Danish strategy for adaptation to a changing climate

March 2008

The Danish Government

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Foreword

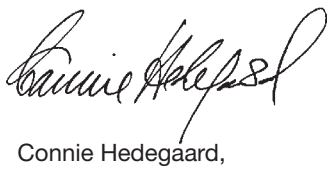
The UN Intergovernmental Panel on Climate Change (IPCC) indicates that our climate will change. Science tells us that the planet will see more extreme weather events in the form of drought, flooding, storm surges, hurricanes and rising sea levels due to melting glaciers. Responsible politicians must take account of this now at the start of the 21st century. It would be irresponsible to just cross our fingers and hope that things will be alright in our lifetimes. Therefore Denmark is fully committed to reaching a global agreement that can reduce greenhouse gas emissions before it is too late. However, we must also try to adapt to the climate change, for example, by planning on the basis of the comprehensive knowledge we already have about climate change. For even if we manage to have a binding international agreement in force in 2009, significant climate changes will inevitably continue for the next couple of decades. It is first and foremost these climate changes that this national adaptation strategy must counter.

Throughout its history, humankind has adapted to local climate and other conditions of existential significance. We have dressed according to the weather, and built houses using our knowledge of local climates. We have gathered increasing climatic knowledge, which has made Denmark a robust society. We are not only capable of surviving, but also of looking ahead and planning our future. With this strategy, the government will ensure that we take a further step and begin to incorporate our knowledge about the future climate in today's planning and initiatives, which we know will have an impact for many years to come. The goal is naturally a society that will continue to be environmentally, economically and socially sustainable.

Since climate change is expected to have wide-ranging impacts, all sectors of society need to take up the challenge. This means private citizens, businesses and public authorities, all of whom are climate-sensitive to one degree or another. Perhaps we do not think of this on a daily basis, when everything is functioning as it should, but we will remember it when extreme conditions occur. When roads suddenly disappear, when dirty water appears without warning in the basement, or when farmers find that the water in their fields does not drain away and therefore damages crops, we notice our vulnerability. And haven't most people noticed that even though not everything can be attributed to climate, there are certain patterns that seem to fit together a bit too well? Why not just adapt before it's too late? That is the attitude behind the government's adaptation strategy. It will be more costly to wait until dikes and dams have collapsed than to maintain, improve and plan in good time.

Every day decisions are made, which have long-term and far reaching consequences. From the time a tree is planted until it is felled, generations pass. Many buildings are still standing despite having been built hundreds of years ago. Our dams, sewers, roads and bridges are expected to have lifetimes of up to 100 years. It is therefore important that they are designed to withstand better what the future will bring.

With this climate change strategy, the government proposes to adapt Denmark in time. It is important that the state and municipalities take initiative, but without cooperation from citizens, businesses, city planners, the construction sector - everyone responsible for infrastructure and many other important players - our efforts will be futile. We must ensure that efforts are well-planned, sustainable and timely.



Connie Hedegaard,
Minister for Climate and Energy

Increased precipitation is expected to affect the entire hydrological cycle. In the future increased runoff from the land will contribute to more stratification in the sea and will affect fishing. Photo: Anne Mette Jørgensen/DMI.

Introduction

Climate change is a reality, and an important part of global warming is due to human activity. A two-fronted effort is needed to counteract the impacts of anthropogenic climate change. On the one hand national and international agreements are needed to reduce greenhouse gas emissions, and on the other hand initiatives are needed to help society adapt to the future climate.

The government's strategy focusses on the necessity of national adaptation to climate change. There are already a number of areas where it is relevant to consider adjustments that take future climate into account, including long-term investments and infrastructure planning. It can also be relevant to take the expected climate changes into account in contingency planning and in the health sector, for example, in connection with monitoring and warning systems. Climate change will take place gradually over an extended time horizon, and therefore the societal consequences will depend upon how society adapts, for example legislation, infrastructure and building to the expected changes.

Climate change will come to Denmark, but it is still uncertain to what extent and when. For example, it is expected that local sea levels will rise by between 0.45–1.05 m in connection with storm surges by the year 2100. Any given effort to adapt to climate change runs the risk of being either under-scaled and insufficient or over-scaled and unnecessary, taking resources from other priority areas.

How adaptation efforts should be designed will be the result of considering the consequences of climate change, the likelihood of their occurrence and the costs of prevention. In this context, attention must be paid to autonomous adaptation by the individual. Thus the basis of adaptation efforts can be compared to considering adequate insurance, where the cost of the premium and the risks of damage correspond.

With this strategy, the government will provide a basis describing how the expected climatic changes could affect a number of areas. Such an overview allows for consideration of whether, and if so how and when public authorities, businesses and citizens should take the climate change into account and adapt, if necessary. Without a systematic foundation, there is a risk that the impacts of climate change will only enter into the planning process randomly.

The goal of the strategy is that in future climate change should be considered and integrated into planning and development in the most appropriate way. The strategy contains a number of sight-lines to enable authorities, businesses and citizens to react promptly and autonomously to the challenges climate change will pose to Danish society. By autonomous adaptation we mean that authorities, businesses and private citizens react to the consequences of climate change in a timely manner within the legislative, economic and technological framework. The strategy focuses mainly on the general activities to be undertaken to ensure the process.

At present we do not have sufficient knowledge to solve all the problems. Adaptation to climate change is a long-term process and it is still uncertain what the consequences of climate change will be, and how quickly they will take effect. Therefore the strategy will need to be continuously adjusted.

The government's strategy for adaptation to climate change should be seen in connection with government efforts to reduce greenhouse gas emissions. Reducing emissions and adjusting to climate change are not either/or propositions; both are necssary.

The government's strategy for adaptation to climate change focuses on the necessity of adaptation at national level. It should be noted, however, that in recent years the government has undertaken a number of initiatives to reduce greenhouse gas emissions with respect to combating the increased greenhouse effect and consequent changes. The government has introduced an ambitious energy plan describing the goals of the Danish energy policy until 2025. The government has also presented a plan for meeting Denmark's reduction commitment of 21% of 1990 emissions; cf. Denmark's National Allocation Plan 2008–2012. Furthermore, Denmark will host the United Nations Climate Conference, COP 15, in 2009. The goal for this Conference of the Parties is to agree on a new, ambitious global climate agreement with participation of both the United States and countries with developing economies.

Regardless of how ambitious a climate agreement the parties are able to negotiate, the consequences of the greenhouse gases already emitted and their accumulation in the atmosphere alone mean that adaptation to climate change is necessary. Therefore we must focus on nationwide adaptation to climate change. It is this situation that the strategy addresses.

1. Summary of the government's strategy for adaptation to a changing climate

In its fourth assessment report, the UN Intergovernmental Panel on Climate Change (IPCC) concluded that there is a 90% probability that the global warming of the last 50 years is due to man-made greenhouse gases. Global warming is taking place much faster now than the Climate Panel has previously estimated, meaning we are facing a warmer future, whether we take action or not.

Climate change is a reality, and in recent decades there has already been an accumulation of greenhouse gases in the atmosphere necessitating both national and international action to reduce emissions and adapt society to the future climate. Future climate changes – even with a global effort to reduce greenhouse gas emissions – will necessitate local measures to deal with their consequences.

With this strategy the government emphasizes the importance of timely adaptation to climate change. The government gives weight to autonomous adaptation as far as possible, whereby authorities, businesses and private citizens react to the consequences of climate change on their own initiative in a timely manner within the given legislative, economic and technological framework. In cases where autonomous adaptation is not optimal, there may be a need to initiate politically planned adaptation measures.

In Denmark we can generally expect a warmer climate with milder, wetter winters and warmer, drier summers. There will be more annual precipitation, but less in summers, which will see both periods of drought periods and heavier rainfall. The sea-water levels are expected to rise both on the west coast and in other castal waters, and the maximum storm strength is expected to rise. The risk of more extreme events, with long heat waves and more violent storms will also increase.

1.1 Aim of the strategy

This strategy is based on the notion that adaptation to climate change is a long-term process, and that it is still uncertain what the consequences of climate change will be and how soon they will take effect. The government will therefore initiate an information campaign and organise the area, with the aim of ensuring that climate change is incorporated into planning and development so that public authorities, businesses and citizens have the best possible basis for considering whether, how and when climate change should be taken into account.

The strategy comprises the following measures:

- a targeted information campaign, including creation of a web portal operated by an information centre;
- a research strategy that will include estalishment of a coordinating body to ensure that Danish climate research focuses on the adaptation question to a greater extent; and
- establishing an organizational framework, including establishing a horizontal coordination forum for adaptation that will ensure a coordinated effort among public authorities.

The strategy includes a description of the vulnerability of those sectors where climate change is expected to have significant consequences. Focus will be on autonomous adaptation measures already underway, and what is necessary to advance this process.

In a number of areas it will already be prudent to undertake adjustments that take into account present IPCC knowledge concerning the future climate, for example, with respect to long-term infrastructure investments and decisions.

How the adaptation effort should be designed will be the result of considering the consequences of climate change, the probability of their occurrence and the costs of prevention. In this context attention must be paid to undertaking autonomous adaptation.

1.2 Sectors in which climatic changes may be significant

This strategy focuses on what will be attainable in the individual sectors within the next 10 years. By "attainable" is meant that a measure should be scientifically, technically and socio-economically appropriate for implementation within the given period. A common feature is that a more detailed socio-economic analysis is often required before implementation of a concrete measure.

Within the various sectors the following are relevant:

Coastal management: Adaptation to climate change in connection with coasts and harbours is expected to be necessary as a result of rising sea levels and more storms, if the present safety levels and operational conditions are to be maintained. New construction, dismantling or renovation of dikes or port installations may be necessary and will require knowledge of the extent of climate change and risk analyses based on the probability of extreme water levels in the lifetime of a particular construction. In addition there is a need for ongoing adaptation of rescue and storm surge preparedness as well as information on conditions significant to planning coastal constructions in future risk areas.

Buildings and construction: It is estimated that in the short term there is no need to change legislation concerning building safety under extreme weather conditions. There will be a need for greater attention to indoor climate, especially temperature and humidity conditions. There may be a need to authorise new construction technology solutions as a means of supporting the reduction of extreme indoor temperatures during heat waves. A compulsory labelling regulation for small individual cooling units that are spontaneously installed may be necessary. Finally there may be a need for an information campaign aimed partially at construction technicians concerning recommended future design parameters and partly at building owners concerning typical weaknesses in load-bearing constructions, including how to improve conditions.

Road regulations and rail standards must be harmonised with the expected climate changes, just as extension and renovation of roads and railways must be adapted to expected climate changes. Road drainage systems must be considered in light of the risk of increased precipitation intensity. The transport sector has already taken initiatives for new road regulations taking into account the expected climate changes. Rising temperatures will increase the need for insulation of safety installations and signal boxes along railway tracks. A risk analysis must be undertaken with respect to possible wind damage to roads and railways.

A risk analysis is needed of sewer systems including standards and regulations for road and railway drainage systems.

Water supply: Adaptation to climate change with repect to drinking water might include reorganisation of water extraction, taking into account the future groundwater resources and water flow/quality of watercourses and wetlands.

A precondition of planned reorganisation of water extraction wil be that goals are set such that it is possible to determine 1) how large a quantity of water really should be subject to reorganisatino and 2) in which areas this will be possible. Such gradual adaptation of water extraction should start no earlier than after 2009, when the first generation of water plans under the Water Framework Directive must be drawn up.

Energy supply: Energy plants have an investment horizon of 10–30 years, therefore there will be ongoing replacement and adaptation of plant capacities according to need. Changes in energy supply are expected, including greater production of renewable energy and altered consumption patterns with less heating in winter and more cooling in summer.

