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Adapting to a changing climate

Norway's vulnerability and the need to adapt to the impacts of climate change

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Norway's vulnerability and the need to adapt to the impacts of climate change

Recommendation by a committee appointed by Royal Decree of 5 December 2008
Submitted to the Ministry of the Environment on 15 November 2010

To the Ministry of the Environment

Through the Royal Decree of 5 December 2008, the Norwegian government appointed a committee to study society's vulnerability and the need to adapt to the effects of climate change. The committee hereby submits its report.

Oslo, Norway,
15 November 2010

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Abbreviations

ACIA	Arctic Climate Impact Assessment
AMSDE	Annual Meeting of Sustainable Development Experts (in the OECD)
AMAP	Arctic Monitoring and Assessment Programme
ECCE	European Climate Change Programme
EU	The European Union
UN	The United Nations
ICES	The International Council for the Exploration of the Sea
IPCC	The Intergovernmental Panel on Climate Change
IPY	International Polar Year
NAO	North Atlantic Oscillation
NorACIA	Norwegian follow-up of ACIA
OECD	The Organisation for Economic Co-operation and Development
UNFCCC	United Nations Framework Convention on Climate Change
BE	National Office of Building Technology and Administration
DN	Norwegian Directorate for Nature Management
DSB	Norwegian Directorate for Civil Protection and Emergency Planning
IMO	International Maritime Organisation
NVE	Norwegian Water Resources and Energy Directorate
PBL	The Planning and Building Act
KS	The Norwegian Association of Local and Regional Authorities
Klif	Climate and Pollution Agency
SSB	Statistics Norway
SLF	Norwegian Agricultural Authority

Section I
Introduction

Chapter 1
Main conclusions and recommendations

1.1 Main conclusions and recommendations

Our climate is changing, and we must adapt to these changes. The magnitude of climate change will depend on the extent to which Norway and the international community are able to limit emissions of greenhouse gases. Hence, the most important thing we can do to address climate change is reducing emissions. However, regardless of how successful we are in reducing emissions of greenhouse gases, global temperatures will rise throughout the 21st century, with associated consequences. This report addresses the impacts of climate change in Norway and what we as a society can do to handle them.

Nature and society are constantly changing and have always been affected by climate variations. These changes have also had dramatic impacts in the past, and adapting to them has been demanding. Adapting to changes in climate is therefore not a new issue. However, the rate and extent of the expected climate change is new and unprecedented. Effective adaptations made today are therefore necessary to reduce Norway's vulnerability in the future.

Climate change concerns each and every one of us, and society as a whole. Climate change threatens many aspects that we value as a society; some of which may be unavoidably lost. Increased risk of incidents such as landslides, avalanches and floods will pose particular threats to local communities and individuals, and increased humidity and precipitation can destroy considerable material and cultural assets. Our natural environment will be altered by rising temperatures. Some species and ecosystems will not be able to adapt in step with climate change and will thus become extinct.

Compared with most other countries, however, Norway is both less vulnerable and better equipped to meet climate change. For many countries, the impact will be greater and there will be fewer resources available to handle the consequences. This report mainly reviews the impact of climate change on Norway. The consequences of climate change for Norway must nevertheless be considered in light of the challenges that other, more vulnerable, parts of the world will face.

In order to quantify potential changes in Norway's climate in this century, the committee based its forecasts on three climate projections. Based on these projections, the committee has analysed the impacts of climate change on the environment, different areas of society and official? authorities. Combined, these climate projections and the vulnerability assessment depict the risks associated with the potential impacts of a changing climate.

The climate projections show that the climate in Norway can be expected to change considerably during this century. Norway's annual mean temperature is expected to increase by between 2.3 and 4.6 degrees Celsius, with the greatest increase during winter and the least during summer. There are major regional differences; the temperature increase will be at its greatest in northern Norway and least in western Norway. Calculations show that Norway's annual precipitation can be expected to increase by between 5 and 30 per cent leading up to the year 2100, but there will be major seasonal and regional variations. It is also expected that there will be more incidents of torrential rains and massive snow fall. The ocean temperature is expected to increase along the entire Norwegian coast and in the North Sea. It is expected that acidification of the ocean will increase, causing the pH value to sink by 0.5 units. By 2100, the sea level along the Norwegian coast could rise between 50–100 cm along the southern and western coasts, 40–90 cm in northern Norway and 20–70 cm in the innermost areas of the Oslo and Trondheim fjords. The height of storm surges will increase correspondingly. Various climate projections yield somewhat different figures for these changes. The committee recommends that the consequenses and measures be assesse-

don the basis of the projection(s) that foreshadow the greatest challenges for the various sectors.

Norway is vulnerable to climate change in a number of areas. This vulnerability is caused by both the climatic changes and by the ability of the natural environment and society to meet these changes. A warmer climate increases the pressure on the natural environment in the Arctic and in the High North in addition to higher altitudes. These areas are characterised by marginal natural conditions, and it is here that the temperature increase is expected to be the greatest. Species and ecosystems will become more vulnerable, and measures to adapt will not always be able to prevent the loss of biodiversity.

Infrastructure and buildings constitute significant material assets, and society depends on a functioning infrastructure. Much of our infrastructure is exposed to weather and wind conditions today, and will also be increasingly exposed to a changing climate. The vulnerability varies between the different infrastructure sectors. Nevertheless, insufficient maintenance and repairs is a common challenge, and will be amplified by climate change. At the same time, the various infrastructure elements are interdependent, and this will contribute to increased overall vulnerability.

Areas where climate change can provide opportunities for new economic growth have been identified within the primary industries, and the energy, petroleum, tourism and shipping sectors. Utilisation of this potential may, however, prove to be incompatible with objectives and adaptation needs in other areas. For example, the utilisation of new opportunities for economic activity may be in conflict with the objective of emission reductions, as well as the a risk of increasing vulnerability in the environment.

Adaptation involves acknowledging that the climate is changing, understanding how these changes may affect nature and society, and making choices that will mitigate or minimize the negative aspects of the impacts, while at the same time taking advantage of possible opportunities that derives from a changing climate. Knowledge about future climate change – how fast and to what extent the climate will change – is neither complete nor certain. Current climate research does not provide any definite answers, but do give an indication of the direction in which the climate will change.

It is the committee's opinion that we know enough to conclude that efforts to adapt must be introduced immediately. Infrastructure, buildings and facilities that will be standing and functional in 50 to 100 years require planning, and must be constructed so that they are able to withstand climatic conditions that differ from the current conditions. It is usually less costly to prevent foreseeable problems from occurring than to attempt to mitigate the consequences once they have occurred. It can be difficult to ensure sufficient emphasis on long-term planning when long-term needs have to compete for attention and resources with immediate and acute demands. The committee believes it is necessary to work towards establishing a broad understanding and consensus of the need to include a long-term perspective in all planning within the public administration sector, as well as among politicians, in order to enable society to adapt to climate change.

Climate change considerations are just one of many that must be made in planning. In the committee's assessment it is important that adaptation is not separated from other planning processes. This entails that the authorities responsible for a particular area of society must also be made responsible for handling the impacts of climate change, and that they integrate these considerations into their regular planning and decision-making processes.

To a certain extent, society will adapt to climate change regardless of whether or not adaptation measures are introduced. Experience shows that such adaptations will usually be a response to a particular incident. It is the committee's opinion that this form of adaptation will be insufficient in ensuring a more resilient society in the future. Arrangements must therefore be made so that the agencies currently responsible for an area of society are given the opportunity to take charge of preventive long-term adaptations. Efforts are already under way, but they must be intensified.

In the discussions of consequences, vulnerability and needs for adaptation, the committee has assumed a temperature increase somewhat higher than the politically stated goal of preventing a global temperature increase greater than two degrees Celsius. The committee emphasises that the negative consequences will be far greater if the two-degree goal is not achieved. Intensified efforts for rapid and substantial cuts in emissions are therefore necessary. The committee will still recommend that adaptation efforts be based on the assumption that the temperature may increase by more than two degrees Celsius.

The committee recommends the following principles for climate change adaptations:

- *A comprehensive approach to adaptation*
  The committee recommends a comprehensive approach where the effects of greenhouse gas emissions, pollution and the natural environment are always assessed when adaptive measures are planned. Special considerations must be given to the High North. The potential opportunities afforded by an ice-free Arctic, allowing for increased economic activity, must be balanced against the increased vulnerability this will entail for the natural environment and society.
- *Management of the natural environment must have an ecosystem-based approach*
  The natural environment is particular vulnerable as there are limits to the adaptive measures society can implement to support adaptation in nature. Largely, society can implement changes in land use and natural resource management to minimise the total impact on the natural environment and the ecosystems. The committee consider this to best be achieved through ecosystem-based management, where the focus on preserving functional ecosystems helps reduce vulnerability, and maintaining or increasing, the natural adaptive capacity at current levels.
- *Adaptation must be integrated into the regular planning processes*
  The responsibility for adapting to climate change in a given area should be delegated to the responsible authorities. In areas without clearly defined and delegated responsibility, the responsibility should be assigned to the institutions that have the best professional and organisational qualifications to handle adaptation.

The committee recommends the following adaptation measures:

- *Climate change considerations must be given higher priority in the planning system.*
  The committee regards a strong land use planning system that takes climate change into account as the most important step our society can take in order to adapt to a changing climate.
  - The committee recommends that adaptation considerations are incorporated into new regulations associated with the Planning and Building Act. The committee also recommends that the municipalities are provided with earmarked funds to strengthen their planning capacity and skills so that adaptations can be integrated into land use planning.
  - Stormwater and rising sea levels are two areas where a national authority has yet to be assigned. The committee recommends that a national authority is assinged within this area as soon as possible, and the Norwegian Water Resources and Energy Directorate (NVE) are given particular consideration in this respect. It is necessary that the authority that is assigned this responsibility is provided with the necessary additional resources to be able to efficiently undertake these tasks.
- *Increased uncertainty must be handled*
  All planning processes must take into account the uncertainty of climate change. This alters and creates new demands on planners and planning authorities. The committee recommends that skills, methods and tools are developed in order to support planning under increased uncertainty. The committee further recommends that the national coordinating secretariat for adaptation, (cf. also Chapter 9) is assigned the responsibility for issuing guidelines and advice on how to address the uncertainty associated with climate change.
- *The knowledge base must be strengthened through studies, monitoring and research*
  Knowledge and experience acquired through responding to current weather and climate is important also for adapting to future climate change, but new knowledge is also necessary.
  - The committee recommends the development of more accurate and detailed terrain mapping. There is a special need for better mapping of areas that are vulnerable to stormwater runoff and natural hazards such as slides and floods. The committee recommends that the Norwegian Mapping Authority reecievesthe necessary resources and a mandate to develop a national programme to establish a detailed terrain model.
  - Existing monitoring programmes must be improved, and new programmes developed, particularly for monitoring the natural environment and hazards. The committee also recommends strengthening the monitoring of wind and short-term precipitation.
  - The committee recommends strengthening research on climate change, the effects and impacts of climate change, and

adaptation. The committee recommends that the funding of existing research programmes is strengthened and that a new research programme is established if necessary.
  - The committee recommends the establishment of a national climate service centre, which would update the basis for modelling and organise climate and hydrological data for the authorities and others. The centre should be part of the Norwegian Climate Centre.
  - The committee recommends regular updates of the knowledge base concerning climate change. The climate projections for Norway, including an analysis of vulnerability and adaptive needs, must be updated at least once per decade. The responsibility for coordinating this work should be assigned to the national coordinating secretariat for adaptation (cf. also Chapter 9).
- *Capacity in the public administration must be enhanced*
  Resources must be increased, as adaptation requires coordination of local, traditional and research-based knowledge about climate change.
  - The website klimatilpasning.no must be strengthened as a key source of knowledge and advice for all those who will be affected by climate change.
  - The committee recommends that the training programme for municipalities and other levels of government is strengthened and expanded with four regional centres to be established within existing institutions.
  - At the regional level, the county governor's office should be strengthened to enable it to fulful its supervisory function and to provide guidance to the municipalities.
- *Adaptation back-log must be rectified*
  Society is not adequately adapted to the current climate due to insufficient maintenance of infrastructure and lack of protection of the natural environment.
  - The committee recommends that protection of the natural environment is given priority and that incentives are developed to promote this objective.
  - The committee recommends strengthening the efforts to promote protection against avalanches, landslides and floods.
  - The committee recommends giving greater priority to the efforts to ensure an intact and resilient ecosystem, which is crucial for the opportunities for various species and the natural environment to adapt.
- *Coordination of the adaptation efforts must be improved*
  The Ministry of the Environment's coordination must be improved by establishing a secretariat for the practical coordination of the adaptation policy as a permanent function with sufficient capacity and resources.
- *The adaptation efforts must include an international responsibility*
  Norway has a responsibility to contribute to ensuring that vulnerable countries and countries with fewer resources can become more resilient as they encounter a changing climate.
  - The committee recommends that this be adopted as a high-priority area in Norwegian foreign aid.
  - The committee recommends that Norway undertakes financial obligations in the international effort to adapt to climate change, both in order to improve the general adaptive capacity and to strengthen the measures to prevent natural disasters.
  - The committee recommends that adaptation is integrated into the international cooperation with regard to marine resources, and in particular the management of the Arctic.

1.2 Recommendations for various areas of society

In addition to the ten main points described above, the committee has recommended measures in the discussion of the various areas of society in Section III. These proposals are not exhaustive and are not intended to replace the assessments undertaken within the sectors, but are proposals that the committee believes should be given priority in order to improve the adaptive capacity within these areas.

In order to reduce the vulnerability of the natural environment to climate change, the committee recommends:

Mapping and monitoring
- Review of the current mapping and monitoring of ecosystems and the effects of climate change, in order to clarify the need for change or supplemental programmes.
- Further development of methods for monitoring the natural environment must be given pri-

ority. The monitoring must be aimed at needs derived from climate change developments, e.g. the development and use of relevant indicators.
- A comprehensive operational monitoring system must be established for the marine ecosystem.

Research-based development of knowledge
- Improvement of research related to the impact on ecosystems, particularly changes in species composition, biodiversity and the productivity of key species.
- Improve the knowledge base for the development of ecosystem-based management
- Improve research related to the tipping point for dramatic changes.
- Development of better value estimation systems for natural and ecosystem services for use in the management of natural resources.
- Improve knowledge about the effects of ocean acidification on marine organisms.

The management regime
- A control system and expertise must be developed so that ecosystem-based management can be used in all relevant sectors and on all administrative levels.
- Improve cross-sector coordination of the adaptation efforts in order to ensure a comprehensive approach.
- Review and adapt the regulations in order to ensure better protection of the natural environment, including establishing regulations to promote optimal fish stock resilience.
- Improved protection of natural habitats in order to ensure both biodiversity and carbon storage through resilient and well-functioning ecosystems, while at the same time also reducing vulnerability to climate change.
- Protected areas must be given priority and structured so that species may migrate and counteract genetic depletion.
- More effective counteraction against undesirable alien species.
- Improve the policy instruments for protecting endangered species and habitats that may come under greater pressure as a result of climate change.

In order to improve adaptation in the health sector, the committee recommends:
- Improve the international cooperation and the national efforts to monitor the spread of vectors that could transfer disease such as malaria and dengue fever. The monitoring of the spread of allergenic plant species must also be improved.
- Research on:
  - heat and heat waves, how they impact mortality rates and their significance for society.
  - relationships between climate and pollen allergies, how individuals can prevent allergies and medical treatment of allergies
  - the relationship between health effects and water and sewerage system failures.
- Maintain expertise on tropical diseases and infections in the health service.

In order to improve adaptation in the civil protection and emergency preparedness sector, the committee recommends:
- A comprehensive review of the vulnerability, organisation, resources and expertise must be conducted in the sector in light of the new challenges presented by climate change.
- Regulations and guidelines for risk and vulnerability analyses must be reviewed and adapted to ensure that adaptations are taken into consideration.
- Supervisory authorities at various administrative levels must be authorised to include adaptation as a supervision area in all relevant contexts.
- A plan must be developed for training and skills enhancement based on the review of the sector's competence needs.

