The
Federal Government

German Strategy for Adaptation to Climate Change

adopted by the German federal cabinet on 17th December 2008

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Summary

The German Adaptation Strategy (**D**eutsche **A**npassungs**S**trategie, DAS) creates a framework for adaptation to the consequences of climate change in Germany. This strategy primarily represents the contribution of the Federal Government and thus provides guidance for other stakeholders. It lays the foundations for a medium-term process in which, in cooperation with the Federal Länder (federal states) and societal groups, risks will be progressively identified, action needs ascertained, appropriate objectives defined and developed and potential adaptation measures implemented. The German Adaptation Strategy thus pursues an integrated approach to assessing risks and action needs, supporting sustainable development. And it reflects Germany's international responsibility.

The Strategy in its five chapters sets out the basic principles of the strategy, the present state of knowledge with regard to the expected climate changes (worldwide and in Germany), their potential consequences and ways of dealing with uncertainty factors. In addition to giving a concrete description of possible consequences of climate change and outlining action options for 15 fields of action and selected regions, it provides an overview of the international context and Germany's contribution to adaptation in other parts of the world. Last it describes the forthcoming steps in the continuing development of the German Adaptation Strategy.

The aim of the Adaptation Strategy is to reduce vulnerability to the consequences of climate change, to maintain or improve the adaptability of natural, social and economic systems, and to take advantage of any opportunities. To facilitate a precautionary approach to sustainable planning and action in the private, scientific, business and public sectors, there is a need to:

- Improve the knowledge base with a view to better define and communicate opportunities and risks, and to identify options for action,
- Create transparency and participation by means of a broadly based process of communication and dialogue, and support various stakeholders, for example by providing decision support and information on which to base decisions,
- Supporting public awareness raising and information through widespread public relations work,
- Developing strategies for dealing with uncertainty factors.

There are gaps in our knowledge and considerable uncertainties about the details of how our climate will change in the future. However, the latest analyses of regional climate models for Germany (see Chapter 2) show that it is possible to make first reliable statements about the direction and/or range of possible changes in cases where the different models come to similar results. This can be used as a basis for estimating the consequences for sectors and regions and identifying needs for action. When assessing the consequences of climate change the Federal Government intends in future to act on the basis of a multi-model approach and refrains from specifying any individual scenario or model as reference for adaptation activities.

As the central next step in developing the Strategy, an Adaptation Action Plan is to be drawn up in collaboration with the Länder and other relevant stakeholders. This Action Plan will be submitted to both houses of parliament (Bundestag and Bundesrat) by March 2011. To this end, an Inter-ministerial Working Group on Adaptation will be established. The Action Plan will include principles and criteria for prioritising action needs, derived specifications for federal measures, an overview of concrete measures by other stakeholders, information on financing of adaptation, and proposals for progress review.

1. Framework and objectives of Germany's Adaptation Strategy

The climate is changing worldwide. These climate changes are bringing about changes in the conditions under which people live – and Germany is no exception. Experts expect far-reaching consequences if we do not succeed in at least keeping global climate change within limits. The long-term objective of Germany and the European Union is therefore to limit the rise in mean global temperature to 2°C above the pre-industrial level, which requires a substantial reduction in greenhouse gas emissions. Even with a limited temperature rise of this magnitude, the environmental, social and economic consequences of the climate change that is already taking place will make their effects felt. If the 2°C target is met, it is expected to be possible to mitigate the consequences by means of appropriate and timely adaptation measures and thereby avoid serious consequences. If we do not succeed in limiting the rise in temperature, substantial harmful effects can be expected. Then it would be necessary to make much greater adaptation efforts worldwide, and these would be more difficult and involve higher costs. Reducing greenhouse gases in all countries is thus the central requirement for minimising the need for adaptation – and hence the cost of adaptation – in the long term. This means that the two approaches – measures to reduce greenhouse gas emissions and measures to adapt to climate change – are inseparable.

In this document, the Federal Government presents the German Adaptation Strategy which was announced in the Climate Protection Programme 2005. In doing so, it is taking the first step in meeting its obligations under Article 4 of the United Nations Framework Convention on Climate Change. This lays down that the Parties shall formulate, implement and regularly update national and, where appropriate, regional programmes to facilitate adequate adaptation to climate change. This German Adaptation Strategy is also in line with the ideas for a European adaptation strategy which were initiated by the European Commission in its Green Paper on "Adapting to climate change in Europe – options for EU action" of June 2007 and which are to be given concrete shape with the presentation of a White Paper during 2009.

The long-term objective of the German Adaptation Strategy is to reduce the vulnerability of natural, social and economic systems and to maintain and improve their capacity to adapt to the inevitable impacts of global climate change.

To this end it is necessary to

- Identify and define possible long-term climate impacts for Germany and its regions,
- Identify and communicate dangers and risks (→ *Glossary*), i.e. to quantify and make transparent as far as possible the probability, damage potential and uncertainty factors of climate change and their time component,
- Create and raise awareness of stakeholders,
- Provide a basis for decision making that enables the various stakeholders to take precautions and to gradually incorporate the impacts of climate change in their private, business and public planning and activities,
- Indicate action options, coordinate and define responsibilities, draw up and implement measures.

The Federal Government sees the German Adaptation Strategy as a medium-term process which will progressively ascertain action needs and develop and implement adaptation measures in conjunction with the relevant stakeholders. As the next important step in this process, the Federal Government will submit by spring 2011 an action plan for adaptation to climate change which will give concrete shape to the implementation of this strategy. The Federal Government's approach is based on the following principles:

- **Openness and cooperation**
  Adaptation to the consequences of climate change is a challenge and task for society as a whole. It affects a large number of stakeholders – not only governments and administrative authorities. This German Adaptation Strategy focuses on structuring the process and specifies key areas for the contribution of the Federal Government [for current activities by the Länder, see Appendix]. The strategy also outlines action options for certain scopes that can provide guidance and serve as a basis for the dialogue with the Länder and other stakeholders in order to define adaptation measures more specifically. The competencies of the Länder, as laid down in the Basic Constitutional Law, must be taken into account here. In the present strategy, the Federal Government puts forward proposals for shaping this dialogue.

- **Approach based on knowledge, flexibility and the precautionary principle**
  An essential precondition for appropriate political and economic action is the availability of the most reliable estimates possible of future climate changes and their consequences. The information on expected climate changes which follows in Chapter 2 is based largely on the findings of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and, as far as the changes expected in the various regions of Germany are concerned, on a comparative analysis of the latest findings of the available regional models. The findings of these models are subject to substantial uncertainties. However, where the various models come to similar findings regarding the direction and intensity of likely changes, it is possible to make relatively robust statements about future trends in climate parameters. This strategy also contains a synoptic inventory of existing findings about the potential consequences of these changes for people, the environment and several economic sectors. This inventory takes into account not only the analyses of existing studies, but also the findings of a number of expert conferences and discussions and the results of a survey conducted at sectoral level in the Länder. The inventory shows that there is a need for broader and deeper analysis of the possible impacts. However, it also makes clear, that in view of the (existing) risks and to engage inappropriate precautions it is necessary to adopt a stepwise approach, to devise action options and develop and implement measures. Accordingly, the strategy is designed open and flexible. Improved knowledge, additional findings or new requirements can be added later and the strategy can – where necessary – be adapted. For this reason one major aspect of the strategy is to improve the knowledge base by obtaining high-quality climate data offering greater spatial and temporal detail and taking the resulting climate models as a basis for improved climate change impact and adaptation research.

- **Subsidiarity and proportionality**
  Risks and opportunities resulting from climate change will have different impacts on Germany's different regions and economic sectors. Any adaptation measures necessary will therefore have to take account of regional differences and should be taken at the decision level appropriate to the individual case. In many cases this will be the local or regional level. An important guiding principle here is strengthening individual responsibility. To some extent the federal level can only play a supporting and assisting role. Adaptation measures should be cost-effective and commensurate with the risks, and should take advantage of opportunities. Efforts should be made to ensure targeted use of synergies, especially with climate protection measures. In view of the existing uncertainty factors, planning and decision processes should, wherever possible, give preference to alternatives that are capable of strengthening adaptability in general, or at least not weakening it.

- **Integrated approach**
  Climate change and its consequences affect all areas of life, economic activity and the environment in ways that differ in space and time. They may exacerbate conflicts of use (e.g. use of land or waterbodies). At the same time, adaptation measures in one scope may have repercussions on other scopes. Integrated cross-sectoral approaches should be pursued in order to prevent such conflicts of use and objectives, and to promote and take advantage of synergies with the pursuit of other policy objectives.

- **International responsibility**
  The Federal Government also regards adaptation to the impacts of climate change as an increasingly important aspect of international and bilateral cooperation. In other parts of the world, the impacts of climate change will very probably have much more serious effects on people, the environment and economic and social development than in Germany or parts of Europe. What is more, many of these countries, especially many developing countries, have only a very limited capacity to adapt. Thus in addition to the targeted agreements on substantial reductions in greenhouse gas emissions, the issue of adaptation to the consequences of climate change is a central aspect of the negotiations on a future international climate regime under the United Nations Framework Convention on Climate Change. The subject is also becoming increasingly important for cooperation on development, security and environmental policy and for migration policy. For this reason the German Adaptation Strategy also includes information on the positioning of the German contribution.

- **Sustainability**
  The German Adaptation Strategy is embedded in the Federal Government's sustainability policy. The Federal Government's adaptation and sustainability strategies are intended to complement each other, especially since the theme of "climate and energy" is one of four focus themes in the latest progress report on the National Sustainability Strategy. Furthermore, the Adaptation Strategy is intended to supplement and support other cross-sectional strategies, such as the National Strategy on Biological Diversity, the sectoral strategy on agro-biodiversity or the proposals by the inter-ministerial working group on "Rural areas", by taking up elements of these strategies which focus on improving adaptive capacity und reducing climate-induced risks.

2. The climate is changing!

2.1. Existing and expected climate changes worldwide

Data from observations over the past 100 years show clear evidence of global warming. Since the beginning of the 20th century there has been a rise of 0.74°C in global mean annual temperature (Fig. 1, yellow line). What is more, in the last fifty years global mean annual temperature has risen by an average of 0.13°C per decade (Fig. 1, red line). According to the Intergovernmental Panel on Climate Change (IPCC), there is a "very high probability" (i.e. a probability of over 90 percent) that the greater part of the warming observed since 1950 is due to human activities. Moreover, in 2007 the IPCC stated in its Fourth Assessment Report[1] that mean temperatures in the northern hemisphere for the second half of the 20th century were *very probably* higher than for any other 50-year period during the last 500 years, and were *probably* the highest in at least the last 1300 years[2].

Mountain glaciers and snow cover display a marked decrease in both the northern and the southern hemisphere. Another example is sea level. During the 20th century the worldwide rise in sea level averaged about 17 cm (12 to 22 cm). The reasons for this are the expansion of seawater due to global warming and the melting of glaciers, ice caps and continental ice sheets.

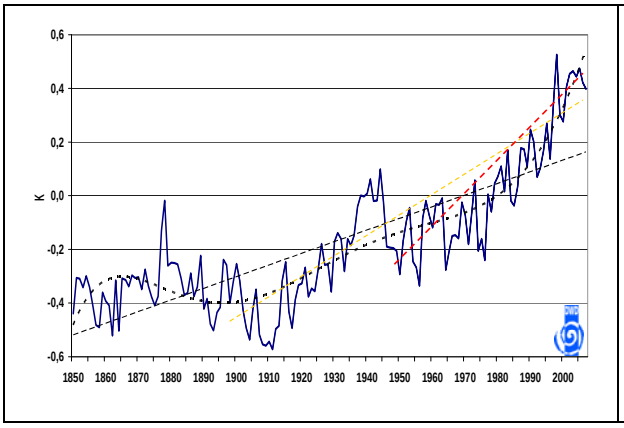

Fig. 1: Observed deviation of global mean annual temperature from the mean of the reference period 1961-1990 with linear trends for the periods since 1850 (black line with short dashes), 1900 (yellow line) and 1950 (red line), and polynomial fit of time series (black line with long dashes) [data source: www.metoffice.gov.uk/hadobs and German Weather Service (DWD)]. (period shown: 1850 - 2005)

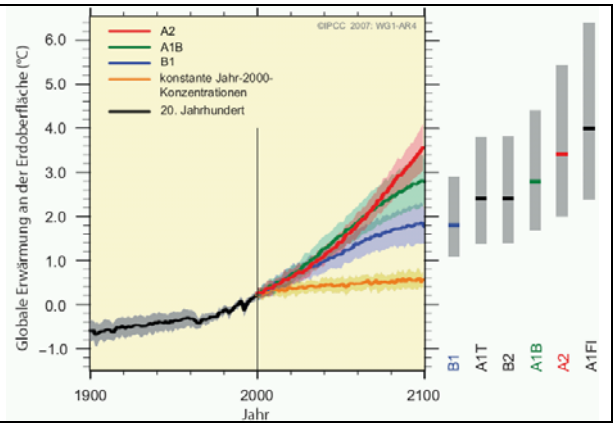

Fig. 2: Global warming at the Earth's surface (relative to 1980–1999) for scenarios A2, A1B and B1. The shading indicates the spread of the individual model results. Orange line: greenhouse gas and sulphate aerosol concentrations were kept at 2000 levels. Grey bars: best estimate (line within bar) and probable spread. [IPCC 2007]. (period 1900 - 2100)

Fig. 2 shows the possible scale of future changes in global mean temperature if there is no significant change in present worldwide emission behaviour and if the greenhouse gas concentration in the atmosphere continues to rise. This figure is based on a large number of model simulations ("climate scenarios") and a broad selection of climate models. It shows that depending on the assumptions made, global warming will reach between 1.8 and 4.0°C by the end of the century (uncertainty between 1.1 and 6.4°C). Rainfall intensity and distribution could also alter as a result of climate change: In high latitudes, rainfall will probably continue to increase, whereas in most subtropical land regions it will probably decrease. Both trends are in line with the precipitation patterns observed today.

[1] The conclusions of the Fourth Assessment Report are based on studies and measurements up to the end of 2005.
[2] IPCC (2007): SPM WG I, p. 10 (German version)

Experts expect the greatest warming to take place over continental areas and in the polar regions. The ice in the Artic Ocean will continue to shrink – indeed, some models predict that it will almost entirely disappear during the summer months in the second half of the 21st century. In the various scenarios studied by the IPCC, sea level will rise by a global average of 18 to 38 cm (B1) or as much as 26 to 59 cm (A1FI) by the end of the 21st century.

The climate models also suggest an increase in the frequency of extreme events such as heat-waves and local intense rainfall. According to the IPCC, there is a 66 percent probability that tropical cyclones will become more intense and will in future move across oceans, coasts and land masses with even higher peak wind speeds and heavy rainfall.

2.2. Existing and expected climate changes in Germany

During the 19th century the mean temperature in parts of Central Europe fell by up to 0.9°C. A relatively warm phase at the start of the 19th century, around 1810, was only observed in certain parts of Central Europe (e.g. Hohenpeißenberg in Germany, or Vienna and Innsbruck in Austria). The lowest mean annual air temperatures in Central Europe were observed during the decade 1880-1890. Mean precipitation, by contrast, was not significantly different from the situation in the 20th century. In the 19th century, Alpine glaciers grew until about 1850; since then they have been on the decline.

Between 1901 and 2006 the mean air temperature in Germany rose by nearly 0.9°C ("linear trend", Fig. 3). The decade 1990-1999 was actually the warmest decade of the entire 20th century. The first six years of the 21st century were also considerably warmer than the average for the current normal climate period 1961-1990 ("multi-year mean"). The temperature rise observed in the southwest of Germany since 1901 is particularly large. For example, the mean annual temperature in the Saar region rose by around 1.2°C. Temperatures in the north-east, by contrast, have displayed a much smaller rise since 1901, for example only 0.4°C in Mecklenburg-Western Pomerania.

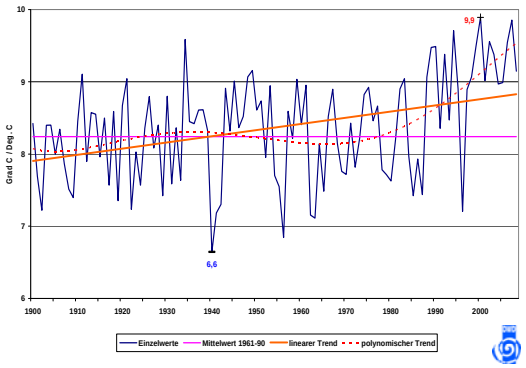

Fig. 3: Time series of mean annual temperature in Germany with linear trend and polynomial fit to illustrate the long-term trend from 1900 - 2006 (German Weather Service (DWD), 2007 (www.dwd.de/presse)).

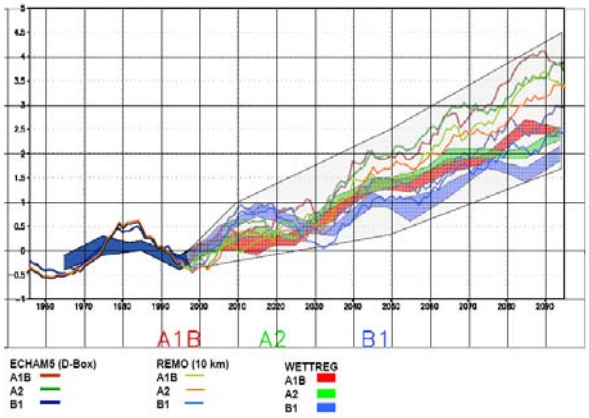

Fig. 4: Change in mean annual temperature [°C] in Germany compared with 1961-1990 for the scenarios A2, A1B and B1 [MPI-M, CEC 2007]. (period shown: 1950 - 2090)

Precipitation is another area where changes can be observed in Germany. Compared with the beginning of the 20th century, the regional average for mean annual precipitation in Germany has increased by about 9 percent, though it has to be noted that the first two decades of the 20th century were relatively dry. Moreover, rainfall in 11 of the past 15 years has been higher than the average. Spring rainfall shows a marked increase. For March in particular, a comparison of the

106-year period 1901-2006 with the corresponding monthly average for the normal climate period 1961-1990 reveals an average increase in rainfall of 31 percent. No significant trend can be detected for the summer. However, the distribution of rainfall over the summer months has changed: reduced rainfall in July and August is largely offset by heavier rainfall in June. For the reference periods mentioned above, by contrast, winter rainfall shows a general increase of around 20 percent. In spite of this observation the winter trend is not statistically significant, as the rainfall quantity varies very considerably from one year to another. There are also very large differences in rainfall trends within Germany. For example, the increase for the year as a whole is largely confined to western Germany, whereas in eastern Germany the increases recorded in winter are mostly offset by decreases in the summer.

As far as wind speed is concerned, no significant trend can be detected here either. Long series of mean wind speeds show some periodic fluctuations, but these are not sufficient to be described as a trend.

With a horizontal grid interval of between 120 km and over 200 km, the spatial resolution of the global climate models is currently too low to permit regionally differentiated information for Germany. Use is therefore made of regionalisation methods which employ not only statistical and dynamic regional climate models (also known as "regional models"), but also the information from the global model calculations. The statistical regional models use statistical methods to project the meteorological time series from selected climate stations in Germany into the future, whereas the dynamic regional models use numerical physical methods to take the global climate projections and regionalise them for Central Europe with the aid of a finer spatial grid with a horizontal resolution ranging down to 10 km.

Fig. 4 shows how mean annual temperature in Germany is expected to change over time for 3 different climate models (global and regional) and 3 emission scenarios: The results show that, depending on the trend in anthropogenic emissions of greenhouse gases, the mean annual temperature could rise by 0.5 to 1.5°C for the period 2021-2050 and by 1.5 to 3.5°C for the period 2071-2100, compared with the figure for the current normal climate period 1961-1990. Regional climate models (→ *Glossary*) can be used to arrive at spatially differentiated statements about the possible future climate (see above).

The findings of the four existing regional climate models for Germany (REMO, CLM, WETTREG and STAR)[3] indicate clear trends: In addition to their dependence on the choice of emission scenario (see Fig. 4), the results also vary depending on the choice of regional climate model. If we consider the spatial distribution of warming for a medium emission scenario (Fig. 5), the dynamic climate models REMO and CLM and the statistical model STAR show a large measure of agreement on the structure of a temperature rise that increases towards the south. Regionalisation by the statistical model STAR is based on the temperature trend supplied by the global climate model: for the period 2021-2050 this results in a temperature rise of 2°C. By contrast, the dynamic climate models indicate a temperature rise for this period that is only half as large, namely 1°C. For the period 2021-2050 the statistical model WETTREG shows a temperature rise that tends to increase from east to west, with figures of around 0.5°C. For the period 2071-2100 this model also forecasts the smallest temperature rise with figures of around 2°C, whereas the dynamic climate models REMO and CLM predict temperature rises of up to 3.5°C – or even slightly more in the Alpine regions of Germany. However, all the models agree on the season that will be most affected by the temperature rise: the warming will be most noticeable in the winter months.