Agriculture and forestry: A longer growing season is expected to allow for the introduction of new crops and increased yields, meaning greater productivity in agriculture and a need for increased fertilisation. Furthermore, changed precipitation patterns are expected. Increased insect pressure is expected to lead to the use of more and different pesticides. The consequences of these changes may result in a need to adapt existing regulations with respect to environmental-policy goals, for example evaluation in 2008 of the Action Plan for the Aquatic Environment III and the Pesticide Plan 2004–2009. A changed precipitation pattern will also change drainage and irrigation requirements. An information campaign aimed at businesses and consulting services will be central to promoting autonomous adaptation. The ongoing change to close-to-nature forestry in the public forests will be reassessed in order to speed up or adjust. Voluntary conversion to natural forest management of private forests will be promoted through targeted information and the existing subsidy schemes.

Fishery: It is expected that, as a result of changed fishing possibilities, commercial enterprises, will develop new equipment, fishing methods and types of boats. Adaptation and development of new management systems is expected to occur within the present international cooperation on fisheries management and marine ecosystems. There will be a need for models and databases to quantify and qualify the significance of the climate changes. It is expected that there will be a need to restructure fish and shellfish cultivation in both fresh and salt water. There is a need for an information campaign aimed at both businesses and the administrative/political system to promote autonomous adaptation.

Nature management: A number of activities are already underway to ensure a healthy and robust nature under the changed climate conditions, for example restoration of selective river valleys to natural wetlands with extensive operation and care, an effort against oxygen depletion in the sea and fragmentation of nature as well as preventing and combating invasive species. Such activities will continue to have high priority. In order to ensure that sectors' adaptation efforts take place considering natural and environmental effects, the existing regulations on assessing environmental impact (in the first instance EIAs and SEAs) should be reviewed and perhaps adjusted. Moreover, there will be an information and guidance programme for municipalities in connection with climate change adaptation at municipal level.

Land use planning: The state authorities will continually assess whether there is a need to draw up requirements for municipal planning. These could, for example, be worked into "Monitoring of state interests in municipal planning". Relevant risk analyses will be included as an important decision-support tool in the form of a risk map. It is further expected that the ”European Floods Directive” will lead to designation of the areas at potential risk of flooding and, in the longer term, risk management plans for these areas.

Health: Adaptation of programmes for public health emergency management, prevention and treatment, infectious disease monitoring, etc. may be relevant in connection

with more heat waves and other health risks associated with climate change (infections, allergies, etc.). There may also be a need for increased information efforts targeting risk groups. Attention to health is otherwise integrated into many of the other sectors' efforts.

Rescue preparedness: Ongoing adaptation of rescue preparedness is already underway, for example, as a result of the hurricane in 1999 and the storm surges and floods of recent years. This development will continue on the basis of observed weather events, experience from efforts undertaken and expectations for the future. As part of a political agreement on rescue preparedness after 2006, which includes the period 2007–2010, the extent of state rescue preparedness will be examined. Weather-related events will naturally be included in this examination, partly with regard to risks and threats and partly in connection with the capacity of the rescue preparedness. Since 2007, the municipalities have based rescue preparedness on local risk evaluations, which include risks caused by weather events. This means that at the same time there is an increased focus on existing national advisory efforts.

Insurance aspects: Climate change will entail ongoing adaptation from the insurance companies in the form of higher premiums and/or coverage exemptions, and it could be a question of developing new financial instruments for risk transfer between the non-life insurance companies and the rest of the financial sector and setting rates based on expected developments in claims.

Responsibility for ensuring the necessary sector-specific adaptation to climate change will lie in the sector ministries. Adaptation to climate change will often be cross-sectoral, for example in agriculture/environment/nature and health/construction/environment there will be a need for coordination between the ministries and regulations and developments in the EU and other international fora. This will be ensured by the cross-sectoral Coordination Forum for Climate Change Adaptation and the national information centre recommended to be established for this purpose.

1.3 Cross sectoral initiatives

There is a need for a more general and at the same time goal-oriented information campaign, partly to inspire the stakeholders faced with climate challenges and partly to get citizens to change their behaviour. In addition, there is a need for Danish climate research to include more research on the consequences of climate change and adaptation-relevant research and technological development, including socio-economic research.

Targeted information campaign

The focal point of the information effort will be the establishment of a web portal for climate change adaptation. To provide Danish society the possibility of timely adaptation to climate change, it is important that easily accessible information concerning the expected changes is available.

The portal will be the entry point for information on trends in a number of climate variables such as temperature, precipitation and wind. Correspondingly, there should be access to a number of oceanographic data such as mean sea levels, storm surge levels, oxygen content and sea temperatures. A number of decisions based on climatic developments share the need for information such as terrain elevation and groundwater conditions, so this data will also be available on the portal.

The vast majority of this data has a geographic association. Hence it will be necessary to establish a common geographical foundation to ensure that data can be efficiently compared and used across geographical and administrative boundaries.

As considerations about climate change adaptation will be repeated from municipality to municipality, for example, or within the same group of business people, it would be prudent to work out a series of examples of typical calculations or cases to be arranged on the portal by theme. The process up to a decision on undertaking a measure can be quite complicated. Therefore, examples of how the decision process can be structured may be useful. Furthermore, guidance should be given about how both private and socio-economic analyses can be carried out in advance of climate-related decisions.

The government will:

- Create a web portal for climate change adaptation. The portal will provide easy access to the latest knowledge of the subject and be developed so it can be used by authorities, business people, specialists and citizens. The portal will thus help support autonomous adaptation.

Research strategy

Research on climate and climate change has over a number of years played an important role for our understanding of future climate conditions, how the changes will affect Danish society and how we might counter climate change.

Therefore, in recent years there has been increasing focus on the climate question in Danish research circles, and a number of competent climate research environments have developed. In the past few years a number of initiatives that will strengthen Danish climate research have been undertaken. By far the greater part of research efforts up until now have aimed at understanding and describing the altered climate conditions, including the possibilities of limiting antropogenic climate change, and have only to a limited extent focused on the challenges associated with adapting Danish society to future climate change.

Therefore, there is a need for climate research to focus to a larger extent on the question of adaptation. Adaptation to climate change must be included as an important element in other research, so that climate change adaptation research constitutes an important contribution to more coherent climate research. More recent elucidation and analyses of Danish climate research point to the need to develop tools to prioritise future efforts. Furthermore, there is a need for strengthened efforts with respect to coodination and knowledge-sharing in the Danish climate research milieu.

The government will therefore launch initiatives to promote:

- development of modelling tools for socio-economic evaluation of measures in the climate change adaptation area to the extent they do not already exist; and
- establishment of a coordinating unit for research in climate change adaptation that will create better coordination and knowledge-sharing of climate change adaptation research in Denmark and in relation to the rest of the world.

Future organisation

With this strategy for climate change adaptation the government anticipates that all sectoral interests will collaborate on the task. Therefore, in addition to the above-mentioned coordinating unit for research in climate change adaptation, it is recommended that there be established a cross-sectoral Coordination Forum for Climate Change Adaptation with an information centre as a secretariat to see that coordination initiatives are implemented.

Cross-sectoral Coordination Forum for Climate Change Adaptation

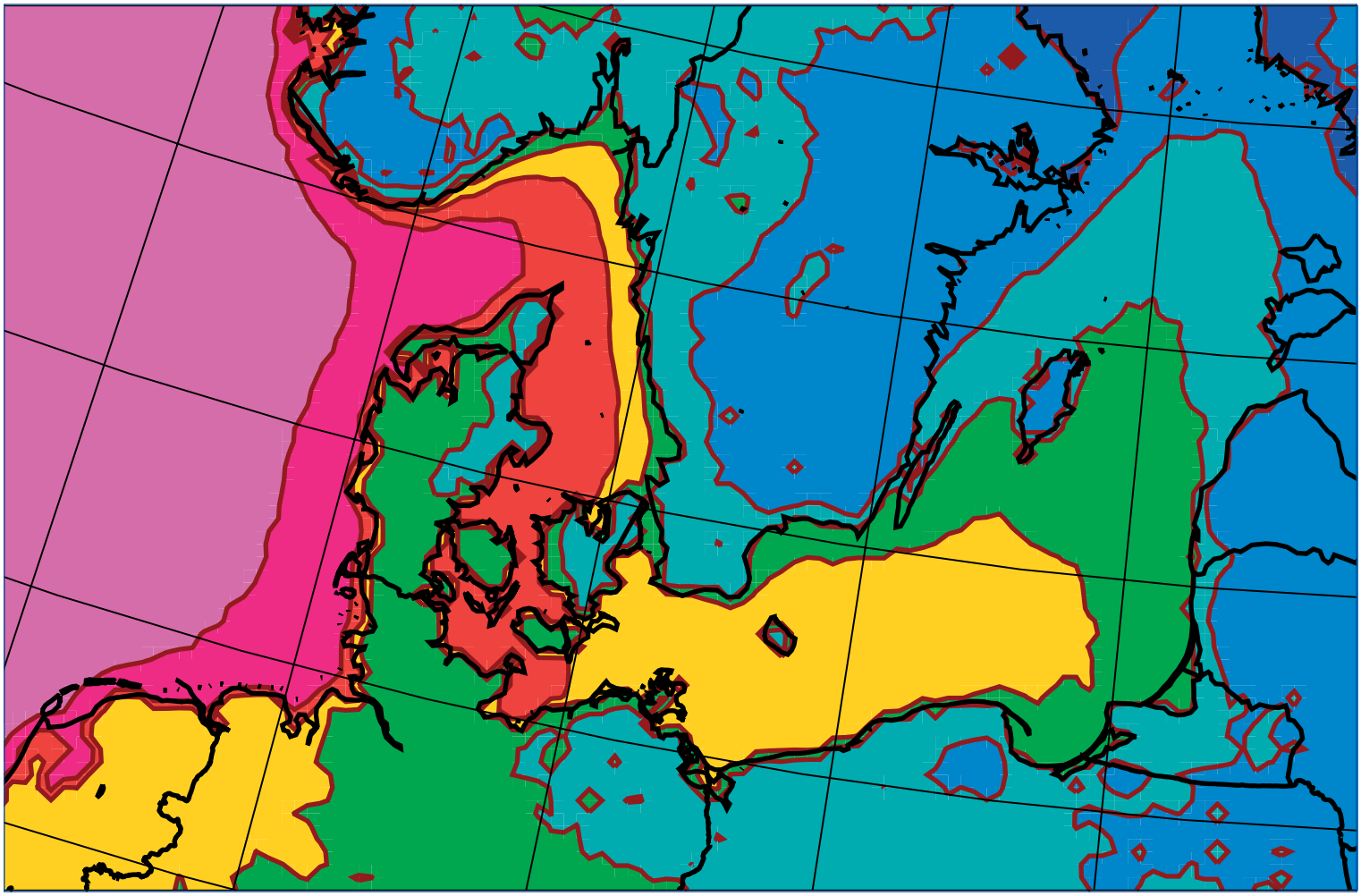
The overall goal of the Coordination Forum is to ensure that the government's strategy for climate change adaptation is implemented. In addition, the Coordination Forum will ensure a common basis, cooperation and coordination across sectors and authorities. The forum will also coordinate a follow-up of the strategy. All relevant state authorities and one representative from the municipalities, regions and the coordinating unit for research, respectively, will participate in the Coordination Forum.

Information centre for climate change adaptation

To ensure that the Coordination Forum's initiatives are implemented, it is recommended that an information centre for climate change adaptation be set up. Since the Ministry of Climate and Energy has general responsibility for coordinating Danish climate policy, the information centre will be placed under this Ministry. An important duty of the information centre will be communication, a key aspect of which will be creation and operation of the web portal for climate change adaptation.

Coordinating unit for research in climate change adaptation

The coordinating unit is to ensure that the synergy effect between current and new projects is exploited, and help advance cross-sectoral cooperation and knowledge-sharing among the various milieu. NERI/University of Århus initiated and financed the coordination unit in 2008. The activity will be continued and developed in cooperation with Danish Meteorological Institute (DMI) on the basis of support from the Danish Council for Strategic Research.