In order to improve adaptation in the transport sector, the committee recommends:

Safeguarding the transport infrastructure
- Integrate climate considerations into all planning processes, reports and analyses of the transport system.
- Conduct surveys and vulnerability assessments for structures or infrastructure sections that are particuarily vulnerable relative to various types of events.
- Maintain a strong focus to protect roads and railways against landslides and avalanches, and include considerations of climate change in the risk assessment of landslides and avalanches, as well as the efforts in the development of the National Landslide Database.

Improve the management regime
- Make adaptation a managerial responsibility in the sector's control structures.

- Review and revise the current regulations and follow up amendments with training courses and information. Give priority to the development of recommended standards for municipal roads.
- Review contracts and contract forms and develop methodologies for service-life evaluations and cost–benefit analyses.

Resource management
- Give priority to clearing the maintenance backlog and improving the ongoing maintenance.
- Integrate climate change considerations into existing plans for inspection, maintenance and renovation.
- Develop better analytical methods, including future maintenance costs in the basis for the decision.

Improve emergency preparedness
- Improve and develop the work with proactive emergency preparedness systems with emphasis on adaptations to weather conditions and weather-related events in the road and railway networks, including increased use of weather prognoses and systems for transport information.
- Safeguard shipping traffic by improving traffic monitoring and control. Develop a better basis for reducing acute accidents by improving anchorages, ship grounding sites and ports of refuge.

Improve the knowledge base and the dissemination of knowledge
- Assess and, if necessary, supplement the current system for monitoring key climate variables and coordinate the existing databases.
- Develop the knowledge base by improving the documentation of adverse events related to weather conditions.
- Continue the cooperation among government transport agencies and departments, NVE and other organisations for online map databases for weather and weather-related event data in the transport network.
- Particular focus on the High North, including improved maritime monitoring, development of a system for automatic identification (the AIS system) and improve the data exchange and integration system.

Special measures for shipping in the High North:
- Prioritise the establishment of regulations, monitoring and control systems, and expertise in handling the particular challenges presented by increased shipping traffic in the Arctic Ocean.
- In order to meet needs derived from increased maritime activity in the High North, special priority should be given to ports, rescue services and emergency preparedness units in Northern Norway.
- To meet the special challenges in the High North, considerable importance should be attached to developing cooperative relations and venues with Russia and other nations with interests in the Arctic.

In order to improve adaptation in the water and sewerage sector, the committee recommends:

Monitoring
- Increasing, improving and coordinating the collection of short-term precipitation data in urban areas.

Research-based development of knowledge
- Improve research and development of technology to enable the water and sewerage sector to handle climate change
- Initiate R&D activities that will generate knowledge about the effect of climate change on extreme short-term precipitation.

Analysis of the infrastructure
- Initiate a study of the water and sewerage sector's current resilience by determining the practical and economic consequences of climate change and estimating the scope and cost of necessary adaptation measures, including an overview of the implications for water and sewerage sector fees.

Knowledge systems and dissemination of knowledge
- Improve research on how municipalities can handle stormwater in their planning. This research should include the preparation of guidelines for how open storm drainage may be planned as zones requiring special consideration in land use plans.
- Help improve the educational programme and increase recruitment to the water and sewerage sector.

The management regime
- Clarify the responsibility for stormwater at the national level by assigning this responsibility to a specific public authority.

- Draft recommended national guidelines for the capacity design of water and sewerage systems to take into account expected climate change.
- Clarify the legal basis for the water and sewerage services so that the owner of the water and sewerage system cannot dismiss responsibility for damage to property as a result of inadequate system capacity and sewage blowback.
- Clarify the municipalities' funding possibilities in the water and sewerage sector, and assess legal changes so that the handling of stormwater in regulated areas can be financed using water and sewerage fees.
- Clarify consumer rights and obligations in the water and sewerage area.
- Consider amendments to the Planning and Building Act and technical building regulations that would allow the opportunity to demand measures for handling stormwater runoff in the vicinity of existing settlements.

In order to improve adaptation in the power supply sector, the committee recommends:

- Improve research on all implications of climate change that may impact the power supply grid, including changes in the frequency of lightning strikes.
- The Norwegian energy sector should assess the need for investment in various sections of the power supply grid in order to optimise the potential of increased influx. The need for grid development and grid reinforcement must also be assessed in this context. At the same time, this should be considered in connection with an upgrade of safety measures adapted to a changing climate and an increased need for contiguous protected areas.
- Strengthen expertise with regard to adaptations in the energy sector. As the authority in charge of emergency preparedness, NVE has a particular responsibility to implement measures that increase the energy companies' awareness of climate change and adaptation.
- As the supervisory authorities within their respective areas, NVE and the Directorate for Civil Protection and Emergency Planning (DSB) must ensure that the sector is also familiar with and complies with the regulations related to the effects of climate change. They must also assess the need for incorporating climate change-related issues in their guidelines.

In order to prevent climate change from amplifying the adverse effects of waste and pollution, the committee recommends:

Research

- Improving research on how climate change will affect the spread of pollution.

The management regime

- Review the database of areas registered with polluted land with a view towards undertaking a new risk assessment that includes climate change.
- Formulate recommended requirements for seepage from landfills.
- Ensure that there is sufficient infrastructure for the treatment of waste generated during floods and continued bad weather.
- Improve the handling of stormwater runoff (this is discussed in greater detail in Chapters 9.2 and 16.1) and/or expand the capacity of the treatment plants.
- Improve the emergency preparedness for acute pollution.

In order to improve adaptation in the construction industry, the committee recommends:

Research-based knowledge development

- Establishing a separate strategic research programme in the Research Council of Norway for the construction industry with main emphasis on the consequences of climate change.

Knowledge systems and dissemination of knowledge

- Identify policy instruments that help disseminate knowledge about climate change and adaptation to all parties in the industry. The Building Research Series from SINTEF (the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology) may be one such policy instrument, but will not necessarily be sufficient alone.
- Make greater use of the Norwegian Climate Change Adaptation Programme, the Norwegian government's information platform, to provide information to the construction industry, although this is primarily aimed at the public sector, especially the municipalities.
- Facilitate continuous updates of the national database for construction quality: www.byggkvalitet.no.
- Prepare a national strategy for applying "green" knowledge in local adaptation efforts (cooling, handling of stormwater).

- Increase the resources for preventive advice to house builders and home owners.
- Make better use of existing climate data in the planning, design and construction of buildings.

The management regime
- Include climate monitoring in the Directorate for Cultural Heritage's environmental monitoring programme and establish a separate preservation programme for buildings of cultural and historical significance that are particularly exposed to climate change.
- Establish clear competence requirements for all commercial parties in the building sector, and requirements that companies have a system for continuous and further education of their employees.
- Establish regional climate indices or climate zones in order to clarify the requirements that should be established for all buildings and for use in municipal land use planning.
- Introduce stricter national requirements for documentation of building materials, including requirements for the properties of the materials as well as requirements pertaining to climate change.
- Introduce stricter requirements for more robust construction practices and requirements for the use of life-cycle analyses in the construction and operation of buildings.
- The incentives for renovation of municipal buildings should be strengthened, e.g. by amending the requirements for municipal accounting and providing advice on the organisation of municipal property management.
- National authorities should be more involved in international forums for the development of international standards for adapting buildings to climate change.

In order to improve adaptation in the agricultural, forestry, reindeer husbandry and wilderness-based industries, the committee recommends:

Resource mapping
- A review of the resource base mapping programme (forestry resources, soil, grazing resources, land cover and land use) in order to clarify the need for changes.
- An analysis of the condition of the technical facilities in these industries, with particular attention to the status of the agricultural drainage systems.

Monitoring
- A review of the monitoring programmes (e.g. plant health, animal health, forest health, import control regime, land cover and cultural landscape) in order to clarify whether these are sufficient to meet the needs for monitoring the effects of and adaptations to climate change in the primary industries.

Research-based development of knowledge
- Priority should be given to research programmes involving the effects of, and adaptations to, climate change in the primary industries, with a focus on e.g.:
  - How changes in the Norwegian climate will impact existing and new pests.
  - How technology and methods in agriculture and forestry can be adapted to a warmer, damper climate with significantly longer frost-free periods.
  - How genetic resources (cultivated plants, trees and domestic animals) can contribute to sound adaptation and how they will be affected by climate change.

Technological development
- Overview of adapted operating methods and technological solutions.

Knowledge systems and dissemination of knowledge
- Systems must be developed for the dissemination of knowledge and integration of new knowledge concerning adaptation.
- Access to both academic and vocational expertise must be ensured through prioritisation at all education levels.

Land use management
- The management of agricultural land must include consideration of the fact that the value of this land may change in the event of climate change, both as a basis for production and relative to natural values. The management of agricultural land must therefore also be developed so that the potential of these areas for purposes such as stormwater runoff and damage prevention in other areas are not overlooked.

The management regime
- Laws and regulations must be reviewed to ensure that regulations do not pose an obstacle to adaptation measures. Regulations must also be included that ensure that adaptation is a factor that is assessed in all relevant contexts by the administrative authorities. They must be

flexible enough to allow autonomous adaptation of the reindeer husbandry industry and accommodate traditional knowledge.
- Ecosystem-based management of harvestable resources should be further developed and operationalised for industries utilising natural resources. This means resource utilisation which also takes into consideration the sustainability of the ecosystem, which in turn depends on the way the climate develops.
- The resource management (of productive areas and genetic resources) must be such that the current management takes into account the significance (value) of the resources in a changed climate.
- The number of reindeer must be assessed based on a climate change perspective, and the management of the land available for reindeer husbandry must focus on avoiding fragmentation, as fragmentation reduces the reindeers' adaptive capacity.

In order to improve adaptation in the fisheries and aquaculture industries, the committee recommends:

Resource mapping
- Map the resources in the northernmost marine areas where ice cover has prevented mapping.
- Increase focus on monitoring climate-induced changes in the composition of the ecosystems along the coast and in our southernmost marine areas.
- Update and further develop the series of measurements for the marine climate and marine organisms.

Research
- Develop ecosystem models that can quantify the impacts of climate change on the productivity and distribution of marine organisms from plankton to fish and marine mammals.
- Increase knowledge about the combined effects of climate variability and climate change on fishery resources.
- Develop climate models for coastal and fjord areas with a resolution high enough to allow simulation of changes in environmental conditions for the aquaculture industry.
- Study the effects of ocean acidification on fishery resources and their food base.
- Develop methods for ecosystem-based management of fisheries resources.

Technological development
- Development of technology that makes the aquaculture industry less vulnerable to extreme marine climate conditions and less vulnerable to disease and parasites. Promote the development of multi-cultures in the aquaculture industry.
- Further develop reduced energy catch methods and vessels as well as catch methods with reduced impact on benthic fauna.

The management regime
- Norway must help improve the international management regime in order to prevent conflicts over marine resources as their productivity and patterns of distribution gradually change.
- Norway must actively promote adaptation in the harvesting of fishery resources through the established international cooperative channels and through special bilateral cooperation with the other Arctic states.

In order to improve adaptation in the petroleum industry, the committee recommends:
- Strengthening knowledge about the impact climate change will have on petroleum activities. Priority should be given to research and development of knowledge about changes in climate variables that affect the petroleum industry, particularity wind, wave, and ice conditions.
- Climate change considerations must be incorporated into design parameters relevant to newbuilds and modifications/maintenance of facilities that will be in use up to, or beyond, the middle of this century.
- Assessments of new or expanded petroleum operations must be based on the precautionary principle. Consideration of the potential for damage in the event of petroleum accidents must be assigned particular importance in the assessments of whether licenses should be granted for exploration and production in the vulnerable High North.

In order to improve adaptation in the insurance industry and likewise improve the role played by insurance schemes in the adaptation efforts, the committee recommends:
- Establishing a database for public use and research using aggregate, anonymised data on cli-

mate-related damage from the insurance companies and the Norwegian Natural Perils Pool.
- Increasing the quality and standards for the renovation and repair of buildings by establishing stricter requirements for the parties that carry out the work and limiting the insurance companies' opportunities for cash payment of claims.
- Review the Natural Damage Insurance Act and scheme in order to assess the differentiation of assets related to the risk of natural damage and the opportunities for modifying the scheme so that it becomes more preventive, e.g. by earmarking some of the premium for preventive measures, such as measures relating to open storm drainage and possibilities for delaying runoff.

In order to improve adaptation in the tourism sector, the committee recommends:

- Funding research on how climate change might affect tourism.
- Developing further guidelines for tourism in Arctic areas.
- Making it a requirement that risk, vulnerability and security measure assessments also include climate change assessments.

In order to improve adaptation of the Sámi culture and society, the committee recommends:

Research and development
- Increased funding for research on traditional Sámi knowledge, using the Sámi languages as a key source.
- Developing courses and educational programmes on adaptations using traditional Sámi knowledge as an important starting point.
- More research on the biological threats in the High North area, such as autumnal moths and other pests.
- Land use research to understand how climate change may affect land cover, vegetation, forests and agricultural conditions in the Sámi area.
- Knowledge about altered competitive conditions among land-based primary industries as a result of climate change.

The management regime
- Review of the parameters for Sámi industries in light of the need for adaptation.
- Implement ecosystem-based management of land-based and harvestable marine resources.
- Increase resources for the Samediggi - the Sami Parliament (the Sámi Parliament) to establish expertise and facilitate its role in the adaptation efforts.
- The Samediggi - the Sami Parliament should be given an active role in key processes and bodies with tasks in national planning related to adaptations.

In order to improve adaptation to the impact of the global ramifications of climate change and help facilitate international adaptation, the committee recommends:

- Norway must ensure that the national adaptation efforts do not, directly or indirectly, exacerbate the challenges of adaptation in countries that are more vulnerable, but must support and improve actions that facilitate adaptation in these countries. One way of doing this is to ensure high food self-sufficiency while also assisting the establishment of sustainable production systems in more vulnerable and less wealthy countries.
- Norway has a responsibility to help ensure that vulnerable countries and countries with fewer resources become more resilient in their encounters with a changing climate. This will require increased funding, and existing efforts will have to be adapted so as to ensure sustainable development. Norway must help ensure new international financing schemes that will generate long-term, predictable funds to support adaptation measures and to cope with more frequent natural disasters.
- Through management of the Norwegian Arctic areas, as well as through international forums, Norway must contribute to systems and legally binding agreements that ensure preservation of the vulnerable natural environment in the High North.

1.3 Overview of this report

Section I provides a summary of the committee's recommendations and assessments of society's vulnerability to climate change. The composition of the committee, its mandate, limitations and work are reviewed. The framework for the current climate policy is described in a separate chapter.

In Section II, the committee assesses the various climate changes our society is facing and presents projections for climate and hydrology in

Norway leading up to the next century. The climate in Norway will become warmer, and there will be more precipitation and humidity. There are major geographical and seasonal variations. Together the climate projections for Norway provide a picture of the risk represented by the potential effects of a changing climate. The committee has analysed the impacts of climate change on the various sectors and the authorities based on these projections.

Section III looks at consequences that climate change may have in various sectors of society. The committee has based its assessments on its mandate from the following focus areas: the natural environment, health and safety, infrastructure and buildings, and business and industry. The individual chapters contain a summary of the committee's proposed adaptation measures. In Chapter 16, the committee presents a comprehensive assessment of consequences, vulnerability and need for adaptation in the Norwegian society.

Section IV presents the adaptation efforts at the different administrative levels. The chapters review functions that are relevant to adapting to climate change, the status of the adaptation efforts and barriers to and possibilities for adapting to climate change at the municipal, regional and national levels. The basis for the review is the current responsibilities and policy instruments for social planning. In addition, the need for development of frameworks and tools will be identified in order to create better conditions for taking climate change into consideration in social planning.

Section V looks at how society best can handle the effects of climate change. The committee presents its recommendations for how Norway's adaptation efforts may be improved.

Section VI contains an assessment of the financial and administrative consequences of the committee's recommendations.

Chapter 2
The committee's mandate, composition and work

By Royal Decree of 5 December 2008, the Stoltenberg II government appointed a committee to prepare a wide-ranging government report on Norway's vulnerability and adaptive needs as a result of climate change.

2.1 The committee's mandate

"The objective of the report is to help facilitate sustainable development through increased knowledge about the significance of climate change for Norway and to provide advice regarding how the authorities and other parties best can proceed to prevent negative impacts from these changes on people, society and the environment. In cases where climate change also represents a potential for increased economic growth, this should be made clear, and advice should be given on how society best can utilise this potential. The committee may base its work on the assumption that a more detailed assessment of policy instruments will be conducted by the authorities after the task has been completed. The committee's work will result in an Official Norwegian Report (NOU), which will be published by 1 November 2010.

