Natura 2000 sites. Any new initiatives in connection with the assessment of the existing legislative framework should be considered in relation to climate change adaptation in agriculture.

Green corridors and "stepping stones" between habitats could be made an intrinsic part of spatial planning. Thus, the Planning Act[15] could have significance for climate change adaptation of Danish nature and landscapes.

Major parts of the *remaining legislation* (on e.g. environmental assessment of plans and programmes and on impact assessments) provide for other instruments that can contribute to ensuring climate change adaptation of Danish nature.

Summary

So far, there has been no complete mapping of nature's possibilities to adapt to climate change. It should be assessed whether existing regulation in this area is apt to support climate change adaptation. In this connection, it would be relevant to apply, and possibly to amend, a number of acts, including the nature protection act, the environmental targets act and the planning act.

As the need for knowledge is being gradually met, it would be relevant to disseminate new knowledge to various nature administrators such as land owners, municipalities and authorities at state level. It is essential to remember that nature can be used in general climate change adaptation measures to cushion the effects of climate change, e.g. to serve as a buffer in situations involving heavy rainfall or to prevent nutrient run-off.

[15] Statutory Order no. 1027 of 20 October 2008 on planning *(Lovbekendtgørelse nr. 1027 af 20./10/.2008 om planlægning)*

4.3.2 Human health

The health-related impacts of climate change will depend partly on the extent and nature of climate change and partly on more general socio-economic conditions including health, environmental, and educational aspects. Vulnerability and opportunities for climate change adaptation will also vary from individual to individual, and a warmer climate with more extreme rainfall and storms can have indirect implications for health and accidents through changed behaviour.

Important effects of climate change
The greatest health-related impact is expected to occur during the last part of the period up to the year 2100 when climate change is presumed to be greatest. Noticeable consequences may however occur earlier, e.g. in connection with extreme weather events with heatwaves or flooding.

- *Heatstroke and dehydration during heatwaves:*
  Heathwaves can lead to e.g. heatstroke and dehydration which at worst may be life-threatening. People in the northern parts of the world are less used to coping with high temperatures than people who live further south. The elderly, patients in hospitals and individuals suffering certain diseases are at high risk. Babies and young children will also require extra attention.

- *Positive as well as negative impacts of staying outdoors:*
  The human body creates Vitamin D after only short exposure to the sun, however too much sun exposure can cause skin cancer and birthmark cancer. Staying more outdoors can have positive effects, e.g. in the form of more outdoor physical activity, fewer problems with indoor climate and less disease transmission in kindergartens etc. Staying more outdoors could, however, also cause more symptoms in people with pollen allergies and possibly also lead to more people becoming allergic to pollen.

- *Infections and similar when temperatures increase and in connection with flooding:*
  Flooding of built-up areas has been documented to increase the risk of infections in connection with e.g. work to clear up basements flooded by polluted wastewater. There is a risk of health problems if the building is damp and possibly also mould infested. Flooding which affects the access to or the functioning of important institutions in society may also affect human health. For example, flooding may cause delays in the treatment of patients. Temperature increases and increased risk of extreme weather events will increase the risk of food- and water-borne infections. Outbreaks of a number of tick-borne diseases like inflammation of the brain and Lyme disease will also be a risk. In the long term, there will also be risk of insect-borne diseases that are restricted to tropical or subtropical diseases today. After longer periods with warm seawater, an increased concentration of certain marine bacteria will comprise an infection risk for fishermen and swimmers, and there may be more incidents of algal blooms and dangerous jellyfish.

- *More powerful storms and extreme weather events can increase the risk of injury:*
  More powerful storms, cloudbursts and more frequent lightning bolts: Experience reveals that a greater number of injuries can be linked to e.g. an increase in outdoor activity and more outdoor work in the building and construction industry.

- *Milder winters with lower mortality and less damage:*

Milder winters may lead to fewer cold-related diseases and deaths and fewer injuries from ice and snow.

- *Warmer summers and more precipitation enhance the risk of damp and mould:*
  The combination of warmer summers and more humid autumns and winters, as well as a greater occurrence of cloudbursts, can enhance the risk of damage to buildings from damp and mould and lead to greater nuisance from house dust mites in homes. Damage from damp and mould in buildings can cause health problems and exacerbate asthma and hay fever. Respiratory irritation may increase the risk of respiratory infection. Furthermore, the existence of a greater number of house dust mites may lead to an increase in symptoms (asthma and hay fever) and intensified preventive treatment. Moreover more people are likely to develop allergies.

- *A longer growing season will mean a greater risk of pollen allergies etc.:*
  With a longer pollen season, higher pollen counts and more mould spores in outdoor air, many people will experience more symptoms (asthma and hay fever) and will need intensified preventive treatment. Furthermore more people are likely to develop allergies (hay fever and asthma). Very allergenic pollen species, such as ragweed, have already found a habitat in Denmark.

- *A warmer climate will mean less outdoor air pollution:*
  A warmer climate could also mean there will be less need for heating and thus less pollution from heating sources.

The most prominent negative impacts for human health are assessed to be the follow-on effects of extreme weather events (extreme rainfall, predicted heatwaves, etc.) Many negative impacts on human health are likely to appear after extreme rainfall and flooding events in the form of certain infections and effects of damp and mould etc. New, climate-related infections may develop which may be dangerous and difficult to fend off. Increased occurrence of allergenic pollen and damp-related problems in homes due to general climatic changes are deemed to cause some increase in the already widespread health consequences from these factors. In all events, the extent and magnitude of human health problems will rely on preventive measures.

Division of responsibilities between the authorities and private citizens
Private citizens are responsible for the appropriate design, use and maintenance of their private homes, private land, and workplaces, and for providing assistance to vulnerable family members. Individuals can follow the advice of authorities and health-care staff on precautions during heatwaves and when cleaning up after events involving flooding from sewage. Vulnerable groups may need assistance from public authorities, *see below*.