Future climate scenarios are used as a basis for assesing the need for adaptation. Here is an example showing the change in the number of days with temperatures below freezing in the period 2071--2100. Data source and graphic: DMI.

2. The future climate

The global perspective

In its fourth assessment report, the IPCC concluded that since the middle of the 20th century there is a more than 90% probability that global warming is due to man-made greenhouse gases. Global warming is taking place much faster now than the Climate Panel had previously observed. The new results show that we are facing a warmer future. Precisely how much warmer depends on emissions of greenhouse gases. Without political intervention, the average global temperature is expected to rise by between 1.1 and 2.9°C in the IPCC's lowest emissions scenario and between 2.4 and 6.4°C for the highest scenario between 2090 and 2100 compared to 1980–1999. The IPCC's baseline estimation is for a temperature rise of 1.8 to 4.0°C. Changes in the extent sea ice and glaciers are expected to continue and possibly increase in speed. Increased melting and warming of the oceans will contribute to higher sea levels. The occurrence of weather and climate extremes is expected to increase sharply, which will mean more intense precipitation events and longer periods of drought.

If greenhouse gas emissions are not reduced significantly, the consequences of warming are expected to be significant. In Europe, it is expected that nearly all regions will be negatively affected by climate change, and this will present challenges in many economic sectors. Southern, central and eastern Europe will experience a series of negative effects related to higher temperatures and drought. In northern Europe, more mixed effects are expected at first, including some advantages such as reduced need for heating, increased crop yields and increased forest growth. Subsequently, as climate change takes effect, negative impacts such as more frequent flooding, more unstable ecosystems, etc. will surpass the positive impacts.

The selected climate scenarios as a basis for the strategy

As a common basis for a Danish climate change adaptation strategy, two IPCC scenarios – A2 (medium high) and B2 (medium-low) – and a scenario based on the EU target that man-made global warming should not exceed 2° with respect to pre-industrial times (EU2C) are used. The choice of the three scenarios is in accord with IPCC recommendations to use two or more scenarios in order to illustrate the range of possible climate developments.

Scenario	A2		B2		EU2C	
Year	**2006-2035**	**2071-2100**	**2006-2035**	**2071-2100**	**2006-2035**	**2071-2100**
Land						
Annual average temperature	**+0.6° C**	**+3.1° C**	**+0.7° C**	**+2.2° C**	**+0.7° C**	**+1.4° C**
Winter temperature	+0.6° C	+3.1° C	+0.7° C	+2.1° C	+1.0° C	+2.0° C
Summer temperature	+0.5° C	+2.8° C	+0.6° C	+2.0° C	+0.7° C	+1.3° C
Annual precipitation	**+2 %**	**+9 %**	**+2 %**	**+8 %**	**0 %**	**0 %**
Winter precipitation	+8 %	+43 %	+6 %	+18 %	0 %	+1 %
Summer precipitation	-3 %	–15 %	-2 %	–7 %	-2 %	–3 %
Maximum daily precipitation	+4 %	+21 %	+5 %	+20 %	+11 %	+22 %
Seas						
Average wind speed	+1 %	+4 %	+1 %	+2 %	+1 %	+1 %
Maximum sea level on the west coast		+0.45-1.05 m				
Both sea and land						
Maximum storm force	+2 %	+10 %	0 %	+1 %	+1 %	+1 %

Table 1. Estimated Danish climate change expressed as the change compared to 1961-1990 for the three climate scenarios.[1] (source: DMI)

[1] The margin of error of temperature calculations is 1.5°C for scenarios A2 and B2 and 0.7°C for EU2C. This means that with 90% probability temperature increases under the three scenarios will be between 0.7°C and 4.6°C in 2071-2100.

The climate changes that the three scenarios give rise to in Denmark in the short and long terms have been mapped out by DMI (see table 1). The table shows that we can expect a warmer climate under all three scenarios. Since 1873, the temperature in Denmark has risen by about 1.5°C and precipitation has increased by about 15%.

Increased precipitation

The increase in winter precipitation is expected to continue while less rain is expected in summer, which in the scenarios is characterised by both drought and heavier downpours. This is most characteristic under A2 and B2, where in long-term further increases of between 18% and 43% in winter precipitation are expected.

Milder winters

Winters are expected to be milder and more wet. Long-term winter temperatures are expected to rise by 2-3°C and plant growing seasons will be extended by 1–2 months on average. The rising winter temperatures are significant for the relationship between the proportion of rain and snow impacting snow loadings on buildings.

Warmer summers

In the long term, summer temperatures are expected to rise by a further 1-3°C, leading to greater evaporation, while the sea surface temperature will also rise.

Higher sea levels

A general rise in sea level of 0.15–0.75 m is anticipated on the west coast and in Danish coastal waters. In extreme storm surge situations an increase in the maximum water level is expected of between 0.45–1.05 m on the west coast under the A2 scenario.

More wind

There is a tendency towards more powerful storms in Denmark. Since 1971 there have been 14 hurricanes and hurricane-like storms, as many as in the preceding 80 years. In the long term, the average wind speed is expected to increase by 1%–4% under the three scenarios, while the maximum storm strength is expected to increase on both sea and land, most notably under A2, i.e. by 10%.

More extreme weather

Calculations with climate models show that increased greenhouse effects result in changes in the frequency, intensity and duration of extreme weather conditions. DMI's calculations show, for example, more and longer-lasting heat waves and increased wind strength during the strongest storms. It is noteworthy that all three scenarios result in about the same extreme downpours, which are expected to be about 20% stronger than today.

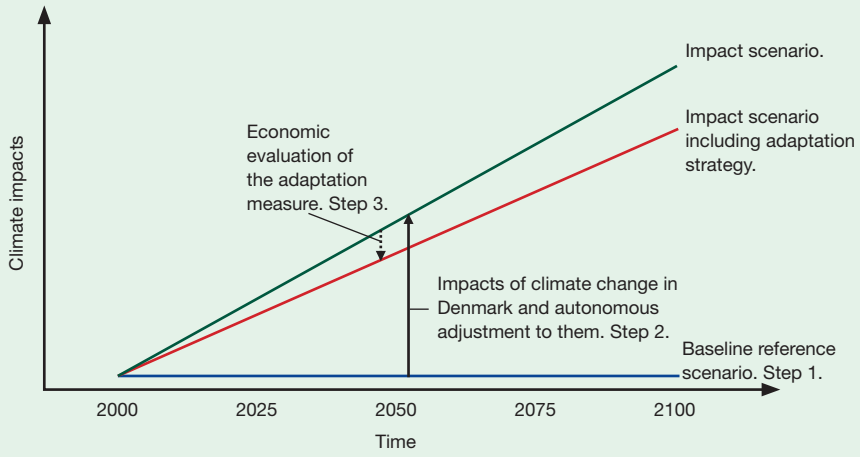
3. Challenges in individual sectors

Future climate changes will – even with a global effort to reduce greenhouse gas emissions – necessitate local measures to mitigate their consequences and help take advantage of any benefits. The government emphasises that adaptation to climate change should be autonomous as far as possible. This means that authorities, businesses and citizens react to the impacts of climate change in time within the given legislative, economic and technological framework. In cases where autonomous adaptation is not the best solution, there may be a need to implement politically planned adaptation measures.

A given impact from climate change poses a specific problem in the form of a need to come up with an adaptation. Adaptations are divided into two types: autonomous and planned, the latter based on new central policy decisions.

Planned adaptation measures must be compared with a reference scenario with the expected climate impacts and autonomous adaptation. As a baseline, the reference scenario is set out without climate effects (step 1), after which the expected climate impacts, including autonomous adaptation, are added to the reference scenario (step 2). The reference scenario including climate impacts forms the background for an estimation of the extent to which the planned adaptation measures will give socio-economic benefits compared to solely autonomous adaptation (step 3).

Illustration of climate change adaptation's three steps



Autonomous adaptation is characterised by the individual consumer's, producer's and public authorities' reactions to the physical climatic consequences within the given legislative, economic and technological framework. The planned measures can also be of very different character, ranging from new infrastructure to guidelines and information.

This strategy focuses on what will be attainable in the individual sectors within the next 10 years. By "attainable" is meant that a measure should be scientifically, technically and socio-economically appropriate for implementation within the given period.

In this chapter the 11 sectors in which climate change may be significant are reviewed. As far as possible each sectoral section is built upon six overall parts. The first part describes the **challenges facing** the sector. Next **the autonomous adaptation** already taking place is described as well as further adaptation expected within the applicable regulations and legislation. This leads to an assessment of the need to **change legislation or regulations** to ensure effective autonomous and planned adaptation in the longer term. Where possible, examples are given of specific **proposals for planned changes in extensions/renovations** to illustrate the scope of the future adaptation effort. Various measures give rise to a natural need for a **targeted information campaign** with examples intended to inspire other stakeholders facing similar challenges. Finally, every sector is rounded off with an evaluation of the need for more detailed **socio-economic analysis** to quantify the consequences of the suggested measures. These analyses will constitute an important part of the future decision basis for implementing measures, the main purpose of which is climate change adaptation.

Adaptation is a long-term process marked by uncertainty regarding what consequences climate change will bring, and how soon. At present there is no available basis, including socio-economic analyses, for decision-making on cross-sectoral government measures in this area.

3.1 Coastal management, dikes, ports etc.

Higher sea levels and stronger storms with higher storm surges are expected. This means a higher risk of flooding and more erosion along many stretches of coast. Since the strongest storms will come from the west, the increased risk of flooding and erosion will vary widely from the west coast of Jutland, to the Wadden Sea tidal areas and to the interior shores of Danish waters. Moreover, new waterfront construction, port-related operations and sanding up of harbour entrances will pose special problems. Cities located at river mouths at the bottom of fjords may face a very complex set of problems, since they can be under pressure from higher sea levels, increased precipitation and runoff, as well as changes in groundwater levels.

The opportunities for continuous climate change adaptation are generally good, and in some areas are already underway. Where coastal erosion is countered by regular beach nourishment with sand, individual site owners just increase the amount of sand to correspond to actual needs. The same applies to channel dredging, where the amount dredged can be increased as required. Also in the case of reinforcing dikes/dunes or adapting harbour installations and ferry berths, which are relatively simple constructions, it will be possible for individual owners to adapt to ongoing climate changes.

Breakwaters lessen sand erosion and ensure beach access for the disabled. Rising temperatures will mean longer swimming seasons, but also more algae in the water. Photo: Danish Coastal Authority

Generally speaking, it is individual land owners' own choice to protect themselves from flooding and erosion. Therefore, there are no general laws or regulations stipulating protection, or to what degree owners must protect themselves. However, the Danish Coastal Authority will recommend minimum heights for building footings and dike heights upon request. These figures are determined in consultation with the Storm Council, and compliance with them is one of the prerequisites for compensation for flooding losses from the Council. The recommended heights now include an addition for future sea-level rise.

With respect to new construction or renovation of dikes, coastal protection or harbour installations, it is important to consider how many years' climate change should be included in the basic design, since these installations have a lifetime of 50 –100 years, and the climate is expected to change dramatically in that period. It is also important to consider whether it is possible to accept the reduced safety of dikes and other high water protection resulting from climate changes or indeed whether to give up dikes or coastal protection altogether and return to a more natural coastline with more frequent flooding and natural erosion. No matter which solution is chosen, any emergency or storm surge measures should be adapted to existing conditions.

As a basis for choosing an approach, there should be specific information about future development and changes in climate. This means, for example, average water levels, extreme water levels and subsequent coastal erosion. In the case of public installations, it is also important that, after a decision has been made, information is provided about how information about climate change affected the decision. It is important that the chosen lifetime of the installation be announced and the rationale for it.