"The committee shall study the risks that climate change entails for the natural environment and society. The committee shall give an account of the geographical areas, industries and sectors that are most exposed to negative impacts of climate change.

"These impacts shall be studied with particular focus on

- health and safety for humans
- physical infrastructure and buildings
- business and industry
- the natural environment and primary industries

"An account shall be given of the effects of climate change that entail increased risk of extensive material damage with significant financial consequences. In particular, an account shall be given of factors that result in increased risk of loss of life or serious damage to health or the environment. An account must also be given of the economic and institutional factors that increase society's vulnerability to climate change. Factors of importance to the traditional Sámi culture and economy shall also be studied.

"The committee shall undertake a discussion of the principles that should be considered when determining the ways in which society should respond to uncertainty concerning the scope and effects of climate change. In light of the risk assessments, the committee shall identify, discuss and recommend policy instruments and measures to reduce society's vulnerability. In particular, measures shall be sought that can be rapidly implemented in order to limit future negative impact of climate change in the most exposed areas.

"The framework for society's long-term adaptation shall be studied and analysed. The committee shall then discuss and recommend policy instruments and measures to help facilitate the incorporation of climate change considerations in affected areas of society. Only policy instruments and measures within the public authorities' area of responsibility will be recommended. The division of responsibilities and roles between the authorities and various administrative levels shall be assessed.

"The committee shall review relevant research programmes and discuss the areas in which there is a special need for more knowledge concerning the consequences of climate change and relevant strategies and measures for adapting to it. The committee shall discuss the ways in which long-term research can help reduce uncertainty as regards the consequences of climate change and help promote the development of policy instruments and measures for adaptation and the ways in which this new knowledge should be put to use in the government administration. The committee is asked to assess the ways in which the need for knowledge concerning climate change and measures for adapting to it can be developed and disseminated among the authorities and other intere-

sted parties, as well as the general population. An assessment of the need for and dissemination of knowledge shall be coordinated with the steering group for the Klima 21 (Climate 21) strategic forum for climate research, which is responsible for the development of a comprehensive strategy for climate research.

"An estimate shall be made of the long-term financial costs and benefits for the sectors that will be most severely affected by climate change. The committee is asked to provide an account of the distributional consequences of climate change and discuss relevant measures for limiting these consequences. It is requested that the committee discuss the financial consequences of relevant policy instruments and measures.

"The committee is asked to provide a comprehensive assessment of how climate change will affect the international community and specify the potential impact on Norway. The committee's work shall be based on updated projections for climate change for Norway as a whole, as well as for the various regions in the country. These projections shall be based on risk assessments, i.e. both the probability that a given scenario will occur and an assessment of the impact this scenario will have on the natural environment and society. Less likely scenarios that entail major consequences for people, society and the environment shall also be assessed. The committee's analyses shall be conducted in such a way that they provide a basis for assigning priorities with regard to various sectors. This requires that assessments of both vulnerability and risk are based as much as possible on shared methods and criteria. The committee is asked to assess the need for conducting a joint scientific risk analysis as a basis for the committee's assessments. There is considerable focus on the relevant challenges in many countries, and the field is undergoing rapid change. The committee is therefore asked to assess the need for preparing an overview of relevant policy instruments and measures to reduce society's vulnerability and improve the ability of other countries to adapt, in particular a study of relevant conditions in Sweden, Finland and the United Kingdom.

"In its work, the committee should seek close dialogue with and involvement from affected parties, authorities, organisations and businesses in order to ensure that the committee's assessments and recommendations also reflect the affected parties' expertise and assessments. It is assumed that the committee will obtain expert studies on specific topics and assessments from selected professional institutions and authorities as needed."

2.2 Composition of the committee

The committee has had the following composition:
County Governor Oddvar Flæte, Leikanger (chair)
Director Arne Bardalen, Oslo
Senior Adviser Linda Dalen, Trondheim
Professor Helge Drange, Bergen
Manager Ingeborg Gjærum, Oslo
Senior Researcher Inger Hanssen-Bauer, Bø
Section Head Hege Hisdal, Oslo
Senior Researcher Grete Hovelsrud, Bodø
Head of Department Janne Karlsen, Oslo
Sverre Atle-Larssen, self-employed, Ringsaker
Head of Department Elisabeth Nyeggen, Oslo
Head of Department Preben Ottesen, Oslo
Head Teacher Steinar Pedersen, Tana
Senior Engineer Gordana Petkovic, Oslo
Research Director Svein Sundby, Bergen
Research Director Haakon Vennemo, Oslo
Chief Municipal Executive Jostein Aanestad, Sogndal

The committee's secretariat has consisted of:
Senior Adviser Astri Hildrum (Head of Secretariat, from February 2009)
Senior Adviser Marianne Karlsen (Head of Secretariat from January 2010)
Senior Adviser Tor-Ivar Wammer
Adviser Nina Neby Hansen
Senior Executive Officer Maria Kløverød Lyngstad
Haavard Stensvand, Head of the County Preparedness Management Office, County Governor of Sogn og Fjordane (50 per cent position)
Adviser Anne Stoltenberg (20 per cent position)

The Secretariat for the Norwegian government's adaptation efforts in the Norwegian Directorate for Civil Protection and Emergency Planning (DSB) acted as the provisional secretariat from December 2008 to February 2009. The secretariat has assisted in organising meetings and drafting the text, and reports and interim results have been published on Klimatilpasning.no. The secretariat served as an observer on the committee during the period from January 2009 to February 2010.

The Climate and Pollution Agency has provided support in the administrative and information work. Much of the information work has been outsourced and has been performed by the Centre for International Climate and Environmental Research (CICERO).

2.3 The committee's work

The committee commenced work in January 2009 and has held 18 committee meetings, conducted a study trip to the United Kingdom and collected input and knowledge from a wide range of sources.

2.3.1 Limitations and methods

This report represents the first comprehensive, systematic review of how vulnerable Norwegian society is to a changing climate and the opportunities it has to adapt to climate change. The committee regards this report as the initial step in a continuous, long-term, general effort to promote adaptation in Norway.

Adaptation to climate change is a broad and extensive field, and the committee has been given a wide-ranging mandate. As specified in the mandate, the review of the various sectors of society is not sufficient to replace the assessments made within the specific sectors. The committee has placed significant emphasis on ensuring the best possible basis in order to also be able to indicate challenges and adaptive needs in various areas of society. Considerable emphasis has been placed on an extensive gathering of available information and knowledge.

In the mandate, the committee is requested to base its work on a shared method and criteria for assessment of vulnerability and risk. The committee has chosen to base the comprehensive risk scenario for Norway on the climate projections presented by Klima 2100. The vulnerability analysis consists of the review of how vulnerable an area of society is to this risk scenario and what capacity the areas of society or the sectors have to cope with this risk. This is described in more detail in Chapter 6.

The committee has based its work on the four focus areas defined in the mandate when a sector is selected for an assessment of its vulnerability and adaptive need. Statistics Norway's classification of industries was used for a more detailed specification of the different sectors of society. In addition, the committee has made use of discretionary assessments of the relevance of climate change for various sectors of society.

Even though adaptation efforts are still in an early phase, both in the government and in the relevant research institutions, the efforts to adapt are already under way in many areas. Within many sectors, there is an increased awareness of climate change, and initiatives to adapt to climate change have been introduced. This mainly applies to sectors which already have been severely impacted by the climate; e.g. power supply, agriculture and transport. At the same time, there is limited knowledge and few adaptation initiatives in other areas. This applies to both areas that are less exposed to the climate and areas that are highly vulnerable to climate change. As a result, the various sectors have different starting points for their adaptation efforts, which in turn influenced the committee's choice of approach and the detail to which the committee was able to pursue the analyses. Thus, the reader will find that the amount of information on which the discussions are based will vary with regard to both the sectors in Section III and the administrative levels in Section IV.

The committee's work has been influenced by the fact that the knowledge base in this field is relatively underdeveloped. Research on adaptation is in a growth phase, but there are many gaps in the knowledge related to the impacts on both the natural environment and society. Both government administration and research are based on experience, and the empirical basis is limited. The committee has solved this through extensive dialogue with various involved parties and specialist institutions, and by basing its work on experience gained from current efforts with regard to climate-related issues in various sectors.

The committee has chosen an approach that emphasises a broad dialogue combined with the use of existing literature and new reports. In order to survey the status of and challenges facing adaptation, it has been necessary to contact a wide range of people currently working on projects relevant to such adaptation. The objective has been to develop a comprehensive picture of the variation in the ways in which different involved parties experience vulnerability to climate change, and tie this in with the cutting-edge research in the fields of climate and adaptation. These efforts are discussed in greater detail in Chapters 2.3.2 and 2.3.3. A list of questions related to vulnerability to climate change was developed as a basis and guide for the dialogue in meetings with various experts. The questions and the pamphlet have been included in the appendix to this report.

Although the committee stresses that the knowledge base is currently incomplete, we want to emphasise that it does provide a sufficient basis for the assessments and conclusions in this report. However, limitations in the underlying knowledge entail that the committee does not have a proper basis for quantifying the impact,

cost or benefit in all areas. For instance, the committee has been asked to estimate the long-term socio-economic costs and benefits for the sectors that will be most severely impacted by climate change, discuss the economic consequences of relevant policy instruments and measures, as well as to provide an account of the distributional consequences. Estimates of the financial and distributional effects of climate change and adaptive measures are demanding. The climate system is complex, and the relationships between climate change and the impacts on the natural environment and society are numerous and, at times, uncertain. In addition, society will continue to evolve in the next century. Moreover, adaptation is cross-sectoral and integrated, making it difficult to isolate one area from the others with regard to costs and benefits. By necessity, socio-economic analyses that delve far into the future must include discretionary assessments. This must be kept in mind when considering the possible socio-economic and distributional consequences indicated by the committee.

The committee has expertise in a number of relevant sectors, but not in all. Therefore, the committee has mainly adopted a general, comprehensive approach to society's adaptation to climate change. At the same time, we have tried to consider sector-specific issues in depth whenever possible. The committee assumes that adaptation will follow the principle of responsibility. In keeping with this principle, the committee assumes that the individual sectors have, and will assume, responsibility for studying and developing knowledge for sector-specific adaptation.

The committee has not discussed emission reductions. Our task is to report the consequences of climate change and make proposals for how society best can handle the challenges associated with those changes. At the same time, the committee assumes that emission reductions are a necessary condition for sustainable adaptation in the future.

2.3.2 External reports

In order to gain an overview of the available knowledge about the climate and adaptation, the committee has obtained ten external reports, which provide a basis for the reporting work:

- Hanssen-Bauer, Inger et al. (2009): *Klima i Norge 2100*. (Climate in Norway 2100) The Norwegian Climate Centre, Oslo, Norway.
- Aaheim, Asbjørn et al. (2009): *Konsekvenser av klimaendringer, tilpasning og sårbarhet i Norge. (Consequences of climate change, adaptation and vulnerability in Norway.)* CICERO, ECON Pöyry and Vestlandsforskning (the Western Norway Research Institute). CICERO Report 2009:04.
- Vennemo, Haakon (2009): *Hvordan forholde seg til klimaendring – en prinsippdrøfting*. (How to relate to climate change – a discussion of principles). Sensible Research, Memo 2009–101.
- Harvold, Kjell et al. (2010): *Ansvar og virkemidler ved tilpasning til klimaendringer*. (Responsibilities and policy instruments in the adaptation to climate change). Collaborative report: Norwegian Institute for Urban and Regional Research (NIBR) / Norwegian Institute for Water Research (NIVA) / CICERO / Institute of Transport Economics (TØI).
- Rottem, Svein Vigeland et al. (2010): *Globale og regionale følger av klimaendringer. Konsekvenser for Norge*. (Global and regional impacts of climate change. Consequences for Norway.) Fridtjof Nansen Institute, Lysaker, Norway.
- Øyen, Cecilie Flyen et al. (2010): *Klima- og sårbarhetsanalyse for bygninger i Norge. (Climate and vulnerability analysis of buildings in Norway.)* Sintef Building and Infrastructure, Oslo, Norway.
- Rasmussen, Ingeborg and Haakon Vennemo (2010): *Samfunnsøkonomiske virkninger av klimaendringar i Norge*. (Socio-economic effects of climate change in Norway). Vista Analyse, Oslo, Norway.
- Ottesen, Preben (ed., 2010): Helsekonsekvenser *av klimaendringer i Norge*. (Health effects of climate change in Norway). Norwegian Institute of Public Health and the Norwegian Directorate of Health.
- NVE (2010): *Klimautfordringer i kraftsektoren 2100*. (Climate challenges in the power sector 2100.) Norwegian Water Resources and Energy Directorate, Oslo, Norway.
- Solbakken, Jan Idar and Stine Rybråten (2010): *Klimatilpasninger: Samiske næringer – fiskeri, utmarksnæringer og jordbruk*. (Adaptations to climate change: Sámi industries – fisheries, wilderness-based industries and agriculture) Sámi University College and CICERO.

These reports vary in their nature and scope. Some are broad reviews of the literature, while others focus on a single field. Many of the reports are the first comparisons of their kind in Norway. This mainly applies to the report *Klima i Norge 2100*, which is the first comprehensive overview of possible climate scenarios in Norway in the next century. The committee prepared a pamphlet

with a presentation of highlights in *Klima i Norge 2100* (Hanssen-Bauer et al. 2009) and *Konsekvenser av klimaendringer, tilpasning og sårbarhet i Norge* (Aaheim et al. 2009). This pamphlet was distributed and used as a basis for the dialogue with parties outside Norway. The report *Konsekvenser av klimaendringer, tilpasning og sårbarhet i Norge* is the first review of available literature relating to the impact of and vulnerability to climate change, and the report *Helsekonsekvenser av klimaendringer i Norge* is the first report related to the impacts of climate change on the general state of health in Norway. Similarly, the report *Globale og regionale følger av klimaendringer. Konsekvenser for Norge* is the first comprehensive study of the ways in which Norway will be affected by the impact of climate change on the international community.

These ten reports are included as electronic appendices to this report and can be downloaded from the Ministry of the Environment's website. Please note that the contents of these reports are the property of the authors and do not necessarily reflect the assessments of the committee.

In addition to reports, the committee has received input from the City of Bergen, the Norwegian Directorate for Nature Management, the Norwegian Directorate for Civil Protection and Emergency Planning, the Norwegian Refugee Council, Cities of the Future, the Norwegian Association of Local Authorities, Norwegian Water, the Norwegian Mapping Authority, the Directorate for Cultural Heritage and the National Office of Building Technology and Administration (SBE).

2.3.3 Involvement in the study

The committee has held a number of meetings with representatives from the government, organisations and business and industry, and organised public events with broad participation. This process has been absolutely necessary as a basis for the report, as well as to help increase awareness and understanding of climate change and its impact. According to the committee's mandate, contributing to the development of knowledge and stimulation of the public debate is an important part of the committee's work.

On 11 March 2009, the committee held a conference with relevant ministries and government agencies in order to obtain an initial overview of the status and help provide direction for the committee's work. At the conference, the committee was briefed about the Official Swedish Report *Sverige inför klimatförändringarna – hot och möjligheter* (Sweden facing climate change – threats and opportunities) (SOU 2007:60). The conference provided valuable methodological input and helped provide direction to the ongoing committee work. It also confirmed the impression that adaptation is evolving as a field and emphasised the need to further build on the existing work – in addition to establishing initiatives in areas where adaptation efforts have not yet been introduced.

In order to thoroughly acquaint itself with issues in key fields and areas of society, the committee held twelve expert meetings with selected parties involved in the following areas:

- Management of the natural environment: 10 September 2009 and 15 October 2009
- Transportation: 22 September 2009
- Buildings: 6 October 2009
- Energy: 8 December 2009
- Water and sewerage: 18 November 2009
- Land-based primary industries: 19 January 2010
- Health: 27 January 2010
- Insurance 4 February 2010
- Sport and outdoor recreation: 11 February 2010
- Marine industries: 18 February 2010
- Sámi industries: 13 April 2010

A total of more than 200 people attended the expert meetings. With one exception, the minutes have been prepared and subsequently commented on by the participants. The exception was the expert meeting on Sámi industries, which was organised as a discussion of an inital draft of the report on Sámi industries by the Sámi University College and CICERO. Input from this meeting has therefore been included in the report.