Local and regional governments (hospitals and general practices) share responsibility for some of the efforts aimed at preventing and dealing with the effects of extreme weather events that are harmful to health. The municipality is responsible for providing assistance to vulnerable groups who are not self-reliant (e.g. nursing home residents and individuals reliant on home care). They are also responsible for ensuring that children at daycare centres and schools are protected during extreme weather events.

The *Danish Health and Medicines Authority* is responsible for monitoring health conditions, and central, regional and local authorities may ask for the Authority's guidance, e.g. about hygiene and environmental matters.

With regard to preventing and mitigating any negative health consequences of damages to surroundings during extreme weather events, see the sectors and industries responsible for buildings, construction, transport, the environment and emergency preparedness.

SSI is a public institute responsible for e.g. monitoring and managing outbreaks, providing advice on certain infectious diseases to health-care staff, as well as specific disease prevention and control.

The primary diagnosing of infectious diseases takes place at regional level and is carried out by physicians at hospitals and by general practitioners.

Hospital owners are responsible for ensuring solar protection features and the availability of rooms with cooling at hospitals, as well as for safeguarding important functions against breakdown during flooding.

Possibilities for adaptation
In the health area, the effects of climate change may primarily be addressed by collecting knowledge about e.g. the spread and infection patterns of infectious disease and by providing consulting services to relevant authorities, health-care staff and private citizens about risks in connection with heatwaves, flooding with sewage water, mould and damp, etc.

Public health emergency response plans prepare for extreme events and ensure that the relevant authorities are able to cope with special challenges like these.

Initiatives completed and in progress
Considerable data and knowledge is already being collected today which can support health-related climate change adaptation measures in the future. This includes knowledge about pollen and mould spores, which is being disseminated via radio, TV and the printed press. Moreover, European cooperation is in place on the collection and dissemination of this data[16].

A series of initiatives has been set in motion in the health sector to address climate change. These pertain to the dissemination of knowledge and consultancy about specific climate change impacts, including e.g.

- Information to citizens, health-care staff and local government etc. about precautionary measures during heatwaves, flooding events, situations with damp and mould in buildings, prevention of injuries from the sun etc. This information is available on the Danish Health and Medicines Authority's website as well as on the Danish Portal for Climate Change Adaptation (www.klimatilpasning.dk).
- Following the documentation of infections with TBE virus in a limited area of northern Zealand in 2009, the SSI performed a number of analyses to clarify the risk of TBE in other parts of Denmark and is providing advice on e.g. the need for vaccination. Furthermore, information and guidance about personal protective equipment and hygiene in connection with clean-up work after flooding events is available on www.klimatilpasning.dk.

[16] Via www.polleninfo.org

- The Danish Health and Medicines Authority is providing consultancy on the prevention of disease arising recreational use of surface water.

The Danish Health and Medicines Authority, including the national health inspectors, is responsible for providing guidance about public health emergency preparedness to regional and local governments. For this purpose, the Authority has prepared guidelines for regional and local governments on public health emergency preparedness planning. These guidelines also contain information about extreme weather events and they are updated on a regular basis. Furthermore, the Danish Health Act requires all Danish regions and municipalities to submit their public health emergency response plans for consultancy to the Danish Health and Medicines Authority. The Authority provides comments and advice to these plans, e.g. if the region or municipality in question has omitted to include extreme weather planning in the plan. Acute consulting services may also be provided in concrete situations.

The Danish Health and Medicines Authority has taken the initiative to amend the existing statutory order on physicians' reporting of infectious diseases (pursuant to the Act on Epidemics[17] and the Act on Authorisation of Healthcare Professionals and of Professional Healthcare [18]) so that it will meet the expected changes described below for modernisation of the system to monitor infectious diseases.

The Danish Health and Medicines Authority has also published a report on health impact assessment in theory and in practice (*Sundhedskonsekvensvurdering – fra teori til praksis*) which may be used by relevant authorities when planning this type of assessment. Health impact assessments can be a tool to elucidate the health-related impacts of different solutions in climate change adaptation measures.

Barriers and opportunities for future action
In a number of areas existing measures are not sufficient to meet future needs to adapt to climate change. This is the case for e.g. knowledge about and the required data to cope with infectious diseases.

<u>Knowledge and consulting services</u>
Climate change enhances the need for modernising the monitoring system for infectious diseases due to risks of these spreading from other parts of the world to Denmark. Modernisation can be achieved by integrating data from different sources so that the data is collected in a single place where relevant personnel can find knowledge about diagnosis of infectious diseases. At the same time, electronic reporting to this database may replace existing manual and paper-based reporting.

According to the Emergency Management Act, all sectors, including the health sector at regional- and local-government levels, must have their own emergency preparedness for extreme events, including for extreme weather events. The Danish Health Act requires all Danish regions and municipalities to carry out public health emergency preparedness planning.

The Danish regions and municipalities are obliged to prepare risk and vulnerability assessments pursuant to the Statutory Order on public health emergency preparedness planning etc. (*bekendtgørelse om planlægning af sundhedsberedskabet mv.*) Extreme weather should be included

[17]Act on measures against infectious diseases (*Lov om foranstaltninger mod smitsomme sygdomme)*
[18] Act on Authorisation of Healthcare Professionals and of Professional Healthcare (*Lov om autorisation af sundhedspersoner og sundhedsfaglig virksomhed*)

in these efforts, as the health service's own vulnerability to extreme weather has to be assessed (e.g. vulnerability to flooding) and its ability to perform the various health-related tasks that may arise as a consequence of extreme weather.

Health impact assessments can provide knowledge about the health-related effects of different solutions to address climate change and thus provide an informed basis for deciding on the best solutions for public health in terms of climate change adaptation. A step-by-step performance of the assessments starting with a screening can identify where a more resource-demanding assessment might be required. Today, however, actual health parameters are only included to a limited extent. Typically, these are only included as exposure descriptions and rarely in the form of assessments of the effects on public health.