Aside from beach nourishment and channel dredging, other adaptation measures will require socio-economic analysis of the degree to which the coastal area must be adapted to future climate change and how such adaptation can be effected.

3.2 Buildings and infrastructure

Buildings, roads, railways and sewers will each be treated in a separate section because the climate change challenges they face differ widely.

Buildings

A great deal of the infrastructure value of society lies in buildings. About DKK 120 billion is spent on construction each year. Public spending constitutes 15–20% of this. Buildings can be vulnerable to climate change, which can increase the risk of collapse, declining health and significant loss of value as a result of more storms, snow or subsidence damage, water encroachment, deteriorating indoor climate and reduced building lifetime. The greatest challenges in the short term are that stronger storms will constitute a safety risk in those parts of existing buildings that do not meet the building code's safety requirements. In addition, the risk of collapsed roofs from snow calls for reconsideration of snow-load standards. In the longer term, more and longer-lasting heat waves could have health-related consequences, especially for the elderly and weak, in nursing homes, for example.

Autonomous adaptation must be expected with regard to limiting snow-load and storm damage as well as controlling indoor climate in particular. With respect to strengthening existing buildings, however, ad-hoc adaptation will be limited if owners are not familiar with weaknesses in the bearing elements of their buildings. Autonomous adaptation will only occur in new construction if those who set the European and Danish wind load standards determine that these standards be increased, for example. As for counteracting consequences of heat waves, installation of air conditioning in existing buildings could be expected, along with a demand for buildings with more efficient indoor climate control.

In general, it is the responsibility of individual building owners to see that applicable regulations are complied with, and it is also they who will seek solutions for satisfactory indoor climate. It is estimated that there is no need, in the short term, to change the laws pertaining to building safety under extreme weather conditions. As for countering heat waves, the new regulations regarding the energy framework in the building code represent a step towards promoting solar screening and heat-deflecting windows, which will make it easier to regulate indoor climate.

To ensure reasonable standards of energy efficiency, noise and other environmental loads from small, individual, spontaneously-installed air-conditioners, a compulsory labelling regulation can be introduced.

No special, planned measures are recommended for building extensions or renovation.

As support for ongoing adaptation, there may be a need to inform owners of existing buildings of the typical weaknesses in the bearing elements, with corresponding instructions on how to remedy them. In the same manner, there may be a need for instructions on new building solutions to reduce indoor temperature extremes during heat waves, especially for vulnerable buildings. Finally, there may be a need to inform construction technicians of recommended future-oriented design parameters, for example, concerning maximum snow load and wind speed, temperatures and durations of future heat waves and the maximum precipitation intensity a building should withstand.

There may be a need for economic analyses as a basis for measures in the two main areas named above. Uncertainty in such analyses comes partly from doubt about the significant climate parameters and partly from lack of knowledge about the costs of taking given changes into account. There is a lack of knowledge of how many existing buildings would be damaged as a result of increased storm activity, the types of damage and the cost of prevention.

With regard to cooling, there is a lack of knowledge of how far the ongoing adaptation will go and which solutions the market will offer and owners will choose.

The increasing risk of heavy downpours will put great pressure on sewers and roads. New road regulations will help ensure more effective drainage systems. Photo: Jesper Balleby/Jyske Vestkysten.

Roads and railways

Roads, bridges, tunnels and railway lines will be vulnerable to increased precipitation, groundwater levels, temperatures and winds. Electrified railway lines may face increased wind damage with great economic and traffic consequences as a result of stronger storms and higher wind speeds. The electrical power units themselves are vulnerable to higher wind speeds.

Undersized drainage systems in and along roads will lead to accumulation of water on the roads' bearing layers, which will reduce their bearing capacity and effective lifetime. Inadequate drainage during intensive precipitation is also a significant safety risk due to aquaplaning of vehicles and it results in reduced accessibility due to road closures.

On the basis of expected climate developments, the road sector therefore decided to implement by 1 April 2008 the Waste Water Committee Report no. 27: "Functional practice for drainage systems during rainfall", which is also used by the municipalities in connection with sewer design. Moreover, an analysis is underway of the conditions that must be identified before a revision of road regulations and instructions for invitations to tender for drainage work, which will prevent damage that intense precipitation would otherwise inflict on roads.

Higher groundwater levels associated with extreme precipitation will mean an increased risk of landslides on excavation slopes. There is a risk that the bearing capacity of bridge and tunnel foundations, supporting walls and sheet pilings will be reduced by increased groundwater levels. This can be a great problem, especially for foundations on sand.

For railways, higher groundwater levels mean an increased risk of erosion of track cuttings and embankments. Modern safety installations are significantly more sensitive to temperature increases than older installations and this presents a particular problem.

Autonomous adaptation to climate change is important because of the complexity and long lifetime of roads and railways. An exception is safety installations, which may be heat-protected in the course of 1–5 years. Furthermore, improved maintenance in the form of cleaning existing road drainage systems can retain drainage capacity corresponding to that of a new installation.

Road regulations and railway standards must be reviewed and revised in accord with the expected climate changes.

In connection with the expansion and renovation of roads and railway lines, adaptation to climate change is expected to be at the same time as work is carried out or preparatory work will be carried out for adaptation at a later time.

An information campaign should be directed at the municipalities responsible for smaller roads. It is also important that the way climate change has influenced any decisions made in connection with new construction or renovation of roads and railway lines is explained. The chosen lifetime for an installation should be described, as well as how climate change was accounted for in the decision.

It is expected there will be a need to undertake a large number of economic analyses to be able to optimise the timing and extent of road and railway adaptation to climate change.

Sewers

Public sewer renovation now costs about DKK 1 billion annually, and this is financed by user payment. Sewers have a lifetime of 50–100 years. More and heavier extreme rainstorms will cause increasing flooding of land and cellars. In addition, more and heavier precipitation means a lowering of water quality in waterways and lakes and a lowering of bathing water quality from rain-provoked discharges from treatment plants and sewer system overflows. This may also mean a risk that the objectives of the EU Water Framework Directive and the Bathing Water Directive will not be met.

The long-term outlook for autonomous adaptation of sewers is good. Adapting to heavier rains is a marginal cost if done in connection with sewer renovation. Most municipalities already take advantage of this possibility by following the recommendations in the Waste Water Committee's *Report no. 27*, namely that sewer systems, including treatment plants, meet established functional standards, taking into account the expected changes in precipitation, throughout their lifetimes. The requirements in the Report state: "In common sewerage areas surface flooding may occur no more often than every ten years. In areas with separate sewerage, flooding may occur no more often than every five years."

There may be a need for planned adaptation with respect to meeting the Water Framework Directive's environmental objectives. In this context, water planning should include an evaluation of whether special measures are needed as a result of increased flow due to changes in precipitation. The action plans will be drafted in 2009 and evaluated every six years. It will therefore be possible to take climate change into account continuously. For climate change in relation to the Water Framework Directive, see also sections 3.3 Water supply and 3.7 Nature management.

It may also be necessary to plan adaptation with an eye to being able to foresee the occurrence of deteriorating bathing water quality as a result of microbiological pollution caused by rain-provoked discharges from treatment plants and rain-provoked overflows from the sewer systems. Planned adaptation could include treatment of wastewater discharge to reduce its micro-organism content.

The current rules for bathing water must be amended in accord with the Bathing Water Directive. The above problems are expected to be solved to a certain degree by the new bathing water regulations, by means of bathing prohibitions, warnings or improved cleaning of wastewater. Adaptation to climate change will to a certain extent be possible in connection with sewer renovation. However, it must be noted that an increase in sewer dimensions, all things being equal, increases the risk of overflow from the system.

Individual municipalities may implement information campaigns to inform residents and businesses of the precautions they should take to minimise the extent of damage in the event of flooding. The Danish Environmental Protection Agency published guidelines in 2007 giving municipalities some new tools for thinking across the usual municipal sectors when climate change must be taken into account in connection with construction and operation of sewage systems and sewer renovation. During heavy precipitation events municipalities must issue warnings and information concerning deterioration of bathing water quality.

It is being considered whether payment regulations can be changed to give property owners greater motivation to undertake alternative surface-water drainage methods, such as percolation. For example, this could be done by changing the calculation method of the water drainage fee, so that in addition to the cubic-metre-dependent contribution a fee is charged on the basis of the size of the connected area (roof surface and other paved surfaces). The economic consequences the effects of extreme precipitation on bathing water quality are not included in the new Bathing Water Directive.

3.3 Water supply

Changed precipitation and distribution with a moderate increase in winter precipitation and a small decrease in summer precipitation could affect groundwater formation and the need/possibility of water extraction. Greater winter precipitation could bring about greater groundwater formation and increasing groundwater levels. On the other hand, drier summers and reduced flow from watercourses in the summer period could limit the possibilities of groundwater extraction, especially with regard to impacts from low additions of water to the groundwater from watercourses during the summer.

Autonomous adaptation to climate change will occur when it is not possible to maintain water levels in watercourses and wetlands while at the same time maintaining water supply. In such cases, autonomous adaptation can take place by moving water extraction to areas where water resources are more abundant or the effect on watercourses and wetlands is less.

A reassessment of permits for water extraction to comply with water provision targets and watercourse quality is not expected to result in amending rules, guidelines, etc. It will be possible to include this in ongoing activities.

A precondition of a planned relocation of water extraction will be that goals are set so that it is possible to determine 1) the quality and quantity of water extraction to be relocated and 2) in which areas this will be possible. Such a gradual adaptation of water extraction should start at the earliest after 2009, when the first generation of water plans under the Water Framework Directive must be drawn up.

Planning and reassessment of permits for water extraction will be undertaken by the municipalities, the national environment centres, water suppliers and to a certain extent the regions on the basis of the existing regulations. Therefore, information campaigns may be relevant with respect to these stakeholders.

Relocation of water extraction could bring a socio-economic bonus, inasmuch as the population will be ensured drinking water. Nothing has been decided about final financing, but it is expected to be possible within the existing framework.

Lack of groundwater, especially for supplying the large cities in the summer half-year, may in the long term (after 2030) necessitate reassessment of the socio-economic consequences of the Water Framework Directive. Furthermore, there may be a need to amend the regulations for irrigation with respect to nature's need for water.

3.4 Energy supply

Every Dane uses on average 155 gigajoules of energy annually. About 85% of energy consumption is derived from fossil fuels, the remaining 15% comes from renewable energy sources such as biomass, waste and wind. Energy consumption for heating, in particular, fluctuates with the winter temperature. From a mild winter to a cold winter energy needs for heating can climb by up to 20%. Heating production plants are scaled to be able to handle such fluctuations without problem.

Climate change with higher average temperatures and higher wind speeds will affect energy consumption. A winter temperature rise of 2–3°C is expected to reduce heating requirements significantly. A rise in summer temperatures, on the other hand, could lead to increased cooling needs.

Increased wind speed can on the one hand lead to greater electricity production from wind turbines, but on the other hand, in storm situations wind turbines must be shut down to avoid storm damage. Increased precipitation in the Nordic region may lead to greater electricity production from hydro power. In contrast, longer periods of drought in the Nordic region may also provide better opportunities for Danish electricity exports.

Danish as well as foreign electricity distribution grids may be damaged by storm impacts. The Danish distribution grid is currently being cabled underground is expected to be fully cabled within the next 10 years. When the distribution network is fully cabled underground, the consequences of climate change will be less significant. Increased wind speeds are not expected to cause serious problems for wind turbines, since they are protected against extreme wind speeds.

Energy supply is characterised by a typical investment horizon of 10–30 years. Production plants can be adapted to new framework conditions and to a certain extent to altered climatic conditions. The existing energy production plants are relatively invulnerable to the climate changes expected in the next 20–30 years. Ongoing changeover and adaptation of plant capacities are taking place as required.