On 25 June 2009, the committee held a national conference in Oslo to present the report *Klima i Norge 2100* and to obtain input on how the scenarios will impact the various sectors and industries. The committee and the participants were presented with expected regional climate projections, existing adaptation initiatives in Norway, and expected impact of climate change on selected areas and industries: the natural environment and natural resources, cellulose and paper, tourism and outdoor recreation, production of power, banking and insurance, and water and sewerage. There was extensive media coverage of the conference, which attracted almost 100 participants.

The committee has held seven conferences open to the public in all parts of the country. The conferences were held in:

- Florø on 8 June 2009
- Alta on 1 October 2009

- Lillesand on 2 October 2009
- Bodø on 15 October 2009
- Trondheim on 16 October 2009
- Stavanger on 27 October 2009
- Drammen on 28 October 2009

The conferences focused on regional and local issues and involved municipalities, county authorities and the county governor's office. In the conferences, the committee's climate researchers presented regional climate scenarios. The results of the report *Konsekvenser av klimaendringer, tilpasning og sårbarhet i Norge* were also presented. County authorities and key government agencies contributed with introductions to debates about the government agencies' work on adaptation, and the meetings involved different organisations at the local and national levels.

In total, more than 500 people attended the open meetings and the conferences, providing input relating to regional and local issues. The various meetings have been documented and the minutes are available on the Norwegian Ministry of the Environment's website. The meetings were also covered by national and local media.

The committee members and the secretariat have held bilateral meetings with a number of involved parties, including political leaders and officials from seven relevant ministries: the Ministry of Transport and Communications, the Ministry of Agriculture and Food, the Ministry of Fisheries and Coastal Affairs, the Ministry of Health and Care Services, the Ministry of Justice and the Police, the Ministry of Local Government and Regional Development and the Ministry of Petroleum and Energy. In addition, the committee has held meetings with the inter-ministerial coordination group for adaptation to climate change, several research institutions, trade associations and interest organisations.

A number of experts and interested parties have been invited to attend the committee's own meetings. The committee meetings have also been used to encourage dialogue and input, e.g. the committee meeting in Bergen on marine-related challenges, which was hosted by the Institute of Marine Research. The committee also met with the City of Bergen and presented its work to the Municipal Executive Board. In Bergen, the Bergen Chamber of Commerce and Industry organised a seminar on adaptation in the maritime industries.

The committee and the secretariat have prioritised attending, contributing to and obtaining input on topics relevant to adaptation in national and international venues. These included Møteplass Marin (May 2009), a national meeting in the Cities of the Future project (May 2009), the third GLOBEC Open Science Meeting (Victoria, BC, June 2009), the Ministry of Agriculture and Food's climate conference "Landbruk – en del av løsningen" (Agriculture – part of the solution) (June 2009), Nord-Norge mot år 2020 (Northern Norway towards 2020) – Trade Conference in Bø, Norway (August 2009), the "Climate Change in the Barents Region" Conference (Vadsø, Norway, September 2009), Nordisk konferanse om skogforsking (Nordic Conference on Forest Research) (September 2009), Nature and Youth's "Student og Klima" (Student and Climate) conference (October 2009), the Norwegian Pollution Control Authority's "Havforsuring og klimaendringer" (Ocean acidification and climate change) conference (October 2009), the research programme Climate Change and Impacts in Norway's (NORKLIMA) conference for researchers, "Klimaendringer og konsekvenser for Norge" (Climate change and its impacts on Norway) (October 2009), the seventh ETAP forum on eco-innovation: "Adapting to Climate Change through Eco-Innovation" (Copenhagen, Denmark, November 2009), Klimadagen i Hordaland (Climate Day in Hordaland County) (January 2010), Folkehelsekonferansen 2010 (Public Health Conference 2010) (April 2010), Klimaforum Oslo (Climate Forum Oslo) (May 2010), Vannfestivalen i Bergen (Bergen Water Festival) (May 2010), the "Klimatilpasningstiltak for VA-sektoren" (Adaptation measures for the Water and Sewerage Sector) seminar (August 2010), Klimakonferanse 2010 (Climate Conference 2010) in Hamar, Norway (September 2010), first Annual Meeting of ECDC Expert Group on Climate Change (Stockholm, Sweden, September 2010), Kystnæringskonferansen (The Coastal Industries Conference) (September 2010), Clim-ATIC international project conference: "Mainstreaming climate change adaptation for rural peripheral communities" (Florø, Norway, October 2010), and many others. Many committee members have also held lectures as part of the National Emergency Planning College's course "Klimatilpasning i samfunnsplanleggingen" (Adaptation to climate change in social planning).

The committee also organised a study trip to the United Kingdom in order to learn about experiences gained from the British adaptation efforts. The committee chair and the secretariat met with the European Commission in April 2009 after it had submitted its White Paper.

The input the committee has received throughout its work provides a valuable basis for the report. The minutes from the committee's meetings and the minutes from expert and regional meetings are included as electronic appendices to this report and can be downloaded from the Ministry of the Environment's website.

2.3.4 Main features of the input

The committee has received vast volumes of input covering a wide range of topics. The scope is naturally too broad to allow presentation of all the input here, but the most important input topics will be summarised in the following.

There is a consensus in the input that the significance of climate change to society should be reported in full. Many have also supported the open approach that the committee has chosen with wide-ranging involvement of relevant expert institutions, the authorities and other parties. The committee has received many good examples of applied adaptation measures from various sectors and local communities.

The committee has received a lot of input regarding the impact of climate change on various ecosystems. Climate change appears as the major amplifier of the impact on the natural environment and nature-based industries. Much of the input particularly highlights the High North, where marginal ecosystems and traditional economic activity, such as reindeer husbandry and coastal fishing, are under increasing pressure. The impact of climate change on the natural environment and nature-based economic activity are discussed in further detail in Chapters 7, 10, 11 and 16.

Much of the input also points out that there are limits to how far the adaptation measures can go. Ecosystems will be affected by ocean acidification, and species living in marginal habitats will have little opportunity to adapt. Cutting greenhouse gas emissions is the only available measure for limiting the adverse effects in these areas. This is discussed in more detail in Chapters 7 and 11.

Many have also pointed out to the committee the dilemma linked to increased activity in the High North. For example, they have noted the major increase in shipping activity in the Barents Sea over the past decade. This creates new opportunities for industry, but simultaneously increases the impact on the environment, the risk of accidents and the need for emergency preparedness in the High North. In addition, the need for expertise on the Arctic and structural materials adapted to Arctic conditions is stressed. These issues are discussed in more detail in Chapters 7, 9.1 and 10.2 and Sections IV and V.

A number of interested parties emphasise the importance of land use in adaptation efforts. They stress the fact that land use affects the vulnerability of buildings, infrastructure, agriculture and the environment, among other things. Some parties argue that Norwegian land use is currently unsustainable, and point out that it is important to have large undeveloped land areas in order to maintain biodiversity. Many also emphasise that land-use planning will be a key element in society's adaptation. Land use and land use planning are discussed further in Chapters 7, 9 and 13 and Section V.

Many of the interested parties emphasise challenges related to insufficient maintenance in various areas. Increased maintenance has been identified as critical in reducing the vulnerability to climate change for buildings and much of the infrastructure. At the same time, it is also pointed out that maintenance is "invisible" work that is not often adequately prioritised. Some people have recommended redefining maintenance as adaptation in order to address this. The adaptation deficiency as a result of maintenance backlog is reviewed in more detail and discussed further in Chapters 9 and 16.5.

The committee has received quite a lot of input on challenges related to increased volume and intensity of precipitation due to changing climate. Some parties argue that increased volumes of waste water and stormwater runoff will pose a major challenge for densely populated and urban areas. Some express concern that the municipalities are not sufficiently prepared for this, and stress the need to strengthen both the national and local stormwater handling capacity. Challenges related to the handling of stormwater are discussed further in Chapters 9.2 and 16.1.

Some of the input has emphasised the development possibilities in relation to adaptation efforts, such as increased potential for production of hydropower, new solutions in aquaculture, benefits related to longer growing seasons and new opportunities for tourism. The committee has also been made aware of cases where adaptation measures have been cost-effective, for example Stavanger municipality constructing their cultural centre 1 m higher above sea level than originally planned. Opportunities for economic activity arising from climate change are primarily discussed in Chapter 10.

Many have underlined that the capacity for adaptation will be affected by a number of factors and that there should be a wide-ranging and comprehensive approach to the adaptation efforts. Climate change concerns virtually all sectors of society, and it has been argued that the adaptation policy must include all relevant affected parties, sectors and administrative levels. Others have pointed out that both adaptation and emission cuts will require changes in society, and that the policies in those two areas must therefore be considered in this context. Some parties have suggested that the current adaptation efforts are too fragmented and that the interaction between administrative levels should be strengthened. These comprehensive needs are primarily discussed in Sections IV and V.

Many have emphasise the need for a clear division and delegation of responsibility for adaptation to climate change and areas relevant to that adaptation. Among other things, the need for a clear delegation of authority for stormwater runoff is stressed. In addition, many people have pointed out a general need for a clear division of responsibility among administrative levels and expert fields. Responsibility and the division of responsibility are discussed mainly in Section IV.

The importance of adaptation knowledge and expertise has been mentioned by many parties. There have been calls for increased research on, as well as identification and monitoring of, a number of areas related to climate and adaptation. At the same time, this knowledge must be shared through education, courses and information, as well as the use of relevant interested parties. The knowledge requirements are mentioned in all chapters and subchapters of Section III, and are discussed in more detail in Chapters 16.3 and 16.4.

Many pointed out the key role municipalities play in the adaptation efforts and that the municipalities' conditions for adaptation are crucial to society's adaptations to climate change. Among other things, expertise and resources are highlighted as the most important areas of the municipalities' adaptation efforts. Many people have stressed that many municipalities lack sufficient expertise in land use planning and adaptation and need to improve their capacity and strengthen their resources. Some people also note the need for coordination of local efforts. The adaptation efforts in local communities and municipalities are discussed in more detail in Chapters 11.1 and 13 and Section V.

Chapter 3
The current framework for climate change adaptation

3.1 The national framework

Norway's climate policy is based on the scientific understanding of the greenhouse effect as described in the UN Intergovernmental Panel on Climate Change's (IPCC) reports, and in the international commitments that Norway has assumed through the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. The Norwegian Ministry of the Environment has the overall national responsibility for climate policy, which includes the policy for adaptation to climate change.

At the national level, the challenges with regard to adaptation are discussed in the report *Klimatilpasning i Norge. Regjeringens arbeid med tilpasning til klimaendringene* (2008) (Adaptation to climate change in Norway. The Norwegian government's climate change adaptation efforts) and in the Minister of the Environment and International Development's climate policy report to the Storting (the Norwegian Parliament) of 12 May 2009 (Regjeringa 2009). The report states that the most important task is to reduce greenhouse gas emissions. At the same time, the report also points out the impact of climate change on Norway and how our society best can adapt to a changing climate. The objective of the adaptation efforts is to minimise the vulnerability and exposure of society to climate change, as well as to contribute to improving Norway's capacity for adaptation.

The government's report and the establishment of the Secretariat for Climate Change Adaptation in the Directorate for Civil Protection and Emergency Planning (DSB) in 2007 are new approaches to help achieve a coordinated adaptation effort.

The government's report from 2008 emphasises that the responsibility for adaptation is shared between government authorities, business and industry, as well private individuals. Each individual sector and individual administrative level has a separate responsibility for reducing the impact of climate change within its respective area of responsibility. This entails that all interested parties must study their own vulnerability to climate change, plan their handling of climate change, as well as initiate and implement measures. The report outlines three general types of measures for the period from 2009 to 2012. These measures are related to vulnerability and adaptation need studies, increased knowledge and information and competence building. The appointment of this committee was one of the measures introduced.

3.2 The international framework

The IPCC issued its first report in 1990. The report led to the acknowledgement of the risk of global climate change as a result of greenhouse gas emissions.

In 2000, the IPCC published a series of emission scenarios (IPCC 2000), which formed the basis for most impact assessments and adaptation studies, including those in Norway. The series comprises four main scenarios: A1, A2, B1 and B2, which differ from each other in terms of various assumptions about population growth, economic growth, the distribution of growth between wealthy and poor countries, as well as the extent to which countries are willing to cooperate to solve global problems. The emission scenarios were used to determine climate trends in global climate models. The global climate projections will be scaled down by means of regional climate models and other methods and can then be used in the national, regional and local adaptation efforts (Aaheim et al. 2009). In 2007, the IPCC issued its fourth assessment report. The general picture is mainly the same as it was 15 years ago, but the conclusions are more certain and the perceived threat is greater. The IPCC provides the scientific basis for both international and national climate change measures.

The UN Framework Convention on Climate Change (UNFCCC), negotiated in 1992, serves as

the global framework for the member states' efforts to combat climate change. The Convention entered into force in 1994. Today, almost every country in the world (193 countries) has ratified the UNFCCC. The Convention commits the parties to reduce greenhouse gas emissions. Specific targets and mechanisms for achieving them were established in the Kyoto Protocol, which was adopted in 1997. The UNFCCC also considered measures for adapting society to a changing climate. Participating countries are committed to develop integrated national adaptation plans and programmes which facilitate adaptive measures. Several measure programmes have been developed to improve the individual countries' adaptation efforts, particularly developing countries that are regarded as exceptionally vulnerable to climate change

3.3 Adaptation strategies in other countries

There is no general international definition of climate change adaptation. Currently, each country identifies the impact of climate change on nature and society itself, and defines its adaptive needs on the basis of that definition. Measures to increase resilience and reduce vulnerability to climate change depend on institutional, social, economic and natural parameters. There is broad international agreement that a shared adaptation standard is neither desirable nor appropriate. Nevertheless, the elements of the various adaptation efforts have much in common, even if the measures may be very different. These elements are related to the improvement of the data base and the knowledge base for adaptation, studies and analyses, the need for competence building, the importance of intact ecosystems and sustainable management of natural resources, and the links between adaptation, prevention and emergency preparedness.

The following are examples of how the adaptation efforts are organised in the European Union and in two European countries. Aaheim et al. (2009) concludes that government reporting efforts have been important in the development of a national climate policy in the countries in question. It has been partly important in assessing the need to develop a separate adaptation policy area for climate change and partly important in assessing the need for an improved research effort with regard to vulnerability and adaptation to climate change. However, it may have been equally important that the focus on adaptation has resulted in a revitalisation of the climate change debate in general.

3.3.1 The European Union

The European Union sees its role as particularly relevant as the effects of climate change are transboundary and vary from region to region. Adaptation will require financial transfers among the European Union member states in order to ensure that the poorer regions can implement adaptation measures. The coordinated European effort is necessary for sectors integrated at the European level, such as agriculture, water, biodiversity, fisheries and energy grids. The European Commission's White Paper from 2009 outlines a two-phase adaptation policy in the European Union with the goal of improving the EU countries' ability to cope with a changing climate. In the first phase up to 2012, the policy calls for work along four main axes:

1. Knowledge base – projections, cost–benefit analyses and reporting systems. The primary element is the development of an Internet portal for climate change adaptation, a so-called clearing house.
2. Integrating adaptation in key areas, which initially entails a review of policies and regulations for the agriculture, biodiversity, health and social care system, production system and infrastructure sectors.
3. The development of policy instruments – not very specific, but possibly a set of policy instruments, primarily government funds from the EU countries themselves, but also, for example, the development of funds based on quota auctions (European Union Emissions Trading Scheme = EU ETS), insurance, etc.
4. Improve international cooperation.

To safeguard these efforts, a working group has been established under the European Commission, along with expert groups in key sectors such as water, biodiversity, energy, transport and agriculture. The working groups contribute knowledge on national strategies and help facilitate the European Union's adaptation policy.

3.3.2 Sweden

In 2005, the Swedish government decided to study the effects of climate change and how Sweden could reduce its vulnerability. The resulting report ("Sweden facing climate change – threats

and opportunities", Swedish Government Official Report, SOU 2007:60) was submitted in October 2007. The Swedish committee based its vulnerability assessments on sector-specific and area-specific analyses.