According to the Planning Act, to a greater extent than is the case today, health impact assessments may be linked to, and may be a part of, environmental impact assessments. There may be a need to clarify expectations for health impact assessments in connection with local environmental impact assessments. This can be done on the basis of the rules pertaining to so-called strategic environmental assessments which are used primarily for the assessment of large regional projects.

Regulation

2004 saw the introduction of a requirement for assessing health conditions in connection with environmental impact assessment reports. However, the consistent use of health impact assessments of climate change adaptation initiatives may be prohibited by the fact that current legislation is unclear as to what such an assessment should include, *see the section on knowledge and consulting services.*

Summary

Opportunities for future climate change adaptation in the health sector include the continuation of initiatives already launched, e.g. information and consulting services to the public, the authorities and health-care staff about climate change adaptation and health. More precisely, these services involve e.g. information to the public about infectious diseases, pollen and mould spore counts; advice to regional and local governments about the incorporation of extreme weather in public health emergency response plans; and guidance to the public about precautionary measures during heatwaves or when cleaning up after flooding with sewage water. Finally, there may be opportunity for using health impact assessments more extensively to assess potential alternative climate change adaptation measures within different sectors and industries. This would provide a better foundation for choosing the best solutions for public health in terms of climate change adaptation.

4.4 Cross-sectoral areas

4.4.1 Emergency preparedness

Extreme weather events such as storms, hurricanes, storm surges, heavy rainfall and periods with droughts will affect the work of the Danish fire and rescue service.

The scope of the assignments of the Danish fire and rescue service will rely widely on what other sectors do to prevent climate change impacts, e.g. in terms of land use, the design and dimensioning of buildings, sewerage and roads, coastal management and coastal protection, and human behaviour. The task of the Danish fire and rescue service is therefore to manage other remaining risks for society.

Climate change is not expected directly to entail new tasks for the Danish fire and rescue service. A more likely trend seems to be the more frequent occurrence and greater intensity of events for which a response is required. The Danish fire and rescue service is responsible for limiting and mitigating damage and injury to people, property and the environment. These responsibilities are being assessed on an ongoing basis against the need for developments in terms of equipment and manpower, including training.

Important effects of climate change
Climate change could demand a greater number, as well as more resource-demanding, emergency responses and assistance from municipal as well as national fire and rescue services.

Responses to storm and water damage include efforts to fortify and identify vulnerable buildings and infrastructure, prevent flooding with sand bags and pump water away from low-lying land areas. Other responses include assisting in establishing an emergency power supply. Moreover, an important task is to protect the environment when e.g. sewers are at risk of flowing over with sewage water, or when industrial areas have been flooded, tank systems have leaked, etc. In situations when flooding leads to contamination of drinking water, the Danish fire and rescue service can assist with the distribution of clean drinking water.

There is moreover a series of rescue assignments related to serious road accidents and other accidents involving personal injury, e.g. during storm or cloudburst events. In the event of particularly intense storms, snow storms and flooding, it may also be necessary to rescue and provide housing and food relief for those in need (e.g. when public transport, roads and bridges have been closed down and similar).

More frequent and longer-lasting periods with drought in summer may lead to greater risk of forest fires. This may result in a greater number of and more comprehensive tasks for the Danish fire and rescue service, including fire guarding, emergency drinking water supplies, fire extinction and fire-damping operations. Furthermore, an increase in maximum day temperatures during summer could lead to heatwaves of an intensity, scope and duration which may require the Danish fire and rescue service to assist in home nursing efforts and in the public health emergency response.

Traditionally, the national fire and rescue service has been deployed abroad in the event of natural disasters, including, in particular, floods. The national fire and rescue service could therefore be assigned more international response tasks due to more extensive and more extreme climate-related

events. Nordic and EU agreements exist on mutual assistance in the event of large accidents and disasters, including climate-related events.

Division of responsibilities between the authorities and private citizens
Pursuant to section 24 of the Emergency Management Act, the individual sectors must make plans to ensure the preservation and continuation of essential and critical functions and services within their fields in the event of an accident and disaster. This division of responsibilities between sectors also applies to the physical impacts of climate change.

The Danish fire and rescue service comprises the municipal and the national fire and rescue services which are deployed to prevent, limit and mitigate damage and injuries to people, properties and the environment.

The municipal fire and rescue service is responsible for efforts within the individual municipality. A municipality may call upon the assistance of another municipal fire and rescue service or the national fire and rescue service if required, due to the nature and scope of the task. The municipalities are responsible for determining and funding the capacity of their respective fire and rescue services.

The capacity of the national fire and rescue service is determined and funded by central government, which also covers a number of municipal costs, such as training of voluntary and managerial staff. The national fire and rescue service is obliged to provide assistance to the municipal fire and rescue service and is typically called upon in connection with large-scale events which, due to the nature and scope of the task, require special or extra equipment and manpower. Experience indicates that climate-related events typically involve situations in which the municipalities do not have the required capacity to cope with the consequences, and in which the capacity of the Danish Emergency Management Agency will be utilised to its full.

The capacities of municipal fire and rescue services are being aligned to local risk conditions. This entails e.g. using realistic scenarios that, statistically, are relatively frequent, whereas events that are relatively seldom are often not included in the basis for determining the required capacities.

Thus, the individual municipality is responsible for and determines the level of the fire and rescue service, including assessing the extent to which the municipality must be able to perform the task independently. The individual municipality's investments in preparedness with regard to climate change impacts may differ.

Thus, there is a close relationship between local- and central-government responsibilities in the area of emergency preparedness. The municipalities are unable to perform all of the tasks that may arise, and should therefore include assistance from the national fire and rescue service in their plans. The national fire and rescue service should therefore be designed with a capacity to meet the predicted extreme events that are not covered by the municipal capacity planning and which typically concern larger geographical areas, often involving several municipalities.

Possibilities for adaptation
The capacity of the Danish fire and rescue service must be adjusted regularly. One of the consequences of ongoing adaptation is the possibility to take more long-term challenges into account, such as climate change when making development and priority decisions.