[3] On the basis of the driving global model ECHAM5

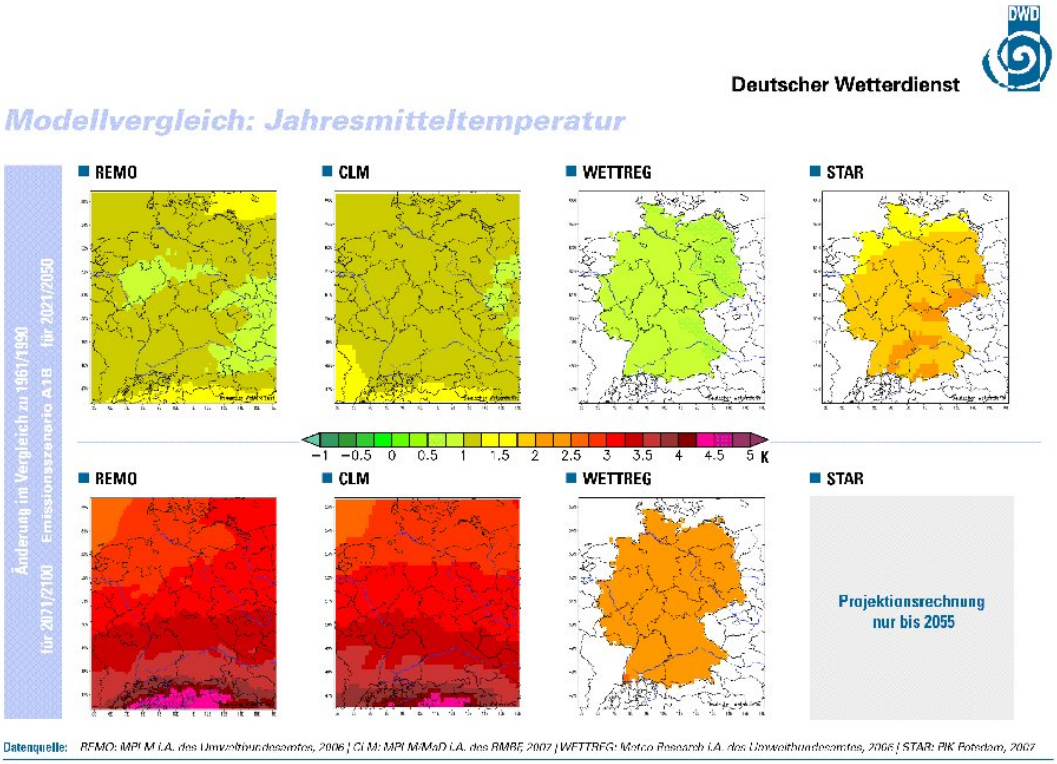

Fig. 5: Change in mean annual temperature for the periods 2021-2050 (top) and 2071-2100 (bottom) compared with the model-specific control period 1961-1990, as projected by the regional climate models REMO, CLM, WETTREG and STAR for the A1B emission scenario. (*STAR supplies only model calculations until 2055*)

The rainfall figures show particularly striking evidence of climate change. Although they remain more or less constant over the year as a whole, there is reason to expect shifts in the rainfall cycle in Germany (Fig. 6 and 7). The results of all four models suggest that summer rainfall could show nationwide decreases of up to 40 percent, with the south-west of Germany again being particularly hard hit (Fig. 6). By contrast, winter rainfall could increase by between 0 and 40 percent depending on the model (Fig. 7). For the central upland regions of the states of Rhineland-Palatinate, Hesse and north-eastern parts of Bavaria, the statistical WETTREG method even indicates areas where winter rainfall in the period 2071-2100 could show an increase of up to 70 percent compared with the control period 1961-1990. Moreover, the dynamic climate models CLM and REMO indicate an additional increase in rainfall in the spring, though the size of the increase is less than in the winter months.

The comparative studies of WETTREG and REMO[4] indicate that there could be an increase in the frequency and intensity of extreme weather events. For example, the number of summer days (T>25°C) could double by the end of the century, and the number of hot days (T>30°C) could actually triple. First analyses suggest that the intensity of intense rainfall ("cloudbursts") could also increase. As far as the frequency of storm days is concerned, these first studies do not reveal any differences from present-day conditions. However, there is a need for more detailed studies here.

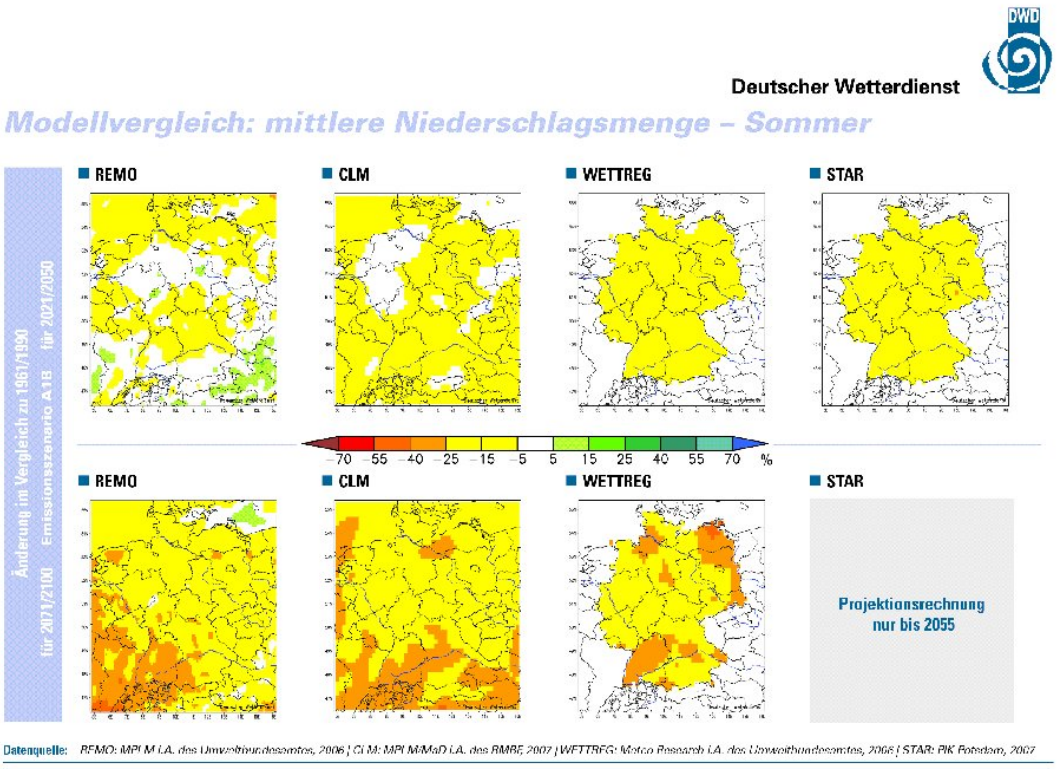

Fig. 6**:** Relative change in mean summer rainfall for the periods 2021-2050 (top) and 2071-2100 (bottom) compared with the model-specific control period 1961-1990, as projected by the regional climate models REMO, CLM, WETTREG and STAR for the A1B emission scenario. (*STAR supplies only model calculations until 2055*)

[4] See final reports on http://www.umweltbundesamt.de/klimaschutz/index.htm

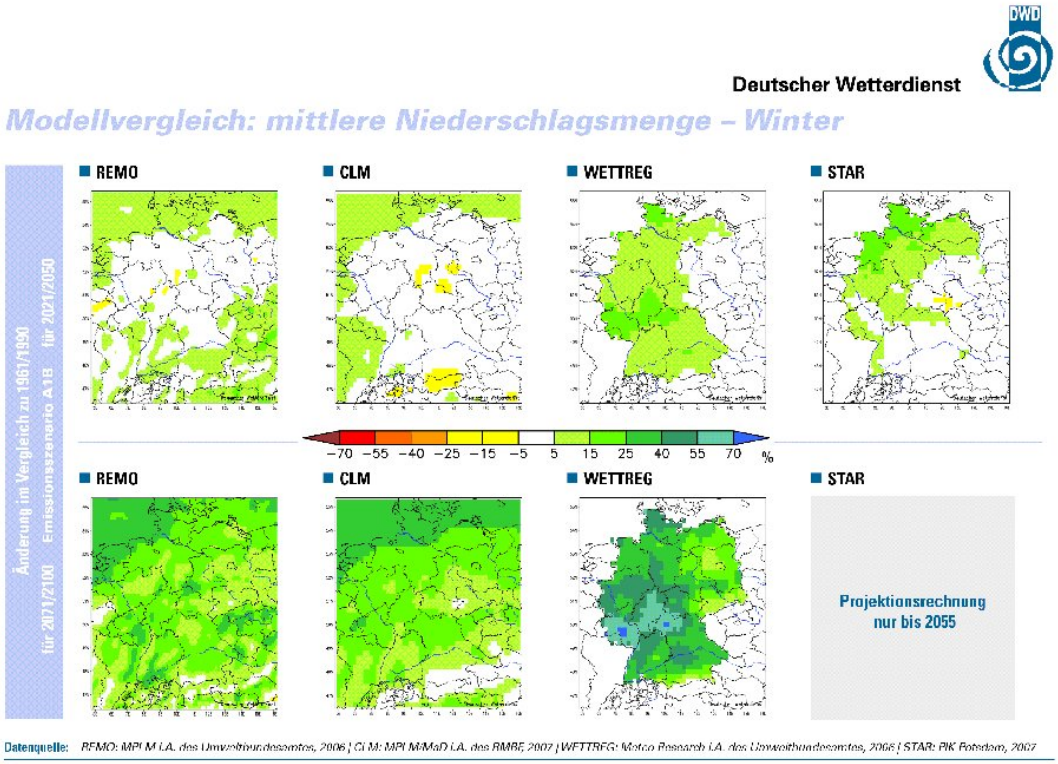

Fig. 7: Relative change in mean winter rainfall for the periods 2021-2050 (top) and 2071-2100 (bottom) compared with the model-specific control period 1961-1990, as projected by the regional climate models REMO, CLM, WETTREG and STAR for the A1B emission scenario.

2.3. Dealing with uncertainty factors

The model calculations on global and regional climate change and its consequences involve a number of uncertainty factors. These may cancel each other out on balance, but they may also accumulate. For example, it is not possible to predict the worldwide trend in emissions of greenhouse gases and aerosols with any certainty. Emission levels depend on numerous factors, including in particular population growth trends and future changes in land use, the pace of future economic growth, trends in energy prices, and the development and application of low-emission technologies. Also it is not possible at present to determine the climate impact of the various greenhouse gas emissions or the complex feedback processes that take place in the atmosphere.

In order to deal with such uncertainty factors and nevertheless remain in a position to take action, agreement is reached on emission scenarios with a central framework of data previously defined by the IPCC. Nevertheless, since our understanding of all climate processes is nothing like complete, the models cannot be more than approximations to reality and can never represent all the factors in the system we know as “Climate”.

The further the projections go into the future and the smaller the size of the regions considered, the more uncertain the results tend to become. To describe the range covered by the uncertainties outlined, climate research employs different global and regional models in which the boundary conditions also vary (ensembles). Then the model results are superimposed. The larger the ensemble of model projections (multi-model ensembles), the better it is possible to evaluate the uncertainty and variability of the model results. The results for a single model are not sufficient.

For Germany results have been basically obtained from four different regional climate models (see Chapter 2.2) and three different emission scenarios (A1B, A2, B1). This ensemble permits drawing conclusions about possible consequences of climate change, because it takes account of plausible spreads in the arrays where uncertainty factors exist. It is planned to expand the ensemble approach by using further global models to drive the regional models.

In future planning processes where the Federal Government has to assess the expected opportunities and risks of climate change, it will not base such assessments on individual scenarios or models, but will take account of the ranges and uncertainties of future climate trends derived from the various emission scenarios and climate models available.

The climate change consequences listed below are derived from the model results shown above. They are plausible, provided the real development of the climate follows the projected trends over long periods.

One important aspect for all sectors and fields mentioned in the following chapters is to include probability estimates in planning criteria, and to take decisions in the face of uncertainty. Climate change may necessitate additions and modifications to numerous sectoral plans and areas: in management approaches to date, it has been crucial and sufficient to study data series and extreme events from the past. Now there is an urgent need to include events (and especially extreme events) that are probable or possible in the future. Possible approaches include defining risk premiums or making increased use of probabilities.

Principles for decisions in the face of uncertainty
(Examples from the water management sector)

Priority for flexible measures capable of subsequent adjustment
When selecting appropriate adaptation measures, preference should be given to measures which are capable of flexible subsequent adjustment and which take account of existing uncertainty factors.(also known as no-regret measures). Example: systematic use of preventive flood protection, e.g. keeping land clear of construction or ensuring that rainwater can infiltrate, and early warning systems, to supplement technical flood control measures.

Promotion of measures with synergies for various climate change consequences
It is important, for example, to promote measures which have a mitigating effect on extreme events – and that means both flood events and low water situations. These may be measures to improve the hydromorphology, e.g. by reconnecting backwaters , but also by relocating river dykes .
Another example of synergies is increasing the size of water retention areas. This not only promotes groundwater recharge, but also reduces surface runoff in flood situations.

3. What are the consequences? – What can be done?

3.1. General climate impacts, trends, time horizons

Climate changes have taken place during the last three decades and have influenced nature and the environment. Signs of this include melting glaciers or an earlier onset of spring.

The temperature and rainfall projections for the future (Chapter 2) give reason to expect further climatic effects. The greater the magnitude of global climate change, the stronger these effects will be. The consequences of climate change can be classified as follows:

- Consequences arising from continuous changes (e.g. seasonal shifts in vegetation periods, earlier start to breeding by bird species in a region, long-term changes in groundwater recharge, or reduced heating requirements in winter). In most areas of activity, the consequences will mostly be appreciable in the medium term.
- Consequences dictated by more frequent or more intense occurrence of extreme events, such as intense rainfall, storms and storm surges, heat-waves or long periods of drought. These also include forest fires, floods, drougths, and heat stress.
- Consequences of increasing climate variability (→ *Glossary*). Climate fluctuations could acquire short-term importance, e.g. droughts might occur in rapid succession, thereby overtaxing the capacity of the agricultural and forestry sectors to cope with them. This will make the task of adaptation even more complex.

Climate change has impacts not only on nature, but also on industry and society. Regional differences in the availability and use of natural resources – e.g. water – but also influences on the environment, such as loss or fragmentation of habitats or land renaturing, may have regional and local effects on adaptive capacity and hence on the scale of climate change impacts.

There may be regional differences in the positive or negative nature of the impacts. In agriculture and forestry, for example, prolonged periods of drought may threaten harvests, but new climatic conditions may make it possible to grow new varieties. Certain sectors, e.g. the tourism industry, expect advantages for the coastal areas of Germany as a result of higher average temperatures.

Many of the consequences arising from gradual changes cannot be attributed to the single factor of climate change, since they are also influenced, for example, by population growth, changes in settlement patterns, the use made of the natural environment, or quite generally by economic or societal change.

A strategy for adaptation to climate change must acknowledge the close connections with other trends and any possible interactions. It must be closely coordinated with the political initiatives for shaping these processes of change and must be keyed to the objectives of sustainability.

3.2. Impacts on nature and society – identifying action options

The following sections describe the possible consequences of future climate change for 15 sectors and areas, mostly in qualitative terms, and identify options for action in varying degrees of detail. In some areas there is need for more detailed investigation of the possible impacts of climate change and relevant adaptation options.

All sectors have to rely on a set of facts and data which can be used as a basis for detecting critical changes and which should be used as a basis for taking decisions on future action (see Chapter 5.2). In addition to the availability of results of climate research and climate (effect) models, other important basic requirements for all sectors are the use and optimisation of monitoring systems and the establishment of knowledge networks. Long-term climate impact monitoring, which in the best case provides joint coverage of the relevant environmental media, is an important contribution to documenting and demonstrating climate change impacts with concrete data. Such monitoring can also be used for progress reviews of adaptation measures (Chapter 5.2).

3.2.1. Human health

Climate change has a wide variety of impacts on human health. Changes in climate and weather conditions could lead to increases in infectious diseases and non-infectious diseases (such as cardiovascular disease and allergic disorders) or in injuries due to extreme weather events.

Infectious diseases

A milder climate favours the propagation of pathogens that are native to Germany (e.g. hanta virus, TBE virus and borrelia infections, which are transmitted by ticks). On the other hand, pathogens which in the past have not been native to Germany and have been introduced accidentally by people or animals could in future become established and be transmitted in Germany as a result of changed climatic conditions. If infected people or animals come into contact with powerful vectors (e.g. certain mosquitoes or ticks), this could lead to propagation of these infections. It is conceivable that the "Asian tiger mosquito", *Aedes (Stegomyia) albopictus*, which can transmit dengue fever or Chikungunya viruses, could become established in Germany. The course of these viral infections is characteristically severe, with high fever. Leishmaniasis is an infectious disease that has hitherto not been native to Germany, but evidence has already been found in the last years in Germany of pathogens, vectors (sand flies) and autochthonous occurrences of this illness.

Rising temperatures can affect the safety or storage live of food. Infections caused by salmonella, campylobacter and other pathogens from deteriorated food are already among the commonest infectious diseases. If temperatures continue to increase, there is reason to fear a rise in the number of such gastro-intestinal infections.

Under the German Infection Protection Act, monitoring of infectious diseases also involves monitoring a number of pathogens, the occurrence of which may be influenced by changes in the climate. The list is not exhaustive, however. Pathogens and/or infectious diseases which are not notifiable under the Act but which are climate sensitive could become increasingly significant in future.

An interdisciplinary approach involving all relevant ministries, sectoral authorities and research institutions is necessary to cope with these challenges. The federal and Länder authorities should obtain and analyse additional data to enable them to ensure timely identification of epidemiological trends in Germany and a better understanding of their causes and relationships,

facilitate better risk assessment, and develop prevention and intervention strategies. This would, in particular, require:

- Epidemiological studies of vector migration, introduction of tropical diseases, and impacts on native pathogens.
- Fundamental research into means of biological control of vectors.
- Fundamental research to characterise possible changes in pathogenicity and/or in the life cycles of pathogens and their vectors and reservoirs, and into the development of suitable treatment strategies and vaccines.
- Examination of the existing monitoring system to ascertain whether it adequately covers climate-sensitive native or imported pathogens and their animal vectors or reservoirs.
- Development of suitable strategies for early detection of suspected and actual cases of infection arising from the appearance of pathogens new to Germany.
- Systematic investigation and modelling of populations (humans, animals, vectors) with regard to the number of new diseases and cases of certain climate-sensitive infections.
- Promotion of the prevention of infections due to climate-sensitive pathogens.
- Identification and characterisation of pathogens of risk infections worldwide in a combined international effort.
- Development and improvement of laboratory methods for detecting climate-sensitive pathogens in order to ensure diagnostic identification of infected persons and contaminated blood products and organs.
- Experimental investigation of the dangers of transmission, colonisation and propagation of risk pathogens in Germany.
- Development of new therapeutic products, vaccines and vaccination methods.
- Analysis of changes and trends in food-transmitted infections.

Non-infectious diseases and health consequences

The health consequences of extreme events such as intense rain, floods, storms, avalanches or landslides are mostly injuries, some of which are fatal. One dramatic example of an extreme event is the heat-wave summer of 2003: in Germany alone, some 7,000 people died of heart attacks, cardiovascular disorders and kidney failure, and also respiratory problems and metabolic disorders. Such extreme events have widespread impacts on somatic and psychosomatic health in the areas affected.

At the Baltic coast and in lakes, accumulations of nutrients can combine with mild temperatures to produce increased algal blooms (cyanobacteria). Since certain blue-green algae produce numerous toxins, there is a marked reduction in the quality of the affected waters, especially for their use for bathing. Contact with the contaminated water can result in irritation of the skin and the gastro-intestinal tract, and also in liver damage and other serious harmful effects on health.

An increase in allergic reactions is connected with prolonged occurrences of atmospheric allergens, and shifts in their timing.

In 2007, in view of the increasing incidence of allergic disorders, the Federal Ministry of Food, Agriculture and Consumer Protection launched an allergy action plan intended to make everyday life easier for allergy sufferers. Special mention must be made here of the Ambrosia action plan[5] coordinated by the Julius Kühn Institute. At the ministry's request, an information sheet (available online) was published on ways of reducing contamination of animal feeds with the seeds of *Ambrosia artemisiifolia L.*. The Federal Government's activities are supplemented by the German Weather Service (DWD), which provides pollen forecasts for ambrosia in cooperation with the German Pollen Information Service. A number of Länder have also set up action programmes.

[5] www.jki.bund.de/ambrosia

Bavaria, for example, is pursuing a policy of primary prevention to minimise the spread of the invading mugwort ambrosia and its pollen emissions by destroying the plant[6]. The Federal Government should investigate jointly with the Länder whether such action could be taken nationwide.

Further climate-induced health impacts are possible:

- More frequent high-pressure situations in summer could favour the formation of ground-level ozone, which can lead to breathing problems,
- Increased exposure to sunlight could increase the risk of skin cancer, and
- Unfavourable changes in ecosystems (such as forests) which are needed for recreation or to ensure a balanced urban climate could have further adverse effects on health.

In order to take measures against the effects of climate change on non-infectious diseases, especially in vulnerable population groups (e.g. children and elderly people, patients suffering from several diseases simultaneously), it is necessary to take a large number of additional factors into account, for example changes in living, housing and environmental conditions, changes in health habits and medical care. A reliable basis of data has to be created to develop a health policy transfer concept which, among other things, should make evidence-based recommendations about the adaptation strategies required. The information and public relations work should address not only the specialist target group, but also the general public and its particularly vulnerable groups.

Information and health care

Despite the well developed health system that exists in Germany, the German public is still not sufficiently aware of the need to adapt to climate-induced health problems. Due to inadequate knowledge and lack of information on direct and indirect impacts of climate change on health, there are also deficits in the relevant facilities for public education and prevention. As an important precondition for adaptation measures, the federal and Länder authorities should therefore promote appropriate targeted information for the general public, individual risk groups, and also multipliers such as health care and disaster control personnel. Together they should draw up a health policy concept including recommendations on prevention of heat-related health problems and other health risks associated with climate change, and also proposals for action on coping with weather extremes and natural disasters from a health point of view.

For example, the Federal Government is meeting this challenge by identifying key areas through the work of the Robert Koch Institute (RKI 2010). Moreover, the Environment and Health Action Programme (APUG), an initiative run by three ministries (Environment, Health, and Food and Agriculture), makes a contribution to informing and educating the public and promoting cooperation between all responsible agencies and administrative levels.

Efficient early warning systems, e.g. for heat problems or for geological risks such as landslides, reduce the danger of health consequences. The German Weather Service (DWD) operates a heat warning system that provides the Länder, and if necessary districts, with information about imminent heat-waves in the form of early warning forecasts. The federal and Länder authorities should seek to ensure closer networking between the DWD, the informed agencies at federal state and district level, health and disaster control facilities and institutions such as schools and kindergartens, so that both preventive and response measures can be taken locally (cf. climate biomonitoring concept in Chapter 5.2).