In an extension of the SOU, a comprehensive proposition was issued to the Swedish government regarding a coherent climate and energy policy (Prop. 2008/09:162). The proposition addresses policy instruments intended to reduce greenhouse gas emissions and includes a separate chapter on adaptation. The proposition points out that climate change results in an increased risk of floods and slides (landslides, avalanches, etc.) due to increased precipitation and streamflow.

The proposition emphasises that the adaptation efforts must be strengthened and coordinated at national and regional levels. The adaptation efforts must include all of society and be integrated into the sector responsibility. In the proposition, several measures are proposed for adaptation, e.g. in the areas of monitoring and information work and quality assurance of drinking water.

3.3.3 The United Kingdom

The United Kingdom has, to a greater extent than any other European country, institutionalised adaptation to climate change. As early as 1997, the British Ministry of the Environment, in cooperation with research institutions at Oxford University, established the *United Kingdom Climate Impact Programme* (UKCIP). UKCIP functions as an independent adviser to the authorities, as well as business and industry, on the design of studies of vulnerability and adaptive strategies.

The Climate Change Act (CCA) of 2009 specifies guidelines for assessment of vulnerability and adaptation efforts at national, regional and local levels. The CCA required the British government to conduct a national vulnerability assessment and implement an adaptive strategic plan, Climate Change Risk Assessment (CCRA), every five years. The first of these plans is scheduled to be submitted in 2011. The CCA authorises the government to require reporting on vulnerability assessments and adaptive strategies from all government agencies and departments at all administrative levels. The CCA also clarifies the authorities' responsibility for preparing the country for the impact of climate change. As part of these efforts, regional climate change impact assessments are being prepared throughout the entire United Kingdom.

Uncertainty is an argument in and of itself for

The United Kingdom recently revised its indicator-based reporting system for local authorities (National Indicators). As part of this revision and the introduction of CCA, an indicator (NI 188) for planning adaptation to climate change was introduced in April 2008. Two other climate indicators are linked to emission reductions. The National Indicators comprise a total of 198 different indicators. NI 188 measures the degree of implementation of vulnerability and risk assessments as well as planning for adaptation and the extent to which these processes have been institutionalised in the local authorities through planning processes and routines for administrative procedures. Local authorities may be awarded between one and four points, depending on what they have done in the various areas covered by the indicator. The local authorities' score influences the size of the financial contribution they may receive from the national government. This provides the local authorities with an economic incentive to plan for the consequences of climate change.

The most recent addition to the British vulnerability and adaptation efforts is *UK climate projections 09* (Defra 2009). These are climate projections that have been developed for decision-makers and are to be used in vulnerability and adaptation studies.

In addition to NI 188 and the CCA, the British Planning Act 2008 imposed a commitment on local authorities to include climate change considerations in their planning and development. This entails that the local development plans must be adapted to the consequences of climate change. Particular emphasis has been placed on future floods as this causes the most damage in the United Kingdom.

3.4 Principles for handling uncertainty

The climate system, nature and society, and how they interact, are too complicated to allow for a simple and accurate estimate of the effects of climate change. As a result, knowledge about both climate change and its impacts is uncertain.

Climate change constitutes a new aspect of uncertainty related to social development and increases the uncertainty in the decision-making basis for social planning. However, this uncertainty should not become a hindrance for adaptation. The committee has found that uncertainty related to climate change tends to increase the need for development of strategies and measures. sound, flexible plans, rather than delays.

In many cases, delays may increase vulnerability, and planning without taking climate change into consideration will result in a society that is less resilient as regards climate. Waiting to see what happens may be a sensible tactic in some cases, but scientific uncertainty and lack of experience with the challenges of climate change, are not reasons enough to postpone the development of plans and the implementation of measures.

In keeping with the mandate, the committee will conduct a discussion on the principles that should be considered when determining how society should handle the uncertainty related to the scope and impact of climate change. Uncertainty is associated with many different aspects of topics in this report. There is no completely reliable formula for planning under uncertainty. Thus, in the following section we will offer a few intital observations and discuss certain criteria for setting priorities when there is uncertainty in the adaptation efforts. For a further discussion of coping with uncertainty in social planning, cf. Chapter 19.

3.4.1 Climate change increases uncertainty

Uncertainty related to climate change is not isolated from other uncertainties in societal planning, but is part of a complicated interaction among various processes – both natural and man-made.

According to the committee's mandate, this report will discuss the ways in which research over a period of time can help reduce uncertainty regarding the impact of climate change. It is the committee's assessment that uncertainty will not be completely eradicated by increased knowledge, but it can be reduced.

More knowledge increases the chances of making good prognoses and decisions. Complete certainty, however, is unattainable as that would require a static, unchanging world and because science itself rarely can provide solutions set in stone. Nor does more knowledge automatically guarantee less uncertainty. On the contrary, more knowledge can also increase our awareness of the number of factors that affect the climate, and as such, actually increase uncertainty.

Not everything is uncertain with regard to future climate trends. The magnitude and scope of the changes is uncertain, but not whether the changes will occur: we know that the temperature and sea levels will rise, that the annual precipitation in Norway will increase and that extreme weather will occur more often. At the same time, we also know that society will evolve. The acknowledgement that the climate and society are changing forms the basis of the need for adaptation.

3.4.2 Criteria for decisions under increased uncertainty

In the following, we will describe certain criteria that may be useful in making decisions under conditions of uncertainty.

The goal of sustainable development

The goal of sustainable development is basic to all government administration in Norway and is therefore also the main goal of this report. In this context, the goal entails that human activities in society and the natural environment must occur in such a way that we do not make nature and society less resilient to climate change. Therefore, it is important that the choice of adaptive measures be based on the total (or combined) effects of those measures.

The cost–benefit criterion

Society cannot prevent all negative consequences of climate change; this is neither realistic nor is it beneficial. When priorities are set, there is a need to balance the cost of an adaptive measure against the expected beneficial effects of that measure.

In this kind of situation, the cost–benefit criterion is a potential decision criterion. According to the cost–benefit criterion, a given measure should implemented if the beneficial effect of that measure, adjusted for the probability of the effect occuring, is equal to, or greater than, the cost of the measure. In a number of cases, we can assume that a benefit is greater than a cost without making any consideration of the benefit to adaptation. These are usually called win–win measures because we win by implementing regardless, and we also gain the benefit of the adaptation. Assessed as adaptive measures, these measures have a negative net cost. In other words, win–win is a characteristic of a measure that can help us in the decision-making process and thereby be a criterion for making the decision. Thus, win–win amounts to a special case of the cost–benefit criterion.

The use of cost–benefit analyses is discussed in more detail in Chapter 16.2.

The precautionary principle

The precautionary principle has played a key role in international environmental policy during the past decade. This principle came to the world's attention during the International Climate Conference in Rio de Janeiro in 1992, and Norway has committed itself to this principle through the UN Framework Convention on Climate Change (UNFCCC). There is no complete consensus on how to define this principle. In Norway, the precautionary principle is incorporated in the new Act relating to the management of biological, geological and landscape diversity (the Nature Diversity Act), which states (in Section 9):

> When a decision is made in the absence of adequate information on the impact it may have on the natural environment, the aim shall be to avoid possible significant damage to biological, geological or landscape diversity. If there is a risk of serious or irreversible damage to biological, geological or landscape diversity, lack of knowledge shall not be used as a reason for postponing or not introducing management measures.

In practice, this means that nature shall have the benefit of the doubt if there is a major risk of damaging the biological, geological or landscape diversity. The precautionary principle shall also apply to adaptation in cases where possible measures will affect the natural environment.

Risk aversion

The precautionary approach is closely related to the concept of risk aversion (Hovi 2001, Vennemo 2010). A risk-averse decision-maker will typically assign a profit of NOK 1 million less importance than the disadvantages of losing NOK 1 million. Among other things, risk aversion explains why private individuals take out insurance policies. For a homeowner, it may be rational to take out a fire insurance policy even if the annual premium greatly exceeds the expected annual insurance payment. Although the risk of a worst-case scenario occurring is small, the consequences would be dramatic should a fire actually break out. Briefly stated, risk aversion supports the precautionary principle and establishes a norm that it is better to prevent than having to repair.

It must be expected that municipalities and the State will lean towards risk aversion in the same way as the individuals they represent, and it must be expected that a social planner will base social planning on risk aversion.

Section II
A changing climate

Chapter 4
The past and present climate

Box 4.1 General comments about Section II A changing climate

Section II is based on the report "Klima i Noreg 2100" (Climate in Norway 2100) (Hanssen-Bauer et al. 2009), which was prepared on commission from NOU Climate Change Adaptation in order to provide a joint scientific basis for assessments of vulnerability and adaptive needs.

Climate is defined here as systematised weather observations over a time period of 30 years, and this forms the basis for quantifying climate and climate variability for a given place or area. Weather observations over a short period of days, weeks, months or a few years are not sufficient for describing climate conditions.

The climate in Norway is extremely varied, both geographically and seasonally; and is very mild when compared with other areas at the same latitude. This is mainly attributed to heat transported with the Prevailing Westerlies in the atmosphere and the Gulf Stream in the ocean. Variations in these streams will have a major impact on our local climate.

The global and regional changes in the climate over the last 150 years cannot be explained without taking into account human influence through emissions of greenhouse gases and aerosols in the atmosphere, as well as through changes in land use. These changes have been especially pronounced in the past 50 years. It is expected that climate trends in this century will be affected by the amount of greenhouse gases and aerosols in the atmosphere, in combination with natural climate variations. The latter depend on the interaction between oceans, land and the atmosphere, as well as the frequency and intensity of volcanic eruptions and variations in incoming solar radiation.

This section includes discussions of the atmospheric climate, the marine climate including sea ice, hydrological conditions including floods, glaciers and permafrost, landslides and avalanches. These chapters summarise the current knowledge about expected climate change in Norway. In order to assess the possible effects of future climate change, it is also important to consider these changes relative to the climate, both past and present. A general description of the historical climate trend and the current Norwegian climate and its surroundings has therefore been included.

The climate projections for the future focus on three periods: the next 10 to 20 years, a period leading up to the middle of the century and a period leading up to the end of the 21st century. The first period is considered separately. In such a short time period, the changes that are attributed to anthropogenic influences will be minor – or on the same scale as natural climate variations. Consequently, the climate trend for the next 10 to 20 years will primarily be governed by natural climate variations.

Climate projections leading up to the middle and end of the century are mainly based on modelling results from the reports issued by the UN Intergovernmental Panel on Climate Change (IPCC 2007), but they are further processed in order to provide information on a regional scale. There are many sources of uncertainty associated with the model estimates, and consequently there is considerable disparity in the results. Thus, "low", "medium" and "high" projections have been estimated for temperature, precipitation and sea levels. No quantified probabilities have been assigned to the various climate projections, partly because the IPCC has not assigned any probability to the different views about the scope of future greenhouse gas emissions. However, the question of probability is discussed on the basis of what we currently know. Recommendations concerning the use of the climate projections are based on this.

4.1 What is, and what controls, the climate?

4.1.1 Atmospheric and ocean circulation control the climate

Large parts of Norway and the surrounding marine areas have an average annual temperature that is 5 to 10 degrees Celsius higher than for equivalent latitudes in other parts of the world. The differences in the atmospheric winter temperatures are even greater: up to 20 degrees Celsius higher than the mean temperature for that latitude. Heat transported from further south in both the atmosphere and the oceans contributes to this difference.

The heat transported by the atmosphere is mainly associated with Norway's central location in the North Atlantic Prevailing Westerlies. Wind from the southwest transports warm, damp air toward the Norwegian coast. This manifests itself in particular during winter when regular, often pronounced, low-pressure systems come in from the southwest, bringing mild winters with high levels of precipitation, especially west of the watershed divide. Nonetheless, there are some winters with only a few, weak low-pressure systems. Those winters are usually cold with little precipitation, e.g. many winters in the 1960s, and the 1995–96 and 2009–10 winter seasons.

The occurrence of stormy, mild winters and relatively dry, cold winters is related to regular variations in the atmospheric circulation above the North Atlantic. These variations are usually called the North Atlantic Oscillation (NAO). The NAO is an important reason why we have significant natural annual variations in wind, temperature and precipitation throughout all of mainland Norway. Northern Norway is also affected by Arctic air masses, but the effect of the NAO is noticeable in this area as well. Svalbard is on the border between the cold Arctic ice cap and more temperate areas, and the effect of the NAO is less regular there than it is farther south.

Norway's topography also affects regional climate variations, particularity in regards to precipitation. With westerly winds, areas west of the watershed divide will get the majority of the precipitation, whereas southerly and easterly wind directions bring more precipitation to the south and east.

It is not currently possible to forecast the NAO in the future, nor can periods with a greater frequency of south-easterly winds be forecast more than one week in advance. Over the next 10 to 20 years, these natural variations will be greater than, or equal to, the expected future anthropogenic climate change. Since the current climate models can only predict long-term changes in the climate, a model-based climate projection for Norway leading up to 2030 is not very informative.

Heat transported by the ocean is tied to the extension of the Gulf Stream. Each second, between 8 and 9 million cubic metres of warm, salty Atlantic Ocean water pass by the Faroe Islands on their way into the Nordic marine areas. This heat source, as well as the nutrients in the water mass, is especially important for the marine ecosystems in the North Sea, the Norwegian Sea and the Barents Sea. Heat transported by the Gulf Stream is the reason why the entire Norwegian coast and much of the Barents Sea is ice-free during winter, and it affects the air temperature, especially in coastal regions.

The NAO varies from year to year and from decade to decade, and it affects the strength of the Gulf Stream. There are indications that the ocean temperature in the entire North Atlantic Ocean varies over fairly long periods of roughly 50–70 years. These long-term climate fluctuations, called the Atlantic Multi-decadal Oscillation (AMO), also have a much greater geographical range than the NAO. A weak Gulf Stream will partially counteract the effect of global warming in Norway, whereas a strong Gulf Stream will intensify the effect. Variations in the Gulf Stream are therefore significant for climate trends in Norway and adjacent marine areas. Variations in the heat transported by ocean currents are described in the climate models used in this report. In the same way, the AMO will amplify or diminish the anthropogenic warming in the North Atlantic and to some extent on adjacent land areas.

In the same way that the climate models cannot forecast the NAO trend for the next 10 to 20 years, the models cannot tell us anything about whether the next 10 to 20 years will have an increased or reduced transport of heat in the oceans. Therefore, the models cannot yet indicate the periods in which we will have amplified or diminished heating due to variations in ocean currents.

4.1.2 How do we measure climate variability and climate change?

The natural variations in air and ocean circulation cause significant climate variations in Norway for periods which can span several decades. In order to have a solid definition of climate in relation to these fairly short-term periods, an international

standard 'normal' period of 30 years has been introduced. Current standard normal climate values are calculated using the period 1961–1990 as the baseline period, and it is the climate in this period that is described in the following section.

Temperature, growing season and heating season

The annual mean temperature for Norway is about 1° C, but varies from 6° C on the west coast to lower than -4° C in the alpine areas. The west has a temperature-determined growing season (days with a mean temperature above 5° C) of up to 225 days, whereas the growing season in the alpine areas and in parts of the Varanger Peninsula in the far north amounts to less than 70 days. The total number of heating degree days (which are a measure of the energy need for indoor heating) varies from more than 6 000 in the interior of the east, the alpine areas and the interior of northern Norway to less than 3 000 on the outermost part of the west coast. The number of "hot days" (24-hour periods with a mean temperature above 20° C) is highest in the lower lying areas near the Oslo Fjord.

Precipitation and hydrology

Norway's average annual precipitation is 1486 mm. Of this precipitation, it is estimated that 346 mm evaporates, whereas 1140 mm is runoff. The Upper Gudbrandsdalen Valley and the interior of Troms County are the driest areas in Norway (with an observed annual precipitation of less than 300 mm), whereas the regions some miles inland from the west coast are the wettest (with more than 5000 mm of estimated annual precipitation in some places). The 24-hour precipitation value, which on average is exceeded three to four times annually, varies from less than 15 mm in the driest areas to about 150 mm in the wettest areas of the west. The highest annual runoff is from the Ålfotbreen Glacier (approximately 5400 mm), and the least is observed in the Upper Gudbrandsdalen Valley (about 350 mm). The Oslo Fjord, Southern Norway and the Fosen Peninsula have the highest annual evaporation (estimated to be in excess of 500 mm). The glacial areas in the alpine areas have the lowest evaporation (approximately 50 mm). The water content of the maximum annual snow cover varies from almost none to more than 3000 mm. On average, coastal catchment areas only have a few days each year with snow cover, the alpine areas have snow cover for more than 300 days each year, and glacial areas have almost permanent ice and snow cover.