The expected consequences of climate change for the national fire and rescue service are an increased need for investing in capacity to be able to cope with extreme events. This may lead to other priority-making with regard to procurement, development, maintenance, and the composition and geographical location of equipment.

Examples of ongoing adaptation include:

- The Danish Emergency Management Agency includes extreme weather phenomena in its consulting services for, and inspections of, municipalities.
- The Danish fire and rescue service includes knowledge about extreme weather phenomena when determining its capacity and utilisation of these data in the services' online data-entry and reporting system, ODIN.
- Ongoing procurement, development, maintenance, composition and location of equipment.
- Continuous training and drills and exercises for employed, conscripted and voluntary staff as well as experts and specialists.
- Collection of national and international experience data and evaluations of fire and rescue responses to extreme weather events, as well as drills and exercises.
- Regular updating of relevant emergency response plans, including plans for calling upon extra manpower and other resources, crisis communication, etc.

Initiatives completed and in progress
The equipment of the national fire and rescue service has already been adapted as a consequence of recent years' storm surges and flooding events. For example, the following equipment has been procured to meet the needs of the future: pumps, supportive equipment, drop-down and fall protection, mobile generators, vehicles suitable for driving in flooded areas, etc. Similar action has been taken by local governments.

The response of the national fire and rescue service to the cloudburst on 2 July 2011

On Saturday 2 July 2011, the Greater Copenhagen area was hit by a cloudburst of unseen proportions. The city's sewer systems were unable to cope and the cloudburst lead to massive flooding of roads, underpasses, basements and low-lying areas. Several critical and essential functions were disabled temporarily and extensive response efforts were required. These included a great number of individual but simultaneous responses across a large geographical area, putting the entire Danish fire and rescue service under huge pressure. The municipal fire and rescue services did not have enough resources and the national fire and rescue service had to deploy all of its available capacity from Zealand and Jutland to cope with the acute consequences of the cloudburst in Copenhagen.

The acute response lasted throughout the evening and into the night of 3 July 2011. It took several days before the flooded Amager motorway could be reopened. Work to complete urgent repairs to critical infrastructure and to re-establish critical functions (public transport, energy supplies, IT and telecom services etc.) also took several days. Less urgent repairs took much longer.

The many direct and indirect consequences of the cloudburst required extensive and acute crisis management and operations by many parties both during and after the event.

The cloudburst revealed a need for new initiatives against flood risks from extreme rainfall events, including additional equipment to pump and divert stormwater.

Barriers and opportunities for future action

Knowledge and consulting services
2008 saw the completion of a study of the capacity and resources of the national fire and rescue service. Having thus assessed the overall capacity of both the municipal and the national fire and rescue services, the study recommends that the national fire and rescue service's operational capacity be expanded with modern supportive equipment and greater drainage and pumping capacity.

Although the Danish Emergency Management Agency has procured more drainage capacity since 2008, the cloudburst events in Copenhagen and Lolland/Falster in the summer of 2011 revealed that the municipalities lacked the required capacity, and that the Danish Emergency Management Agency's capacity was just barely enough to deal with the situation. The Danish Emergency Management Agency is therefore still concentrating on the mitigating efforts to limit the impacts of climate-related events through regular experience sharing (nationally and internationally) and through evaluations of the rescue and fire services' response to extreme weather events.

In its local-government guidance on risk-based determination of capacity needs, the Danish Emergency Management Agency states that more frequent and more intense storms, storm surges and downpours, and longer periods with drought, may lead to a need for a greater number of, and more resource-demanding, responses and assistance by the Danish fire and rescue service.

Summary
The government's report on the Danish fire and rescue service (May 2010) suggests that the service should prepare for a greater need for mitigating the follow-on effects of more climate-related events, such as hurricanes/storms, powerful rainfall events, cloudbursts, storm surges and extreme water levels. On the basis of experience from climate-related events that has hit Denmark in recent years, it must be assumed that there will be a need for equipment to tackle the impacts of climate change in future as well. The size of the investments required depends on e.g. whether there are enough preventive measures in other sectors, as well as on future organisation and coordination of the rescue preparedness services at local and central-government levels. The closer the collaboration and coordination of equipment procurement and resource use across local and central-government levels, the better and more cost-effectively the effects of climate change can be managed.

4.4.2 Insurance

Climate change will bring more powerful storms, cloudbursts, sudden thawing, droughts and similar weather phenomena. The more powerful weather phenomena entail a risk of more and larger insurance claims on homes, movable property, cars and businesses. The total insurance amount paid out in the period 1999 to 2012 was more than DKK 25 billion.

More powerful storms, cloudbursts, droughts and other weather phenomena increase the risks for insurance companies. The insurance companies are trying in different ways to address these risks, e.g. through

- strengthening preventive efforts aimed at claimants;
- stipulating requirements for preventive measures (or design of e.g. basements);
- charging higher premiums in especially vulnerable areas;
- making use of reinsurance or coinsurance options;
- reducing e.g. maximum coverage.

Important effects of climate change
The most important impacts for the insurance industry are as follows

- *Unpredictable weather reduces possibility for addressing risks:*
  When the weather and climate change impacts are less predictable, the insurance companies, in turn, have less possibilities for predicting damages and thus also for addressing the risks. As a consequence, the companies will try to minimise the uncertainty through measures like the ones mentioned above.

- *Higher reinsurance premiums:*
  Danish insurance companies are typically re-insured in large international reinsurance companies which also insure financial losses from earthquakes, tropical storms and other large natural disasters, and to some extent also acts of terrorism. An increase in the intensity of cloudbursts and other extreme weather events in Denmark will lead to an increase in the costs of reinsurance. The international reinsurance company Swiss Re as thus announced that the cloudburst that hit Copenhagen in July 2011 will lead to higher reinsurance premiums. These higher premiums will very likely trickle down to Danish insurance customers.