Linking health care with other areas

There is a close connection between health care and physical planning: appropriate architecture and urban and landscape planning can help to alleviate climate-induced warming of cities, and hence heat stress. Particularly in urban agglomerations, there should exist unobstructed fresh air corridors to guarantee the supply of fresh air. This can be made through unobstructable fresh air

[6] http://www.lzg-bayern.de/aktuell_wgt.htm.

channels and extensive green spaces as “cold islands”. Urban planners and local authorities should take steps to counteract the trend towards further sealing of open land for settlement and transport purposes (see Chapter 3.2.2).
Furthermore, private and public building owners should, especially in community facilities (such as hospitals, nursing homes and retirement homes), ensure adequate heat insulation and (passive) cooling facilities, if possible by solar cooling.

Health risks arising from other extreme events (such as storms or floods) will have to be reduced, especially by means of appropriate public behaviour, preventive measures in the building sector and in local authority infrastructure, risk and crisis management systems by infrastructure operators, emergency plans and modified coastal protection and flood control.

3.2.2. Building sector

Climate researchers expect climate change to have a growing impact on the building sector. Prolonged heat-waves in summer, increased intense rain in particular in the winter, and stronger storms could present a threat to buildings, structures and the related infrastructures (such as sewage systems). At present, however, it is impossible to assess the consequences of more frequent wet winters and a potential increase in sunshine duration in the summer. This could, however, give rise to requirements in the building sector with regard to preventive measures and protection of people and physical assets from the effects of climate change.

The future effects of climate change will vary from one region to another. Particularly in densely built-up settlement areas, the effects of climate change are obscured by the effects of the urban climate. Compared with the surrounding area, the climate in cities – depending on the degree of urbanisation – tends to be characterised by shorter sunshine periods, higher temperatures, lower relative humidity, greater cloud cover, lower mean wind speeds and gustier winds, and also increasing annual rainfall. Urban climate effects with health impacts could be intensified by climate change (see Chapter 3.2.1).

For different regions and locations, principles reflecting building specifications for the individual climatic conditions and existing local circumstances have been developed (Federal Building Code and relevant ordinances and guidelines). Construction planning, technology and execution have reached a high standard in Germany, and are suitable for a wide variety of climatic demands or can be adapted to meet the latter. For example, technical building regulations can, if necessary, be adapted relatively quickly to take account of new developments and findings (e.g. by raising the assumed loads by 10 percent or 20 percent). In addition, the rules of the German standards organisation (DIN) require DIN standards to be reviewed every 5 years to determine the need for revision.
With regard to weather events that are currently still considered extreme, there is a special need for adaptation when it comes to building on slopes, in areas with swellable soils (such as clay) and groundwater influence, and building in flood-risk areas and areas of former opencast and underground mining.
It is therefore necessary to develop and improve existing and proven instruments for practical construction and planning and, if need be, create new instruments.
Standards in the building sector and assessment aids underlying these standards (e.g. maps showing zones of wind-driven rain) are currently based largely on data from past observations. Data on possible future climate trends, by contrast, are not taken into account. However, since buildings and infrastructures are frequently used for a hundred years or more, it would be advisable to do so in future. The federal and Länder authorities should investigate the possibility of adapting principles and standards in response to climate change and to take account of future conditions. At the same time there is a need to find ways and means of promoting the implementation of appropriate building by private and public building contractors.

Building planning and technical facilities should also be adapted to take account of climate-induced changes. There will continue to be a need for heating during the winter season, though this need will probably show a slight reduction as a result of rising temperatures. In building planning and technical building services, however, there will be a need for greater adaptation to higher mean summer temperatures and longer periods of heat, especially where top-floor flats are concerned. Where good summer thermal insulation exists, for example in the form of shade elements, suitable thermal insulation or ideal building orientation, it will largely be possible to avoid overheating problems in buildings. As a result, there will not usually be any need for technical air-conditioning equipment, especially in the housing sector. These measures combine aspects of climate protection and adaptation, and ideally supplement each other (see Chapter 3.4).

In future, controlled ventilation systems will not only ensure that spent air is regularly replaced by fresh air. It will probably continue to be necessary to heat the fresh air during the winter season – preferably by means of renewable energy sources – and to cool it during heat periods in the summer, as is already the case in many passive houses today.

In the future it is likely that decisions for or against specific construction methods and materials will have to take greater account of the performance and stress resistance of building materials in relation to extreme weather events. New buildings can be planned on a forward-looking basis and make use of new materials and construction methods. In older buildings this is possible when extensive refurbishment and modernisation measures are carried out. Historical buildings represent a special challenge here.

Since extreme events will in all probability become more frequent, preventive building maintenance will be particularly important. The availability of information, e.g. about monitoring systems and guidelines, will be an important basis for adaptation and climate protection measures in the building sector.

3.2.3. Water regime, water management, coastal and marine protection

The possible impacts of climate change on the water regime manifest themselves in long-term trends (such as groundwater levels, changes in Alpine discharge patterns, e.g. Rhine and Danube, changes in water quality), and also in the increased frequency of extreme events (e.g. floods, storm surges and droughts). Climate change effects also intensify existing regional differences in the availability of water. Climate change increases the challenges involved in the complex interactions of water uses, and this creates a wide range of adaptation needs for water resources management, flood control and coastal protection. Competence for implementation in all these areas rests within the Länder authorities.

Studies indicate that the following climate change effects can be expected in the field of water management:

- The probability of flooding will increase as a result of heavier and more frequent intense rainfall. There could be an increase in the frequency and size of storm surges.
- Milder winters will reduce the proportion of total precipitation accounted for by snow; this will reduce temporary storage of water in the form of snow, which means that precipitation will result in immediate runoff. The danger of winter flooding will increase.
- More frequent occurrence of low-water periods, usually as result of summer droughts, with effects on cooling water abstraction and the ecological situation. In addition, earlier melting of snow will mean reduced compensation of low water in the Rhine and Danube during the summer months.
- The possible increase in extreme wind and rainfall events increases the danger of erosion, and this may result in pollutants, fertilisers and pesticides from a variety of areas entering the groundwater and surface waters. Flood events often impair water quality as well, for example by shifting contaminated sediments or flooding industrial and sewage plants and private oil

tanks. Moreover, during intense rainfall events the capacity of combined sewage systems in settlement areas may be exceeded, thereby resulting in increased nutrient inputs into rivers and lakes. As a result, there may be extremely frequent but localised appearances of pathogens.

- A progressive rise in water and soil temperatures of aquatic systems in the summer can for example lead to a reduction in the oxygen concentration of lakes and rivers. For aquatic fauna and flora this means additional stress, since they are already suffering from high water temperature and limited water volume. Low oxygen concentrations and high water temperatures favour redissolution from sediments during low-water periods, and may therefore result in entrainments of nutrients into the water. In addition, the worsening of the dilution ratio leads to increasing pollution of waters by discharges, e.g. from sewage works, and also by diffuse inputs.
- Since drinking water supplies in Germany mostly make use of local groundwater resources and are only drawn to a limited extent from bank-filtered water or surface water (e.g. reservoirs), no fundamental drinking water supply problems are expected even under changed climatic conditions. Nevertheless, regional exceptions cannot be ruled out in areas suffering from prolonged droughts.

  Low summer water levels in surface waters increase the concentration of undesirable substances in the water. These substances place a strain on the ecosystem, and in cases of drinking water abstraction from bank-filtered water may increase the complexity and cost of drinking water purification.
- An increase in the frequency of summer droughts leads to increased drying out of wetlands and bogs. This adversely affects the capacity of intact wetlands and bogs to act as buffers in heavy rainfall events.

The additional action needs and options with regard to climate change effects are:

Inclusion of climate change effects in integrated river basin management

Integrated management of river basins is laid down in the Water Framework Directive (Directive 2000/60/EC) and the Flood Risk Management Directive (Floods Directive 2007/60/EC). It implies coordinated management of the protection and use of all bodies of water in a river basin – on a transboundary basis. The specific aim is to achieve good water status. In future, the effects of climate change will become increasingly important for water and its management. There is a need to investigate whether the monitoring programmes under the Water Framework Directive are sufficient for reliable registration and assessment of these effects.

When drawing up programmes of measures and management plans under the Water Framework Directive (initially by the end of 2009, thereafter at six-yearly intervals), preference should therefore be given to alternatives which can be expected to ensure robust and efficient compliance with the requirements even under a broad spectrum of climate change effects. This applies in particular to investment in measures with a prolonged use. In the context of the Water Framework Directive, priority should be given to measures that maintain or improve the natural adaptive capacity of water bodies and their diversity of biotopes or habitats (e.g. by means of water and meadow renaturing, by improving water retention over large areas through designation of retention areas, and appropriate agricultural management). The provision on minimum flow rates, especially in flowing waters, in the draft German Environmental Code (UGB II, Water Management section) represents an important step forwards towards adaptation.

The Floods Directive explicitly includes the impacts of climate change on the management of floods arising from surface waters and in coastal areas (see Chapter 3.3). Basic data for planning and action, such as the six-yearly risk analyses, hazard/risk maps and flood management plans, are regularly adapted to take account of the latest state of knowledge about the effects of climate change.

The Federal Government supports the implementation of the Water Framework Directive and the Floods Directive by means of research into methodological aspects. Both directives will be transposed into national law in the German Environmental Code, Water Management section. The Federal Government will also coordinate the German position regarding cooperation in the 6 international river basins.

Furthermore, the Federal Government has long supported the Länder, and will continue to support them, in the implementation of inland and coastal measures under the "Joint Task for the Improvement of Agricultural Structures and Coastal Protection" (GAK). Moreover, under a special GAK framework plan federal financial assistance totalling 380 million euro is to be provided between 2009 and 2025 for additional coastal protection measures made necessary by climate change.

Adapting the infrastructure

When reviewing and if necessary adapting existing water supply and disposal infrastructures, climate change effects have to be seen in close connection with impacts of other change processes such as demographic or economic change and changes in land use. This applies, for example, to adaptation of supply and sewage systems, water reservoirs, chemical treatment of drinking water etc., in order to prevent flooding of combined sewage systems as a result of intense rainfall events, supply problems during periods of drought, and bacterial growth due to inadequate flow rates or excessive temperatures in pipes.
Drainage of rainwater, for example, will in future have to be reviewed from the point of view of land take, demographic change and reduction in pollutant loads, and organised on a sustainable basis. The draft German Environmental Code[7] therefore includes requirements for dealing with rainwater. Rainwater is to be soaked away locally or be used for irrigation or discharged into a body of water by means of drains kept separate from waste water sewers.

Dams, reservoirs and retention basins form a significant part of the water management infrastructure. Such impounding systems are increasingly being integrated on a multifunctional basis in the catchment areas overall water management system for drinking water supply, hydro power and discharge regulation (low-water equalisation, flood control). However, one precondition for multifunctional use in the context of adaptation to climate change is adaptive reservoir management, i.e. differentiated management of storage capacity in terms of time and space, having regard to the environmental and water resources requirements of downstream residents.

Efficient use of water

On the whole, the water supply situation in Germany can be expected to remain secure in the future as well. It is nevertheless possible, especially in the event of prolonged and more frequent regional drought phases and low water periods, that regional conflicts of uses may occur with regard to surface waters and in particular with regard to abstraction of near-surface groundwater (e.g. for crop watering). In connection with demand management, technical methods and improvements for more efficient use of water are possible, and should be considered where this is reasonable (principle of proportionality):

- Use of "grey water", roof drainage water or process water for technical and industrial purposes that do not require drinking water quality
- Further development of water-saving methods, especially in manufacturing processes in trade and industry
- Precautions against water losses in distribution network,
- More efficient cooling of power stations and low-loss irrigation of agricultural land
- Use of purified and microbiologically safe wastewater for watering farmland.

[7] Draft Environmental Code (UGB II), Water Management section

It should however be borne in mind that intensified water cycles always mean "intensified substance cycles". In other words, contaminants may accumulate if the purification technology is not intensified to the same extent.

Support of individual precautions in the flood control sector

Intense rain events, which occur locally and with little warning and often cause considerable damage, show that public flood control precautions can neither prevent nor avert such events. This is particularly true in view of the high probability that even in the long term it will not be possible to assign intense rainfall events to predictable risk zones. As a suitable precaution, the danger of flooding from sewage systems should therefore be reduced where necessary by appropriate modifications to the systems and/or there should be a requirement to investigate the possibility of by-law provisions requiring that all building connections be fitted with non-return valves.
Since short-notice warnings in high-risk areas have little effect, public agencies must provide information and raise awareness to encourage people to take their own precautions and modify their behaviour (protect their belongings). This can be done by various stakeholders: the federal level can provide assistance here. Ideally, however, local authorities should be the points of contact for information on local impacts and individual adaptation options.

Climate change in marine protection policy: precautions and impact management

For years now, Germany has been working within the regional cooperation organisations for the protection of the Northeast Atlantic (OSPAR) and Baltic Sea (HELCOM), also to take account of climate change in marine protection policy (see OSPAR Quality Status Report 2000 and the 2007 HELCOM report on "Climate Change in the Baltic Sea Area"). In addition, the Federal Government's Advisory Council on Global Environmental Change (WBGU) has addressed important points in its special report "The Future Oceans – Warming Up, Rising High, Turning Sour".

With regard to the oceans it is important to limit all factors which result in warming and/or acidification. Marine protection policy itself has few fields of action of its own and profits from all measures that help to prevent or at least reduce the increase in greenhouse gas concentrations in the atmosphere. As well as the existing burdens on the marine environment, e.g. through fishery uses and substance inputs, the warming and acidification of the oceans has adverse effects on biological diversity and the resistance of marine ecosystems. Protective measures such as the establishment of well managed and sufficiently large protected areas make an important contribution to ensuring that species which suffer from climate-induced stress factors are protected at least from certain anthropogenic stress factors, and thereby improving their chances of survival. The federal and Länder authorities have already designated a number of protected areas under HELCOM and OSPAR. These form part of the network of marine protected areas which has been jointly agreed by the two organisations and is to be set up by 2010.

International cooperation plays an important role in marine protection, since not only the direct coastal states influence the marine ecosystem.
Marine protection is based on a holistic ecosystem approach. This requires the integration of all policy areas that could impact the quality of the marine environment in general, and its biological diversity in particular.

One important example of such an integrative approach is the European Marine Protection Strategy, with the Marine Strategy Framework Directive which entered into force in July 2008. The National Marine Strategy adopted by the Federal Government in October 2008 supplements this and gives it concrete shape for Germany.

The European marine protection policy is connected with the goals of creating a worldwide network of marine protected areas by 2010, the establishment of which was decided at the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002. The international community of states reaffirmed this decision in the context of the "Protected Areas" work

programme at the Seventh Meeting of the Conference of the Parties to the UN Convention on Biological Diversity.

3.2.4. Soil

The soil as an ecosystem is of special importance in connection with possible consequences of climate change and relevant adaptation measures. Proper soil protection also includes site-appropriate plants and appropriate ground cover.

The climate influences many soil processes and hence the development of soils, and also soil properties and soil functions. Climate change has effects on nutrient and hydrologic cycles and soil formation processes (substance cycles, humus formation, carbon sequestration and erosion processes), which affect and can to some extent impair important natural soil functions.

To reduce adverse effects resulting from changes in soil and humus formation and thereby reduce carbon sequestration, there is a need for localised land use strategies (see also current research programme of the Federal Ministry of Education and Research on "Sustainable Land Use Management" in Chapter 5.2). Agricultural activities based on good professional practice also take account of soil protection.

Climate-induced changes in the soil system have direct impacts on natural production systems, the hydrologic cycle (from both a qualitative and a quantitative point of view) and biological diversity. At the same time, all current preventive measures help to reduce or prevent soil erosion and harmful soil compaction and to preserve the organic fabric of the soil in the interests of protecting its ecological performance, are suitable measures for adapting to climate change.

In many cases the protection of soil functions is provided directly by measures taken in other sectors, namely agriculture and forestry, water management, nature conservation and regional planning, or in close consultation with these sectors (see the relevant sections under 3.2). A factor of crucial importance for drawing conclusions about suitable adaptation measures is measuring, gathering data and making available reliable data on climate change effects. In the case of soils this calls for more detailed research and the optimisation and, if necessary, expansion of existing monitoring programmes (see box in Chapter 5.2).

There is a need to step up soil protection with regard to the risks of erosion and declining humus content, especially in hydromorphic soils. To avoid conflicts of objectives, the federal and the Länder authorities discuss and coordinate protection objectives and adaptation strategies for the soil with all stakeholders on a cross-departmental basis (agriculture, forestry and water management, nature conservation, atmospheric and climate research).

3.2.5. Biological diversity

Numerous indications of climate change impacts on biological diversity (→ *Glossary*) in Germany have already been documented. They have been observed to affect annual rhythms, the propagation and reproductive success of species, the composition and structure of communities, and changes in intra-species diversity. Since species react to climate changes in different ways, new combinations of species will form, i.e. there will be changes in the combinations of species that share a common habitat or are dependent on each other. The synchronisation of certain development phases could be disturbed (for example, certain fish species spawn at times when there is an abundant supply of food for the new generation). There will also be changes in food networks and competition situations.

Estimates indicate that up to 30 percent of the existing animal and plant species in Germany could die out in the coming decades as a result of climate change, because their adaptive capacity is limited. At the same time, species introduced by man will increasingly become established in nature, while already established species will spread or new species will settle. According to

model calculations, there will be an above-average tendency for the declining species to include those that are already rare and endangered (especially species on the Red List).

In particular, adverse effects are expected in the case of mountain and coastal species and species with specialised requirements such as aquatic and wetland habitats or localised special sites. In some cases these habitats offer no alternatives in the event of climate change. They could suffer particularly serious effects of climate change, e.g. as a result of increasingly dry conditions, unusually strong warming or rising sea levels. The sensitive ecosystem of the Wadden Sea (tidal flats) could be endangered if prolonged immersion and erosion led to loss of habitats. Species with poor propagation characteristics will also be particularly affected.

For species and their habitats, changes in land use are probably just as important as direct climatic effects. Climate change will probably lead to an increase in the land required for the individual measures. Apart from expected additional space requirements for achieving nature conservation objectives (e.g. for biotope networks and alternative habitats), other factors competing for the scarce land will be the possible expansion of renewable primary resources cultivation, additional dyke construction, and measures to safeguard transport routes. It will be important here for the federal and Länder authorities to take appropriate measures to meet the quantitative and qualitative targets of the National Strategy on Biological Diversity and of the Federal Nature Conservation Act for protected areas and networks.

Many planned measures for preserving biodiversity (such as biotope networks and renaturing projects) help to maintain or strengthen the adaptive capacity of natural systems. The many and various efforts to reduce pollutant and nutrient inputs into ecosystems by means of national and international environmental legislation also support the conservation of habitats and biodiversity. Implementation of such measures, which are listed in the National Strategy on Biological Diversity and which in some cases have already been started, is therefore another important element in the German Strategy for Adaptation to Climate Change.

In the interests of an integrated approach, the federal and Länder authorities should investigate and take integrating measures that utilise synergies between nature conservation, climate protection and adaptation, and which maintain biodiversity. This is possible, for example, where measures make use of the carbon storage function of wetlands and also their ability to cushion the repercussions of extreme events on the water balance. Important steps for the development of such measures have already been set in motion by the National Strategy on Biological Diversity, the EU Commission's communication "Halting the loss of biodiversity by 2010 – and beyond" which is supported by the Council and the European Parliament, and the National Sustainability Strategy. In its sectoral strategy on "Agro-biodiversity", the Federal Ministry of Food, Agriculture and Consumer Protection has proposed concrete measures for the conservation and sustainable use of agro-biodiversity as a contribution to adapting to climate change (see Chapter 3.2.6). The creation of a separate data and methods base is also outlined in the Länder concept for "climate biomonitoring", which also deals with the topics discussed below (see Chapter 5.2).

The following sections describe specific action needs and options for measures which go beyond the requirements mentioned above and which can be followed out of the need to adapt to climate change.

Establishing effective biotope networks

The Länder – in close collaboration with stakeholders at all levels from local to European – should establish and improve effective biotope networks to enable species and populations to adapt in the event of a shift in their climatically suited habitats. The development of biotope networks should also be taken into account in the further development of agro-environmental measures and other measures belonging to the second pillar of the EU common agricultural policy, and under a National Water Meadows Programme. The fragmentation of natural systems must be reduced, as must land take. To this end a suitably prudent approach must be taken to

settlement, infrastructure and transport planning, and appropriate measures must be taken alongside rivers and existing transport routes. In 2009 a research project currently in progress will yield a method that could be used to decide priorities for linking habitat corridors in the national trunk roads system. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Ministry of Transport, Building and Urban Affairs have set up a joint working group to develop solutions for implementing the planned network concept nationwide. Since the permeability of the countryside does not stop at national boundaries, the federal and Länder authorities will strive to coordinate the planned measures with the neighbouring European states as well.

Further development of the system of protected areas

The federal and Länder authorities should analyse options for adapting the existing system of protected areas to future requirements arising from climate change. Natura 2000 already offers not only suitable areas for refuge and adaptation on land and at sea, but also areas of non-use. It thus makes a contribution to mitigating the adverse effects of climate change. The Länder should take the requirements arising from climate change into account when preparing or revising maintenance and development plans and management plans for protected areas and any buffer zones that need to be established.

Support for species and biotopes likely to be particularly affected

The federal and Länder authorities, in cooperation with research institutions and associations, should establish monitoring and research programmes which document impacts of climate change and of climate protection and adaptation measures and which outline them in comprehensible form with the aid of indicators, provide reliable information about expected developments and validate such information against the monitored results. As far as possible, these should be based on existing monitoring and research programmes.

In the interests of a precautionary approach, the federal and Länder levels should take account of the findings of climate (impact) research, including the relevant uncertainties, in nature conservation programmes and instruments (e.g. species protection, biotope protection, area protection and contract-based nature conservation programmes). This must include expected climate-induced changes in the situation regarding endangerment of species and attainability of targets. Among other things, these results and analyses are also important for assessing intervention measures and designing compensatory measures. There is a lot of lost time to make up when it comes to introducing species into protection programmes in the marine sector.

In the case of species severely threatened by climate change (see above), simultaneous steps should be taken to reduce other existing threats to and adverse uses of their biotopes. The conservation of sufficiently large populations with corresponding genetic diversity is an important precondition for adaptation processes.