4.2 The climate of the past

In Norway, we have reliable instrumental meteorological measurements dating back about 150 years. Since the end of the 19th century, the observations have had sufficient geographical coverage to provide a good description of variations in temperature and precipitation in different parts of the country. In this subchapter, we describe the climate over the past 100 years. We have also included a description of the climate over an even longer period. This section focuses on studies of the climate in the past.

4.2.1 Climate variability in Norway after the last Ice Age

The last Ice Age ended 11 700 years ago. During the Mesolithic Age, from 9 000 to 6 000 years ago, Scots pine grew in parts of the Hardangervidda mountain plateau. Even the largest glaciers in Norway periodically melted away between 7,000 and 6,000 years ago, because the summer temperatures were about 1.5–2° C higher than during the period 1961–1990. In the Middle Ages, the Scandinavian climate was also generally mild, with a mean temperature that was 0.5–1° C higher than during the period 1961–1990. The mild climate made it possible for people living in northern regions to settle on Greenland. During the so-called Little Ice Age in the mid-18th century, most Norwegian glaciers reached their maximum extent for several thousand years.

The changes described above are attributed to natural climate variation. The warm period during the Mesolithic occurred because the Earth was closer to the sun during the northern summers, in addition to the Earth's axial tilt being greater than what it currently is. The reasons for the mild climate approximately 1000 years ago and the cooler period about 300 years ago are most likely related to variations in solar activity and to the frequency of major volcanic eruptions. During periods with several major volcanic eruptions, less solar energy penetrated the atmosphere due to direct and indirect effects of the particles and gases released into the atmosphere during eruptions. During periods with less volcanic activity, more solar energy will penetrate the atmosphere. Variations in solar activity also cause fluctuations in solar radiation, and this affects the climate on

Earth. There are hypotheses stating that solar activity indirectly affects the formation of clouds and thereby has a secondary effect on the climate, but there is no agreement as to how large this effect may be.

Much of the natural climate variation is regional and not global. For example, there is reason to believe that the warm period in the Mesolithic primarily occurred at Arctic latitudes, while the tropics were not significantly warmer than they are today.

4.2.2 Climate variability in Norway during the last 100 years

Data series of climate variables show major annual and decade-on-decade fluctuations. These are mostly caused by natural variations in the climate system. However, many data series also reveal trends over longer periods of time. These may be attributed to both natural and anthropogenic climate forcing.

Temperature, growing season and heating season

The annual mean temperature for mainland Norway has increased by about 0.8° C over the past hundred years, and the trend in the different regions, as shown in figure II.1, varies from 0.05° C to 0.10° C per decade (table II.1). This is in keeping with the increase in the global mean temperature for the same period. However, as expected for a limited geographical area, the temperature in Norway shows far greater variation year-on-year than the global temperature. Consequently, there have been periods with both increased and decreased temperatures. The climate was fairly cool at the start of the 20th century, whereas the 1930s were relatively mild. It then became cooler again in the 1960s and 1970s, but since 1965, the temperature has increased by about 0.4° C per decade. The growing season has become longer throughout the whole country, and the total number of heating degree days has decreased.

Precipitation

For mainland Norway, the annual precipitation has increased by slightly less than 20 per cent since 1900. Much of the precipitation increase has occurred after 1980. The first row in table II.2 shows the long-term trend in the different precipitation regions depicted in figure II.2. The largest increase in annual precipitation has been in Østfold County and in Western Norway (+2 per cent per decade), while there has not been any increase in the Varanger Peninsula.

Wind

There is no clear trend since 1880 in the occurrence of storms in our marine and coastal areas. There appears to have been an increase in the frequency of storms in many areas between the 1960s and the 1990s. This is probably related to a gradual intensification of the NAO during the same period. Since the mid-1990s, the storm frequency has started to decrease.

Snow

Long-term variations in snow conditions have been analysed at weather stations with 100-year-long time series. The snow season has become shorter in most locations during the 20th century. Many stations also report a negative trend in the maximum annual snow depth. However, it must be noted that there are few weather stations in the alpine areas.

Permafrost

Temperature measurements performed since 1999 show that the permafrost in the Norwegian alpine areas is now rapidly warming up, at a rate of around 0.3° C per decade at a depth of 25 metres. The warming is observable down to depths of 60 metres below the surface in Jotunheimen, where Norway's highest alpine areas are located.

Streamflow and floods

Streamflow varies considerably from year to year and decade to decade. The observed temperature increase has generally resulted in increased streamflow during winter and spring. There has been a trend towards earlier snowmelt and resulting earlier spring floods in recent years. There is also a trend indicating that south-eastern Norway has had longer periods with low streamflow in the summer. At the same time, heavier rainfall floods, which were common in the warm 1930s, have become more frequent again after 1987.

Oceans and ice

The hundred-year-long time series for ocean temperatures for the Atlantic Ocean water that flows along the Norwegian coast and continues into the Barents Sea shows a gradual warming trend, alt-

hough there are major variations at different time scales. Although the sea level off the Norwegian coast has risen 14 cm in the last 100 years, no general increase has been measured in the sea level along the Norwegian coast during the same time period. The reason is that mainland Norway continues to rise after the last Ice Age. In the innermost reaches of the Oslo and Trondheim Fjords, the land is rising at a little less than 50 cm per century, with lower sea levels as a result. On the outermost reaches of the south and west coasts, the land has been rising much less rapidly, which has resulted in a slight rise in sea level.

The size of Arctic summer sea ice, expressed as the mean size in September, has decreased by about 30 per cent over the past 30 years. During winter, the reduction has been relatively modest so that the reduction in the annual mean has been 10–12 per cent during the period. In the Barents Sea, the reduction in the ice cover has been greatest during the winter and least in the summer. The latter trend is attributed to the fact that there is generally little ice in the Barents Sea during the summer.

4.3 The current climate trend

The period from 1961 to 1990 is an internationally agreed-upon reference period for climate. This will be used as a baseline for "normal climate values" until there are observed values available for a new reference period from 1991–2020. There have been significant changes from the 1961–1990 period to the most recent thirty-year period from 1979 to 2008. A map of climate conditions during this period is available at *www.klimatilpasning.no*.

In this chapter, we describe the changes observed for a number of climate and hydrological variables during these 18 years. These are changes we should keep in mind during short-term planning of up to 20–30 years.

Temperature

The annual temperature for mainland Norway has increased by 0.5 to 0.6° C; i.e. nearly 0.3° C per decade (table II.1, second row) and by over 1.3° C in Svalbard. The largest increase has been in winter. For mainland Norway, the mean winter temperature has increased by about 1° C. The smallest increases (0.3–0.4° C) are associated with the summer and autumn.

Hot days

The area where there are 24-hour periods with a mean temperature higher than 20° C has increased considerably. The area with "hot days" has expanded in the east, and now also includes large areas along the southern coast and smaller areas in the inner fjords of Rogaland and Hordaland counties, as well as the inner reaches of the Trondheim Fjord. The largest number of hot days still occurs in the inner reaches of the Oslo Fjord.

Growing season

The temperature-determined growing season (the number of days with a mean temperature above 5° C) has increased by 1–2 weeks throughout most of the country. The growing season is at its longest in the outermost regions of the west coast, and the highest values for the growing season in this area have increased from 225 to 238 days. A vegetation index based on satellite mapping also shows that the growing season has increased throughout large parts of the country.

Heating needs

A temperature-determined total number of heating degree days indicates that the energy needs for heating dwellings has decreased throughout the country. The most significant reduction in the total number of heating degree days (more than 300) occurred throughout much of Eastern Norway, in the interior of the Trøndelag and Nordland counties as well as throughout much of Finnmark County. The smallest reduction (100–150) occurred in the outer regions of the west coast and in the two Trøndelag counties.

Mean precipitation

The annual precipitation has increased in all regions, and there was a mean increase of 5 per cent for mainland Norway (nearly 3 per cent per decade, table II.2, row 2). Throughout much of the west, the annual precipitation increased by 5–10 per cent, but the greatest increase in percentage was in a small area in the interior of Troms County and in the south-western parts of the Finnmarksvidda plateau. In Northern Norway, there are also some small areas that have less annual precipitation than in the period 1961–90. For the country as a whole, the increase was greatest in winter (17 per cent), and in the wettest regions of Western Norway, the increase was about 25 per

cent. The precipitation in the autumn has decreased by 3 per cent. The precipitation in the spring has increased in all regions, and the increase for the country as a whole has been about 10 per cent. For the composite series from Longyearbyen and the nearby Svalbard Airport, there was no change in the observed annual precipitation between the two periods. The precipitation has decreased there during winter, spring and summer, but has increased in the autumn.

Heavy precipitation

There have been only minor changes in heavy precipitation (24-hour precipitation values that are only exceeded 1 per cent of the time).

Runoff

It has been estimated that the annual runoff in Norway has increased by 2.5 per cent. The most consistent increase has occurred in the glacial river basins, and the annual runoff in the glacial rivers from the Jostedalsbreen Glacier has increased by 10 per cent. Norway's mean annual runoff has increased most during winter (23 per cent), but with major regional variations. The greatest increase is observed in Eastern Norway (51 per cent) and the smallest increase has been in Finnmark (1 per cent). During summer and autumn, there has been a reduction in runoff of about 1 per cent. Especially Eastern and Southern Norway, the Fosen Peninsula and Nordland County have become drier in the summer. For glacial river basins, the runoff has increased in all seasons. The glacier mass balance, an expression of accumulation and melting of snow and ice, has decreased considerably in the Jotunheimen mountain range, while it has increased since 1988 for the western, more maritime, glaciers. The increase in glacial runoff since 1993 in summer and autumn is attributed to the increase in glacial melting combined with more precipitation in the form of rain in the glacier-free part of the river basins.

4.4 Climate trend towards 2030

Projections for climate trends up to the middle and end of this century are described in the next chapter. In many sectors, there is a need to know what the expected climate trend will be in the coming decades. Over such a short time period, we expect that natural variations may be comparable to, or overshadow, the anthropogenic changes. However, recent analyses indicate that anthropogenic climate change may also have made a substantial contribution to the changes in the last two decades.

Therefore, we recommend that data for the most recent 30-year period (1979–2008) be used for planning purposes in the next two decades. If an estimate is to be made of extreme events, it is still advisable to use as long a period as possible, but also to include data for the last 30 years. In addition, signals that are expressed through climate projections should also be assessed.

Chapter 5
Future climate

5.1 Model basis

Several different emission scenarios have been developed with a view toward forecasting future climate change. Population growth and economic and technological developments are important factors on which these scenarios are based. In estimating future climate change, it is common to use three main scenarios for greenhouse gas emissions, known as scenarios B1, A1B and A2. B1 is a scenario based on the assumption that global greenhouse gas emissions will be significantly reduced. A1B is a "medium" scenario, whereas A2 is described as a business-as-usual scenario. Thus, climate change will be greatest with an A2 scenario and least with a B1 scenario.

Global climate models are the most frequently used tools in the efforts to quantify the future climate. The climate models are based on well-established natural laws expressed as mathematical equations and predict, for example, air and sea temperatures, ocean currents and wind, cloud cover, precipitation and sea ice on the planet. Together with natural laws, the climate models include simplified descriptions of, for example, heat radiation, cloud cover, sea ice, soil moisture and the distribution of snow and ice on land and sea.

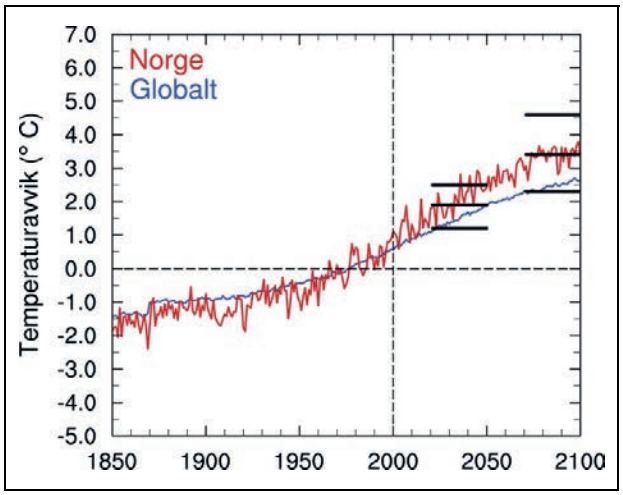


Figure 5.1 Temperature increase, A1B emission scenario

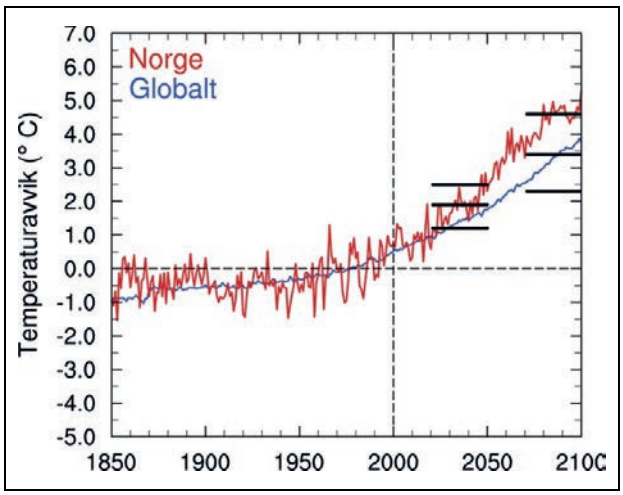


Figure 5.2 Temperature increase, A2 emission scenario

The climate models generate daily weather in the atmosphere and in the sea, which give us the climate over a longer period of time. The weather and climate generated by the models depend on external forcing by factors such as variations in the influx of solar energy and particles from major volcanic eruptions, internal variations that are attributed to the exchange of heat and moisture between the atmosphere, land areas and the oceans and anthropogenic impact due to emissions of greenhouse gases and aerosols. Anthropogenic impact is usually expressed by means of emission scenarios B1, A1B and A2.

Climate projections

The results from global climate models are used to prepare climate projections. These are specific figures that estimate changes in precipitation and temperature in the near and distant future. Then, global projections are scaled down to regional levels. By downscaling, we achieve a more detailed picture with a practical value. Norway, for

instance, is divided into 13 precipitation regions and six temperature regions; cf. the map below. In the following, projections that show changes in precipitation are presented in per cent, while the temperature changes are presented in degrees Celsius.

Data for the atmospheric climate are prepared based on the results of a number of linked climate models and a combination of emission scenarios B1, A1B and A2. For temperature, a comparison was made among a total of 72 different downscaled climate projections, whereas the precipitation data is a result of a comparison of 22 projections. Combining various climate models and emission scenarios improves the accuracy of the projections.

In the report, climate projections are divided into three groups. The mean value of the downscaled temperature and precipitation projections is called M (mean projection). In addition, a high projection (H) is presented, where only ten per cent of the projections have a higher value. Likewise, a low projection (L) is presented, where only ten per cent of the projections have a lower value.

In addition, some of the projections are further analysed to provide climate information at a resolution of 1 km, and these data cover all of Norway. The results are used to calculate changes in variables such as growing season and hydrological variables (e.g. streamflow including floods and drought, soil moisture and ground water) and can be presented in the form of a map. These highly detailed maps make it easy to forget that the information they provide is uncertain. In order to interpret the results of these projections for specific locations in this perspective, it is important to consider their location vis-à-vis the "low", "medium" and "high" climate projections.

Sources of uncertainty

There are many types of uncertainty associated with climate projections, at both global and regional levels. Some of the sources of uncertainty can be quantified, whereas others can only be estimated. Uncertain information can be divided into four categories:

Natural climate variability: Natural variability in the climate occurs both in small geographical areas and on a much larger scale. These fluctuations typically last from a few years up to one or several decades and, in some cases, more than a century.

Natural climate forcing: Changes in climate forcing outside of human control, such as volcanic eruptions or changes in solar radiation.

Anthropogenic climate forcing: Effects of human activity, primarily greenhouse gas emissions and particles from the combustion of coal, oil or natural gas. Logging, changes in land use, and cement production are other factors that affect the climate.