- *Targeted changes in premium and coverage:*
  For both citizens and enterprises, climate change will entail a risk of higher premiums, lower coverage or the introduction of special terms for taking out insurance. Differentiated premiums (so-called "micro tariffing") might be used more extensively, which means premiums will be determined based on where buildings are located (are they located where the risk flooding is particularly large or small?), the special characteristics and technical design of buildings, as well as their history of damages. This will entail that particularly exposed properties may be at greater risk (e.g. if the sewer system is under-dimensioned or if the property is in a low-lying area, and if potential damages cannot be prevented through ordinary preventive measures such as backflow blockers) and therefore cannot be insured or can only be insured against paying extremely high insurance premiums. This, in turn, may affect loan opportunities. Owners of such properties will have a hard time selling their

property. In the city of Odense, the local water utility company ultimately had to buy seven houses.

Division of responsibilities between the authorities and private citizens
Generally speaking, there is no legislation which limits the possibilities of insurance companies to adapt their premiums and coverage to the realities of climate change. The insurance companies can adapt their insurance products to the altered risk conditions, and the costs of climate change therefore become a matter between the insurance companies and its policyholders.

Central government can ensure appropriate framework conditions for adaptation efforts by local governments, utility companies and private citizens, *see the section on wastewater.* As the party responsible for e.g. wastewater, local governments can limit the costs of damage by ensuring an appropriate management of surface water, appropriate planning of new land developments and appropriate emergency preparedness management, *see sections above.*

Damage due to storm surges or lake and watercourse flooding events are normally not covered by insurance companies. However, under certain conditions these damages are covered by the Danish Storm Council. A storm surge is when a flooding event is caused by an extremely high water level at sea. Flooding as a consequence of extreme water levels in watercourses and lakes is covered by the flooding scheme. Payments to the Danish Storm Council may have to be raised when risks of damage from storm surges and flooding events are greater. Payment is collected via the fire insurance policy. The contribution to the Danish Storm Council was raised in 2011. Due to this as well as to the incremental model for own risk (excess), it is expected that claims payments will be available for a number of years ahead.

Possibilities for adaptation
The insurance companies can cope with climate change by changing the coverage, compensation and premiums, and by placing special requirements on policyholders. Less attractive reinsurance options can also be addressed through these means.

Furthermore, by using differentiated premiums more extensively, insurance companies can be more accurate in their pricing of climate change risks. Thus, it is possible that premiums in future will be determined increasingly according to e.g. location (is the risk of basement flooding, storm damage etc. particularly high or particularly low?), the characteristics and technical structure of the building, the damage history of the building, etc. Furthermore, insurance companies may also raise the policyholder's own risk (excess).

In general, it must be assumed that if insurance premiums better reflect actual risks, then the individual will have more incentive to adapt to climate change, and this will reduce the number of damage incidents. From an overall financial consideration, it therefore makes sense that premiums reflect risks.

Initiatives completed and in progress
Insurance companies are increasingly focussing on the possible consequences of climate change, e.g. by adapting insurance products, preparing tools in collaboration with municipalities, and by ensuring the right knowledge base is available for processing insurance cases, *see box below.*

Danish insurance companies have reacted in different ways to the large compensations they have had to pay out in recent years due to cloudburst events. Some companies have informed insurance

clients with claims from flooding that building materials, wooden flooring, plaster walls, etc. which can be damaged by water will no longer be covered in future if damaged from cloudbursts. They advise their clients to repair their current damages using materials that can withstand water, e.g. floortiles, or similar, made from inorganic material. If the clients follow these recommendations, they will be fully covered in future as well.

Other clients have had their policy cancelled. They have been told they could only remain as clients if they installed a backflow blocker that can prevent sewage from intruding their basements. Other companies have raised the premium on insurances or the policyholder's own risk (excess).

Adaptation initiatives within the insurance industry today

Use of insurance companies' cloudburst data
A collaboration project is under way between the sector organisation on insurance and pensions *Forsikring og Pension* and the municipalities of Copenhagen and Frederiksberg. The idea is to provide the municipalities with access to the insurance data on cloudburst events from the past five years. There were more than 90,000 cloudburst claims during the summer of 2011 alone, totalling approx. DKK 5 billion in compensation, of which the major part were in Copenhagen and Frederiksberg. This data is superimposed on the municipalities' theoretical risk maps in anonymised form. This should make it easier for the municipalities to make the most appropriate solutions for society. The elaborate maps will make it easier for municipalities to see e.g. whether damage occurs mainly where the sewers run over and whether they occurs e.g. on the right or the left side of the street. It is expected that this will make it easier to target capital investments more appropriately than today. As far as is known, this type of collaboration is unique to Denmark.

Online weather service for the insurance industry
Jointly with the Danish Meteorological Institute and COWI, the insurance industry has developed an online weather service, *Forsikringsvejret.dk.* This service provides everyone with hour-by-hour and extremely geographical accurate updates of weather events when a cloudburst, storm or lightning hits Denmark. Moreover, the site offers two-day weather forecasts and a text-messaging service providing severe weather alerts for any given geographical location, so that homeowners or farmers etc. will have time to take necessary precautionary measures. All services are offered free of charge.

Because the case worker at the insurance company has access to the exact same weather data as claimants, both parties can more easily come to an agreement on what happened and what is covered. At *Forsikringsvejret.dk* you can also find advice about how to prevent damage to your house as a consequence of cloudbursts and storms.

The service uses all of the weather stations available to the Danish Meteorological Institute. This means that around 70 Danish weather stations provide the data on wind conditions and more than 250 stations provide the data on precipitation. Before the data is displayed on the weather service, it is automatically checked for any measurement errors, and once a week the data is reviewed manually to achieve the highest level of quality assurance. The service updates weather data by the hour and weather forecasts every six hours. Work is under way to develop a smartphone application with alerts and prevention advice. It will be easy and relatively cheap for the municipalities to have their own application made which combines alerts and prevention advice to citizens with advice and information from the individual municipality.

As far as is known, *Forsikringsvejret.dk* is the only service of its kind in the world. The insurance industry will cover development and operation costs.