Example of wetlands: Here it is necessary to reduce the impacts of regional increases in summer drought and temperatures. In particular, this can be achieved by devising and implementing concepts and programmes which regenerate wetlands, stabilise hydrological conditions in bogs, and also reduce drainage of grassland. It is also necessary to improve the continuity and structural diversity of rivers and to reclaim and remobilise water meadows. Appropriate measures are already being supported by government assistance programmes. They should be intensified and implemented in cooperation between land users and the competent authorities for nature conservation, agriculture and water management.

Furthermore, there is a need for integrated development strategies for coastal ecosystems – including river estuaries – which, where necessary, facilitate the establishment of alternative

habitats for communities affected by the rise in sea level and make use of synergies between nature conservation and coastal protection.

Dealing with invasive species

The federal and Länder authorities should seek a common approach for dealing with invasive species (→ *Glossary*), including marine invasive species. To facilitate measures to prevent problems arising from immigration of such species, suitable early warning systems should be agreed with neighbouring states for groups of species that have not hitherto been adequately covered. As far as possible, biotope networks should be designed so that they do not favour the propagation of invasive species.

Taking account of nature conservation aspects in the generation and promotion of renewable energy sources

In pursuing the goal of expanding the use of renewable energy sources to limit climate change, sustainability criteria must be observed. It has to be taken into account that the principal aim is avoiding adverse effects on nature and landscape. The attractiveness of agro-environmental and contract-based nature conservation programmes must be maintained by comparison with other use options.
Against the background of the expansion of energy crops, it is particularly important that site selection should take account of sensitive biotopes and priority areas for nature conservation.

Landscape planning as a management approach

In future, landscape planning should take a more forward-looking approach to responding to the trends and changes in nature and landscape that result from climate change. The aim must be to support adaptation options and opportunities for flexible development of nature and landscape. Where non-local requirements are imposed with the aim of preventing adverse effects of encroachments on ecosystems, assessments of possible intervention consequences should also take account of the – future – ecological and spatial effects of climate change. With the aid of local authority landscape planning and intervention regulation, greater attention should be paid to climate-relevant functions of nature and open spaces in settlement areas. This also applies in connection with constructional recompaction and internal development. The federal and Länder levels should develop ways and means of achieving the stated objectives under research projects.

Agro-biodiversity

When developing agricultural use systems and methods adapted to climate change, the federal and local authorities should ensure that agro-biodiversity is maintained despite changes in framework conditions. Suitable management systems should be used and developed to improve synergies between agricultural production, nature conservation, soil protection, water conservation and climate protection (see Chapter 3.2.6).

3.2.6. Agriculture

Agriculture is directly dependent on weather and climate. It reacts with varying degrees of sensitivity to changes in the climate. Already existing regional differences in the results of climate change may be further reinforced in the future. Regions which under present conditions are too cool or too wet for agricultural use could profit from gradual warming and longer vegetation periods by growing crops hitherto limited to warmer areas. By contrast, the effects of climate change could be more critical in regions that are already fairly warm and/or dry.

Although an increase in the concentration of CO_2 in the atmosphere could bring qualitative and quantitative improvements in plant growth, this CO_2 fertiliser effect must not be overestimated, because the main factor limiting yields will probably be the growing shortage of water.

Moreover, increasing extremes of weather could endanger crop reliability. Increased stress from heat, cold, drought or damp, intense rainfall, wind and storm can be expected to result in substantial crop failures, especially when the stress occurs during sensitive growth phases such as leaf formation, flowering, or fruit formation and ripening. Thus spring droughts may have more serious effects than summer heat-waves.

There could also be an increase in damage due to more frequent intense rainfall and hail and – especially in fruit growing – frost risks arising from earlier flowering. Weather extremes may also reduce the winter hardiness of crops, i.e. their ability to withstand frequent winter frosts. Invasive and heat-loving plant pests are a potential cause of further damage, but to date it is particularly difficult to assess the individual consequences of this aspect.

In livestock farming, higher summer temperatures could reduce food uptake and productivity, resulting in substantial production setbacks. For example, the performance of dairy cattle falls off at temperatures in excess of about 20 to 25°C. Climate change is also of considerable importance for the introduction and propagation of new vector-transmitted diseases, as the vectors could encounter more favourable conditions for propagation and survival (see Chapter 3.2.1). The outbreaks of bluetongue in ruminants since mid August 2006, which resulted in substantial economic losses, may be due to climate change. The virus, which originates from South Africa, was able to spread in Europe because – contrary to earlier findings – it is also transmitted by native species of midges (biting midges). Although it is still unclear how the pathogen came to be introduced, the unusual climatic conditions of the past two years are being associated not only with the initial spread of the disease as a result of favourable conditions for propagation of the bluetongue virus in the midges, but also with "overwintering" of the infection due to the absence of a vector-free period during the winter.
It follows from the consequences outlined above for agriculture that Germany's farming sector must be put in a better position to adapt to the expected climate changes if the need arises. Measures at farm level and in the fields of animal and plant breeding, agricultural advisory services and politics could contribute to adaptation. In some areas there is a need for more detailed research and development (see Chapter 5.2, *Sectoral adaptation research*). Measures to adapt to increasing weather extremes are more difficult to achieve: this is a field where multi-risk insurance policies might be a suitable instrument for the agricultural sector.

In its decision of September 2008, the German conference of ministers of agriculture draws attention to the measures currently in progress under the extensive federal and Länder programmes and supports the need for their development and improvement. In particular, this includes:

- Continuing effective species protection legislation that puts plant breeders in a position to develop appropriate crop varieties and, if necessary, to perform breeding work on other crop species or include them in their breeding work.
- Promoting water retention in drought-risk farm and forestry landscapes through the "Joint Task for the Improvement of Agricultural Structures and Coastal Protection" (GAK).
- Promoting irrigation infrastructure via the Joint Task.
- Promoting methods of improving soil fertility, soil structure and natural regulatory mechanisms as part of agro-environmental measures.
- Knowledge transfer, especially with regard to adapted forms of land management, livestock farming, animal nutrition and animal health.
- Promoting animal breeding and management measures in livestock farming.
- Dialogue and knowledge transfer with experts from the Länder.
- Monitoring of climate changes to raise awareness of the need for adaptation measures.

- Promoting innovations in plant breeding by means of the innovation programme.

In the plant breeding sector, innovations should be fostered with regard to adaptation to climate change, crop nutrient balances, resistance properties and quality characteristics. This should also take account of increases in the natural yield potential and genetic diversity of crop plants in the interests of broader crop rotation.

Growing renewable primary resources should be used as an opportunity to broaden the spectrum of usable plant species and thereby achieve positive effects on agro-biodiversity by reducing the rigidity of crop rotation patterns.

The federal and Länder authorities should take measures aimed at the conservation and sustainable use of a broad base of genetic resources. These should give priority to in-situ measures, but should also include ex-situ measures. With regard to possible impacts of climate change and the conservation of adaptive capacity, the contribution (properties and ecological relationships) of agro-biodiversity should also be analysed and evaluated – with the aim of maintaining and strengthening it.

At the end of November 2008, the ministers of agriculture in the EU reached political agreement on the Common Agricultural Policy in the context of the "health check". Part of the agreement is an increase in modulation. This means that the direct payments to farmers will be reduced and the resources thereby liberated will be allocated to the European Agricultural Fund for Rural Development (EAFRD). Among other things, this fund can be used to finance measures which put the agricultural sector in the EU in a better position to respond to new challenges and opportunities in the fields of climate change, water management, protection of biological diversity, and generation of bio energy[8].

3.2.7. Forestry and forest management

The natural occurrence of tree species is determined by the site as a result of a variety of factors including climate, soil and water. In the past, man has influenced the forests and altered their structure. These forest ecosystems have nevertheless constantly adapted to the environmental conditions. However, the scale, direction and speed of the current climate change process are threatening to overstrain the adaptive capacity of the forests. With increasing heat in summer and the increasing duration of dry phases, the forests are suffering from heat and drought stress. Areas at risk here are in particular the dry and warmer regions of eastern and south-western Germany, and in general sites with poor water supplies or forests that are not well adapted for other reasons. In addition, there may be an increased danger of forest fires.

At the same time, greater stress increases the risk of losses due to pests such as the bark beetle. Mass outbreaks of certain pests such as nun moths or may-bugs may become more frequent, and pests that have hitherto been insignificant or disregarded may increase.

The mountain forests in the Alps could be particularly affected by climate change. The effect of climate change could be greater there than in lowland areas. At the same time there could be a marked increase in the risk of natural disasters (intense rainfall, debris flow, floods, rock falls). This could further increase the importance of forests for the protection of settlements and infrastructure.

Timely adaptation of forests to climate change is necessary to reduce the future risk of increasing calamities and associated disruptions of the timber market and forest functions. Forest owners should press ahead with the work of converting forests from monocultures to site-appropriate, low-risk mixed stands. Appropriate game populations are an important requirement here.

[8] http://ec.europa.eu/agriculture/healthcheck/index_de.htm

However, climate change is only one of many stress factors for forests. Many stands are currently in a poor state of health as a result of air pollution, and especially today's high inputs of nitrogen from the atmosphere. This phenomenon has been familiar since the 1970s under the heading of "new types of forest damage". The effects on soil and vegetation will continue to be felt for a long time to come.

Longer vegetation periods as a result of higher temperatures and the CO_2 fertiliser effect, i.e. the boosting of plant growth by the higher CO_2 concentration in the atmosphere, could increase timber production if adequate water and nutrient supplies are available. Compared with the climate-induced stress factors, however, the positive effects can probably be ignored.

Recommendations regarding individual tree species are still the subject of controversial discussion. The federal and Länder authorities should therefore reassess the recommendations on growing all tree species, differentiated by location, having regard to the aspects of climate change, the long production periods and the associated uncertainties and risks. All this presents great challenges to researchers and practitioners.

Furthermore, the federal and Länder authorities should reduce information deficits in order to convince the more than 1.3 million forest owners of the need for adaptation measures. From a silvicultural point of view the aim should be mixed forest stands which are as stable as possible and which possess greater resistance to large-scale calamities such as storms and bark beetle and have a better capacity to adapt to changing climatic conditions. When selecting tree species and varieties, it is important to ensure that these are adapted to the site and its expected development. In addition to native tree species, Douglas fir and other foreign species may offer options, but attention must be paid to nature conservation aspects.

In view of the uncertainties about climate change scenarios and their impacts on long-term forestry production, forest owners should take care to ensure a broad spread of risks and maximum flexibility of action options.

In the medium term the Länder should expand the scientific decision bases for climate-appropriate forest conversion. These could for example include monitoring, establishment and operation of experimental plots, site mapping, forestry plant breeding, provenance research, regional growing recommendations, research into timber harvesting techniques, and possible uses for timber under new climatic conditions. In the medium term, the federal and Länder authorities should also intensify the dialogue and transfer of knowledge with and between forestry experts. As part of the "Joint Task for the Improvement of Agricultural Structures and Coastal Protection" (GAK), the federal and Länder levels are already promoting various measures designed to adapt forestry to climate change, e.g. conversion of monocultures into stable deciduous and mixed stands. The near-natural forests that should be targeted from a nature conservation point of view are supported by appropriate game populations. Measures also exist for the prevention and management of calamities. In addition the federal and Länder authorities should in the near future investigate whether further measures are necessary, for example the promotion of water retention measures in areas with a particularly negative water balance. The federal and Länder levels should further develop environmental monitoring of forest health, in order to permit timely detection of changes and ensure sufficient response time to initiate measures.

3.2.8. Fishery

The North Sea and Baltic Sea are subject to intensive use in their coastal areas and in the Exclusive Economic Zone (EEZ). In addition to shipping, sand and gravel extraction and wind power generation, these uses include fishing and commercial fish processing firms, which are of outstanding economic importance in the structurally weak coastal regions. Fishing, with a large proportion of part-time businesses in both freshwater fishing and small coastal fishing, is an integral part of the traditional economic activities and way of life in these regions. This gives rise

to synergies with the local and regional economy – especially tourism, which is an important economic factor in coastal regions.

In the North Sea and Baltic Sea, climate changes could bring medium and long-term changes in the marine ecosystems and thereby alter the possible uses. This process has already started. On the one hand one can expect direct physico-chemical impacts (ocean warming, changes in the system of currents, ocean acidification) on the reproduction, growth and mortality of commercially used fish stocks and on the ecosystem as a whole. On the other hand, mainly as a result of the lack of cold winters with ice, species hitherto native to more southerly seas have increasingly joined the native species in the North Sea and in some cases are breeding there; examples include sardines, anchovies and red mullet. The plankton and bottom-living organisms of the North Sea and Baltic Sea are increasingly being joined by invasive non-native species, which are largely introduced by shipping traffic. These species may find favourable living conditions as a result of climate change.

This is accompanied by changes in the habitats and food bases of the fish populations in the North Sea and Baltic Sea, which we are not yet able to evaluate adequately. Changes in the spectrum of species may have a positive or negative effect on commercial fishing yields, for example via the interactions between invasive and native species (e.g. through competition for food or additional sources of food). Moreover, changes in the geographical distribution of commercial fish populations may result in changes in their accessibility to the fishing industry, with corresponding market impacts. There is reason to expect that small coastal fishing businesses, which do not usually have a very strong financial base, will tend to be particularly badly affected.

To a large extent it is not yet possible to forecast the effects of climate change on fish stocks and on unfished species. Stock forecasts by fishery experts and decisions by fishery managers should therefore allow for large safety margins. The Federal Government will make every effort to ensure that these safety margins are considered in the final management decisions taken in the relevant bodies (like the Fisheries Council). At the same time steps should be taken to restore the full reproductive capacity of overfished stocks by means of appropriate catch quotas. The incorporation of the sustainability principle in the reformed Common Agricultural Policy (CAP) of the EU, and the incorporation of the CAP in the EU Maritime Policy with its environmental pillar, the Marine Strategy Framework Directive, has already created the political basis for a sustainable approach to fishery management that takes account of climate change aspects.

The promotion and development of technical measures for adapting fishing to the effects of climate change is almost always associated with short and medium-term reductions in profit due to investments and/or initial drops in yield resulting from the use of new fishing methods, which are often still at the experimental stage. Willingness to experiment and acceptance by fishing personnel could be considerably increased by means of suitable funding instruments and close cooperation with scientists.

The Federal Government, in cooperation with the Länder, will make every effort to ensure the further development of suitable measures for adapting fishery management to climate change and their implementation under the CAP. These include:

- Alternative/adaptive management
    - Long-term management and replenishment plans with continuous scientific back-up, review and adaptive components,
    - Expense management, co-management.
- Technical measures
    - Improved catch methods, increase selectivity of nets,
    - promote the restoration of the full reproductive capacity of overfished stocks and
    - create incentives to avoid discards (e.g. pay systems, real-time catch monitoring and short-notice small-scale avoidance of certain areas, so-called “real time closures”).

- Increase the buffer capacity of the resources used and the fishing firms using them, by
  - Taking account of the future alterations due to climate change, including their uncertainties, in stock forecasts and management plans,
  - Minimising these uncertainty margins by
    - Targeted research into key biological/physical processes and
    - Creating long-term data series to improve understanding of the large-scale ecosystem,
  - Restoring or maintaining the full reproductive capacity of the stocks,
  - Establishing protected zones to improve the resistance of fish stocks to the effects of their use,
  - Promote the creation of reserves to cover climate-induced losses/restructuring.
- Use alternative elements for controlling fisheries;
  - Tapping into new consumer behaviour,
  - Improving consumer information; eco certification,
  - Strengthening interaction between fishing and tourism as an alternative source of income.
- Sustainable aquaculture, especially using species that can be supplied with plant feedstuffs.
- Maintaining the natural diversity of the native fish fauna
  - Establishing monitoring systems that provide information about the status of the natural fish fauna (species, numbers, distribution) to permit timely countermeasures in the event of negative changes.
- Optimisation in the fisheries sector, by means of improvements to the framework conditions for resource-conserving aquaculture.

3.2.9. Energy industry (conversion, transport and supply)

Effects of climate change may also tend to have impacts on the energy industry in Germany. A general rise in temperature will probably reduce energy demand for heating purposes, whereas the demand for cooling energy will increase. Extreme weather events such as storms, droughts and periods of high and low water may impair the operation of installations and equipment for energy conversion, transport and supply. The consequences could be shortages, rising energy prices and supply disruptions. Possible impacts on the energy industry relate largely to the supply and demand situation for electricity and heat, but also to the fields of primary materials supplies and power transmission and distribution.

A crucial factor for power generation in thermal power stations – such as coal, gas and nuclear power plants – is adequate availability of cooling water. This means that such power plants could be affected in the summer months by low water levels and by higher river water temperatures. Power plants that draw cooling water from the groundwater (e.g. through drainage shafts) could be affected by falling groundwater levels during long periods of drought. Only power plants with dry cooling systems are independent of cooling water, but their electrical efficiency is slightly lower than that of plants of similar construction that use cooling water. In future, energy supply companies could find that they are more frequently forced to reduce the output of power plants cooled by river water to ensure compliance with the requirements of water legislation and safety regulations. Alternatively, the temperature of the discharged water would have to be increased. In the heat-wave summer of 2003, for example, authorising authorities issued special permits under water law to safeguard the operation of power plants. As a result, some power plants were able to raise the temperature of the water they discharged from 28°C to 30°C. However, such discharges impose extra stresses on river ecosystems in addition to the higher water temperature that prevails in any case during hot periods.

More intense periods of heat also make themselves felt in the form of increased demand for electricity arising from greater use of air-conditioning systems to cool buildings. Better protection

of buildings from excessive heating, especially by means of heat insulation, external shading and minimisation of internal heat loads, help to reduce power consumption (see Chapter 3.2.2). However, since it is probably not possible to achieve optimum heat insulation for all buildings, likely there will be a gradual rise in heat-induced demand for power during the summer. In the heat-wave summer of 2003, for example, there was an increase in power consumption by households and businesses as a result of the intensive use of air-conditioning systems to cool buildings.

Reliable supplies of resources to conventional power plants could also be affected by climate change. In the case of power plants supplied by waterway, supply problems are possible during prolonged periods of high or low water. Moreover, more frequent and more violent extreme weather events such as storms or lightning strikes could damage supply grids and present a threat to electricity transmission and distribution.

Climate changes can also have an impact on the yield and reliability of systems for the generation of renewable energies. For example, it is possible that climate change effects could have a substantial impact on biomass yields. Since it is hardly possible to protect the quality of the soil as a whole – by contrast with individual installations – the federal and Länder authorities should take this aspect into account in the further expansion of renewable energy sources. Changes in precipitation can have an impact on hydro power plants in particular. Furthermore, it has to be assumed that the threat of stronger winds will lead to more stringent requirements for the strength and stability of solar and wind energy systems.

On the other hand, decentralised and diversified generation structures which include renewables could tend to make supplies more secure, especially if the generation structures are mutually complementary. This is particularly valid for extreme events.

The growing field of energy meteorology is investigating how energy production from the sources of wind and sun, which vary over time and space, can be adapted to changing climatic conditions.

There is a need to identify and evaluate potential supply risks, and to explore way and means of reducing them. In an existing working group at the Federal Ministry of Economics and Technology (BMWi) on “Crisis Precautions in the Electricity Industry”, the federal and Länder authorities and the energy industry are discussing various crisis scenarios and the measures possible under the Energy Industry Act and the Energy Security of Supply Act. However, developing strategies on climate change effects and adaptation to climate change in the energy sector is essentially a task for the energy industry itself. The federal and Länder authorities may be able to provide assistance, contribute knowledge and set new regulatory trends.

Energy supply companies in Germany are already taking precautions on their own responsibility against extreme weather events, e.g.

- largest proportion (on a European comparison) of cable sections to provide protection against strong winds,
- emergency water connections for power plants in case cooling with river water becomes impossible due to summer drought,
- development of the wastewater systems in central energy industry plants to ensure better removal of rainwater as protection against intense rainfall,
- establishment of crisis task forces to permit speedy response in cases of damage and failure due to extreme weather events.

3.2.10. Financial services industry

The financial services industry operates in globalised and interconnected international markets. For this reason the industry, and especially the insurance industry, is affected not only by regional, but also by global climate change and its impacts. What is more, it has to prepare itself for the way politicians and society can be expected to react to climate changes. Such reactions will bring changes in the economic environment and state regulation, thereby creating not only additional risks, but also considerable new opportunities.

On a global scale recent decades have seen a sharp rise in economic losses due to extreme natural events, with a corresponding rise in insurance claims. Apart from the intensity and frequency of such events, the crucial factor determining the size of the loss is where the extreme event takes place and how exposed the facilities are. In the record year 2005, natural disasters resulted in worldwide economic losses of around 210 billion euro and insured losses of around 96 billion EUR. One important factor for the increase in losses is population growth, especially in large cities in exposed risk locations such as coastal regions; another factor is the general rise in the insured sums. But, according to the central reinsurance service from Munich, these two factors are not enough to explain the fact that losses due to natural disasters have more than trebled within the last five decades and that there has been an even larger increase in the resulting payment claims to insurance companies.

The long-term security and safety of existing investments such as energy systems will also be affected by gradual climate changes. Especially stakeholders who take decisions on investments involving particularly long planning periods, such as institutional investors or pension funds, are already reassessing their risks, e.g. infrastructure projects or power plant construction in all parts of the world.

On the investment side of banks and insurance companies there is a need for an active management of the risks and opportunities. This applies not only to the direct physical risks of climate change, but also to the risks arising from changes in the political, regulatory and economic framework conditions. The state supervisory authorities at federal and regional level must take increasing care to ensure that the risk models used are sufficiently robust to guarantee the financial stability of the insurance companies and banks. To this end the US National Association of Insurance Commissioners has already set up a “Climate Change and Global Warming (EX) Task Force”.

Demand for property insurance covering losses due to natural hazards can be expected to show an upward trend in future. In some cases, however, insurers will find it impossible to insure at all certain risks in high-risk regions, on the basis of existing instruments and business models. Another possible way of covering risks is using financial market products that allow transfering climate risks from companies or countries to the capital market (e.g. weather derivatives, catastrophe bonds or GDP-linked bonds).