Insufficient knowledge: The climate system is complicated, and it is not possible to fully understand how it functions. There will always be uncertainty associated with processes in the atmosphere, in the cryosphere (areas with snow and all forms of ice – sea ice, glaciers, ice caps, as well as river and lake ice), in sea water and land areas – and with the interactions between them.

It is rarely possible to forecast natural climate variability. It is also possible that future natural variability between one to ten years could be greater or equal to the effects of anthropogenic climate forcing. Natural climate variability is usually greater and more noticeable regionally than globally. Norway, for instance, has a particularly mild climate given its latitude, but this climate depends on the Prevailing Westerlies transporting mild, humid air streams, as is currently the case. If easterly winds became more frequent during a single, or several winters, this will result in considerably colder winters (such as the winter of 2009–2010).

For the coming two to three decades, it would be most appropriate to compare changes in observed climate from the last 30-year period (1979–2008) with the so-called normal period (1961–1990). This will provide us with a clearer picture of the short-term climate trends than projections from global climate models, which are more relevant for long-term forecasts. For the period from around 2030 until the end of this century, it is recommended that adaptive measures be based on "low", "medium" and "high" climate projections. For this period, it is expected that anthropogenic greenhouse gas emissions will significantly affect the climate.

5.2 Projections for atmospheric climate

Air temperature

All climate scenarios indicate that all seasons in all regions of Norway will become warmer during this century. Low, medium and high projections project increases in the annual mean temperature

in Norway of 2.3° C, 3.4° C and 4.6° C, respectively, by the year 2100. The estimates show that the temperature increase will be greatest during the winter season and least during summer. The annual mean temperature is estimated to increase most in Finnmark County, where the low projection indicates an increase of 3° C, and the high projection indicates an increase of 5.4° C. In Western Norway, the figures are 1.9° C and 4.2° C.

Projections for specific locations indicate that 24-hour periods with a mean temperature above 20° C, which so far have been most frequent in the Oslo Fjord area, along the southern coast and valleys of Eastern Norway, are expected to occur far more frequently in these areas, as well as to occur to an increasing extent in the inner fjord regions and in low-lying interior regions throughout the entire country.

The first row shows the observed linear trend in the period 1900–2008. The second row shows the trend based on observed temperature changes from the period 1961–1990 to 1979–2008. Rows three through five show estimated trends from 1961–1990 to 2071–2100 according to mean, low and high temperature projections, respectively.

24-hour periods with zero crossings

24-hour periods with zero crossings are 24-hour periods with a maximum temperature above 0° C and a minimum temperature below 0° C. The calculations on which this report is based have not included changes in zero crossings, but previous studies indicate that the number of these days per year may be reduced by between 10 and 60 per cent in coastal regions towards the end of this century. In interior and alpine regions, the change is estimated to be between a 10 per cent reduction and a 10 per cent increase. In many places, the number of 24-hour periods with zero crossings will decrease during spring and autumn, while there might be an increase in winter.

Growing season and need to heat buildings

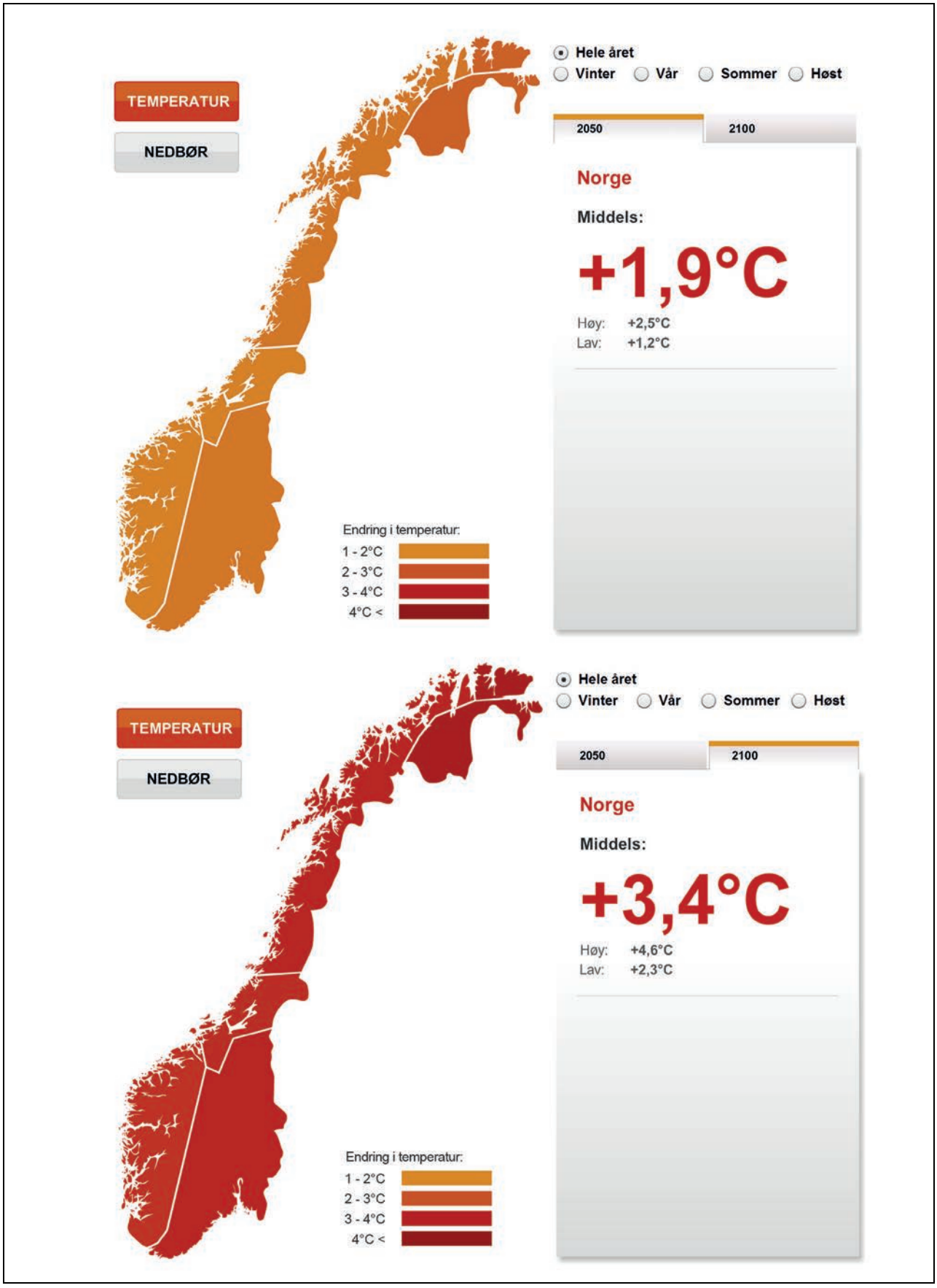
The growing season in Norway is defined as the number of days with a mean temperature above 5° C. It is expected to become considerably longer over the course of this century. Calculations show a one to two-month increase in large parts of the country and two to three months in areas at a

Figure 5.3 Temperature regions in Norway

Table 5.1 Observed and estimated trends in annual mean temperature (in ° C per decade) for different temperature regions (cf. figure II.1) and for Norway (N).

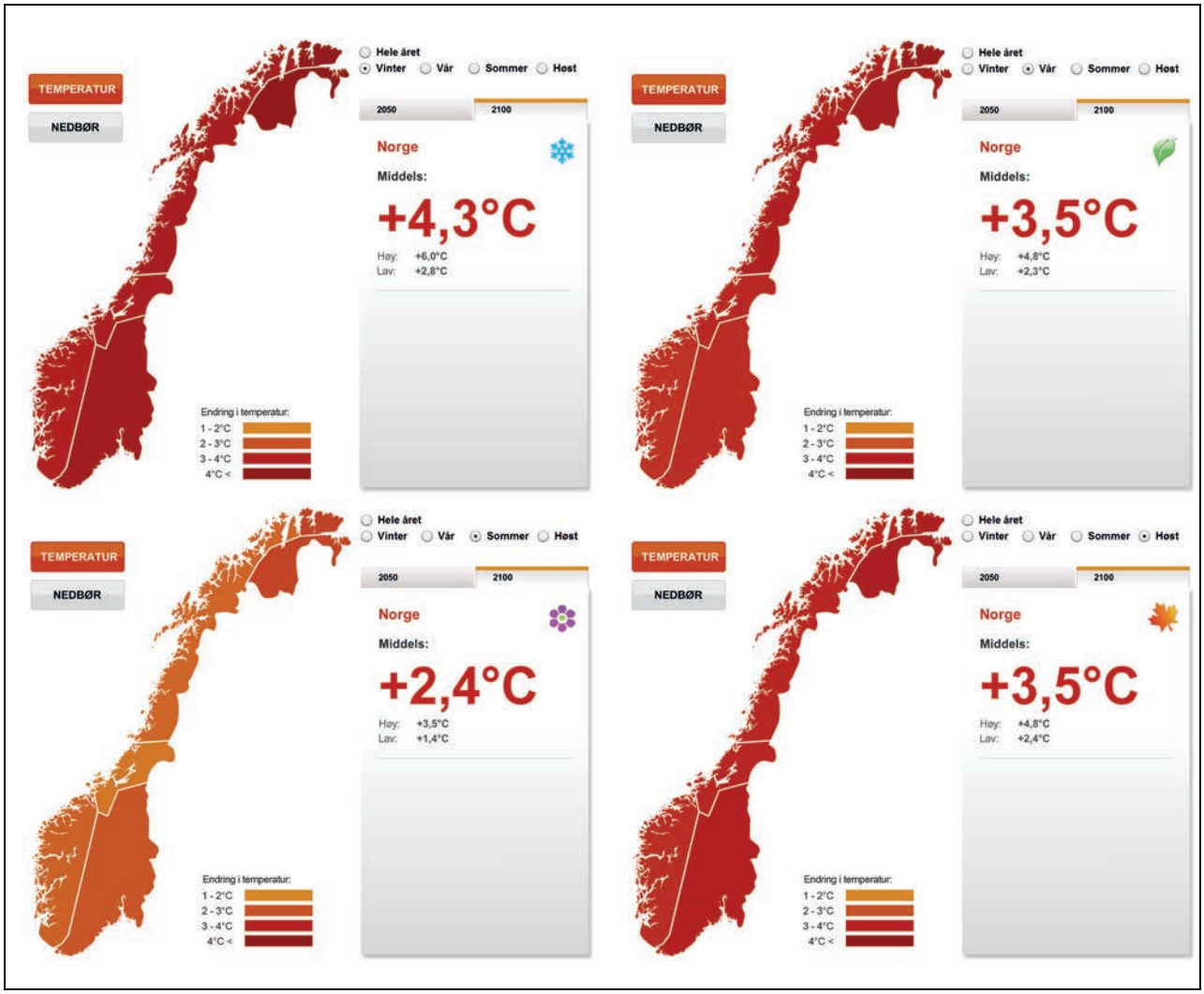
	Linear temperature trend (° C per decade)*						
Temperature region	1	2	3	4	5	6	Norway
Obs. 1900–2008	0.08	0.05	0.10	0.10	0.06	0.07	0.08
Obs. 1961–90 to 1979–2008	0.32	0.24	0.28	0.26	0.27	0.29	0.29
Mean projection	0.31	0.28	0.29	0.31	0.38	0.38	0.31
Low projection	0.21	0.17	0.20	0.21	0.28	0.27	0.21
High projection	0.44	0.38	0.40	0.42	0.47	0.49	0.44

* To calculate the total change over a given period of time, multiply this figure by the number of decades.



Figur 5.4 Map of annual average temperatures 2050 and 2100.

Source: Klimatilpasning.no



Figur 5.5 Map of seasonal temperature variation 2100

Source: Klimatilpasning.no

slightly higher altitude. Projections for specific locations have been used, which are close to the mean projections for summer temperatures. Calculations have not been made for high and low projections, but the increase can be expected to be even greater for the high projection.

The future heating need is predicted to decrease in Norway as a whole. The annual total heating degree days was used as a measure of energy needs for heating. A heating degree day is defined as the difference between the 24-hour mean temperature and a threshold value of 17° C and is set equal to zero for 24-hour periods with a mean temperature above 10° C. This means that a day with a 24-hour mean temperature of -10° C will have a heating degree day figure of 17 - (-10) = 27. The heating degree day total is the sum of these values. At present, the annual total heating degree days is lowest on the western coast with a value of around 3 000. The annual total of heating degree days is about twice as high in the eastern interior regions, alpine areas and inland regions in northern Norway.

According to projections for specific locations, which are close to the low projection for winter, a reduction of more than 750 was calculated in densely populated areas near the south coast and more than 1 000 in the interior and much of Northern Norway.

Precipitation

The average annual precipitation in Norway is expected to increase during this century by 5, 18 and 31 per cent by the year 2100 for low, medium and high climate projections respectively. The national average for the medium projection shows an increase in precipitation of around 20 per cent in

the autumn, winter and spring and 10 per cent in the summer. In the autumn, the medium projection indicates more than a 25 per cent increase in precipitation in Western Norway up to the Hålogaland region of Northern Norway, and in the winter it indicates more than a 25 per cent increase in precipitation in large parts of the east as well as the interior regions of the two Trøndelag counties. In the summer, the medium projection indicates a reduction in precipitation of 5 to 10 per cent in the east and south, whereas it indicates about a 20 per cent increase in precipitation in Nordland County.

The precipitation projections show major differences between the low and high projections in all 13 precipitation regions. The medium projection shows a trend close to the observations that were made throughout the 20th century, whereas the high projection is more in line with the observed trend over the last 20–30 years.

The low projection indicates reduced summer precipitation throughout all of Southern Norway. In the south, it indicates a reduction of almost 30 per cent. In many areas, the high projection indicates an increase in excess of 50 per cent in autumn, winter or spring precipitation.

The medium projection indicates more days with heavy precipitation and higher average amounts of precipitation for these days throughout all of Norway and during all seasons. This also applies to summer in the regions where it is estimated that the average precipitation will decrease. In the winter and autumn, the medium projection indicates more than a doubling of days with heavy precipitation on a national basis.

The first row gives the observed linear trend in the period 1900–2008. The second row gives the trend based on observed changes in precipitation from the period 1961–1990 to 1979–2008. Rows three to five indicate estimated trends from 1961–1990 to 2071–2100 according to medium, low and high precipitation projections respectively.