Barriers and opportunities for future action

Knowledge and consulting services
The data available to insurance companies today (including reinsurance companies) about the economic knock-on effects of future climate change is considerable. The reinsurance companies, in particular, have large and extremely competent climate divisions. Despite this fact it is still difficult to calculate the precise risk and ultimately the premium to be paid. The challenge is therefore to develop methods for more accurate calculation of premiums.

The insurance industry exchanges data with public authorities on insurance claims from extreme weather events, and this makes it possible to build up knowledge about the consequences of climate change, *see above.* Along with more general data about climate, the insurance industry can use this data to provide for a more informed knowledge base about climate change, so that they can adapt and differentiate coverage and premiums to better address risks. The Act on Processing of Personal Data sets the legal framework for how personal data may be exchanged.

Regulation
Climate change impacts, the strength of storms and the follow-on effects on the reinsurance markets are some of the most important challenges facing Danish insurance companies. The question is whether Danish insurance companies can maintain sufficient storm reassurance protection with credit-worthy reassurance companies in future, so that their risk profiles are in check with their capital bases.

It is important to monitor the insurance markets in terms of citizens and enterprises who risk not being able to take out insurance against e.g. water damage.

Summary
So far, climate change has lead to greater indemnification costs which have been covered through increases in premiums and reinsurance schemes. Insurance companies are widely equipped with the necessary tools to prepare for climate change by adjusting coverage and premiums. Furthermore, the insurance industry has already launched initiatives to exchange data with public authorities so the insurance companies will be able to adapt coverage and premiums to risks, and so the municipalities and individual citizens can reduce their exposure to climate change.

However, it is important to monitor the insurance industry in terms of citizens and enterprises who in future risk not being able to take out insurance against water damage.

4.4.3 Spatial planning

Climate change is a challenge for both new and existing designation of land. The municipalities need the right knowledge to incorporate climate change in their spatial planning.

Important effects of climate change
Issues arising from climate change may be linked to increased precipitation, more powerful storms and increased groundwater level. Areas affected by climate change may become unsuited for new development, including urban development, as well as for infrastructure, farming and recreational purposes. However natural, geological and heritage assets may also be lost.

Extreme rainfall and cloudbursts can lead to the flooding of urban districts and housing areas, or to sewers overflowing. Vulnerable road and rail network stretches may be flooded periodically.

Farm land may be permanently flooded in many places, primarily on fields situated close to the coast and where there is no coastal protection, or fields situated near watercourses or in low-lying areas prone to flooding.

Division of responsibilities between the authorities and private citizens
The *municipal councils* are responsible for spatial planning in municipalities. The municipal development plan is an overall plan for land use in the individual municipality. The municipal development plans must not conflict with overall planning and governmental interests. Furthermore, local development plans in the municipality must be in accordance with the municipal development plan and with any national planning directives that relate specifically to the area in question.

In addition to the legally binding provisions (national planning directives), the Minister for the Environment can influence the municipalities' planning through political statements in the national planning report, and through an report on national interests in municipal planning published every four years for use in the municipalities' revision of their municipal development plans.

Furthermore, the Minister for the Environment has specific powers to intervene in local planning to ensure national interests. These powers include, in particular, the Minister for the Environment's power to object to proposed municipal development plans on behalf of all central-government bodies whose interests are affected by the municipal plan (i.e. the concept of national interests). Changes in of new land use, for example in connection with adaptation to climate change, could fall under the concept of national interests.

Possibilities for adaptation
In relation to climate change, spatial planning is an effective control instrument which can contribute to reducing or eliminating negative effects or to exploiting positive effects of climate change for land development and land use.

Local plans are the cornerstones of the Danish spatial planning system. The political strategies and targets of the municipal development plan are defined and made binding for the individual land owner through local plans. Pursuant to the Planning Act, through local plans the municipalities can set out specific requirements when new land areas are designated for development.
For example, through local plans, the municipalities can lay down provisions that e.g. an area may not be subject to new development if any buildings in the area may be subject to subsidence,

flooding or other damage that may pose a threat to the life, health or property of the user of the building.

Central government can address important aspects of the climate challenge through its influence on the revision of municipal development plans, through the national planning report, as well as through the following legislation: the Planning Act, the Act on assessment and management of the risk of flooding from watercourses and lakes (*lov om vurdering og styring af oversvømmelsesrisikoen fra vandløb*) and the Statutory Order on assessment and risk management of flooding from the sea, fjords or other parts of the Danish territorial waters (*bekendtgørelse om vurdering og risikostyring for oversvømmelser fra havet, fjorde eller andre dele af søterritoriet*).

An important aim of central-government initiatives pursuant to planning legislation is to reduce the scope of new building in risk-prone areas where new building would require considerable additional costs in terms of coastal protection/dikes, infrastructure, pumping etc. Furthermore, in the future, the Minister for the Environment will be able to spotlight initiatives via the planning legislation that help achieve the government's climate targets.

According to the government programme, the government aims to ensure that all municipalities prepare action plans for climate change adaptation within two years.

Initiatives completed and in progress
There is a wish to be able to plan explicitly for climate change in local planning. A bill has therefore been presented to amend the Planning Act, providing the municipalities with a new tool that will allow them to e.g. prevent future flooding in the local development plan. The municipalities will be able directly to prepare local development plans aimed at climate change adaptation, e.g. managing extreme rainfall and flooding. So far, the municipalities have only been able to substantiate their decisions in local development plans using architectural and functional explanations. The bill was presented on 29 March 2012.

A task force for climate change adaptation has been established, consisting of a team of experts that provides guidance for municipalities and utilities in their climate change adaptation efforts, including the preparation of municipal climate change adaptation plans. This task force serves as a driver for municipal focus and investment in the field and is helping collect knowledge and experience for onward dissemination to relevant stakeholders.