Today the insurance industry is already in a position to inform clients and authorities about climate-relevant situations and to create financial incentives by means of appropriate policy design – including by limiting the cover in some cases. It is also possible to make use of eco audits in environmental liability insurance and generally to take more account of environmental and sustainability aspects in capital investments.

One aspect of special importance is prospective instead of retrospective underwriting, i.e. taking account of future damage trends when determining insurance premiums instead of basing premiums on past experience alone. Whereas premiums that are always lagging behind lead to growing losses, prospective underwriting takes account of future developments.

In the investment field, a concerted communication and further training programme could communicate the risks and opportunities of climate change and evaluate business, industries and

sectors systematically on the basis of the physical risks and opportunities of climate change. The federal authorities, together with banks and insurance companies, should also engage in an intensive dialogue between the stakeholders, academics and civil society.

Financial risks arising from changes in climate parameters could play a part in commercial accounting, for example in the management report submitted in the context of annual financial statements.

A special problem lies in the fact that the Basel II rules (rules on equity capital and risk management) prohibit banks from using other data than historical data as a basis for their risk management. As a result, little practical use has so far been made of innovative methods taking into account other scenarios of future development – such as Bayesian risk management. The Federal Government will play an active role in international negotiations in this field.

In certain areas of insurance, in future the state could supplement the products offered by the financial services industry, when economic considerations make it impossible for the private sector to bear such risks. This might be due to the fact that the persons concerned cannot afford the necessary premiums or that the size of the potential losses is too great. Such supplements could be offered in different forms, for example as a compulsory elementary loss policy or a state fund solution. In any case, however, it can only be the last resource. Such approaches have repeatedly been pursued, especially in the wake of flood disasters such as the Oder floods of 1997. The Federal Government – in consultation with the Länder authorities – intends to launch a new initiative here.

Current activities

The **Carbon Disclosure Project** (CDP) provides a forum for cooperation between investors and companies on climate change issues. The CDP brings together some 300 institutional investors, including major German financial service providers. Based on surveys of companies, the CDP supplies investors with information about company-specific greenhouse gas emissions and corporate strategies for dealing with the physical risks of climate change. The CDP database makes it possible to compare this information and creates an additional benefit for investors. The fifth international survey was conducted in 2007; German companies took part for the second time.

Insurance companies can play an important role in adaptation to climate change. Insurance companies, reinsurance companies, environmental associations and scientists have joined forces in the **Munich Climate Insurance Initiative** (MCII) to devise strategies for insurance companies to deal with the risks of climate change.

The "**Finance Forum: Climate Change**" (FFKw) focuses on the question of how mitigation and adaptation can be managed with the aid of research and innovation. The forum was set up on the initiative of the Federal Ministry of Education and Research (BMBF) (see also Chapter 5.2).

3.2.11. Transport, transport infrastructure

Extreme weather situations involving snow, ice, fog, hail, heat-waves, storms, intense rainfall, floods, low river levels or heavy seas can interfere with road, rail, water and air transport.

More frequent or more intensive rainfall due to climate change affects road traffic, e.g. through poor vision and wet roads. Landslides and undercutting lead to destabilisation and destruction of road and rail sections. Storms may cause direct obstacles or may damage roads, railway tracks and power lines. Heat-waves during the summer months may produce a rise in accident figures, because concentration generally falls off at higher temperatures.

Prolonged heat also damages the road infrastructure. High surface temperatures on asphalt soften the road surface, resulting in tyre ruts and long-term damage. The possible effects of heat and heavier rainfall resulting from climate change are, however, regarded as manageable for the federal trunk road infrastructure, because modified construction materials can be used to make roads more resistant to heat in the future, and heavier rainfall can be dealt with by enlarged road-specific drainage systems**.** Rising temperatures in winter due to climate change could result in less frequent and less serious frost damage to roads and bridges, and could reduce road accident risks arising from ice and snow. Careful monitoring will be needed here to observe the opposing effects.
The Federal Government will investigate the need to use modified construction materials for adapting the infrastructure of the federal trunk roads in the medium term to withstand prolonged periods of heat, and to scale up the drainage infrastructure to cope with heavier rainfall. The federal authorities (especially the Federal Ministry of Transport, Building and Urban Affairs) will, if necessary, modify the relevant provisions on the dimensioning of the drainage infrastructure.

In the rail transport sector, the possible effects of climate change relate primarily to the infrastructure. A direct risk from storms exists for tall power supply structures and signals. In particular, precautions must be taken against falling trees, e.g. by cutting them back. When adapting the legal framework, it must be remembered that many such trees are on private land. Periods of high and low water can also have impacts on rail traffic. Here there is a risk of flooding of railway installations, especially in places where there is little difference in level between railway tracks and water surfaces. In particular there is a need for research into whether high temperatures call for new maintenance technologies, e.g. whether internal tension stresses in continuously welded rails can rise to dangerous levels. The same applies to measures for air conditioning of vehicles and buildings.

To counteract a possible increase in the risk of forest and embankment fires, it may be necessary to modify the vegetation to take account of climate change by means of appropriate management forms in the vicinity of railway facilities in cooperation with forestry authorities.

Current analyses indicate that air transport is only affected to a limited extent by possible climate changes. Nevertheless, it may be necessary to adapt operations at airports and in the air traffic control sector to cater for more frequent extreme weather situations.

The effects of climate change on marine transport in the North Sea and Baltic Sea must be considered both in regional terms and on a larger scale, since the ports on both seas have worldwide links via marine transport routes. It is important to ensure the safety and operations of marine transport with regard to the possible effects of climate change, as forecasts of the volumes handled by German seaports indicate substantial growth potential. Spare inland waterway capacity could be used to improve connections between seaports and their hinterland – thereby easing the burden on other means of transport such as the roads.

Climate changes, and hence changes in air and water temperatures, rainfall, ice cover, water levels, wind speeds, wind direction or the state of the sea, have direct impacts on marine shipping and shipping routes. In particular, changes connected with extreme weather events are important.

Seagoing ships and navigation, like the development, maintenance and operation of marine transport routes, depend on the oceanographic, hydrological and meteorological conditions on the open seas and in the coastal zone. The predicted rise in sea level will affect ports and other maritime infrastructures. There will also be changes in currents, erosion and sedimentation in the estuaries and sea routes, and these will require more detailed investigation. It may, however, be that new sea routes will open up for shipping, for example the Arctic routes, and there will be a need for timely investigation and coordination of the best ways of using them.

It will be necessary to examine whether climate-induced changes create a need for adaptation of monitoring and advisory services, forecasting and warning services, risk management, emergency

and rescue services, marine technology measures, development measures or modifications to maritime infrastructures.

The usability of inland waterways is critically dependent on the meteorological and hydrological situation in the relevant river basin. The most important parameter is the usable quantity of water (water supply) available in the water circulation of the waterway's catchment area. The amount and its distribution over the year determine the situation in the rivers with regard to flow rate and water level. Water levels in German rivers have always displayed a great deal of variation. These variations could increase still further as the climate changes.

Estimates of the effects of climate change focus both on long-term changes in water supply (means) and on an increase in fluctuations (variability and extremes) which can influence water levels and discharge rates, and hence the navigability of the rivers.

When considering climate-induced impacts on inland waterways, a distinction is made between canals (24 percent of Germany's inland waterway network) and backed-up sections of free-flowing rivers. As far as canals and impounded sections of rivers are concerned, longer-term changes in water supply are more critical than an increase in fluctuations, since in the latter case it is possible to take management measures to keep water levels stable.

During extreme periods of high or low water, there is little or no possibility of using free-flowing rivers for freight and passenger vessels. Without suitable adaptation measures, more frequent extreme water levels could affect the reliability and safety of inland shipping on these stretches and also, in particular, the competitiveness of industries dependent on bulk goods – as the main users of the inland waterway system. Moreover, changes in discharge patterns could also have impacts on sediments (morphodynamics), the river-meadow system, the ecological situation and water quality, and the future maintenance of the waterways. All maintenance and development projects for federal inland waterways are currently taking account of the latest reliable scientific findings on the impacts of climate change. However, the information available to date on future regional developments in water supply is still subject to considerable uncertainties. The first step is therefore to systematically reduce the extent of these uncertainties in order to arrive in the medium term at more reliable information on trends in water supply and draw conclusions about concrete impacts on waterway infrastructure and inland shipping. To develop viable adaptation strategies and measures for shipping and inland waterways, the Federal Ministry of Transport, Building and Urban Affairs (BMVBS) has initiated the research programme KLIWAS.

3.2.12. Trade and industry

Adaptation to climate change also offers opportunities for innovative companies. For example, water-saving and wastewater-free processes have been developed and implemented in many industries in Germany since the 1980s. These are making the water-intensive chemical, paper and textile industries less dependent on water as a primary material and coolant. In drier regions this trend could become even more important in the future. Changes in external temperatures could have an impact on the energy balance of those who need heating or refrigeration or who utilise waste heat on site. Many companies can meet these challenges by means of research, technical innovation, infrastructure adaptation and other investments.

Adaptation to climate change is already in progress in many parts of the world. This is creating new opportunities for environmental technologies – including those for adaptation to climate change – not only in Germany, but also for export and international cooperation. German companies occupy good positions in many of these innovative sectors. One example is in-plant water management and treatment of recirculated water with recovery of still useful dissolved elements. Opportunities also exist for the construction industry through the use of new materials and insulation methods. If trade and industry take advantage in their business models of the

information already available about climate change and its consequences, there are many opportunities they can seize.

However, climate change brings not only opportunities for companies, but also risks. In particular, more frequent extreme weather events such as intense rainfall, droughts, storms, tornados, storm surges or floods could directly affect installations of trade and industry, and their operation. There is also the possibility of restricted operation due to weather-induced interruption of procurement or sales paths, including transport routes.

Extreme events present risks not only to employees, but also to the environment, when hazardous substances could escape from plants. Industrial installations that store or use large quantities of hazardous substances are already subject to basic safety requirements regarding precautions against risks arising from floods or other extreme weather events. This includes regular review and, if necessary, adaptation of plant safety management systems for extreme weather events. In this context "adaptation" means taking timely steps to adapt to changed probabilities and to prepare for potential damage resulting from the effects of climate change.

The Commission on Process Safety (KAS) (Section 51a Federal Immission Control Act (BImSchG)) has the task of identifying ways and means of improving plant safety and proposing appropriate regulations. The regulations have to be up to date with the state of safety technology and must take account of existing standards laid down for other protection objectives. The committee's working group on "Local Safety Hazards" accompanies research projects which draw up proposals for safety rules on hazards arising from wind, extreme rainfall and flooding.
Aspects to be adapted with regard to plant safety include the following in particular:
- the structural design of plants covered by the major accident regulations to cope with more frequent and more violent storms,
- protection of the plant from extreme rainfall and floods,
- alarm and emergency response planning,
- safety management and
- the legal and technical regulations.

The adaptation process should be accompanied by a communication strategy to draw attention to the need for industry to take action on its own responsibility.

Weather-induced disruption of procurement and sales paths including transport routes can lead to expensive production stoppages. Long-term disruptions may affect industrial companies which need large quantities of primary resources or which send their products by ship. Even short-term disruptions can affect the entire modern "just-in-time production" system, which requires reliable, predictable transport chains using road, rail, air or water transport over large distances. And finally, problems with water and power supplies or telecommunications can force virtually any kind of business to temporarily stop operations.

An increase in extreme weather situations could also threaten the reliability of agricultural product yields (see Chapter 3.2.6). This could create new requirements for companies that process renewable primary resources, since they would have to make greater efforts than in the past to avoid dependence on a primary resources from a single region or a limited number of regions. Reliable supplies of primary products are just as important for industrial locations as they are for the energy industry. Where necessary, precautions must be taken for the case that means of transport such as road, rail or water routes should not be available because of weather conditions. In the case of existing or planned industrial locations it is important to take account of both national and international impacts of climate change, e.g. the consequences of an expected rise in sea level in coastal areas. In addition to actual loss or damage, companies may have to put more work into planning for future decisions.

Many German companies now have their own locations and contractors worldwide. These may be more seriously affected by the consequences of climate change than plants in Germany. The effects of climate change may therefore become a criterion of relevance to industrial decisions on international locations. In such decisions, states where the effects are limited and which pursue a targeted and effective adaptation policy could be given preference over those states where critical consequences such as failure of water supplies cannot be ruled out.

The Federal Government, in conjunction with the Länder and industrial associations, will conduct more detailed research into future developments and the influence of all these factors on trade and industry.

3.2.13. Tourism industry

According to estimates by the United Nations World Tourism Organisation (UNWTO), global climate change could, in the long term, introduce considerable changes in travel patterns worldwide. On the one hand, this could present a threat to tourism in numerous regions, and on the other, it could cause shifts in tourist flows. Major changes in travel habits could have considerable repercussions on economic and social structures in the destination countries, for example the accommodation and transport facilities and the social infrastructure of the countries concerned. In addition to the indirect impacts on tourism infrastructure, extreme weather events could also deter people from travelling to the region in question.

Extreme weather events could have an impact on the expected flow of payments to the relevant businesses, resulting in increased capital and third-party costs. There is a need to investigate whether existing financial or actuarial instruments are suitable for adequately addressing the future effects of global climate change.

The economically important winter sports segment in particular is directly affected by climate change. Especially at lower altitudes in the Alps and the German central highlands there already has been a marked decline in the reliability of snow existence over the last fifty years. In future there is reason to expect that winter sports will not be possible at altitudes below 1,500 m in the Alps or below about 800 – 1,000 m in the central highlands.
In future, rising temperatures at lower altitudes mean that it will no longer be possible to produce artificial snow with snow cannons to increase the certainty of snow and extend the season.
In view of this trend, a concentration of ski tourism on the ecologically very sensitive higher regions of the central Alps can be expected. Availiable alternative activities (walking, cultural tours, wellness holidays) will therefore play an important role..
Climate change is expected to have many different impacts in coastal regions as well.

On the other hand, changed climatic conditions could also open new opportunities for the tourism industry, for example through increased numbers of visitors in what has hitherto been the off season, or as a result of tourist flows shifting from southern to northern regions. Many Germans have tended to spend their summer holidays in the Mediterranean countries. The total stream of holidaymakers from central and northern Europe to southern Europe, with around 116 million arrivals, is the biggest touristical migration worldwide, and accounts for 41 percent of internal tourism within Europe. Since there is an increasing probability that southern Europe will experience daily maximum air temperatures of 40°C or more during the peak season, travellers can expected to suffer increased heat stress, which can have unfavourable effects on the well-being of older persons and children in particular. In Germany, by contrast, rising temperatures and lower rainfall in the summer could tend to favour tourism, for example because of an extension of the summer season. The Potsdam Institute for Climate Impact Research expects Germany to become more attractive to tourists. Estimates suggest that the number of tourists coming to Germany could increase by 25 to 30 percent.
Even in Germany, however, summer temperatures could also rise – at least in individual years – to levels that are not conducive to certain forms of tourism.

To be able to make recommendations about which actions to take, the Federal Government is currently promoting the project **"Climate trends and sustainable tourism development in coastal and central upland regions"** (KUNTIKUM). The research project is being run by the Institute for Environmental Communication at the University of Lüneburg. It is investigating how tourism, as an economic sector especially sensitive to weather and climate, can adapt to the effects of climate change. In this cross-disciplinary project, representatives of the tourism industry and tourism policy are working together with experts from the fields of economic science and sustainability and climate research. To make it possible to transfer experience from the survey regions (North Sea coast and Black Forest) to other tourism regions as well, the project is also create an information and communication platform which will also include a further training module.

3.2.14. Cross-sectional topics: Spatial, regional and physical development planning and civil protection

Spatial, regional and physical development planning

Spatial, regional and physical development planning represent the start of the risk avoidance chain, since they develop precautionary regional concepts, use planning documents which are legally binding and valid for long periods, and may involve long lead times before the contents of the plans are put into practice. Spatial planning has the important function of reconciling different claims on the same space.
With the existing legal and planning instruments, spatial planning can support both mitigation and adaptation. The fact that natural hazards may occur more frequently can place restrictions on the use of natural resources. At the same time it gives rise to great usage pressure, since adaptation measures frequently require space as well. Spatial planning, by developing models for adaptable and resilient spatial structures, can play a pioneering role in ensuring a robust and flexible response to the impacts of all societal change processes on spatial structure.
Spatial planning is already a tried-and-tested instrument for climate change mitigation. For example, spatial planning designates suitable areas for wind turbines or defines areas for photovoltaic systems and coordinates them with other claims on their use, such as housing, recreation, tourism, nature conservation, agriculture, or sustainable extraction of domestic primary materials. In cities and urban agglomerations, spatial planning – in conjunction with landscape planning, if necessary – ensures continuous non-built-up areas (green belts) and fresh air channels which primarily help to avoid overheating in summer. Whereas in the recent past physical development planning and individual building planning has frequently optimised housing estates and buildings for maximum sunshine, which can offer energy benefits in winter, future planning will have to devote more attention to solutions that avoid excessive warming of buildings and recreation areas in summer.
The instruments of spatial planning are of great importance for adaptation, especially for implementation of the integrated approach:

Providing for risks by adapting to the expected increase in the intensity and frequency of extreme weather situations

- In river basins, protection from increasing flood risks must be stepped up by means of both passive safety measures (especially non-builded areas) and active river regulation.
  By designating flood areas, usually as priority and reserved areas for flood control (going beyond the designation of flood control areas required by water legislation), regional planning (spatial planning) can safeguard existing discharge and retention areas and prepare for their necessary expansion, on the risk basis of a 200-year flood. By means of regional

and supra-regional consultation, regional planning will make every effort to achieve a considerable expansion of retention areas by the year 2020 and thereby make extensive use of all available potential to provide effective long-term protection against the growing flood risk.

One effective supplementary means of preventing floods (and at the same time contributing to groundwater recharge) is adequate decentralised infiltration of rainwater over the entire catchment area of the river. Regional planning can do much to improve opportunities for rainfall to soak away naturally by reducing new land take of open spaces for settlement and infrastructure, providing planning support for restoration, unsealing, renaturing and reforestation of suitable land, and striving to ensure appropriate agricultural use.

- In coastal areas and on islands, regional planning must lay the foundations for ensuring continued maximum protection from increasing storm surge and flood risks in the future. Adaptation to climate change requires not only dyke building and refurbishment measures, but also the development of new forms of safety precautions – especially passive ones – for the islands and coasts.
- Regional planning should take appropriate precautions to counteract the specific risks in mountain areas. Mountain areas like the Alpine region are complex ecosystems that display particularly sensitive reactions to climatic changes. At the same time, mountain areas are important habitats and cultural and economic areas. The expected increase in extreme weather situations and their results, such as debris flow, rock falls, soil erosion etc., underlines the great importance of planning precautions.
- Regional planning can take greater account of bioclimatic stress areas in future by controlling settlement development from the point of view of health. The predicted increase in the frequency of hot periods and heat-waves in summer will give rise to "heat islands", especially in densely populated areas. To mitigate the effects of heat, there is a need in the context of settlement development to keep areas free for fresh air and cool air formation and outflow. Here there are close points of contact with the fields of action of regional planning and urban development. In particular, the implementation of small-scale climate adaptation strategies requires intensive cooperation between a city and its hinterland (see Chapters 3.2.1 and 3.2.2).

Adaptation to landscape change and possible restrictions on the usability of natural resources

- If groundwater recharge rates fall as a result of climate impacts, regional water shortages need increased regional planning safeguards for water resources and planning efforts to ensure appropriate uses.
- The rise in sea level and the associated rise in groundwater levels, and also the increase in coastal erosion trends, call for additional efforts in the protection of coastal areas and create important new aspects for the development of coastal landscapes (see box on ICZM in Chapter 3.3).
- Climate change creates a need for forward-looking participation in spatial adaptation measures in the tourism sector, especially in coastal and mountain areas. The changes in tourism habits may call for new investment and new infrastructures, and these need appropriate preparation from a spatial planning point of view. The development of new climate-appropriate concepts could be supported by model regional planning projects.
- Climate change will give rise to temperature-prompted evasive und migratory movements of animal and plant species. By providing planning support for safeguarding priority nature conservation areas and a composite ecological system, regional planning can make an effective contribution to adapting species to climate-induced shifts in habitats (see Chapter 3.2.5).

The Conference of German Regional Planning Ministers (MKRO), at its 35th meeting on 29 April 2008, also took decisions on the spatial consequences of climate change.

Civil protection

Civil protection is the sum of all civil measures to protect the population and its basis for life. Among other things, it comprises civil defence, disaster control and disaster aid in the case of natural disasters and other serious predicaments. Civil protection is made up of precaution measures(→ *Glossary*) and response in damage situations , up to disaster scale.

Civil protection has only recently started to address the topic of climate change, which means that there has so far been little investigation on the possible impacts of climate change on this sector. Essentially, civil protection is already geared to deal with extreme events and major damage situations. If weather and climate-induced disasters occur more frequently in future, this can present state-managed civil protection with new challenges relating to its resources, crisis and emergency management and operations planning. At the same time these challenges have impacts on the individual protection and self-help measures of the general public. In the centre of attention is the future frequency and intensity of extreme events such as storms and floods, which threaten human life and cause heavy losses and damages. There is a special risk for critical infrastructures (KRITIS) such as energy and water supply, transport and traffic, and telecommunications and information technology, which have the function of "lifelines of society". The special vulnerability of critical infrastructures is due to their interdependence. Failures in the power supply or IT sectors have numerous repercussions and lead to disruption and failures in all other critical infrastructure sectors.

Thus protection for critical infrastructures[9] is a special challenge for civil protection. Only a small proportion of critical infrastructure facilities are owned by the state. More than 80 percent are operated or controlled by private or privatised companies, which are thus also responsible for the functioning of the facilities. A partnership-based cooperation between federal and Länder authorities and private-sector companies is indispensable to ensure reliable supplies for the public in emergency situations. In cooperation between the Federal Ministry of the Interior and its subordinate authorities and the private sector guidelines and protection concepts have been drawn up. Starting from a basic protection concept, a guide to risk and crisis management in companies and public authorities was devised under a "private-public partnership". This way, for example, protection objectives are to be defined in a structured system for risk and crisis management. Risks are then to be identified for these protection objectives, and appropriate measures planned for risk minimisation and avoidance. The aim of the recommendations is to provide better protection for important processes and plants, and to restore their functionality as quickly as possible after occurrence of incidents. In addition to constructional reinforcement (physical strengthening) of buildings and systems such as water or electricity networks, other important precautions for disasters are emergency and evacuation plans, warning systems and information facilities.