Short-term climate changes with slightly increased wind speeds are expected to mean slightly increased electricity production from wind turbines. This could increase investment in wind turbines and thus lead to expansion of this energy source. Meanwhile, it is expected that conditions such as fuel and CO_2 allowance prices for our alternative forms of electricity production will have much larger influence on the expansion of wind energy.

Higher average temperatures are expected to reduce the need for heating in winter and perhaps increase the need for cooling and summer. Therefore, using the district heating system to produce district cooling could be considered. In district cooling, the energy in district heating water is used to produce comfort cooling. In this way surplus heat from electricity production at combined heat and power plants in summer can be used as an energy source to produce cooling as an alternative to electrically operated air conditioning.

Establishment of district cooling is at present not directly included in the Heat Supply Act and therefore is not included in the public heat supply regulations. The Danish Energy Agency has, together with interested parties in the area, evaluated the prospects and possibilities for district cooling in Denmark.

The evaluation, which was published in a June 2007 report, concluded that district cooling could be relevant in large cities and business parks, depending on local conditions, but that potential energy savings from district cooling are relatively limited. A serious limitation to the expansion of district cooling is that the relevantregulations only allow for private, and not municipal, implementation. There are several examples of municipal district heating companies with great interest in district cooling.

The Energy Agreement that has just come into effect stipulates that municipally owned district heating companies be permitted to establish district cooling activities in companies financially separate from the district heating activities.

3.5 Agriculture and forestry

Agriculture and forestry are each given their own subsection, because planning of operations varies widely between the two.

Agriculture

Rising CO_2 concentrations and temperatures will make for a longer growing season, thereby enabling greater agricultural and horticultural productivity and the introduction of new crops and forms of production. However, this could also bring about an increased and altered need for plant protection based on altered disease and insect patterns and an increased need for fertiliser and the consequent risk of runoff into the water. Greater winter precipitation will increase the risk of nitrogen and phosphorus leaching into the aquatic environment and combined with higher water temperatures, this could mean a greater risk of oxygen depletion. Increased winter precipitation and rising water levels will in some places cause flooding or such high ground water levels that agricultural exploitation may be difficult to maintain. This may be the case along a number of fjords and watercourses. Higher summer temperatures and longer periods of drought may increase the need for irrigation of sandy soils, which may affect the flow in watercourses.

Short-term adaptation can aim at optimising production under given conditions. Long-term adaptation is expected to involve changes in agriculture's structure, technology and land use, irrigation systems, etc, as well as development and adaptation of new species and types of crops. Most adaptations may be undertaken spontaneously within the sector without overall direction and planning, but within the existing legal framework. However, this is presupposed that climate changes occur sufficiently slowly.

The impacts of climate change can be taken into account in the evaluation and reassessment of existing and forthcoming regulations (for example, evaluating the Action Plan for the Aquatic Environment III and the Pesticide Plan 2004–2009 in 2008) of agriculture's environmental impact, resource usage and basis, with respect to both the effects of observed climate changes over a period of at least 30 years and in relation to expected climate changes over a relevant period, depending on the character of the analysis.

Increased winter precipitation is expected to cause more frequent flooding of river valleys, which will create new possibilities for flora and fauna Photo: Gerth Hansen/Biofoto.

Research and development efforts are expected to support development and implementation of new forms of production and technologies that can contribute to exploiting the new possibilities for greater productivity while ensuring that agriculture can meet the requirements of low environmental impact and high food safety. Such research and development activity should take expected climate changes into account and incorporate new research areas relevant to climate changes.

Dissemination of the current knowledge on the nature and extent of climate changes for both the agricultural business and the associated research and consulting sector such as the administrative/political level will be important, so that relevant climate change adaptation measures can be incorporated in ongoing adaptation and regulations in the sector. It is important that research, development and consulting within the sector include awareness that changes in the basic climatic conditions mean that older data and experience should be used with caution.

Climate change and increased CO_2 content in the atmosphere up to 2050 are expected to increase the yield level of many agricultural crops by 10–15%. However, there will probably also be increased costs for fertiliser and pesticides. Increased yields may also be less than expected as a result of the need for increased restrictions on use of fertilisers and pesticides out of concern for nature and the aquatic environment.

There may also be restrictions on cultivation of low-lying areas and on irrigation in dry summers, which will reduce the advantages in these areas. Because of great uncertainty and lack of knowledge about the expected effects of climate change on the interplay

between agriculture and the environment, it is not at present possible to make a socio-economic calculation of these effects. Therefore there is a need for targeted research efforts into the effects of climate change on agriculture and the environment before a qualified economic calculation can be made.

Forestry

Higher temperatures, changed precipitation and increased storm risks will have negative consequences for a number of tree species and forest types found in Denmark. Some of the non-native conifer species will be especially vulnerable. Climate change can therefore mean unstable forests and forest death. All things being equal, this will cause loss of production and loss of the natural, landscape and recreational value of forests.

The long production time of a forest – between 50–80 years for conifers and 80–150 years for deciduous trees – means that it is already necessary to begin adaptation to climate change, regardless of the climate scenario. A number of national forest policy tools have been taken up to make forests and forestry better equipped to deal with climate change. Within this framework individual forest owners will optimise their own operations.

The Forest Act promotes sustainable forest management, inasmuch as it includes subsidy schemes aimed at private forestry, supporting the use of more robust hardwood species, well-suited provenances and cultivation of varied forests with subsidies for good, diversified forestry and afforestation, for example. Furthermore, in connection with granting support for afforestation after storm damage, provisions have been made that new forests must be cultivated with structures and species that can withstand high wind speeds. Therefore, it is deemed that there is no immediate need to change the regulations in this area.

Operation of public forests, which comprise about one quarter of Danish forests, is an important forest policy measure. Since 2005, the national forests have been undergoing a changeover to close-to-nature forestry, which includes greater use of better adapted tree species, assurance of genetic diversity and changing to stable forest cultivation methods. At the present rate, 50% of national forests will have converted to close-to-nature forestry by around 2050. The conversion will be reassessed within the next 10 years in light of new knowledge of climate developments, tree species, etc.

There is a need for an information campaign aimed at private forest owners to promote conversion to close-to-nature forestry.

Once there is greater clarity about the climate scenarios, there will be a need for analysis and reassessment of the effort to transform Danish forestry to close-to-nature management. Such analysis will be included in the reassessment of conversion of the national forests to close-to-nature forestry.

3.6 Fisheries

Higher water temperatures combined with increased precipitation and run-off from land, altered wind patterns and acidification of the sea will lead to changes in the structure and function of marine ecosystems. Some species will benefit from climate change while others will be limited in their growth and survival possibilities. Altered climate conditions can mean that endangered species and stocks will find it more difficult to survive. Salmon and trout, whose eggs and fry are found in streams, will be more vulnerable to temperature changes than other species. Warmer water can also promote the appearance of new types of disease-causing bacteria and toxic algae, which can threaten fish and shellfish populations and food safety. This also applies to marine aquaculture of rainbow trout. Ultimately, warming could mean the end of saltwater farming of rainbow trout in Danish waters.

The fishing sector is expected to develop new equipment, methods and types of boats concurrently with the altered fishing possibilities. Neither changes in the fishing fleet nor changes in land installations can be planned beforehand. This might result in more flexible investment strategies, for example, increased use of mobile processing plants.

Adaptation and development of new management systems could occur within the present international cooperation on fisheries management and marine ecosystems. For example, the present means of regulation with emphasis on quotas could prove insufficient for the management of some stocks, just as integration of new species could also mean there will be a need for other management methods and another type of biological consultancy.

To strengthen the knowledge base it will be necessary to develop updated tools (models and databases) that can be used to quantify and qualify the meaning of climate change for the sea's food chains, ecosystems and fish stocks and their sustainable exploitation.

Dissemination of the current knowledge on the character and extent of climate change for both the fishing sector and at the administrative/political level will be important, so that relevant climate change adaptation measures can be incorporated in both autonomous adaptation by the sector itself (for example, altered types of equipment and fishing methods) and regulations in the sector (for example revision of quotas).

There will be a need to undertake socio-economic analyses in several areas. Warming could bring about greater costs for rainbow trout farming through negative effects on the marine environment. Trout aquaculture cannot in the short term be replaced by other species. It will also be necessary to evaluate the economic situation in connection with converting the industrial fishing sector from its present dependence on North Sea sand eels, for example, and this problem also obviously affects other fisheries. Because regulation of the fishing sector primarily takes place in international cooperation, there will be a need to calculate the socio-economic consequences of adapting the regulatory system in order to maximise the yield of existing and future stocks under altered climatic conditions.

English Sundew is a typical raised bog plant. It is already in Denmark, which is close to the plant's southern limit. Climate change could put it in further danger of disappearing from Denmark altogether. Photo: Peter Brandt.

3.7 Nature management

Already now we can see how wild Danish nature is affected by climate change. This tendency may be expected to continue in pace with climate change. Types of nature, ecosystems and species are affected differently by climate factors, but we can generally distinguish between three types of climate impacts: 1) increased biological production as a result of higher temperatures and longer growing seasons; 2) increased nutrient load and thus increased overgrowth and oxygen depletion of Danish waters as a result of increased precipitation and changed precipitation patterns; and 3) increased erosion and flooding of low-lying coasts, tidal areas and river valleys as a result of sea-level rise, increased precipitation and altered precipitation patterns. The effects will generally mean that a number of nature types and species will be weakened, disappear or become extinct, because they do not have the possibility of moving to other areas or time to adapt. Ecosystems will be less stable and thus more vulnerable to invasive species, diseases and altered competition among species. Reaching established goals for nature and water quality will thus be challenging and demand a special effort.

Nature has a great capability of adapting itself, given enough time, space and diversity. Nature has always either adapted itself to altered conditions or succumbed. The context for nature's adaptation can be improved with a planned effort, for example in nature management, in spatial planning or in efforts in sectors that affect nature. In this way nature will become more robust and adaptable to climate change.

Adaptation to climate change in all sectors should take place with concern for nature and the environment. An evaluation should be made of whether the existing regulations for strategic environmental assessments (SEA) and environmental impact assessments (EIA) are sufficiently inclusive from the perspective of adaptation to climate change. Adaptation guidelines should also be drafted for users of these assessments. Moreover, it should be ensured that existing laws and regulations on use and protection of nature take the impacts of climate change into account.

A number of efforts in the nature management area of great significance for adaptation to climate change are already underway and should enjoy continued priority. This applies especially to: 1) conversion of selected river valleys to natural wetlands with extensive landuse and care according to an overall plan including adaptation to climate change among another of other considerations; 2) targeting of mechanisms in a number of areas, for example, preservation, Natura 2000 planning, water planning, nature restoration and subsidies to achieve better coherence in nature; 3) the action plan on invasive species, very soon to be published by the Ministry of the Environment, which includes analysis of efforts required in light of climate change and recommendations for preventative efforts, efforts in relation to known invasive species and a proposal for allocating tasks in implementing programmes.

The impacts of climate change on the condition of our wetlands will be continuously evaluated in light of new knowledge with respect to adaptation of the necessary efforts to fulfil established environmental goals, for example, the goal to maintain sufficient oxygen levels for marine ecosystems to function. The Water Framework Directive's relatively short time scale for evaluating fulfilment of environmental goals with respect to the long-term perspective on climatic effects provides a sufficient basis to be able to initiate an effort that will take climatic effects into account.

There will be a need for information and guidelines for municipalities on green corridors to use for planning as well as information for authorities and the public on invasive species and how we can ensure they do not gain a footing in nature.

There will be a need for economic analysis in a number of areas including: 1) the costs and benefits of promoting nature's own climate change adaptation through planning and regulating that will result in less fragmentation, ensured growth corridors and reduction of the number of existing stress factors, for example; 2) nature and environment-neutral climate change adaptation in sectors having significance for nature, for example agriculture, forestry and coastal management; 3) pricing a number of goods and services from nature that do not have a direct market value, for example, dilution of air pollution, water treatment and soil preservation, and models for calculating the socio-economic benefits and costs in nature management.