Barriers and opportunities for future action
Knowledge and consulting services
The municipalities will always have the option of choosing not to designate areas for development in their municipal development plan which are low-lying or which for other reasons are at risk of flooding. The availability of a clear and comprehensible overview of all of Denmark, showing the areas that are most at threat from flooding, elevated water levels, etc. would be appropriate in this context, so that the criteria are the same for all municipalities. One way of providing this could be via a map showing the risk-prone areas, including more detailed descriptions of the risks.

Experience tells that many people think that the land uses planned in municipal and local development plans are subsequently automatically realised. It should therefore be stressed that climate initiatives that are allowed according to the municipal or local plans, do not entail an obligation for the municipality to realise the relevant uses or climate measures. Municipal and local

planning efforts can alone ensure that the land use designated supports/allows for climate change adaptation and is not prevented through any future planning and administration by the municipality.

The existing dialogue and close cooperation between the municipalities and the Ministry of the Environment about central-government interests in municipal planning is running smoothly and formal cooperation exists on the municipalities' planning and realisation of the provisions of the Planning Act.

This cooperation means that the Ministry of the Environment can enter into dialogue with the municipalities at an early stage, e.g. on limiting the designation of new land areas in risk areas and on the use of local development plans incorporating climate change.

Information for the municipalities about the location of areas at threat and guidance on the development of sustainable local development plans incorporating climate change will be developed continuously and will be a part of the collaborative work on future municipal development plans.

Regulation

The legislative framework for spatial planning in Denmark already allows the state to use regulation to address the most important aspects of the challenges for planning efforts in terms of climate change adaptation.

In connection with the revision of *Fingerplanen 2012* (a plan for the development of the Copenhagen metropolitan area) the municipalities in the Capital Region of Denmark will be made aware of the possibility to use the so-called green wedges as drainage areas in connection with heavy downpours. The revision of *Fingerplanen* 2012 (a plan for the development of the Copenhagen metropolitan area) will clarify the opportunities for exploiting the green wedges for climate change adaptation purposes. The plan also encourages collaboration across municipal borders and encourages municipalities to incorporate climate change adaptation into all their initiatives and development projects.

Summary

Spatial planning is an effective instrument of control which can contribute to reducing or eliminating negative effects, as well as exploiting positive effects, of climate change in a number of sectors and industries. A legislative bill on local development plans incorporating climate change and a simplification of the Planning Act will allow municipalities to incorporate climate considerations in local development plans, and guidelines on these plans are expected to be prepared in connection with entry into force of the bill. The revision of *Fingerplanen 2012* (a plan for the development of the Copenhagen metropolitan area) will clarify the opportunities for exploiting the green wedges for climate change adaptation purposes.

5. Socio-economic climate change adaptation

Ultimately, decisions on climate change adaptation initiatives are a matter of priority-making.

Socio-economic analyses can contribute to an informed decision basis by calculating the overall socio-economic benefits of possible investments. Socio-economic analyses can also give answers to key questions about

- the extent and timing of climate change adaptation efforts that will provide the best possible investments for society and the economy;
- the socio-economically most beneficial initiatives to include in efforts;
- the socio-economically most appropriate decisions in view of the uncertainties linked especially to extreme events.

Socio-economic calculations of climate change adaptation efforts are particularly relevant in connection with large infrastructure investments at central-, regional- and local-government levels, e.g. road, rail, sewerage or coastal protection construction works, as well as in connection with large building and renovation works of e.g. hospitals, production facilities and when establishing or renewing entire urban areas.

This section outlines how socio-economic analyses can assist in these matters. First some general socio-economic considerations about climate change adaptation are presented. Then follows a description of how socio-economic analyses should be addressed. Finally there is a review of key challenges associated with performing the analyses.

General socio-economic considerations about climate change adaptation
A more detailed decision basis for climate change adaptation requires socio-economic analyses of very specific issues. Socio-economic analyses are therefore especially relevant in terms of local climate change adaptation initiatives, because local conditions are of considerable importance for costs, benefits and timing of the initiatives. In some areas, socio-economic analyses can also support more general decisions which pertain to specific issues for which local variation is less pronounced.

Sector-specific conditions can serve as a general guidance on what is a socio-economically appropriate approach to climate change adaptation. The investment horizons of the different sectors and their opportunities for ongoing adaptation are hugely significant for how they can best address climate change. In a number of events it may be expensive, from a socio-economic perspective, to postpone efforts to when the predicted climate change has become a reality. On the other hand, there may be other situations in which it *will* be cost-effective to postpone dealing with climate change that is predicted to happen many decades from now.

In sectors with long investment horizons, and in which investments, in other words, have long life spans, it may be expensive to postpone adaptation efforts if there are no possibilities for adjusting efforts progressively. In these situations there is a special need to incorporate climate change in ordinary investment plans so that investments and climate change adaptation are coordinated. This can be achieved either by ensuring that new installations can cope with the climate of the future, or by ensuring that the required adaptation can be implemented at a later stage. It is also important to

be aware of the opportunities for ensuring adaptation through preventive measures, e.g. in connection with spatial planning or building applications.

When the effects of climate change are included in calculations, it may turn out that altering existing investment plans may be beneficial, so that investments and re-investments are initiated at an earlier or later stage than previously assumed.

In sectors with short investment horizons, ongoing adaptation in step with observed climate change is possible to a greater extent. Decisions on initiatives can thus be made as new knowledge becomes available about actual, observed climate change. This will allow for more accurate adaptation to climate change. This also applies to investments which, despite long horizons, provide opportunities for adjusting efforts progressively.

In other areas there may be a need for autonomous initiatives, independently of the relevant sector's normal rate of investment. However, also here, it will be necessary to look at adaptation in the context of new and re-investments, in order to ensure that adaptation takes place in the socio-economically most appropriate manner. For example, local surface water drainage and retention may be cost-effective alternatives to an expansion of the sewer systems. Alternative initiatives that can be implemented more or less independently of normal rates of investment should be included in the overall assessment of possibilities for adaptation.