Civil protection issues relate in many ways to competencies of various federal ministries and sectoral policies. These competencies are all aimed at risk management designed for acute crisis situations, and at follow-up risk management concerned with repairing the damage done by disasters while making every effort to reduce or limit future damage potential. Technical measures in the field of preventive flood control or coastal protection, adaptation measures in water

[9] Critical infrastructures, as defined by the Federal Government, are organisations and facilities of great importance to the state, the failure or impairment of which would result in serious supply shortages, considerable disruption of public safety, or other dramatic consequences.

management, protection of human health, safeguarding transport or energy infrastructures, spatial planning or building safety are precautionary measures of crucial importance for civil protection.
At the federal level, the Federal Environment Agency (UBA), German Weather Service (DWD), Federal Agency for Technical Relief (THW) and Federal Office of Civil Protection and Disaster Assistance (BBK) have been working since 2007 in a working group on "Climate change and civil protection", developing joint concepts to equip them as well as possible for any extreme events of relevance to civil protection and disaster assistance.

The federal and regional authorities will continue to develop deployment tactics and technical equipment in the interests of medium and long-term adaptation to the effects of climate change. The Federal Government will make the necessary qualitative and quantitative changes to the relevant scenarios to take account of the longer-term effects of climate change, and will implement the resulting adaptation measures in cooperation with the Länder.

For any further development of civil protection that may be necessary, the main need is for knowledge about future trends in the frequency of extreme events such as storms and intense rainfall. In addition to the further development of deployment tactics and technology, risk communication with all concerned parties – such as companies, associations and the general public – is an important aspect. Here the BBK can continue to perform its coordinating function and support precautionary measures by drawing up guidelines.
The numerous natural disasters occurring in recent years have shown where deficits in civil protection are. Action is needed, for example, with regard to information and alert channels, communication and coordination of the competent disaster control authorities and operational personnel, clear, timely and effective warning and information of the public, and civil protection in the field of health care.
The federal and Länder authorities will adapt the existing effective crisis management to current needs and future developments – such as climate change – and take account of the resulting requirements in emergency precautions.

3.3. Impacts on natural areas, examples of integrated approaches at regional level

Nature and society are vulnerable (→ *Glossary*) to the effects of climate change if the adverse effects of climate change exceed the possibilities of adapting to them. The extent of the possible damage depends on the regional expression of the global climate change and the spatial uses. The means of adaptation depend on the adaptive capacity. Regional adaptation requirements therefore result from regional climate changes (Chapter 2), the means of adaptation (Chapter 3.2) and regional vulnerability to climate change (Chapter 3.3).

A regionally differentiated analysis and evaluation of vulnerability is an important precondition for the development of integrated adaptation strategies at national, regional and local level. Particularly at regional level it is advisable to aim for integrated approaches. Such approaches facilitate trade-offs between different uses when formulating objectives. They also integrate other regional change processes (e.g. demographic change) and can optimise the interaction of the sectoral and cross-sectoral adaptation measures relevant to the region (see examples for the model region Alps and integrated coastal zone management).

Models of the effects of climate change and estimates of vulnerability are partly based on the results of climate research models. As a result, they usually lag behind the latest climate modelling findings. The following section provides information on regions which are expected to be particularly vulnerable to the effects of climate change, on the assumption that no adequate national and international mitigation measures are taken and no adaptation measures are taken in addition to those already implemented. This means that the expected vulnerability can be reduced

by means of extensive mitigation and adaptation measures. The following information is based on analyses of a variety of sources[10] and on older results of regional climate models which have been confirmed by more recent findings (Chapter 2) and refined. It should be borne in mind that the uncertainties in the model forecasts are much smaller in the case of temperatures than they are for rainfall. With regard to rainfall trends, the regional climate models still arrive at widely differing results which do not yet permit any reliable statements about particular regional variations.

There is still a need for work on updating and further developing existing vulnerability studies while making use of more recent findings and the latest results of regional climate models. This should certainly be targeted and should be initiated in consultation with the Länder.

The **Alpine region** is doubly affected by climate change. For one thing, the temperature in the Alps has risen twice as fast as the global average – and all climate models predict a larger temperature rise for the Alpine region in the future as well (an average of between 3 and 4.5°C by 2100). For another, climate change has a particularly strong impact in such a sensitive ecosystem as the Alps. The biodiversity of the Alpine region is very vulnerable because of the frequent high degree of ecological specialisation and since it is characterised by a large number of plant and animal species that occur only there (i.e. they are endemic). It is also clear in the Alpine region in particular that certain adverse effects of climate change can no longer be prevented and the main emphasis will therefore have to be laid on adaptation measures.

The following climate change impacts specific to the Alpine region are predicted:

- The zones in which animals and plants live will shift to higher altitudes, and the existence of many Alpine species will be threatened because climate change means there is no alternative habitat for them.
- Adverse effects on mountain forests and the protection they grant from natural hazards.
- Accelerated melting of glaciers, with water management effects on glacier-fed rivers and lakes.
- Changes in frequency of natural hazards such as rock falls and landslides.
- Sharp decline in reliability of snow in winter sports areas; Germany could be the most affected of all the Alpine countries.

In addition to the ecological impacts, the entire population will be affected through the sectors of tourism, management of natural hazards, settlement development, spatial planning, nature conservation, mountain farming, forestry and water management.

[10] a) The Federal Environment Agency's "Vulnerability Study" dating from 2005, which provided a first combined overview of climate change impacts and vulnerability estimates in a nationwide overall study covering a comprehensive range of methods.
b) The results of the DEKLIM research programme (Federal Ministry of Education and Research), *inter alia* on the vulnerability of the German coastal region.
c) The status report by the Federal Agricultural Research Authority (2007) on climate change effects and adaptation measures for the agricultural sector in Germany.
d) The survey of federal ministries and Länder (2007) on existing or planned adaptation concepts and measures.
e) The Federal Environment Ministry expert conference on "German Adaptation Strategy – Expectations, Objectives, Action Options" held on 15/16.04.2008 in Berlin
f) The joint conference on adaptation research held in Leipzig on 27/28 August 2008 (Federal Ministry of Education and Research / Federal Environment Ministry).

Climate change model region: The Alps

The Climate Action Plan of the Alpine Convention can be taken as a good example of cooperation in a particularly affected mountain region. It also opens up special opportunities for the Alps: with sensibly implemented strategies for sustainable development, the Alpine region could become a model region for climate change mitigation and adaptation.
The Parties to the Alpine Convention have focused their cooperation on climate policy and the development of adaptation strategies for the Alpine region. They are currently drawing up an action plan which is to be approved at the Tenth Alpine Conference in February 2009. This action plan will include both mitigation strategies (e.g. in the energy, transport and tourism sectors) and adaptation strategies (e.g. in the spatial planning, biodiversity and forest, sustainable tourism and water management sectors). Pan-Alpine designation of danger zones with appropriate spatial planning or the creation of an Alpine ecological network (linking of protected areas and biotopes) for migration of Alpine flora and fauna will also form part of the action plan.
The basis for the Alpine-specific adaptation measures will be developed and co-funded primarily by means of joint projects by the Alpine states under the European INTERREG programme for the Alpine region. The project ClimChAlp (Climate Change, Impacts and Adaptation Strategies in the Alpine Space), which was completed in 2008, will be followed from autumn 2008 by the successor project "AdaptAlp" with its focus on climate simulation of the effects of intense rainfall and drought, and the project "ECONNECT", which promotes the creation of a network of ecological corridors in the Alps. This network is supported by the Federal Environment Ministry, which also runs and finances the relevant platform of the Alpine Conference.

In view of the relatively moderate and temperate coastal climate, the regional climate models expect a comparatively small temperature rise for the **coastal regions of the North Sea and Baltic Sea** by the end of the 21st century. However, there could be changes in the frequency of temperature index days, i.e. ice, frost and summer days or tropical nights. Summers are expected to become drier. In the second half of this century the coastal regions could increasingly be at risk from the rise in sea level and a change in storm climate. The rise in sea level and change in the storm regime could, in the long term, lead to accelerated erosion of unconsolidated coastlines in particular (currently about 0.3 to 0.4 m per year) and increased penetration of salt water into the groundwater. A high level of coastal protection measures characterises the region's present vulnerability, which may even increase in the future. However, there is great uncertainty about the probable scale of changes in sea level and the storm climate. The northern German coastal Länder and the federal authorities are therefore making intensive efforts to reduce potential risks in the coastal region by means of integrated approaches to the management of coastal protection[11]. One aspect of special importance is the potential danger to wetlands and low-lying areas and to regions with high damage potential, such as the port of Hamburg, or uses on the open seas.

[11] See for example the General Coastal Protection Plan for Schleswig-Holstein

Integrated coastal zone management

Integrated coastal zone management (ICZM) is an inter-Länder approach to resolve conflicts in between use claims. ICZM is a voluntary and unbureaucratic instrument which is intended to bring about better reconciliation of the protection and development of natural resources and near-natural land with economic and social demands. The basis for this is the National Strategy for Integrated Coastal Zone Management which was adopted in March 2006 under the lead responsibility of the Federal Ministry for Environment. ICZM is intended to penetrate all planning and decision areas. Going beyond mere management, it has an important strategic component, which works with differing ideas about future development and visions for coastal and marine areas. ICZM uses regional planning as a central tool. Ecologically and economically acceptable development of coastal areas is only possible if one takes account of the changing boundary conditions – and here climate change in particular is a crucial factor. The Federal Government supports the implementation of the ICZM strategy through a variety of measures. A number of research projects are in progress here, developing strategies, instruments and measures for environmentally sound and efficient land use in the German coastal zone, testing cooperative learning projects (Michael Otto Foundation), and supporting the processes of dialogue and decision taking for all parts in the establishment of an ICZM coordination unit.

Central parts of **eastern Germany**, the **northeast German plain** and the **southeast German basin** are already affected and will probably be affected in future by a reduction in available water supply. A further reduction in summer rainfall and increased evaporation as a result of rising temperatures would cause a further deterioration in the already unfavourable climatic water balance. This could have impacts on the agricultural sector. The Lausitz area in particular (the south-eastern corner of eastern Germany), where particularly high summer temperatures are expected, is likely to suffer from increased health problems due to heat.

The observed data for **south-western Germany** for the last hundred years already shows an above-average temperature rise. The results of the climate models suggest this trend will continue. This could have repercussions on agriculture and forestry in the region. The models indicate that in the Rhine rift valley, climate change will make itself felt especially in the form of a marked increase in hot days and nights and more frequent and long-lasting periods of heat – a challenge particularly for health care (Chapter 3.2.1). As a result of the emerging shift of rainfall from the summer to the winter months and a possible increase in rain-bearing westerly weather situations, the flood risk in winter will probably increase.

3.4. Climate change mitigation and adaptation – using synergies, avoiding conflicts

When drawing up concepts and selecting measures for adaptation to climate change, care should be taken to avoid counteracting the climate change mitigation efforts. If in doubt, preference should be given to alternatives that also contribute to reducing greenhouse gas emissions, and also the other way round. Examples include:

- Investment in insulation for buildings not only reduces heating requirements in winter, but may also provide protection against noise and health problems due to heat in summer.
- Short-rotation crops (e.g. poplars) in flood areas can produce valuable renewable primary materials and can be a robust and economically important land use and can be in harmony with flood control, provided they are managed appropriately, following nature conservation and flood control requirements.

- Forest conversion stabilises forest ecosystems, reduces potential risks for forestry and timber operations, and raises timber production, which is important from many different aspects.

On the other hand, it is not always possible to achieve a meaningful combination of mitigation and adaptation measures: conflicts of objectives may also occur and should be alleviated as far as possible by means of intensive consultation on supporting measures (integrated approaches).

- Land-use requirements arising from the creation of a biotope network to provide opportunities for migration, propagation and retreat may compete with the expansion of intensive uses of agricultural and forestry land, e.g. efforts to produce renewable primary energy resources in the interests of the climate.
- Increasing the density of urban structures can help to reduce energy consumption, but has adverse effects on adaptation because it reinforces the urban climate effect, thereby increasing summer heat stress and hence the demand for cooling. Careful design of residual open spaces, limited surface sealing, heat insulation for buildings, and greening and shade provision using deciduous trees can counteract negative effects of increasing urban density.

3.5. State of research into adaptation to climate change

Aspects of adaptation to climate change have become an integral part of climate research, as stated in the German national climate protection programme of 2005. For the High-Tech Strategy for Climate Protection of the Federal Ministry of Education and Research , one of the focal points of the new research funding concept is the development and implementation of strategies for adaptation to climate change. Adaptation issues have also gained importance in sectoral research by the other federal ministries:

For example, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, with assistance from the Federal Environment Agency (UBA) and the Federal Agency for Nature Conservation (BfN), uses the environmental research plan to carry out sector-specific research projects (e.g. in the fields of water, health, soil, nature conservation) and methodological research into climate change effects and adaptation options. The Federal Ministry of Transport, Building and Urban Affairs is conducting research projects related to adaptation in the fields of transport (shipping and waterways) and regional planning, as is the Federal Ministry of Food, Agriculture and Consumer Protection in the fields of breeding, crop growing, livestock farming, agro-economics and forestry.

Thus the promotion activities of the federal ministries, those of other funding organisations (e.g. Deutsche Forschungsgemeinschaft, Helmholtz-Gemeinschaft), the universities and Länder, other countries and EU projects are mutually complementary.

Current research funding by the Federal Ministry of Education and Research and the sectoral research initiatives taken by the federal ministries in the field of adaptation to climate change are supported by three pillars:

- Climate system research
- Climate impact research
- Adaptation research.

Climate system research

Climate system research and its outcome are for the Adaptation Strategy also of great importance, because it makes a crucial contribution to a better understanding of the processes and interactions that govern climate. Climate system research forms the basis for scenarios and projections derived from global and regional models. Its findings make it possible to identify essential framework conditions for future developments and thus form the basis for the question of what climate one should be adapting to.

Climate system research investigates the complex relationships between the subsystems "atmosphere", "oceans" and "land surface". Research work with coupled climate models and model validations has been performed, among other things, in projects under the German climate research programme DEKLIM. Climate system research is also carried out in the context of institutional research (Helmholtz Association of German Research Centres, Max-Planck-Gesellschaft, Leibniz Association). The coordination work for the community model COSMO-CLM is supported by a project of the Federal Ministry of Education and Research.

Since 2005 the "Adaptation Service Group" (SGA) at the Max Planck Institute of Meteorology in Hamburg has been working a common basis for methods and data related to climate change. The group aims to take up the dialogue between climate system research and adaptation research and stakeholders at practical level, and to advise those responsible to understand on matters connected with performance, properties and limits of climate models, data or scenarios.

Basically, climate system research already offers a wide range of results and products that can be used to estimate future climatic conditions. In the context of the High-Tech Strategy for Climate Protection, however, there is a need to achieve further decisive improvements.

Climate impact research

Climate impact research investigates the interactions between climate changes and natural systems and human society (socio-economic systems). Its findings help to identify possible measures for adapting to climate change. However, it also makes for a better understanding of human influences on the worldwide climate system. This is another field where basic research has been carried out, for example, by the German climate research programme DEKLIM. A number of other scientific institutes are also actively working on relevant issues of climate impact research. For example, natural and social scientists at the Potsdam Institute for Climate Impact Research (PIK) and other institutions are carrying out interdisciplinary work on robust foundations for decisions in politics, economics and civil society. The most important methodological approaches being pursued in Potsdam are system and scenario analysis, quantitative and qualitative modelling, computer simulation and data integration.

The German Weather Service (DWD), with its impact models in the fields of urban climate, agricultural and water management and the health care sector, is making a valuable contribution to impact assessment. Moreover, in many cases models make it possible to identify potential adaptation strategies.

Adaptation research

Adaptation to climate change primarily means managing the impacts of climate change on man and the environment, prosperity and quality of life, economic and social development. Management of this kind calls for a better understanding and assessment of the risks and of the social and economic potential and conditions for adaptation. For research in particular this means

- identifying the regional and sectoral impacts of climate change,
- identifying knowledge deficits, and
- developing strategies and technical solutions for adaptation measures.

Climate change adaptation issues can be considered and dealt with from a sectoral or a spatial (regional) point of view. The current measures by the Federal Ministry of Education and Research (BMBF) for promoting adaptation research take account of both sectoral and regional approaches:

klimazwei – Research for climate protection and protection from climate impacts
This sponsorship measure by the Ministry of Education and Research, which forms part of the framework programme "Research for Sustainability" (FONA), focuses on the development of practically oriented action strategies related to climate change. During the period 2006 to 2009 it is funding: i) research projects which develop methods of reducing greenhouse gas emissions (mitigation), and ii) projects which investigate measures for adaptation to the inevitable climate change (adaptation). In the field of adaptation,19 research alliances are working, with a funding volume of approx. 15 million euro (http://www.klimazwei.de).

KLIMZUG – Managing climate change in the regions for the future
The key assistance area KLIMZUG (Federal Ministry of Education and Research) pursues a regional approach (cf. 5.3).

GLOWA – Global change in the hydrological cycle
The topic of "Global change in the hydrological cycle" has been the main focus of several major joint projects within the GLOWA assistance measure since the year 2000. The paramount purpose of this research is to develop a basis for decisions that permit sustainable management of the vital resource water. All GLOWA projects are currently in the third and last assistance phase. Two of the five GLOWA projects are based in Germany: in the GLOWA Elbe and GLOWA Danube alliances, various stakeholders in the Elbe and Danube river basins join forces to research scenarios and strategies concerning with the impact of climate change on environment and society in these river basin regions.

Major contributions from ministerial research are:

- The first **"Vulnerability study"** commissioned by the Federal Environment Agency (Zebisch et al. 2005) (see Chapter 3.3).

- In 2007 the Federal Ministry of Transport, Building and Urban Affairs (BMVBS) launched its initiative "Shaping the future in times of climate change – **Shipping and waterways** in Germany". In this initiative its sectoral authorities (German Weather Service (DWD), Federal Institute for Navigation and Hydrography (BSH), Federal Institute of Hydrology (BfG), Federal Institute for Hydraulic Engineering (BAW)), in conjunction with the national and international research network, evaluated basic aspects of climate research with regard to the possible impacts on waterways and on marine and inland shipping. This inventory of available knowledge appeared early in 2008 as a publication by the Federal Ministry of Transport, Building and Urban Affairs. In mid 2008, as a follow-up to this inventory, the Federal Transport Ministry started the five-year research programme KLIWAS ("Impacts of climate change on waterways and shipping – Development of adaptation options") (Chapter 5.2 *Sectoral adaptation research*).

- From the point of view of regional planning, devising specific protection strategies for possible development paths is an important action option. In preparation for the planned model projects on **"Strategies for adapting to space-relevant impacts of climate change"**, the Federal Ministry of Transport, Building and Urban Affairs (BMVBS) and the Federal Office for Building and Regional Planning (BBR) commissioned a preliminary study (2007-2009). This preliminary study is identifying climate change region types and specific protection strategies for possible development paths, and also drawing up (regional) planning action needs and devising measures and instruments for managing these tasks. The centre of

attention here is developments at "regional focal points" and hence adaptation strategies of special regional planning relevance. Since climate change will probably increasingly require taking decisions facing uncertainties, but – in view of the cross-sectional character of climate change – decisions in this context will be taken by a large number of stakeholders, the study is to investigate not only a systematisation of regional planning approaches, but above all opportunities for a "climate risk governance approach" (Chapter 5.2).

The topic of dealing with climate change, especially in relation to adaptation, will continue to be part of the European research agenda, where it is embodied in the Seventh Research Framework Programme (FRP7).

The Federal Ministry of Education and Research and the project institution DLR "Environment, Culture, Sustainability" are partners in the EU ERA-Net CIRCLE (Climate Impact Research Coordination for a Larger Europe). This is a European-level research network which brings together institutions funding research into climate change effects and adaptation. CIRCLE currently has partners in 19 countries. Germany is a strong partner in this consortium, and by managing the work package "CONNECT" it makes a major contribution to dealing with the interface between knowledge and action.

4. Worldwide adaptation – the German contribution

The international community recognised at an early stage the need to adapt to the effects of global climate change. In the 1990s the worldwide community of nationsnations – including Germany – made a commitment under the UN Framework Convention on Climate Change (UNFCCC) to start work on measures to adapt to climate change.

Especially developing countries, which are particularly vulnerable to the adverse effects of climate change, are to be given assistance with the task of adapting to climate change. In view of the uncertainties about the future scale of climate change effects, estimates of the total financial requirement for adaptation to climate change in the developing countries vary widely:

Table 1: Estimated adaptation costs[12] per annum:

World Bank 2006:	9-40 billion US dollars (only a)
Oxfam 2007:	At least 50 billion US dollars (a-d)
UNDP 2007:	86 billion US dollars in 2015 (a, b, e)
UNFCCC 2007:	28-67 billion US dollars in 2030 (a-c)

a) Adaptation costs at macro level in public development cooperation
b) "Climate-proofing" existing miscellaneous infrastructure
c) New investments that are necessary solely because of climate change
d) Adaptation costs at local level (adaptation at local authority level, personnel and organisation development in international cooperation by non-governmental organisations etc.)
e) Adaptation of poverty alleviation to climate change

At the end of 2007 the Conference of the Parties, meeting on Bali, approved an action plan (UNFCCC Decision 1/CP.13) comprising four pillars. One of the pillars is adaptation to climate change, the others being technology, financing, and reduction of greenhouse gas emissions. The action plan reflects the awareness that large parts of the world already need to adapt to climate change. Thereby it is completely undisputed that mitigation must remain the backbone of any ambitious climate policy. In Bali the Parties also gave the green light for the adaptation fund. This is to finance adaptation measures in developing countries and is due to start work in 2009.