3.8 Land use planning

Increased precipitation, altered precipitation patterns and higher sea levels – with consequent higher water levels in fjords and rivers – will increase the problems associated with drainage of low-lying areas, particularly in coastal areas, where about 43 % of Denmark's population lives. The majority of Denmark's approximately 250,000 summer houses and 73 % of camp sites lie within 3 km of the coastal zone. Moreover, as increased volumes of water may result in landslides (for example roads, the chalk cliffs on Møn), which can affect various types of infrastructure. More powerful storms, especially in winter, can increase risks for people, buildings and installations, and can also increase the risk of flooding in low-lying areas. In general climate change can create both problems and possibilities that in the longer term can best be solved/exploited by conscientious planning of land use, for example by exempting certain areas from residences and other installations.

With rising sea levels and higher storm surges, houses on raised columns could be the future norm in coastal areas. Here is an example from Rømø, looking onto the Wadden Sea. Photo: Kuben Byg A/S.

Many municipalities are already underway with adapting their planning to the expected climate changes. This work should be supported and followed centrally, since it cannot be expected that municipalities, businesses and citizens themselves will be able to obtain and interpret relevant information on climate change as a matter of course. Private and public building owners will to a certain extent be able to adapt their decisions about building and construction work to the altered risks and possibilities that climate change will bring, if the relevant information is available. An important source of information is municipal planning, which should therefore always reflect and adapt to the risks and possibilities brought on by climate change.

The national authorities will continually evaluate whether there is a need to draw up requirements for municipal planning. This could, for example, be worked into "monitoring of national interests in municipal planning".

An important aim of national measures under planning legislation could be to limit building and construction in high-risk areas, where they could incur significant extra expenses for remedies, for example, coastal protection, dike construction, infrastructure protection or water pumping.

There should be measures to ensure that updated information on climate developments and relevant risk analyses – for example, illustrated on maps – reaches the municipalities at all times for use in their planning. Information should also be made available for citizens and businesses.

The EU Directive on the Assessment and Management of Flood Risks, which took effect in 2007, stipulates that this type of information must be provided.

Member States must by the end of 2011 indicate those areas thought to be at risk of flooding. The designation will be based on an interim estimate of flood risks, including as a result of climate change. For every designated area, maps must be made by the end of 2013 showing the flooding extent and the potential number of inhabitants that would be affected, potential environmental and economic damage, etc.

On the basis of these maps Member States must draft by the end of 2015 risk management plans for flooding and set adequate targets for managing flood risks.

Planning legislation is therefore an important means of reducing the negative socio-economic consequences of climate change. Regulations for the coastal zone already restrict new construction areas on open coasts. The responsible national authorities will continuously evaluate whether there is a need for a follow-up with further restrictions on new building in risk areas. Socio-economic analyses will be included as a part of the decision basis.

3.9 Health

Both climate and climate-related behavioural changes can be significant for health. More heat waves can mean a greater risk of sunstroke and dehydration, which in the worst case can be life-threatening. Especially the elderly, sick, and small children require extra attention, including in health planning. A number of infectious diseases are related to climatic conditions. Altered pollen production as a result of milder winters, etc., can mean that the number of people developing pollen allergies may rise, and the symptoms may worsen. Warmer summers will cause greater growth of toxic algae and some saltwater bacteria, which can pose a risk to people with weakened immune systems. In addition, warmer summers with more outdoor activity can increase the risk of bee or wasp stings and life-threatening allergic reactions to them. More extreme rain can lead to greater runoff of health-damaging substances and micro-organisms. There may be an increased health risk associated with exposure to mixed rain and wastewater on land and in cellars, for example. There may also be a need to clarify how long the land should remain unused before re-allowing access as a recreational area, for example. The combination of wetter winters, warmer summers and more extreme downpours may cause more moisture damage and mould growth in buildings as well as greater occurrence of dust mites in buildings, with the consequent health problems.

Health measures in regions and municipalities include responding to heat waves, which can be augmented by relatives and neighbours helping those in high-risk groups. Initiatives for increased monitoring of illnesses related to climate change are expected to appear as problems arise. Longer pollen seasons can increase the need for preventative medicine, including vaccinations and advice about behavioural changes with respect to minimising exposure to pollen. Other relevant sectors are expected to contribute to prevention and warnings concerning climate-related health risks, indoor climate problems, allergens, drinking water, recreational water, foodstuffs, etc.

Alteration of the monitoring system for infectious diseases related to climate change may include minor amendment of the Statutory Order on Doctors' Reporting of Infectious Diseases, etc.

An extension of public prevention and treatment programmes and monitoring systems may be relevant in connection with more heat waves, altered infectious disease patterns, increasing occurrence of allergies and accidents and any increased occurrence of skin cancer in the future climate.

With increasing winter temperatures and longer growing seasons, earlier blossoming is expected. The longer pollen season will increase the need for preventative and therapeutic medicine. Photo: Maria Mikkelsen.

Climate change may require reprioritisation or adjustment of information campaigns for the above areas directed to the general public and other groups in municipalities and health services, for example.

There may be a need for socio-economic analyses in such areas as:
- altered/increased monitoring and outbreak control and prevention and treatment of various infections, including those due to pests, insects and bacteria;
- diagnostics, prevention and treatment including vaccination and preventive treatment of pollen and house dust mite allergies and mould allergies.

3.10 Rescue preparedness

More frequent and dangerous storms, flooding, powerful rainstorms, drought, etc. create a need for more resource-demanding efforts and assistance from rescue preparedness.

Higher summer temperatures and long-lasting drought increase the risk of forest and wild fires. Manpower-demanding efforts from rescue preparedness during a wild fire at Stenbjerg Klint Plantage. Photo: Nordjyske Stifttidende/Klaus Madsen.

Rescue preparedness can be deployed in actions to prevent, limit and aid injuries and damage to people, property and the environment. Rescue preparedness can also assist in peak load situations, where other stakeholders with emergency responsibilities are not completely capable of dealing with the consequences. It could, for example, be a matter of draining surface water and other assistance with storm and water damage, extinguishing wildfires, rescue operations of various types and accommodating and caring for distressed and evacuated people. For this, continuous consideration and decisions are required with regard to procurement, development, maintenance, composition and strategic location of equipment.

Continuous adaptation in the form of improving equipment is already underway in many places, for instance, as a result of the hurricane of 1999 and subsequent episodes of storms, storm surges, heavy rains, drought, etc. Examples include pumps, support materials, portable generators, vehicles designed for use in flooded areas, stoppers for

sewers, special materials for use against wildfires, etc. This development is expected to continue in both national and municipal rescue preparedness on the basis of observed weather phenomena and expectations for the future.

Consequences of climate change for rescue preparedness also depend on emergency planning, prevention and implementation capacity in other sectors. According to section 24 of the Preparedness Act, individual ministers must plan within their domain for the maintenance and continuance of society's functions in the event of accidents and disasters.

The Danish Emergency Management Agency (DEMA) will continuously consider available knowledge on climate change and extreme weather activity in connection with material procurement for national emergency preparedness. DEMA's materials investment plans in the logistics area up until 2011 include recommendations to ensure that special vehicles purchased from now on are able to operate in areas with floodwaters of up to 120 cm. DEMA will also further develop its international assistance capacity in the coming years. This capacity may be used in national incidents, including extreme weather events.

DEMA will also contribute to seeing that knowledge about climate change and extreme weather events is taken into account in the risk-based designing of municipal rescue preparedness and planning. The process can, for example, be promoted through DEMA's guidance and consulting, inspection tours, courses and consultancy. Specific measures (procurement, etc.) in the material area are decided independently by the national and municipal emergency preparedness bodies. However, DEMA's authority includes a logistics coordination committee, which can ensure good dialogue, etc.

The above actions and others will contribute to proper material resources being ready in extreme weather events for the municipal emergency bodies, municipal support points, state regional emergency centres and volunteer centres (in Hedehusene and Herning). It should be emphasized that most of the material and equipment has a lifetime (10–15 years) that is shorter than the period before the more dramatic impacts of climate change are expected to occur. The planning horizon is relatively short, and future technological developments should be taken into account. It is therefore important to avoid potential mistaken investments; autonomous adaptation is considered more prudent than authority-driven planned adaptation over a longer time horizon.

3.11 Insurance aspects

Weather and climate effects are core insurance business areas. Insurance companies calculate the risk, set a price for covering it, then spread their own risk over the whole world through reinsurance and pay compensation for damage when it occurs. If the weather and the consequences of climate change become less predictable, the possibility of predicting damage is reduced and as a result price setting and reinsurance possibilities are reduced as well. In the worst case, price setting for insurance becomes impossible and then no one can take out a policy against "weather damage".

Insurance of buildings and personal property is by nature short-term – typically renewed annually, but the effects of global warming are more long-term. The Danish climate scenarios state that the highest water level can increase by up to 105 cm up until 2100, corresponding to a good centimetre per year. This means that the economic effects of sea level rise, for example, or more and stronger storms will be seen gradually in the accounts of insurance companies and, if the price of insurance is not adjusted before this happens, there will be a gradual cost increase in annual insurance premiums as a result.

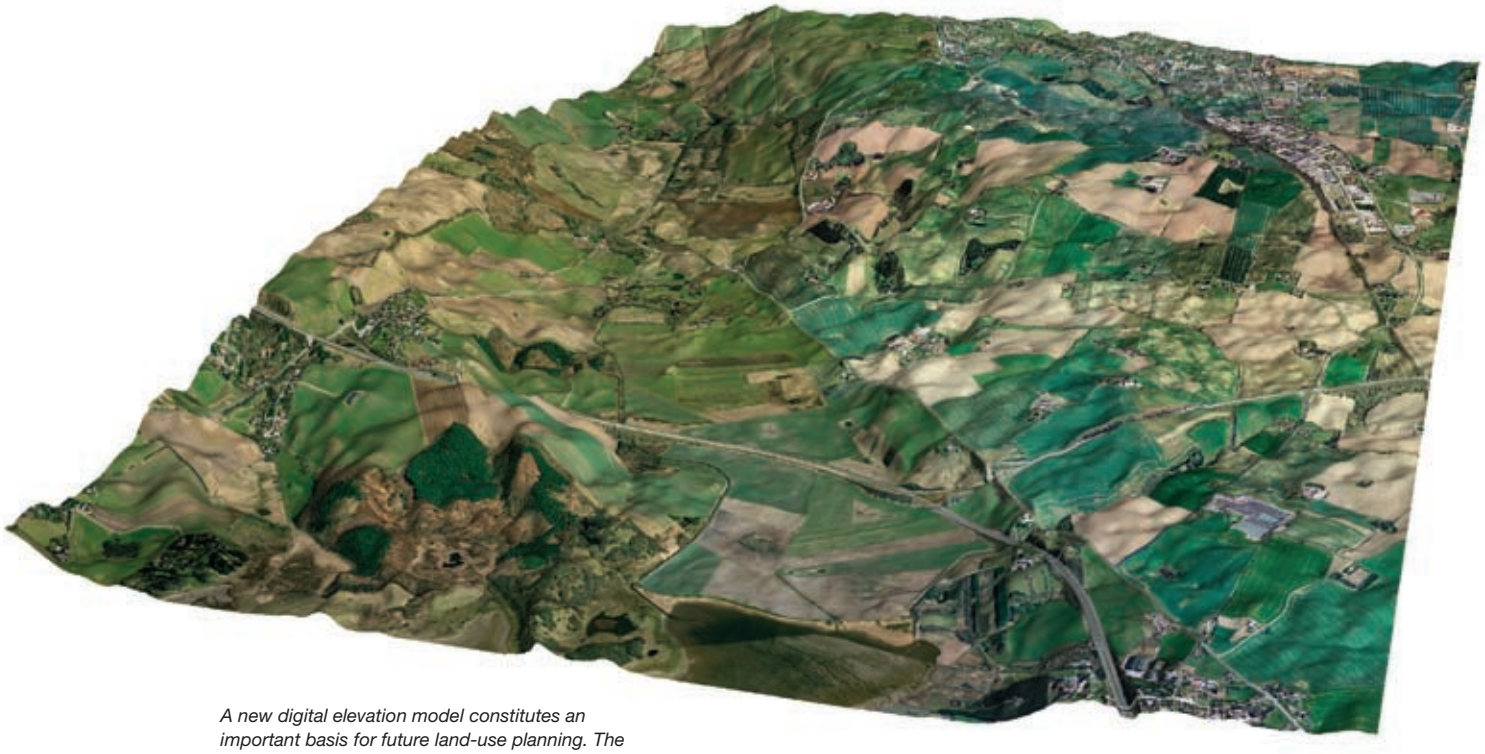
The insurance-related impacts of climate change (for example, higher temperatures, more frequent and stronger rainfall, more frequent and possibly stronger storms and changes in the general sea level) have not been subject to systematic research by Danish insurance companies. Internationally, on the other hand, there has been increasing awareness in recent years of the insurance-related problems stemming from climate change. At the same time, it can be noted that in its initial phases, the work has led to only few practical initiatives (for example, Insurance Scheme AquaPol in the Netherlands, which offers insurance coverage against damage caused by "rain storm").