Socio-economic analyses and climate change adaptation
Socio-economic analyses can contribute with specific knowledge about whether and when it is most appropriate from a socio-economic perspective to launch specific climate change adaptation initiatives.

Socio-economic analyses examine the overall utility value of carrying out adaptation initiatives or the opportunity cost of *omitting* to launch any special initiatives. In other words, the positive and negative impacts are considered for others than merely for those who actually finance the initiatives or who pay the costs of climate change.

The analyses can assist relevant authorities and decision-makers to make priorities for and choose from initiatives relating to specific issues. Socio-economic analyses have general relevance when

- the issue is well-defined and with a clearly defined base scenario;
- specific alternative solutions exist;
- knowledge is available about the costs and benefits of the alternative solutions.

A base scenario is the expected development if *no* climate change adaptation initiatives are carried out, *see the example below.*

Kolding Municipality - assessing watercourse flood protection

As a consequence of a flooding event in Christiansfeld in July 2007, Kolding Municipality has assessed the possibilities for limiting possible future flooding.

A screening analysis identified three possible adaptation measures, on which the municipality performed a socio-economic assessment. These measures were then assessed on the basis of a base scenario. A base scenario represents a scenario in which the increasing risks of flooding in step with climate change developments are not being met by special initiatives. The costs of future events were calculated on the basis of the scope of damage in the 2007 event.

The results of the calculations showed that none of the proposed adaptation measures provide a socio-economic net benefit relative to the base scenario. As a result of the analyses it was recommended that no measures be carried out at present, since the infrastructure so vital to adaptation efforts was going to be renovated at a later stage.

The base scenario and the costs and benefits of various measures vary from place to place. This means that socio-economic analyses of climate change adaptation require knowledge about local conditions.

A socio-economic analysis of climate change adaptation initiatives involves three steps.

- *Step 1: Definition of the objective and of alternative initiatives to achieving it*
  In the first step, the issue and scope of the analysis are defined. The base scenario is described and relevant alternative solutions are identified. The base scenario is a projection of the economic consequences of climate change, as well as the significance of spontaneous, market-related adaptation measures. It is essential that the objective, the base scenario and the alternative measures are concrete and operational.
- *Step 2: Quantification and valuation of advantages and disadvantages*
  The second step of the analysis involves identifying, quantifying and valuing direct and indirect effects. This will often also involve estimates and it is crucial that these are assessed critically.
- *Step 3: Analysis*
  In the analysis proper, the current value of future advantages and disadvantages are compared. Sensitivity calculations are used to map the consequence of the uncertainty linked to key parameters for the results of the analysis, e.g. the significance of the uncertainty regarding the magnitude of climate change.

A cost-benefit analysis calculates the overall socio-economic value of the different measures. This assumes that consequences can generally be quantified and valued. If this is not possible, or if a decision is solely about prioritising a number of alternatives without calculating their actual socio-economic value, a cost-effectiveness approach may be used instead, which assesses which alternative is the most cost-effective to achieve the objective.

The Danish Coastal Authority - a socio-economic assessment of coastal protection

The Danish Coastal Authority has set up a socio-economic analysis for use when deciding whether the existing high-water protection should be fortified along a coastal stretch at Løgstør in northern Jutland. The analysis also looks at whether there will be a socio-economic net benefit from reinforcing the existing high-water protection in 2050 in order to adapt to climate change.

The analysis is based on the damage caused to buildings and infrastructure from flooding, i.e. the physical damage and not other losses of value.

The calculations reveal a net benefit, expressed as the net current value, of DKK 29.9 million. Moreover, the net benefit per DKK public investment in coastal protection is DKK 13. This means that the internal rate of return on capital investments is 80%, which is significantly higher than the 6% stated in the socio-economic manual from the Ministry of Transport as the lower limit for carrying out capital investments.

Because climate change will occur gradually over a long period and will not take full effect until several decades in the future, it is important to examine the significance of different implementation times for the socio-economic viability of the measures. The choice of scenarios and alternative solutions should reflect this. In sectors with a long investment horizon, it will be important to include the timing in general sector investment plans.

The Danish Ministry of Finance's guidance on how to prepare socio-economic analyses, as well as guidance within the individual sector, describes the more in-depth principles of socio-economic analyses.

Challenges in using socio-economic analyses

Base scenarios and the consequences of different measures widely involve future conditions that are different from current, and this poses a general challenge when preparing socio-economic analyses. In the field of climate change adaptation, there are large uncertainties linked to the magnitude of the climate change predicted for future decades, in particularly in relation to extreme events. Ultimately, this means that there will be great uncertainty linked to the costs of damage and the benefits in base scenarios and to the consequences of different measures.

It is therefore crucial to apply a probability-based approach when valuing. Advantages and disadvantages conditional upon the occurrence of certain climate events are therefore weighted by the probability of these events occurring. Thus, the relationship between known consequences (e.g. construction costs and side-effects not related to climate) and unknown advantages (e.g. saved costs of damage) are reflected correctly.

In the light of this, uncertainties associated with other factors should be minimised. This could be achieved e.g. by performing assessments against clearly described adaptation options, as shown in the examples.

Solid data material is essential in socio-economic analyses, if these are to make a sound contribution to the decision basis. Careful mapping of risks and calculation of consequences will ensure a good foundation for socio-economic analyses. The need for reliable data underlines the fact that socio-economic analyses work best when the issue being analysed is well-defined and allows for the setting up of clear alternatives.

In principle, all consequences should be valued, including those that are not actually sold in the market, e.g. recreational values. However, this is far from always possible. In such situations, it will have to suffice to calculate the consequences that can be reasonably valued and it will then be up to the relevant decision makers to weigh the benefits and costs that have not been valued.

Due to the challenges associated with the use of socio-economic analyses in connection with climate change adaptation, guidance on how to use this tool is required. Central-government authorities have already ensured that guidelines are in place in several important sectors and industries, which can underpin municipalities' work on preparing analyses and choosing specific climate change adaptation initiatives.