Measures for containing security risks arising from climate change are also to be seen in the context of adaptation. Since 2007 there has been increased discussion of such risks at the level of the United Nations (e.g. Security Council debate in April 2008), the European Union (Council Decision on a European Action Programme) and at national level (publication of the expert report "World in Transition – Climate Change as a Security Risk" in 2007[13] by the Federal Government's Advisory Council on Global Change (WBGU). The risks relate largely to conflict constellations and to potential new migrations in fragile states or states with weak governmental structures that are particularly affected by impacts of climate change such as increasing water shortage, food shortages and natural disasters.

[12] Harmeling, S. and Bals, Ch. (2008): Adaptation to Climate Change – Where do we go from Bali? An analysis of the COP13 and the key issues on the road to a new climate change treaty.- Ed. Germanwatch, 44 p.
[13] Short and long versions of the WBGU expert report are available on the Internet: http://www.wbgu.de/wbgu_jg2007.html

Germany's role in adaptation measures in developing countries

The emerging impacts of climate change worldwide become increasingly important for Germany's external relations as well. Climate change effects will have particularly serious impacts in many developing countries, especially in Africa and the small island states. The people of these developing countries are the main victims of climate change, which has so far been largely caused by the industrialised countries. Thus in many countries the effects of climate change could adversely affect progress with poverty alleviation and towards the Millennium Development Goals (MDGs).

It is therefore important to include the effects of climate change in poverty alleviation in order to ensure that such efforts are sustainable in the long term. Climate change must indeed be seen as a new and important factor and cross-sectional policy aspect for every single country. Particularly vulnerable developing countries must be helped to draw up and implement a climate change adaptation strategy in the context of their national strategies for economic development and poverty alleviation, and to integrate climate change in all development planning. Important approaches to this can be found in the "National Adaptation Programmes of Action" (NAPA) which exist for 40 LDC (least developed countries)[14].

The federal budget for 2009 allocates about 5.7 billion Euro to the portfolio of the Federal Ministry of Economic Cooperation and Development (BMZ). This is a further indication that Germany is a major partner in the international fight against poverty. The figure includes support for adaptation efforts by development partners. Under the UNFCCC, adaptation is supported by contributions to the climate-specific funds of the Global Environmental Facility (GEF). Germany also plays an active part in the Nairobi work programme on climate change impacts, vulnerability and adaptation, which seeks to help countries improve their understanding of the impacts of climate change. Furthermore, Germany supports adaptation efforts through other forms of multilateral cooperation, e.g. the Strategic Climate Fund of the World Bank.

The aim in bilateral cooperation is to systematically integrate climate change mitigation and adaptation in all relevant bilateral cooperation programmes in consultation with the partner countries. The principal questions here are: How will an individual country be affected in practice by climate change, and how can it make a start on preparing for this scenario of the future? What needs to be done to reduce a country's socio-economic and political vulnerability to climate change and to increase the adaptive capacity of individuals and of the community as a whole? Special priority must be given to adaptation in the hardest-hit sectors: agriculture, water and health.

Efforts to help developing countries to adapt to climate change should also take advantage of opportunities for cooperation in other policy areas, e.g. environmental, agricultural, trade and research policy. Examples include projects for the conservation and sustainable use of ecosystems and integrated resource management, as these form an interface between poverty alleviation, nature conservation, climate protection and adaptation to climate change. International trade initiatives can also help to link the different sectors. One example is the EU action plan "Forest Law Enforcement, Governance and Trade" (EU-FLEGT) which sets out to combat illegal logging. Conservation of forest areas is very closely connected with adaptation to the effects of climate change, e.g. with regard to protection against extreme weather events. Research projects should help to bring about better understanding and observation of climate change impacts in developing countries as well.

Especially in some of the poorest countries, climate change may have impacts on food security. Investment in sustainable agriculture, including agricultural research, consultation and education/training, is of special importance when it comes to combining adaptation to climate change with improved food security, combating poverty, and stimulating economic development

[14] The 38 existing NAPAs are available on the Internet: http://unfccc.int/adaptation/napas/items/2679.php

and diversification of the economic structure. A made-to-measure approach based on the specific situation and the strengths of the countries concerned is the key here. There is often a need for fundamental structural changes going beyond the agricultural sector, with a view to enabling agriculture and rural development to play a greater role in the policies of these countries. Germany and other donor countries will support such processes. It is, however, crucial that the developing countries exercise their own responsibility to build up self-supporting structures that can exist in the long term without help from outside.

Around the world, climate-induced adverse effects on existing economic and environmental framework conditions are already affecting some migratory movements on a regional and supra-regional scale. Droughts or floods, if they result in prolonged adverse effects on agricultural land use (drying out; soil erosion), may reduce or destroy the economic livelihood of the rural (and indirectly the urban) population of whole regions.

The predicted climate changes could reinforce these effects. Resulting persistent deterioration in living conditions could lead to social tensions and destabilisation of society, and to political or possibly religious radicalisation of the population in the countries of origin. This could result in an intensification of the economic, political, religious or conflict-related motives and reasons for flight, and in increased migration. This could in particular affect the countries along the existing migration routes to the European Union and adjacent regions. Studies of the connections between climate change and migration are in progress[15]. Many of these potential cause-and-effect chains depend on timely adaptation efforts and effective combating of poverty or reasons for flight by the countries of origin themselves.

From a migration policy point of view, the German contribution could consist primarily in maintaining or strengthening existing development policy approaches and incentives to combat the reasons for migration, and to align them with with foreseeable future impacts of climate change in the countries of origin. A coherent migration policy, taking account of all these factors, calls for dialogue and cooperation with the countries threatened by climate change. The aim is to prevent that effects of climate change enhance people'speople'sreasons for leaving their homes.

Adaptation to climate change will require considerable efforts and investment in the developing countries. The industrialised countries have undertaken to assist particularly vulnerable developing countries with the task of adaptation to the adverse effects of climate change (Article 4 of the UN Framework Convention on Climate Change). One of the central challenges in the current international negotiations is therefore to develop a suitable financial architecture, in line with the Bali action plan, that provides appropriate support for the developing countries' own efforts in the field of climate change mitigation and adaptation.

Quite apart from this, the Federal Government's German Climate Protection Initiative financed from the revenues of emissions trading made funds totalling some 120 million Euro available in 2008 for projects including international climate change mitigation and adaptation. This is due to be increased to around 225 million EUR for 2009.

[15] e.g. http://www.each-for.eu/index.php?module=main

5. The German Adaptation Strategy: Approach and next steps

The preceding chapters have shown that many areas of life and economic activity as well as the natural environment could be affected by the impacts of the emerging climate change. In spite of the existing uncertainties and the difficulty of arriving at a precise description of the possible scale of climate impacts, it has become clear that for precautionary reasons it is both sensible and necessary to take a strategic approach to preparing and implementing measures for adapting to climate change. The special challenge here is the great complexity arising from the varying nature and extent of the impacts, the large number of stakeholders, the different decision levels, and the cross-sectoral and cross-disciplinary relationships and interactions.

Unlike mitigation of climate change, where the focus is on reducing greenhouse gas emissions as the overriding and quantifiable objective, adaptation to the effects of climate change is concerned with the less clearly focused long-term aim of reducing the vulnerability of natural, social and economic systems and maintaining and improving their adaptive capacity. The aim of adaptation is to facilitate achieving the objectives that exist in the various fields, even in the face of the new conditions created by climate change. This also includes implementing the policy guidelines and objectives approved by the Federal Government in its Sustainability Strategy "Perspectives for Germany" and reconciling the economic, environmental and social dimensions of sustainability[16].

The Federal Government therefore takes the view that the Adaptation Strategy must be designed as a step-by-step medium-term process which, in consultation with relevant stakeholders, takes a transparent and structured approach to stating the needs for action, defining appropriate objectives, identifying and resolving conflicts of objectives, and developing and implementing potential adaptation measures. Cross-sectoral prioritisation of possible adaptation measures is a central task of the further implementation of the Adaptation Strategy.

5.1. The Adaptation Action Plan

The present strategy lays basic foundations and creates a framework for national adaptation to the effects of climate change. The task of giving more concrete shape to further strategic activities calls for a broad discussion with the Länder and social groups. Alongside the climate protection programme, the further development of the German Adaptation Strategy is the second pillar of Germany's climate policy and a central concern of the Federal Government. For this reason the Federal Government intends to draw up with the Länder a joint **'Adaptation Action Plan'** which is to be presented by the end of March 2011. It is planned to submit this Action Plan to the Bundestag (*German Federal Parliament*) and the Bundesrat (*Federal Council of Germany*).

[16] Federal Government's progress report on the National Sustainability Strategy 2008 with reference to the German Adaptation Strategy, see p. 100 ff:
http://www.bundesregierung.de/nn_658608/Webs/Breg/nachhaltigkeit/Content/StatischeSeiten/teaser-entwurfspapier.html

On the basis of the latest climate information, the Action Plan shall include the following aspects (mandate):

- Principles and criteria for identifying and prioritising action needs
- Prioritising federal measures
- Overview of concrete measures by other stakeholders (on the basis of the dialogue and participation process)
- Information on financing
- Proposals for progress review (indicators)
- Further development of the German Adaptation Strategy and specification of next steps.

5.2. Elements of the adaptation process and next steps

In order to give concrete shape to the German Adaptation Strategy and facilitate relevant activities and initiatives, the Federal Government will

- promote cross-sectoral and comprehensive discussion about the German Adaptation Strategy,
- spell out the risks that Germany faces as a result of climate change, and classify and assess damage potentials,
- help to ensure that adaptation becomes an integral part of planning and decision processes in all relevant fields of action,
- create suitable framework conditions for developing and strengthening adaptive capacity (environmental, technological, social).

The following measures and initiatives are planned to achieve this:

- **Awareness raising and information**

  Adaptation often means changes in behaviour and usually involves costs. The implementation of adaptation measures therefore depends to a large extent on whether or not they are acceptable to the stakeholders affected – which may include economic considerations as well. In other words: anyone who is supposed to adapt needs to know the benefits and costs involved.

  The public must be provided with comprehensive and objective information to strengthen the decision-making competence and individual responsibility of citizens when it comes to dealing with the expected effects of climate change. Furthermore, expert audiences need additional information about climate impacts, probabilities and adaptation options. In its information and public relations work, the Federal Government will therefore give greater emphasis to communicating the latest findings about the possible impacts of climate change, the needs for action that may arise from them, and the available options for relevant action. The Federal Government will also pay greater attention to the topic of climate change adaptation when preparing educational material.

- **Dialogue and participation, support for the various social actors**

  The German Adaptation Strategy must ultimately set priorities with regard to possible adaptation measures and therefore – as far as possible – specify clear responsibilities for any measures necessary. In order to defuse or overcome conflicts of interests ahead of decisions, to mobilise individual initiative and to take note of contributions and ideas from the relevant social actors themselves, there is a need to involve a broad spectrum of stakeholders and social groups.

  It goes without saying that the competences laid down in the constitution have to be respected. For this reason alone the Länder are indispensable partners in particular. The Federal Government will therefore continue and intensify its cooperation with the Länder in the field of adaptation, with the aim of ensuring coordination with and between the adaptation strategies already in preparation or planned at Länder level. One important aspect of this cooperation will be the question of how future government and administration activities can systematically factor in the effects of climate change and what conditions need to be created for this.

  Since adaptation usually has to take place at regional or local level, many decisions have to be taken at the level of the municipality or administrative district. The Federal Government will therefore get together with the central associations of the local authorities and with representatives of interested municipalities and districts to discuss the measures and assistance that can be used to develop and implement local adaptation concepts. With a view to active involvement of the general public and expert audiences, these efforts should also make use of suitable formats for electronic participation (e.g. online consultation).

  The Federal Government is also seeking a dialogue with other important stakeholders in society, such as businesses, associations and scientists. To launch the dialogue on the Adaptation Strategy, the Federal Government is to organise a conference entitled ‘Ways to Adaptation’ in May 2009. The aim of the conference is to set in motion, jointly with the Länder and other stakeholders, the process of giving concrete shape to the German Adaptation Strategy. The Federal Government will follow this up by holding stakeholder dialogues, expert discussions and specialist conferences, and by introducing the topic of adaptation to climate change into existing dialogue, participation and consultation bodies**.**

Example: Dialogue with the financial services industry

One key area of the Federal Government’s climate policy is the development of funding options and investment strategies that make it possible to fight climate change and at the same time take advantage of market potential. As part of the High-Tech Strategy for Climate Protection, the “Climate Change” Financial Forum, consisting of leading German financial service providers, has been set up as a dialogue partner for the Federal Government. In conjunction with the ‘Sustainable Business Institute’ of the European Business School (EBS), the Financial Forum is currently drawing up a research programme designed to develop and accompany the research policy dialogue between the Federal Ministry of Education and Research and representatives of the financial services sector and the economical sector. The idea is to put the financial sector in a position to prepare for climate change and to play its part in implementing climate change mitigation and adaptation strategies.

- **Improving the knowledge base**

  The Federal Government will broaden and deepen the scientific basis for the adaptation process by means of research activities under the High-Tech Strategy for Climate Protection, which is coordinated between the ministries and integrated in the framework programme 'Research for Sustainability', and the ministerial research programmes.

  Furthermore, the lead ministries for scientific advisory bodies and councils of experts (such as the Federal Government's Advisory Council on Global Change (WBGU) and the Advisory Council on the Environment (SRU)) will ensure that the expertise of these bodies is taken into account in the preparation of the Adaptation Action Plan.

  The research activities at federal level will focus on the key areas described briefly below.

  Improving the quality of climate knowledge
  Our understanding of the climate system is constantly being improved as a result of ongoing research at the Max Planck Society (MPG), the Helmholtz Association of German Research Centres (HGF), universities and establishments in the Leibniz Association (WGL). Climate research computer systems play an important role here. By the beginning of 2009 a high-performance computer system will be installed at the German Climate Computing Centre (DKRZ) in Hamburg to optimise calculation of the ambitious scenarios for future global and regional climate models. The high-performance computer will permit higher resolution within the models, thereby making future climate models and scenarios more detailed and more accurate.

  Medium-term climate forecast
  For cost-effectiveness reasons, a knowledge of medium-term climate trends is particularly important for precautionary measures and early action on adaptation because many investment measures are planned and financed over such periods of time. In future this decadal period is to be covered by weather and climate scenarios. There are even indications that genuine predictions connected with certain probabilities are possible for ten-year periods. The so-called medium-term or decadal climate prediction is based largely on the fact that local weather is to a certain extent influenced by specific normal atmospheric states (regimes or climate modes). Such large-scale circulation situations tend to vary over periods ranging from months to years. The Federal Ministry of Education and Research will take steps to consider this – and other fstakeholders – and hence to investigate "decadal climate prediction" and make such "prediction" possible at all in the long term.

  Climate impacts and determining vulnerability
  The targeted adaptation process coordinated between the federal and Länder levels calls for a systematic approach with the creation of a common base of methods, knowledge and data on the impacts of climate change, the expected consequences and the effects that can already be observed. Depending on the specific question, climate impact and vulnerability assessment may be performed from a sectoral point of view, from the perspective of the interactions of natural and social processes, or based on a consideration of spatial units (e.g. national, regional or local level). In every case the starting point is a meaningful data basis from climate impact monitoring. Another important methodological instrument is indicator systems that represent climate changes, their scale and interactions. An integrated cross-sectoral approach to the development of indicator systems is recommended and should be pursued in close cooperation between departments at federal, Länder and local level. This work should build on existing indicator systems at federal, Länder and local level, e.g. in the field of sustainability.

  The Federal Government will therefore have proposals drawn up for a methodological approach to vulnerability assessment and suitable indicator systems.

Technical support can be expected among other things from a concept study on indicators and monitoring for the German Adaptation Strategy (research and development project of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety from 2009 onwards). In view of the continuing considerable need for research, the Federal Ministry of Education and Research will also initiate research activities in this field.
At a later stage the indicator systems can be expanded and used for monitoring and evaluation of adaptation measures.

In this context the "climate bio-monitoring" concept drawn up under the lead responsibility of Schleswig-Holstein, Baden-Württemberg and Hesse provides an interesting reference.

The climate bio-monitoring concept of the Länder:

The aim of the procedure set out in the climate bio-monitoring concept is to create a joint methods and knowledge base. This will be used not only to identify early warning signals on the impacts of climate change, but also to make available data compilations and analyses that can be offered to various target groups as a basis for their own work. The concept was agreed in 2006 with all Länder and several federal agencies (Federal Environment Agency, Federal Agency for Nature Conservation and German Weather Service), and is currently being implemented in various Länder. Thanks to their integration in ongoing programmes and the use of reliable and tested observation methods, the methods selected and assessed are highly suitable for building up the necessary data and methods base, especially since extensive studies on this topic already exist in various Länder**.**

Example of a sectoral monitoring system: Soil monitoring

A permanent climate impact monitoring system spanning decades is an important instrument for documenting changes resulting from climate change, for example in soil, with concrete data. Such a monitoring system can also be used for progress review of measures in the field of soil protection. The existing instruments of soil condition survey and soil monitoring, such as long-term field trials, long-term soil observation (BDF), forest soil condition survey (BZE II), forest environmental monitoring (level II) and the data from soil fertility appraisal, provide an important basis for research into climate impact and climate adaptation. With a view to improved forecasting of climate-induced effects on soils and designing regionally differentiated adaptation strategies, scientists should continue to develop process-oriented models on the interactions of climate change, land use and soil. The federal and Länder levels should jointly endeavour to make better use of existing monitoring systems, improve their interlinking and adapt them where necessary. Greater efforts are also necessary to improve data access, quality and availability (e.g. rainfall data for assessing individual phenomena or for erosion modelling).

New key research area "Sustainable Land Management" at the Federal Ministry of Education and Research:

The interactions between land use, ecosystem services and climate change are increasingly becoming a focus of scientific interest. This is because global change with all its various forms and consequences has impacts on land use in most parts of the world. Climate change is identified as one of the major driving forces here. To date we do not know enough about the connections between climate change and ecosystem changes or various forms of land use. This is a question not only of adaptation to climate change, but also of mitigating climate change (land surface as source or sink of climate-relevant gases) and of the contribution that sustainable management of regions/landscape areas can make, without neglecting the necessary key functions of landscape (ecosystem functions and services) and societal objectives.

These questions are closely interconnected, and can only be investigated by integrated research approaches. The Federal Research Ministry has recently opened a funding line for this key area. In sample regions particularly affected by global change phenomena, transdisciplinary and interdisciplinary research approaches should be used to develop strategies, action options and system solutions for sustainable land use management.

Economic aspects of climate change

Economic analyses provide significant arguments for discussing priorities within the adaptation process and for weighing up possible options. Where adaptation is concerned, the following costs and benefits are essential:

- the costs and benefits of (possible) impacts of global climate change without adaptation, which depend directly on the scale and speed of future global climate change and its national, regional and local effects,
- the costs and benefits of alternative adaptation methods, and
- the cost of the residual damage.

Under the High-Tech Strategy for Climate Protection research into the economic consequences of climate change and the economic prerequisites and effects of instruments and measures is being further expanded. Work is currently in progress on formulating a number of open questions that need further research. More detailed assessments are needed of the risks and opportunities associated with the consequences of climate change for industries, economies, globally interlinked value creation chains, and the global economy as a whole. The economic consideration should include the costs or financial benefits that could arise for individual industries and economic sectors as a result of international climate policy agreements and adaptation measures. This will be supplemented by taking account of economic aspects of climate change and adaptation in the ministerial research programmes.

Regional adaptation research

The key assistance area 'KLIMZUG – Managing climate change in the regions for the future' of the Federal Ministry of Education and Research pursues the regional approach. The aim of this assistance measure is to integrate the expected climate changes and the associated extreme weather forms in regional planning and development processes, and thereby prepare a region for life and economic activity under the conditions of climate change. Networks are to be formed, partly to increase the future competitiveness of regions, and partly to advance the development and use of new technologies, methods and strategies for adapting to climate change in regions. The intention here is not only to reduce climate-induced risks, but also, where appropriate, to seize opportunities resulting from climate change. Funds totalling approx. 75 million euro are available for this key assistance measure, which runs from 2008 to 2013. The first projects are already under way.

Sectoral adaptation research

The next necessary step in the strategic further development of the adaptation issue, after klimazwei and KLIMZUG (see above), is the ongoing development of the sectoral approach, developed under the research assistance programme of the Federal Ministry of Education and Research. Work is currently in progress to define topics for "sectoral adaptation research" and to identify the sectors on which the research is to focus. Special importance is attached here to specific areas of need and, where appropriate, value creation chains.
There is also a need for further research into social consequences of climate change and of its adaptation strategies and into adaptation options in specific sectors.

Sectoral adaptation research is in fact nothing new: research into site-appropriate agricultural production under climate change conditions has been a central task of research by the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV)[17] for about 20 years now. Under the heading of "Climate change, mitigation and adaptation" – which in January 2008 was taken up as one of the ministry's seven key research objectives – the individual research institutes, headed by a new institute established at the beginning of 2008 specially for climate research relevant to agriculture, have been working on the following main areas of relevance to adaptation:

- Analysis of the impacts of climate change on agriculture and forestry, horticulture, fishery, the food industry, cultural landscapes, rural areas and aquatic ecosystems, including inventory undesirable immissions (depositions) in agriculture, forestry and fishery.
- Analysis and development of methods, crop systems, products and services for adapting the agricultural industry to changed climatic conditions, including economic and ecological assessment.
- Studies on the characterisation, prevention and control of organisms harmful to plants and abiotic causes of damage, natural contaminants, animal epidemics and zoonoses and, if appropriate, their vectors, in cases where their new or intensified occurrence is due to climate change.