Moreover, there are several preventive measures against weather damage. Therefore, there are countries in Europe that cover damage from flooding via private insurance policies, whereas other countries base their compensation schemes on greater public-sector involvement, and even though this does not affect the size of the overall damage, there are significant and decisive differences to be taken into account. For example, whether private insurance companies should have been able to price products and managing their economic exposure. This requires careful registration of damage and claims, which can be especially difficult to obtain, if claims are paid via taxes.

Stronger and more frequent storms and storms from other directions than previously known constitute another risk element. If the large international reinsurance companies are hit by claims from other parts of the world, this can be passed on to the possibilities of Danish insurance companies to reinsure Danish risks. Therefore the development of new financial instruments for risk transfer between several economic sectors is a possibility.

If insurance companies assume coverage of damage caused by climate change, this will appear in insurance policies. If the scope of exceptions is increased, it will be important to provide this information more widely.

The knowledge direct insurance companies and reinsurance companies have today about the economic impacts of climate change in the future is insufficient, and more relevant data and models for price setting are especially lacking. In this respect, premium-setting based on expected developments could come into play, and the development of new financial instruments of risk transfer could be realised. To the extent that insurance companies exempt coverage, it could become relevant in the long term to see damage in a societal context, regardless of whether it is covered by insurance or not.



A new digital elevation model constitutes an important basis for future land-use planning. The map shows lakes in blue and details of the landscape that can be flooded. Map basis and graphic: The National Survey and Cadastre.

4. Web portal for climate change adaptation

To give Danish society the opportunity to undertake timely adaptation to climate change - both autonomous and planned - it is important that easily accessible information be available on the expected climate changes under each of the selected climate scenarios. This will be ensured by introducing a climate change adaptation web portal with access to all information on climate change. As consideration of climate change adaptation measures will also require additional information, such information should also be placed on the portal.

4.1 Climatic and other types of data

Adaptation to climate change requires that the best possible information be available about future climate change. Climate changes are described with the aid of a number of climate variables, and since climate change also affects Danish waters, information must also be developed on future changes in oceanographic variables. Since many decisions about climate adaptation have a shared need for a number of other data, this shall also be made available on the portal.

The vast majority of decisions about climate change adaptation involve a particular locality. It is therefore important that data searching in the portal be based on a particular locality and give access to all the data concerning it. Thus a uniform, common geographical basis is required. In this way data may be effectively compared and used across geographic and administrative borders, which is of great significance to their usefulness in a climate change adaptation context.

Climate data

Climate data includes a number of measured statistics such as temperature, precipitation and wind, and analyses of this data such as the number of heat waves, duration of heat waves, length of growing season, evaporation, number of days with temperatures below freezing, largest quantity of precipitation over a given period, duration of droughts, groundwater data, extreme snowfall and highest wind speed. To this must be added measurements of runoff and pollen, for example.

If the future courses of these and other data are to be determined, the global climate models will have to be down-scaled. Thus, calculations must be made in much more detail in order to be usable at the regional and possibly local levels. Danish Meteorological Institute (DMI) and National Environmental Research Institute (NERI) have undertaken some of these calculations, but it is a job that must continue and be extended.

Groundwater data

Groundwater data is available today. On the basis of existing data and models, it is generally possible to illustrate the effects of climate change nationally, but not in local detail. The need for further development of groundwater models depends on what problem is to be examined and on what scale. Groundwater models can present a number of relevant variables, for example, groundwater levels and runoff data.

Oceanographic data

Oceanographic data includes measured quantities such as average sea levels, sea temperature, salt and oxygen content, surface current, storm surge heights and ice coverage as well as analyses in the form of 20, 50 or 100 year sea level occurrences, maximum ice coverage and significant wave height, for example.

In order to calculate future changes in oceanographic data, there is a need for a current model, a wave model and perhaps an ecological model. The wave model gives wave heights and duration of calm periods. The current model, aside from ocean currents, gives sea levels, temperature and salinity, thresholds between more and less salt water, ice conditions and salt flow into the Baltic. Nutrient salt concentrations and hypoxia are calculated using the ecological model.

Geodata

Geodata includes geographical data such as place names, buildings, roads, addresses and areas registered in the Cadastre. There is a need for several of these geodata in a long list of decisions based on climate developments.

Denmark has come a long way in accumulating this geographic basis for use in environmental, health, transport, agriculture and rescue preparedness. The geodata that are necessary in connection with the strategy for adaptation to a changing climate are therefore already found in national and municipal authorities.

In addition, a national-municipal cooperative public mapping project is underway, which will define the framework for a common geographic basis for goal-oriented public management. Operational organisation of the project is expected to be fully established in 2008. The aim is to have a common geographical basis covering the whole country by 2010.

Part of the geographical basis is a digital elevation model of sufficient precision and quality to become a reliable basis for designating risk areas associated with sea level rise. The government would like to make an improved digital elevation model available to the public sector. A new nationwide elevation model is expected to be accessible for the state and certain municipalities by the end of 2008.

4.2 Current regulation

Standards and guidelines for expected climate change are part of the continuous adaptation effort. The portal must include links to current standards and guidelines.

4.3 Samples and case studies

Many considerations of climate change adaptation will be repeated from municipality to municipality or within a given group of business people. Therefore, a number of examples of typical calculations or cases could be compiled and grouped together on the portal according to subject. An example of a case is given in box 1, below.

Analysis of flood risks in Aalborg and Roskilde

An example of a climate change adaptation measure that will recur in a number of municipalities is adapting drainage systems to the expected increase in precipitation intensity. The Danish Environmental Protection Agency has had analyses of flood risks in Aalborg and Roskilde undertaken to illustrate the problem. The project was primarily undertaken as a workshop with selected experts in traffic, green areas, urban planning and drainage systems from the two municipalities. The procedure provided a robust and action-indicative result. Among the principal conclusions were:

- If municipalities follow the recommendations for sewer size (Waste Water Committee, Report 27), climate change will be manageable within normal renovation/extension programmes. However, in most municipalities there are a number of hotspots that should be researched in more detail.
- Measures against flooding in cellars are optimally undertaken by individual site owners in the form of high water closures, pumps, etc.
- Municipalities must think broadly and horizontally so that the possibilities for new installations such as having recreational areas and leisure activity sites (parks, football fields, etc.) to serve a double function as temporary water reservoirs in connection with heavy rainfalls.
- Rising sea levels will be critical for most coastal cities, but this is not expected to occur in the next 10 years. Therefore focus should be on ensuring that urban planning in these areas takes long-term climate change into account.

4.4 Decision-support and economic analysis tools

Decisions involving future climate change are in principle not different from other decisions made on an uncertain basis. In any case, it would be natural to put paradigms of decision processes on the portal. A number of detailed examples from various sectors will also help illustrate the various phases of the process. On the whole, the portal will be built up as a tool, designed to guide the user through the whole process from understanding what climate change is, to being able to integrate its consequences into the decision-making process.

Since most decision-making processes will require a number of economic analyses , a catalogue describing a number of economic analysis tools and their possibilities and limitations will be placed on the portal.

4.5 Information on research and development

On the portal it should be possible to find information on the latest climate change adaptation research and development in Denmark and elsewhere. Articles and reports concerning completed projects should be available here and projects underway should be presented with a link to their websites, if possible.

A series of concrete climate change adaptation measures will be carried out over time. Information on these measures should be accessible on the portal and organised according to subject. Danish measures will be supplemented with descriptions of particularly interesting foreign climate change adaptation measures.

4.6 Implementation and coordination

The climate change adaptation portal is implemented through the Coordination Forum on Adaptation and operated by the information centre; cf., chapter 6. The portal is to be presented and developed to appear as a main entry for citizens, authorities, business people and specialists seeking updated information concerning climate change adaptation in Denmark.

5. Research strategy

Climate change will affect large parts of Danish society from now on. At societal level, there is a need for more and better information on climate change, how it affects us now and in the future, and above all how we will meet these challenges. It is therefore important that Danish climate-related research has strong and more professionally coherent research centres that can contribute to and coordinate the necessary knowledge on how we can best and most effectively counter climate changes. There is thus a need for a research strategy.

The goal of a research strategy for adaptation to climate change is to set focus on future research efforts in the area. At the same time, the strategy should illustrate how research can strengthen Danish society's possibilities of adapting to climate change.

5.1 Danish climate research

Climate research, including research in climate change adaptation, encompasses a long list of very different problem areas. The research is often cross-disciplinary, drawing on knowledge from several disciplines. Climate research in Denmark can be roughly divided into five main areas, across the traditional disciplinary lines:

- Basic background knowledge
- Consequences/effects of climate change
- Adaptation to climate change
- Mitigation of anthropogenic climate changes
- Robustness, uncertainty and synthesis.

Research in the areas of *basic background knowledge* and *consequences/effects of climate change* often has a basic science character, and deals with understanding the climate system, ecosystems' structure and function in relation to climate variations, and the general climatic and environmental consequences of increased greenhouse effects.

In the area of *mitigation of anthropogenic climate changes*, research often has a more sectoral character, aimed at finding methods and techniques for limiting climate changes primarily in relation to energy systems and general energy savings. Research in robustness, *uncertainty and synthesis deals* with the realism of climate scenarios and their applicability, which is highly significant for developing solutions for climate change adaptation.

Research in *adaptation to climate change*, which is the hub of this strategy, covers a very wide field of problem areas. The research is often aimed at developing techniques and methods to avoid negative effects of climate change – and to exploit any positive potential. It can, for example, deal with developing drought or flood-resistant plants, protecting buildings during extreme storms or developing new methods of coastal protection. Adaptation research often has an additional characteristic compared to research that otherwise takes place in relevant research areas, for example, public health.

That is, the adaptation question is often integrated into other research or is included as an extra dimension. Moreover, adaptation research also includes developing methods and tools for evaluating the socio-economic consequences of adaptation initiatives and strategies and developing management tools.

In many cases there is a significant overlap between the five research areas. By the same token, in certain cases there is great inter-dependency among the research areas, i.e. the knowledge produced in one area is often a prerequisite for research in another area. This has been the case with research in adaptation to climate change, which is highly dependent on research in the other areas. Research and adaptation to climate change is in many cases based on assessments and models of future climate and developments, including assessments of uncertainties in predictions.

5.2 Focus on climate and climate changes

Over the past 20–30 years there has been a growing research interest in the climate question. This has resulted in development of a number of well-functioning and strong Danish research centres that have contributed knowledge about the climate, climate change, energy savings and new technologies, but have only concentrated on adapting Danish society to future climate change to a much lesser degree .

In a number of areas the research efforts have contributed significantly to understanding the climate problem nationally, regionally and globally. An analysis from 2003 shows a total of 189 full-time researchers and 63 Ph.D. students employed in Danish climate research.

Financing climate research

A significant portion of research in the area of climate has been financed through the research institutions' basic appropriations and private funds and grants from EU research programmes. In pace with the increased focus on climate change, a number of possibilities have opened up for obtaining support for climate-related research through a wide range of research programmes/funds (see the box below).

Research programmes and funds are in most cases not narrowly directed at the climate area, but allow individual researchers and research groups to obtain support for climate research. This was the case for the thematic strategic research programmes in health, environment, energy, fishing and agriculture, for example, that were established in connection with a 2006 agreements on the Globalisation Council's funds. In the same way, there are a number of research councils and programmes that also provide support for climate-related research. Another example is the thematic focus on ocean research under the Danish Council for Strategic Research, which supported research into the effects of climate change on marine ecosystems and population developments.

Research programmes and councils relevant to Danish climate research

The Danish Councils for Independent Research:

The Danish Natural Science Research Council covers research aimed at basic scientific questions in the natural sciences. In 2006 it supported the Galathea expedition's projects on the carbon cycle, for example.

The Danish Research Council for Technology and Production Sciences supports basic research in technology and agricultural production, and has in recent years supported several climate-research projects.

The Danish Council for Strategic Research:

Maritime environment research: In 2007, DKK 20 million was designated for marine environment research in 2007/2008. There is focus on the significance of human activity and altered climatic conditions with respect to the marine environment's physical, chemical and biological state.

Environmental technology: In 2007, DKK 32 million was designated for environmental technology research. In the area of climate there is focus on research into mitigating anthropogenic climate change in the form of developing environmental technologies that can help reduce emissions of the most important greenhouse gases.

Water as a resource and element of nature's cycle: For 2007/2008, DKK 52 million has been allocated for research that may be relevant to climate research. This includes research into controlling and managing drinking water, industrial water and waste water, controlling extreme water conditions (storm surges, floods), hydrological models, process technology, sensor and IT technology for gathering and transmitting field data, etc.

Healthy and safe food: In 2007, DKK 39 million was allocated. Areas of focus include infectious diseases in human beings and other animals (including combating infectious diseases).

Ministry of Food, Agriculture and Fisheries:

One of the areas of activity under the Food Research Programme 2006 focuses on research aimed at climate change adaptation in agriculture. The part of the programme known as "climate, agriculture and environment" has been allocated DKK 32.8 million over a four-year period.

The Basic Research Fund

Supports the creation of basic research milieu of a high international class. In 2007, the Fund supported the Center for Interglacial Climate with about DKK 50 million.

Greater climate research efforts

In recent years a number of initiatives have been taken to strengthen Danish climate research. These include creation of a DKK 50 million basic research centre at the Niels Bohr Institute (see the box above). In addition, in connection with the International Polar Year, the government has allocated DKK 60 million to a series of research projects. An important part of the Arctic research is connected to the climate. It must therefore be considered likely that a significant portion of these research funds will be used in climate-related research.

Under the Food Research Programme 2006, about DKK 20 million was allocated at the start of 2007 for a number of specific climate-related research projects. For example, support was given to a number of research projects looking into the effects of climate change on the functioning of cultivation systems. Moreover, there are research funds allocated through the various research councils and programme committees, as well as from universities' and sectoral research institutions' own basic funds.

Limited focus on climate change adaptation

Even though in recent years there has been a growing focus on climate change adaptation in the public debate, the greater part of research efforts up until now have been directed at understanding and describing the impacts of the changing climatic conditions. There has been only limited focus on solutions to the specific challenges connected with future climate change. A 2003 survey showed that only 2 % of climate researchers were involved in climate change adaptation. The background is obvious: their research efforts in the first phase have been aimed at understanding and describing the background for climate change and highlighting the effects of climate change on nature, basic resources, the environment and Danish society. Meanwhile, there is a need for climate research to also contribute knowledge and ideas that can strengthen Danish society's ability and possibilities for meeting the challenges of climate change adaptation.

In this context several accounts and surveys of Danish climate research point to two particular challenges for Danish adaptation research.

First, it is necessary to develop modelling tools for socio-economic evaluation of climate change adaptation measures. A 2006 survey, which looked at the need for adaptation research, showed that we do not now have the necessary knowledge to assess and compare the various needs for action in the area of climate change adaptation.

Second, as also indicated by the 2006 survey, there is a need for a greater effort with respect to coordinating and knowledge-sharing in Danish research milieu. Danish climate research is characterised by many relatively small stakeholders, and includes such diverse research centres that there is a special need to coordinate efforts among them. The result is that in many cases research efforts seem uncoordinated and the potential for synergy among research milieus is not being exploited to the full. At the same time, the possibilities of obtaining sufficient critical mass are limited, which is significant for participation in larger research projects or the possibilities of obtaining support from foreign research programmes. There is therefore a need to organise the adaptation area, in order to ensure increased knowledge-sharing and coordination among the various research centres.

The government will therefore launch initiatives to:

- create a coordinating unit for better coordination and knowledge-sharing among the various milieus, and
- stimulate development of modelling tools for socio-economic evaluation of measures in the climate change adaptation area.

5.3 Implementation and measures

Coordinating unit for research in climate change adaptation

There is a need to strengthen coordination and knowledge-sharing in adaptation research. Therefore an overarching coordinating unit should be established to ensure that the research milieus coordinate their efforts to a greater degree and draw on existing research results and data as well as foreign research results. The goal is to promote cooperation and knowledge-sharing among the research centres.

NERI/Aarhus University has already initiated and financed the coordination body in 2008. The activity will be continued and developed in cooperation with DMI on the basis of support from the Danish Council for Strategic Research. A coordinating unit will organise the work in cooperation with the horizontal Coordination Forum for Climate Change Adaptation; cf. chapter 6.

In the long term, the goal is that under the auspices of the coordinating unit, a number of horizontal research efforts will be established, including with respect to participation in the EU Seventh Framework Programme (FP7). A coordinating unit must also contribute knowledge and an overview of which research needs are especially important to climate change adaptation, and where there is a need for a special effort. In this context, the unit can contribute knowledge on the needs for climate and climate adaptation research with regard to prioritising future strategic research initiatives.

The goal should be to place greater priority on climate change adaptation in the Danish research world. It is important that climate change research is not limited to a small number of specialised climate research centres. Climate change adaptation must be integrated into a series of other research disciplines, and be included as a natural part of overall climate research.

Development of socio-economic modelling tools for climate change adaptation

Socio-economic modelling tools can contribute important input in connection with evaluating proposals for climate change adaptation measures. It is a question of both the extent of the effort and its timing. Modelling tools can contribute to clarifying and illuminating the consequences of future measures in the climate change adaptation area. The tools must thereby help strengthen the basis for political decision-making so that choosing and prioritising among various measures including the timing of their implementation is done on a qualified economic basis. Socio-economic analyses should furthermore be used to evaluate already-implemented measures.

There is a need to develop and refine existing methods of analysing climate adaptation measures, including with respect to their timing, managing risks and uncertainties, and inclusion of nature-values. In recent years a number of Danish value-setting studies have been undertaken of yields from the environment and nature. It is important to continue to make value-setting studies, so that wider breadth is obtained with respect to types of these yields from the environment and nature and geographic location.

Managing risks and uncertainties associated with socio-economic modelling tools is an area in need of further research. This is especially relevant in the adaptation to climate change area, which is marked by great uncertainty and very long time horizons.

It is likewise important that autonomous adaptation be taken into account in setting basic scenarios, including clarifying the difference between autonomous and planned adaptation, so that it is possible to distinguish better between the status quo scenario and action scenarios.

Under the auspices of the Danish Council for Strategic Research, therefore, funds will be set aside for developing socio-economic modelling tools for adaptation to climate change. The research must aim at developing decision-making tools and criteria that can increase the level of knowledge about the consequences and economic effects of various climate change adaptation measures and strategies.

6. Organisation of further work

With this strategy for climate change adaptation, the government is proposing to gather all sector interests concerning the task. Therefore, it is proposed to create a coordination forum with an information centre acting as a secretariat, to further develop or implement initiatives from the coordination forum. To strengthen cooperation in knowledge-sharing within research on climate change adaptation, a unit will also be created to coordinate and communicate such research together with the established knowledge centres.

6.1 Coordination Forum on Adaptation

A Coordination Forum for Climate Change Adaptation will be created to ensure a common basis and cooperation and coordination across sectors and authorities. All relevant state authorities and one representative from the municipalities, regions and coordinating body for research, respectively, will participate in the Coordination Forum.

As a starting point, it is expected that a minimum of two annual meetings will be held in the Coordination Forum. The Coordination Forum's main duties will include:

- monitoring national and international developments with respect to climate change;
- monitoring other countries' experience with adaptation to climate change;
- monitoring national and international research on adaptation to climate change;
- contributing to the creation of a professional network;
- contributing to active information dissemination and knowledge-sharing with relevant authorities, business people and citizens;
- reporting to the government on the implementation status of the government strategy for adaptation to climate change; and
- participating in the designation of areas for efforts and advising the government on the need for implementation of adaptation measures.

However, the ongoing ministerial responsibility will continue to lie with the individual sector ministries, which are responsible for implementing the relevant initiatives. Existing decision-making procedures will not be changed since the Coordination Forum will not make decisions of a binding character.

6.2 Information centre on adaptation

To ensure that the Coordination Forum's initiatives are implemented, it is proposed that an information centre for climate change adaptation be established as its secretariat. Since the Ministry of Climate and Energy has general responsibility for Danish climate policy, the information centre will be placed here.

The information centre's main responsibilities will include:

- carrying out initiatives agreed in the Coordination Forum;
- drafting a communication strategy;
- communicating the government's strategy for adaptation to climate change;
- communicating general knowledge about adaptation to climate change with reference to the respective sectors for specific knowledge on the subject;
- communicating general results from research in climate change adaptation with reference to the respective sectors for specific knowledge on the subject;
- establishing and operating a climate change adaptation web portal;
- knowledge gathering and communication via participation in national and international meetings;
- reporting Danish climate change adaptation efforts internationally; and
- serving as the secretariat for the Coordination Forum for Climate Change Adaptation.

As can be seen, one of the information centre's main duties will be communication, with the climate change adaptation portal occupying a very central position. When the portal has been set up, it should appear as a place where citizens, authorities, business people and specialists can find updated knowledge on adaptation to climate change with the necessary links to climate data, oceanographic data, groundwater data and geodata that will be made available by the various sector institutions. It is important that the knowledge centre and portal use an identical common geographic basis for all data. In this way, it will be possible to compile data efficiently and use it across geographic and administrative borders.

6.3 Coordinating unit for research in adaptation

There is a need for research in climate change adaptation to be more coordinated across research centres so that a synergy effect among ongoing and new projects is obtained. The goal is therefore to promote cooperation and knowledge-sharing among the separate centres. Therefore, a coordinating unit for climate change adaptation research will be created.

The coordinating unit's main duties will be:

- supplying authoritative climate data and impact data and specific climate research results of significance for climate change adaptation to the climate change adaptation portal;
- coordinating climate change adaptation research in Denmark;
- following up on achievements and results;
- status reporting to the Coordination Forum for Climate Change Adaptation; and
- participating in national and international meetings.

The coordinating unit, within this framework, will arrange the work in cooperation with the Coordination Forum for Climate Change Adaptation.