In mid 2008, following on from the results of the inventory mentioned in Chapter 3.5, the Federal Ministry of Transport, Building and Urban Affairs in conjunction with its sectoral authorities, the scientific network and in consultation with the Federal Environment Ministry, the Federal Ministry of Education and Research and the Federal Ministry of Food, Agriculture and Consumer Protection, launched the five-year departmental research programme KLIWAS ("Impacts of climate change on waterways and shipping – Development of adaptation options"). The initial focus of KLIWAS is on the adaptation needs of the waterway and shipping sector. However, it is also conducting more detailed studies for the marine, coastal, estuarine and inland sectors. The road to reaching decisions on a suitable adaptation strategy

[17] www.klima-bmelv.de

for the sector, and hence the approach of the research programme, is based on three pillars. The first phase involves the creation of reliable foundations by targeted investigation of the spectrum of possible climate projections and the associated water regime characteristics. The second phase analyses the effects of climate change on the cause-and-effect relationships in the waterway and shipping sector (subject areas: sensitivity and vulnerability). This comprises an analysis of the situation with the aid of the entire model chain, from global and regional climate projections through oceanographic and water regime models to morphological, ecological and water quality models. This forms a basis for the third phase, which draws conclusions about adaptation strategies, adaptive capacities and action options for inland and marine waterways and shipping (subject areas: measures and management).
The research programme of the Federal Ministry of Transport, Building and Urban Affairs thus contributes with an important building block to sectoral adaptation research. It also draws attention to reliable cross-sectoral findings regarding future trends in sea level at Germany's coasts and in water regime and discharge patterns in the major German river basins. The preparation and provision of regional climate scenarios and projections – especially for the parameters precipitation, air temperature, evaporation, discharge, water level and flow rate – can offer important starting points and above all concrete products for the water management sector and the Länder, which need the structures mentioned in Chapter 5.3 to support the strategy process.

The Federal Ministry of Transport, Building and Urban Affairs and the Federal Office for Building and Regional Planning (BBR), which is responsible for departmental research, in the model regional planning project "Spatial development strategies for climate change" will identify possible contributions to adaptation and mitigation by spatial planning, regional development and urban development and test them in selected model regions starting in 2009.

Decision-support instruments

To put stakeholders in a position to identify appropriate adaptation measures, the Federal Government is developing instruments for decision preparation and support. These include the development of guidelines or checklists which can help planners and decision takers in businesses, organisations and administrations to recognise their vulnerability and/or the degree to which they are affected and to decide on suitable adaptation measures. This is the intention behind the joint project of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Environment Agency on "Operational and strategic support for the management of climate risks and opportunities", which starts at the end of 2008. Communication of "good practice" is also helpful for decision support; a project catalogue can be seen at www.anpassung.net. A further tool is the 'Technical Information System on Climate Impacts and Adaptation' that is being developed, which will provide risk maps on specific topics on the basis of a geographical information system. As a guide for the development of instruments the tools "Adaptation Wizard", "Business Assessment Tool" and "Local Climate Impacts Profile", which have been developed in the United Kingdom and made available free of charge by the UK Climate Impacts Programme, can serve.

Criteria for prioritisation of adaptation options

The German Adaptation Strategy is keyed to integrated, inter-sectoral assessment. There is therefore a need for generally accepted inter-sectoral, non-asset-specific criteria for the assessment and prioritisation of adaptation measures. Examples of criteria might be the prevention of irreversible changes, the scale of the expected impacts, the possible extent of the damage, or the time to the possible occurrence of consequences. At present there is a lack of agreed criteria of this kind for Germany, and these must therefore be the subject of future research and consultation between the stakeholders. The development of principles and criteria for prioritisation of possible action needs serves the purpose of competent preparation

of measures and planned measures, and will therefore occupy a central position in the preparation of the Adaptation Action Plan.

Identification and progress review of adaptation measures
Progress review, as part of the iterative adaptation process, plays an important part in assessing the effectiveness of strategies and supporting measures. Acceptance in a social, political and economic context also is indicative of the transferability of adaptation measures in the sense of "good practice". In the first stage, therefore, evaluation of the Adaptation Strategy will be carried out with the aid of regular reporting on the activities in progress. In parallel with this, the Federal Government will set in motion the development of suitable tools and indicators for evaluating adaptation concepts and measures (see Chapter 5.2 *Climate impacts and determining vulnerability*)**.**
Progress review must, on the one hand, record climate changes and climate change impacts on environment and society, i.e. the classic sustainability dimensions of environmental, economic and social aspects. On the other hand it should also represent the process of implementing the Adaptation Strategy (by means of 'process indicators').

5.3. Structures for supporting the strategy process

Establishment of an inter-ministerial working group on adaptation to climate change
The Federal Government will set up an inter-ministerial working group on adaptation to climate change (IWG Adaptation Strategy, IMA Anpassungsstrategie) in which all ministries are represented. It will be headed by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The IWG is to prepare the Adaptation Action Plan, bring together the initiatives of the various federal ministries, and play an active part in shaping and accompanying the dialogue and participation process for the Adaptation Strategy, with the aim of ensuring a consistent conceptual approach by the Federal Government. It will submit regular reports for the purpose of updating the Adaptation Strategy and Action Plan and evaluating their implementation, the being the first report submitted in April 2013.

Continuation of federal-Länder dialogue on adaptation to climate change
In the course of continuing and extending the cooperation with the Länder in the adaptation process, and in the interests of close integration of Länder expertise, the "Federal-Länder dialogue on adaptation to climate change" initiated by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety will be carried on with the Länder with a new mandate. The current and planned work in the sectoral federal-Länder bodies (e.g. conference of environment ministers, conference of ministers of agriculture, conference of regional planning ministers) will be supplemented and interconnected.
[For current activities by the Länder, see Appendix I]

Competence Centre on Climate Impacts and Adaptation (KomPass)
In 2006 the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, by setting up the Competence Centre on Climate Impacts and Adaptation (KomPass, www.anpassung.net) at the Federal Environment Agency, created a unit which supports the preparation of the national adaptation strategy with technical and environmental advice. Major functions of KomPass are:

- Processing of technical knowledge about regional climate changes, climate impacts and adaptation with a view to risk assessment and deduction and evaluation of possible adaptation requirements.

- Communicating this knowledge to decision makers in politics, industry and administration, and networking the stakeholders.
- Informing potentially affected parties and the public, and raising their awareness.
- Compiling and evaluating adaptation projects, adaptation options and measures.

The range of services offered by KomPass is constantly expanding and is open to all users. KomPass, via an information platform and as a portal, offers facilities for gaining access to a wide range of adaptation-specific data, programmes, activities and results.

The Climate Service Centre of the Helmholtz Association of German Research Centres
The High-Tech Strategy for Climate Protection of the Federal Ministry of Education and Research views the task of improving information and advisory facilities as a central mission. Within this framework, the Climate Service Centre (CSC) at GKSS-Forschungszentrum Geesthacht is to have the core task of user-oriented acceleration of not only knowledge diffusion, but also research processes in the field of climate modelling and scenario development. The focal element in its services is its networking and coordinating function in the field of evaluating and preparing climate scenario and model data, and disseminating them in the form of suitable data products and advisory services.

The task spectrum of the CSC will be coordinated to ensure a mutually supportive division of labour with KomPass and other federal establishments (such as the German Weather Service). In close cooperation with the relevant research institutions and the German Weather Service, the CSC is not only to make decentralised climate knowledge available, but also to help interpret and use such data. Targeted and application-specific preparation of the data, in close consultation with itse user, will ensure best possible use of climate research information for strategic planning and investment decisions. A significant side effect of this is an intensification of climate mitigation and adaptation research on a broad front.

5.4. Milestones in the strategy process

- Adoption of the German Adaptation Strategy by the Federal Cabinet December 2008
- Establishment of Interministerial Working Group ‘Adaptation Strategy’ (IWG Adapation Strategy) chaired by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety 1st quarter 2009
- Kick-off conference for the dialogue and participation process for Action Plan May 2009
- Presentation of Adaptation Action Plan by IWG Adaptation Strategy April 2011
- IWG’s First Interim Report to both houses of parliament (Bundesrat and Bundestag) on implementation April 2013

5.5. International cooperation

The Federal Ministry for Economic Cooperation and Development (BMZ) is drawing up a strategic approach for guidance on cooperation with developing countries in the field of adaptation. Part of this strategy will be a systematic "climate check" designed to ensure that German development cooperation makes a contribution to climate protection and to improving the resistance of developing countries to the effects of climate change. One particularly important aspect in this context is to strengthen the capacity of our developing country partners, so that they can largely take over for themselves the task of adapting to climate change, planning and implementating the measures. This includes expanding research capacity in the countries in question. The Federal Government will fight for setting the right course for vigorous adaptation at the Conference of the Parties in Copenhagen in 2009. One building block in the Copenhagen Agreement will be appropriate financial support for adaptation measures in developing countries.

The migration policy dialogue and cooperation with third countries along the main migration routes to the EU are based on the principle of coherence. The resulting overall approach to migration policy by the EU and the tools developed within this framework provide a good basis for including impacts of climate change, e.g. increased pressure to emigrate, and should therefore be used accordingly. These tools are also sufficiently flexible to enable them to be tuned to the differences in the present and future importance of climate change and its possible impacts for the various regions of origin and transit. In addition, the global migration policy dialogue (e.g. within the "Global Forum Migration and Development" (GFMD)) should be expanded to include the aspect of future effects of climate change.

The World Meteorological Organisation (WMO) of the United Nations has its own strategy for supporting adaptation measures. National weather services in the WMO, especially in developing countries, provide key information for the development of successful and sustainable adaptation measures. The Federal Government will continue to make resources available to assist it in performing these tasks.

Glossary[18]

Adaptation
Initiatives and measures to reduce the vulnerability of natural and human systems to actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, or substituting more temperature-shock resistant plants for sensitive ones, etc.

Adaptive capacity
A country's or region's entire capabilities, resources and institutions for implementing effective adaptation measures.

Biological diversity
Collective term for the diversity of ecosystems, biocenoses, species and genetic diversity within individual species.

Civil protection
Civil protection is the sum of all civil measures to protect the population and its basis for life from the effects of wars, armed conflicts, disasters and other serious predicaments and to limit and manage such occurrences. Civil protection comprises civil defence, disaster control and disaster aid. Such measures are taken in line with the constitutional competences for disaster control (Länder), civil defence (federal) and disaster aid (federal).

Climate
Climate in a narrow sense is usually defined as the 'average weather', or more rigorously, as the statistical description of weather in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands of years. The classic period of time (= **normal climate period**), as defined by the World Meteorological Organization (WMO), is 30 years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

Climate model
A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity, i.e. for any one component or combination of components it is possible to identify a spectrum or hierarchy of models differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical, or biological processes are explicitly represented, or the level at which empirical parameterisations are involved. Coupled atmosphere/ocean/sea-ice general circulation models (AOGCMs) provide a representation of the climate system that is close to the most comprehensive end of the spectrum currently available. There is an evolution towards more complex models with interactive chemistry and biology. Climate models are applied, as a research tool, to study and simulate the climate, but also for operational purposes, including monthly, seasonal, and interannual climate predictions.

Climate prediction
A climate prediction or climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate in the future (e.g. on seasonal, interannual, or longer-term

[18] Sources: based on IPCC Fourth Assessment Report (2007)

timescales). Since the future evolution of the climate system may be highly sensitive to the initial conditions, such predictions are usually based on probability data.

Climate projection
A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based on simulations by climate models. Climate projections are distinguished from climate predictions in order to emphasize that climate projections depend upon the emission/concentration/radiative forcing scenarios used, which are based on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realized, and are therefore subject to substantial uncertainty.

Climate variability
Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to natural or anthropogenic external factors (external variability).

Danger
Situation, circumstance or process that may result in damage to a protected asset.

Disaster control
Protection of the public from dangers and damage arising from disasters. In Germany, disaster control is regulated by the relevant legislation of the Länder.

Extreme weather event, extreme event
An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. Single extreme events cannot be simply and directly attributed to anthropogenic climate change, as there is always a finite chance the event in question might have occurred naturally. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g. drought or heavy rainfall over an entire season).

Invasive species
Species whose occurrence outside their native territory represents a considerable danger for the ecosystems, biotopes or species native to the region.

Normal climate period
See Climate

Precautions
Sum of all preventive and preparatory measures which can be taken to reduce or avoid potential damage.

Regional climate model
Dynamic methods employ a higher-resolution dynamic (numerical) model to simulate parameters for specific areas of the global model. They use input data from the global climate model. Examples include REMO and CLM. Statistical methods work on the basis that the global models

are capable on a large scale of providing an accurate description of atmospheric circulation patterns. Most of these methods identify statistical relationships between large-scale patterns/weather situations and their local effects, applying past or present relationships to the projections of the global models. Examples include WETTREG and STAR.

Risk
Measure of the probability of occurrence of specific damage to a protected asset, having regard to its exposure and vulnerability.

Sensitivity

The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damage caused by an increase in the frequency of coastal flooding due to sea-level rise).

SRES scenarios
SRES scenarios are emission scenarios used as a basis for the climate projections in the IPCC report *"Special Report on Emissions Scenarios"* (2001). The following terms are relevant for a better understanding of the structure and use of the set of SRES scenarios:

- Scenario family: Scenarios that have a similar demographic, societal, economic, and technical-change storyline. The SRES scenario set comprises four scenario families: A1, A2, B1 and B2.
- Illustrative scenario: A scenario that is illustrative for each of the six scenario groups. They include four revised marker scenarios for the scenario groups A1B, A2, B1, B2, and two additional scenarios for the A1FI and A1T groups. All scenario groups are equally sound.
- Marker scenarios: A scenario that was originally posted in draft form on the SRES website to represent a given scenario family. The choice of marker scenarios was based on which of the initial quantifications best reflected the storyline, and the features of specific models. Marker scenarios are no more likely than other scenarios, but are considered by the SRES writing team as illustrative of a particular storyline. These scenarios have received the closest scrutiny by the entire writing team and in the SRES open process. Scenarios have also been selected to illustrate the other two scenario groups.
- Storyline: A narrative description of a scenario (or family of scenarios) highlighting the main scenario characteristics, relationships between key driving forces, and the dynamics of their evolution.

Uncertainty
An expression of the degree to which a value (e.g. the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g. a range of values calculated by various models) or by qualitative statements (e.g. reflecting the judgment of a team of experts).

Vulnerability
The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation and fluctuations to which a system is exposed, and also its sensitivity and adaptive capacity.

Appendix I: Current activities by the Länder to adapt to climate change

Excerpt from the overall report of the Federal/Länder Working Association on Climate, Energy, Mobility, Sustainability (Ad Hoc Working Group "Adaptation Strategies of the Länder" of BLAG KliNa)

to the 71st Conference of Environment Ministers on 23.10.2008,

here Chapter V:

Climate change effects and adaptation – Status of adaptation strategies in the Länder

The working group is of the opinion that reducing greenhouse gases is one of the most important political challenges of the present time. However, it is no longer possible to halt global warming completely. A responsible climate policy therefore needs to address the problem of adapting to those consequences of climate change that can no longer be averted. Climate change is a worldwide problem – but there are great variations in the nature and scale of the changes that result from climate change. When adapting to the effects of climate change, the regions are confronted with great challenges: whereas climate protection measures always benefit the overall global balance, adaptation measures make themselves felt where they are taken. The Länder have a special role here, because they possess numerous political options in many areas affected by climate change, such as agriculture and forestry, flood control, health, nature conservation and tourism. They therefore need to identify the individual regional vulnerability aspects in their social und economic areas and draw up and implement region-specific adaptation strategies. The numerous activities they have initiated in this field show clearly that the Länder are aware of this responsibility.
The federal and Länder authorities cooperate closely in the preparation of a German Adaptation Strategy. They welcome the fact that this Adaptation Strategy leaves scope for necessary measures by the Länder and is intended to play a supporting role. This joint work should also include the question of how the EU, the German federal and Länder authorities and other responsible stakeholders are to participate in financing the measures for the German Adaptation Strategy and the "Adaptation Action Plan".

A Status of adaptation strategies in the Länder

1. Regional climate models

All Länder except one use regional climate models to obtain climate projections. The majority of Länder (13) use two or more regional climate models, especially the dynamic model REMO and the statistical model WETTREG. The statistical model STAR of the Potsdam Institute for Climate Impact Research and the dynamic model CLM which is currently under development are used in only five Länder.
Three Länder use all four German regional climate models for their climate projections.

2. SRES emission scenarios

All Länder except one currently use SRES emission scenarios in their climate projection work. Scenario A1B, which approximates most closely to the present global trend, is used by 15 Länder. In addition, scenario A2 is also used in seven and scenario B1 in eight Länder. Scenario B2 is the least widely used.

2. Acquisition systems (measuring networks/bioindicators etc.) for identifying climate-induced impacts on man, nature and environment; climate-relevant indicators

All Länder have technical measuring networks for acquiring data on soil, water and air quality. In the agricultural and forestry sector they are to some extent supplemented by agro-meteorological measuring networks, long-term field trials, forest climate stations and phenological gardens. The Länder also operate monitoring systems on habitat types and species of the Habitats Directive, breeding bird maps, and moss monitoring and lichen maps as bioindicators. In the health sector there are also alert systems for infectious diseases under the Protection Against Infection Act.

4. New / additional indicators for systematic climate impact monitoring

On the basis of the measuring networks mentioned in Point 3 and other acquisition systems, the Länder provide numerous suggestions for additional indicators.
Items frequently mentioned include changes in soil humus content and quality, monitoring of actual soil erosion, changes in the frequency and intensity of extreme weather events, occurrence/spread of climate-sensitive disease vectors, occurrence/changes in climate-sensitive indicator species of flora and fauna, and propagation of neophytes and neozoa.
In addition, there is also a need for other agricultural indicators (e.g. quality of crop yields, occurrence of climate-sensitive pests, occurrence of animal diseases triggered by climate-sensitive vectors), forestry indicators (e.g. mountain forest monitoring, periodic landscape-specific tree species and forest type inventory) or health indicators (e.g. heat mortality trends).
Special attention was drawn to the climate impact monitoring concept of the working group on bioindication/impact determination.

5. Studies of the impacts of climate change on the various sectors

Thirteen Länder have already carried out studies on the impacts of climate change on various sectors. These studies are predominantly concerned with water management, forestry, agriculture and health. Studies of the impacts of climate change on biodiversity and soils are less common. The northern German Länder have studies on coastal protection.
Three Länder currently have neither sectoral nor cross-sectoral studies of the impacts of climate change.

6. Existing integrative adaptation strategies of a sectoral or cross-sectoral nature

Nine Länder have already developed climate change adaptation strategies. These relate largely to water management, especially flood control, and forestry. There are also adaptation strategies in the health sector, especially heat warning services, and coastal protection. Six Länder have neither sectoral nor cross-sectoral adaptation strategies. In most cases, however, these are in preparation, or initial action recommendations exist for individual sectors.

7. Progress with preparing strategies or measures for adaptation to the impacts of climate change

Here one can see the dynamic nature of this field in the Länder. With the exception of one Land, adaptation strategies are under development everywhere, primarily in the water management, forestry, agriculture, biodiversity and health sectors. In addition, several Länder are pursuing such approaches in Land and regional planning, tourism and the energy sector. Sectors that have so far played a minor role are architecture/building, transport, soil, and trade and industry.

8. Methods and goals of adaptation strategy or strategies, and Länder policy context

In many Länder the climate change adaptation strategies form part of a comprehensive climate programme or action plan which includes both climate protection and climate change adaptation. In addition, sectoral programmes or concepts that exist in several Länder form the basis for developing sectoral adaptation strategies (e.g. flood control plans, flood risk management plans). A number of Länder are currently developing comprehensive cross-sectoral adaptation strategies which lend concrete shape to other strategies (e.g. sustainability strategy), are supplemented by other strategies (e.g. biodiversity strategy) or provide the basis for a future adaptation policy.

B Conclusions (contribution to Conference of Environment Ministers for proposed resolution)

The Länder request the Federal Government

- to ensure appropriate integration of the Länder in the course of the further preparation and implementation of the German Strategy for Adaptation to Climate Change (DAS),
- to bring about a broad dialogue with all groups and institutions affected by the implementation of the German Strategy for Adaptation to Climate Change (DAS),
- to provide assistance with coordination of an action framework for the establishment and long-term existence of a climate impact monitoring system in Germany,
- to support the relevant regional research activities of the Länder in view of the considerable need for research identified at the National Research Symposium in Leipzig.

Appendix II: The organisation of civil protection in Germany

Civil protection in Germany is based on a very capable state-operated emergency precautions and hazard prevention system. The federal, Länder and local levels cooperate closely and effectively with private assistance organisations.

According to Art 73 No. 1 of the German Basic Constitutional Law, the federal level is responsible for civil defence, which regulates measures to protect the population in the event of attack. Responsibility for measures to protect the population in the context of disaster control basically rests with the Länder. If assistance is needed as a result of a natural disaster or a particularly grave accident, the Länder can call upon personnel and facilities from the federal level in accordance with the German Basic Constitutional Law (Art. 35(2), second sentence). Part of the supplementary federal help in disaster control is an operational sector made up of the Federal Agency for Technical Relief (THW), the Federal Police and the armed forces. The other component is organisational help for the Länder in the field of disaster management, provided by the Federal Office of Civil Protection and Disaster Assistance (BBK), for example via the Joint Federal and Länder Emergency and Crisis Centre (GMLZ) and the German Emergency Planning Information System (deNIS).

Disaster control procedures are regulated by Länder-specific laws in the fields of fire protection and disaster control, rescue services, fire prevention and assistance, and police legislation. Disaster control is governed by the principle of subsidiarity. For this reason the federal authorities may only take action when asked for official assistance und disaster aid.

Disaster control in Germany is based large on voluntary and honorary activity. Honorary commitment is the backbone of the national emergency system. Assistance organisations, fire brigades and technical relief teams (THW) are an indispensable basis for the national assistance system.

The Academy for Crisis Management, Emergency Planning and Civil Protection (AKNZ) of the Federal Office of Civil Protection and Disaster Assistance is the Federal Ministry of the Interior's central training facility for management staff and instructors in the field of civil defence and disaster control. In addition to numerous courses and exercises, it regularly holds workshops and specialist congresses to improve joint crisis management by the federal and Länder authorities.
An important factor in effective civil protection is providing the public with full and speedy warnings and information. To this end the federal level runs a nationwide satellite-based warning system (SatWaS). In the event of large-scale hazards or special cases of damage it is possible to broadcast warning announcements within seconds via various media such as radio, television and Internet portals. Furthermore, the federal and Länder authorities are working on a concept that will permit wake-up calls under the warning system.

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