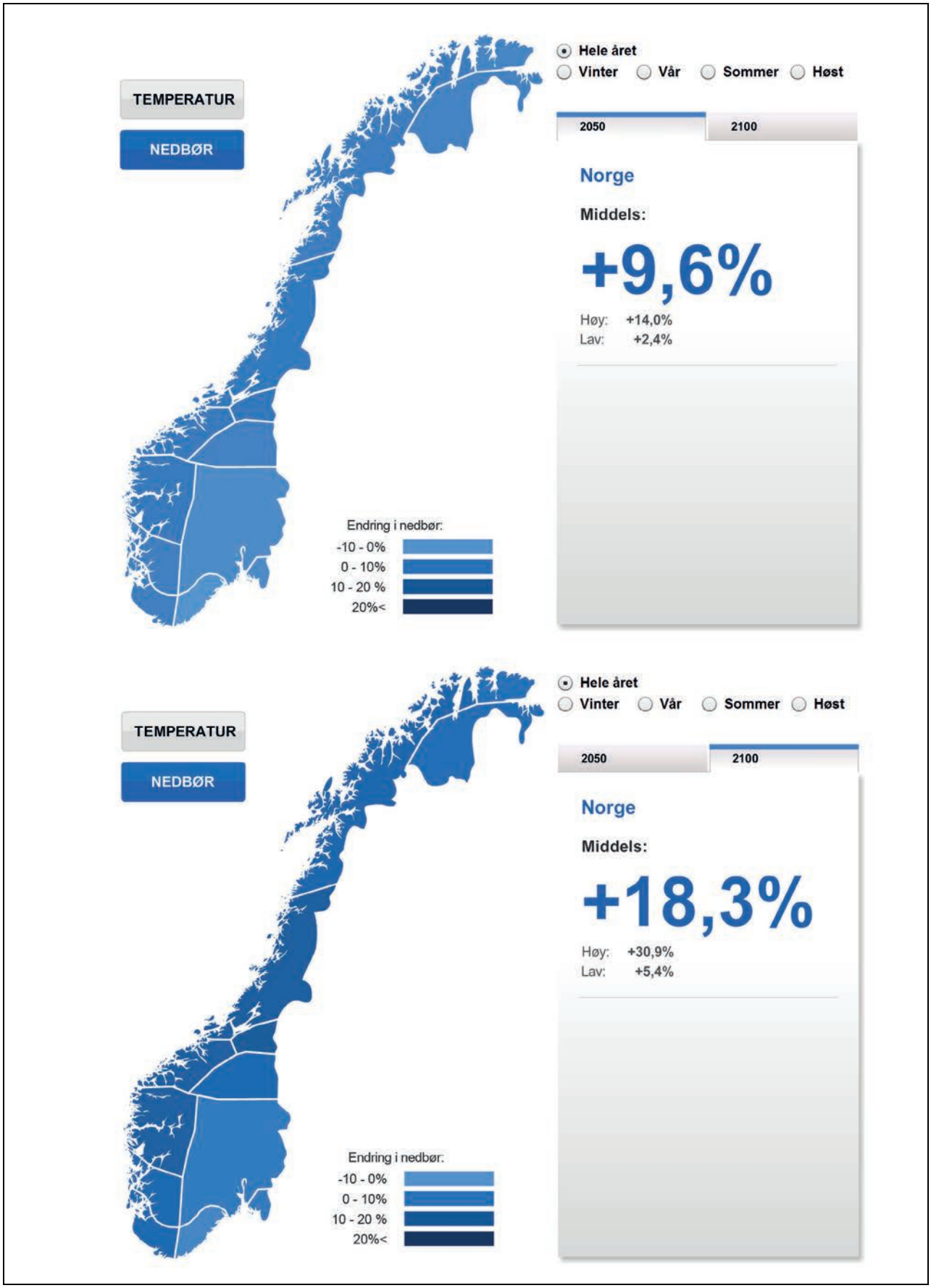
The projections indicate that the number of days with heavy precipitation will increase over the course of the century. In addition, it is expected that the amount of precipitation will increase the number of such days. This applies to all seasons and all precipitation regions. It is also worth noting that the climate models have too low reso-

Figure 5.6 Precipitation regions in Norway

Table 5.2 Observed and calculated precipitation trends (expressed in per cent of the 1961–1990 value per decade) for different precipitation regions (cf. figure II.2) for Norway.

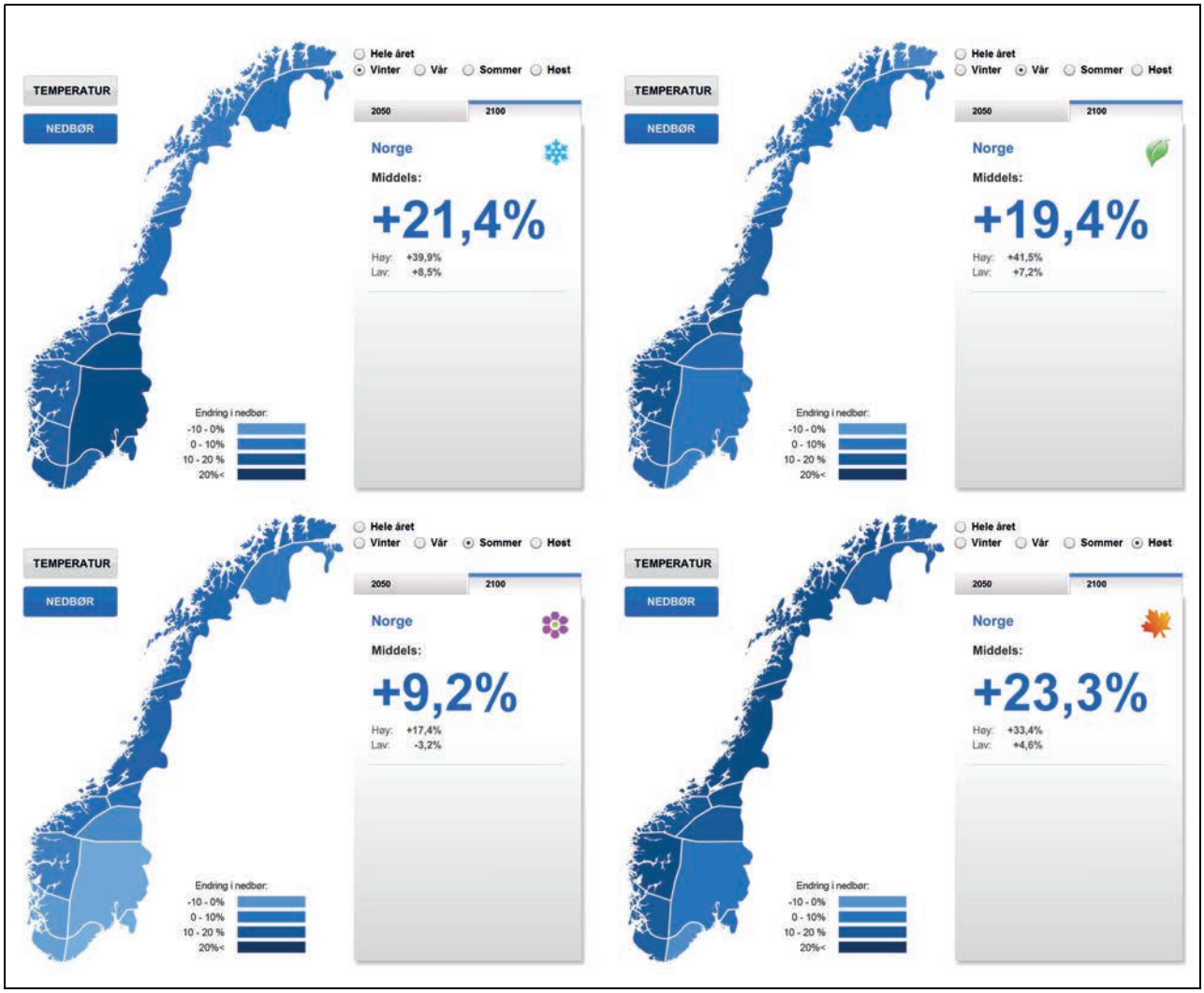
	Linear precipitation trend (per cent of 1961–1990 value per decade)													
Precipitation region	1	2	3	4	5	6	7	8	9	10	11	12	13	Norway
Obs. 1900–2008	2.1	1.3	0.9	2.0	2.0	2.0	1.6	1.8	1.5	1.8	1.9	1.7	0.0	1.7
Obs. 1961–90 to 1979–2008	2.4	2.2	2.5	4.5	3.7	3.3	2.7	3.2	2.5	2.4	2.6	3.9	2.2	2.9
Mean projection	1.1	1.1	0.8	1.7	1.7	2.0	1.7	2.0	2.1	2.0	1.7	1.5	1.4	1.7
Low projection	0.2	0.5	-0.1	0.3	0.6	0.2	0.5	-0.1	0.2	0.1	0.4	0.6	0.1	0.5
High projection	2.0	1.7	1.5	3.0	3.0	3.3	2.4	3.9	3.6	4.7	3.9	2.5	2.7	2.8

* To calculate the total change over a given period of time, multiply the figures in the table by the number of decades.



Figur 5.7 Map of annual average precipitation 2050 and 2100.

Source: Klimatilpasning.no



Figur 5.8 Map of seasonal variation in precipitation 2100

Source: Klimatilpasning.no

lution to give direct information about showers. As a result, there is much uncertainty associated with these projections.

Showers and thunderstorms

The climate models do not have enough detail to provide any direct information about showers. However, the medium projection indicates that days with heavy precipitation are expected to increase in all regions and seasons. This indicates an increased frequency of heavy showers, which in turn may increase the risk of thunderstorms and lightning.

Wind and icing

The climate models show little or no change in average wind conditions throughout Norway leading up to the year 2100. However, some results indicate that adverse wind conditions may become more frequent. Calculations show that increased warming may displace storm paths or polar low-pressure systems northward. This may result in local changes in both wind speed and wind direction, but limitations in the climate models mean that it is too early to draw any conclusions about this. It is not possible to carry out direct estimates of future changes in the risk of icing from the existing climate models.

5.3 Projections of hydrology, landslides and avalanches

Runoff

Runoff is highly dependent on precipitation and changes in precipitation, but it will also be affected by increased temperatures. Temperature has

a significant impact on evaporation and determines the amount of precipitation that will be stored as snow. Thus, temperature affects the distribution of runoff between the different seasons.

It is estimated that the annual runoff will increase for Norway as a whole, but regional differences can be expected. In general, we can expect increased runoff in the autumn and winter, whereas there will be reduced runoff in most places in summer. In glacial areas, increased runoff is also expected in summer.

Snow

It is estimated that the snow season will become shorter throughout all of Norway towards the end of this century. The change will probably be greatest in lower lying areas, where a projection close to the mean for changes in temperature and annual precipitation, indicates that the snow season may be 2–3 months shorter by the year 2100. This means that areas that currently have snow for 2–3 months can be expected to be snow-free most years leading up to the end of the century. In the alpine areas and interior of Finnmark County, the average maximum snow depth may increase leading up to the middle of this century before decreasing.

Glaciers

Glaciers vary in size as a result of changes in both summer temperature and winter precipitation. This means that there is considerable uncertainty concerning the future trend in glacier size. Glaciers located in the interior of Norway, e.g. in the Jotunheimen mountain range, will probably continue to decrease in line with the expected increase in summer temperatures. The coastal glaciers, by contrast, are more affected by changes in winter precipitation. Therefore, their size will increase as long as the increases in winter precipitation are greater than the increased summer melting. Using medium climate projections for the period 2071–2100, the equilibrium line for the glaciers can be expected to be 350 ± 100 metres higher than today. The equilibrium line is the elevation on the glacier where there is a balance between accumulated snow during winter and melted snow and ice during summer. If this trend continues, 90 per cent of all the glaciers in Norway may melt completely, and 30–40 per cent of the total glaciated area may be gone by the year 2100.

Floods

Flood projections are uncertain, as local variations are large. In general, rainfall floods can be expected to increase, whereas the probability of large snowmelt floods will be reduced. Higher temperatures will cause an earlier onset of spring floods, whereas there will be more floods in late autumn and winter. In particular, more intense local precipitation will create problems in small, steep rivers and streams and in densely populated areas.

Drought

Higher temperatures and somewhat lower precipitation during the summer season will lead to reduced streamflow and increased soil moisture deficit. This will result in more serious summer droughts. Small changes are predicted in the short term, but changes are expected to be substantial towards the end of the century. This particularly applies to Southern Norway. Among other things, these changes may have consequences for local supplies of drinking water, as well as for agriculture and forestry. Summer droughts will increase irrigation needs and the risk of forest fires.

Landslides and avalanches

With the exception of clay landslides in lower lying areas below the marine limit, slides mostly occur in steep terrain. It is common to distinguish between avalanches, rock slides and/or rock falls and debris slides, which include quick clay landslides and landslides and/or mud flows.

The climate is one of the main factors that trigger slides, and extreme weather conditions can cause avalanches and landslides and/or mud flows. There is a clear correlation between precipitation, temperature and wind conditions and various types of avalanches. Higher temperatures will reduce the risk of avalanches in areas below 500–1000 m.a.s.l., but increase the risk of wet snow avalanches and slush flows.

Higher frequencies of periods with high precipitation intensity will increase the risk of landslides and/or mud flows. Quick clay landslides generally occur as a result of building and construction activities, but can also be triggered during prolonged periods of precipitation and in situations where there is heavy streamflow. Changes in precipitation patterns may increase the risk of mud flows and slush flows in areas that have not previously been exposed.

There are complex cause and effect relationships behind rock slides and rock falls. This makes it difficult to relate specific climate variables to these types of slides.

5.3.1 Projections for the oceans

Ocean circulation

The North Atlantic Drift transports heat vital to the Norwegian climate. There is speculation as to whether this current will be weakened by a warmer climate. If so, the ocean's contribution to the relatively mild climate in Norway would be slightly reduced. Calculations using climate models show that there is a chance that the North Atlantic Drift will be reduced slightly in this century, but none of the climate models indicate a collapse of the important and extensive ocean circulation in this area. Furthermore, no weakening of the North Atlantic Drift has been registered in the instrumental observations of the past 50 years. The climate models indicate that the increased air temperature will more than compensate for the reduced oceanic heat transport. Therefore, it is expected that the marine areas off the coast of Norway will become warmer.

Local sea temperatures

The resolution of the global climate models is too low to allow an accurate description of the ocean circulation and the topographical details in the North Sea, the Barents Sea and the long Norwegian coast. In addition, we lack information about important processes, such as tides. Therefore, it is necessary to scale down global climate models to a regional level. Downscaling does not correct all of the errors and flaws in the global models, but it is does improve them significantly.

Far fewer climate models have been scaled down for the oceans than for the atmosphere. Therefore, it is not possible to define low, medium and high projections for the marine climate, but a small number of projections for specific locations have been prepared. Estimated changes in surface temperatures in the Norwegian marine areas during this century are:

- The annual mean temperature for the North Sea is expected to rise by 1.5–2° C with a slightly lower warming of 0.5–1.5° C in the autumn. Equivalent temperature increases will apply to most of the southern and western coasts.
- The temperature increase is expected to be 0.5–1.5° C lower for the coastal area north of the Stadtlandet Peninsula than for the areas south of Stadtlandet.
- There is much uncertainty in regards to how the temperature will develop in the Barents Sea as global climate models generally have problems describing the distribution of sea ice realistically. Some results indicate a warming of 0.5–1° C, but there is not enough knowledge to draw any conclusions about this.

Ocean acidification due to absorption of anthropogenic CO2 by the sea

Since the beginning of the industrial revolution, the sea has absorbed about 40 per cent of all of the CO_2 emitted by fossil fuel consumption and cement production. That has caused a drop in the pH value of seawater, making it more acidic, and northern marine areas are especially exposed to this development. The reason is that CO_2 dissolves more rapidly in cold water than in warm water. In open marine areas, the sea is alkaline (> pH 7.0) with typical pH values between 7.9 and 8.3. So far, the pH level has decreased by 0.1 pH units, which is equivalent to a 25 per cent increase in the concentration of hydrogen ions in the ocean.

The acidification is mainly a direct result of anthropogenic CO_2 absorption by the sea, so it occurs independently of global warming. Changes in the circulation patterns and vertical layering in the oceans and in the production of phytoplankton can also affect the pH value in the sea. Acidification is often referred to as "the other CO_2 problem".

The chemical processes that lead to acidification are well known, and the future trend in the pH value of the sea can be calculated with the aid of emissions scenarios. There is considerable uncertainty associated with the size of future CO_2 emissions, but ocean acidification is expected to accelerate over the course of this century. It is estimated that Norwegian waters will see a decrease of at least 0.5 pH units by the year 2100.

There is insufficient knowledge about the ways in which ocean acidification will affect the marine ecosystems, but it is feared that a substantial acidification may have serious consequences. There is particular concern about organisms with shells made of calcium carbonate, as a more acidic ocean will make it more difficult to form and maintain calcium carbonate shells.

Waves

Wave height and direction are determined by atmospheric conditions such as wind and air pres-

sure. It is expected that climate changes that affect wind conditions will result in changes in wave conditions as well.

A few calculations have been made of future wave conditions based on selected climate projections. They show relatively small changes along most of the Norwegian coast. The North Sea and Skagerrak are exceptions with an estimated 6–8 per cent increase in significant wave height for the most extreme waves. Since many of the global climate models have systematic weaknesses as regards the Barents Sea, it is impossible to draw any conclusions about future wave condition trends in that area.

Sea ice

Both the distribution and thickness of the Arctic sea ice have decreased in the past two decades. Since 2005, the old multi-year ice that is ten years or older has for all practical purposes disappeared. There is a major disparity between different climate projections and the rate at which the ice cover will diminish, but many studies indicate that the Arctic may be ice-free in summer by around the middle of this century.

Although the trend shows that the ice cover has been reduced, major annual fluctuations are expected. There is no good method at present for forecasting short-term variations in the ice cover one to two decades in the future.

5.4 Future sea level increase in Norwegian coastal municipalities

The global sea level is now rising at a rate of three millimetres per year. This is mainly due to the expansion of water as the sea becomes warmer, so-called thermal expansion, and the melting of land ice (glaciers and ice caps).

Over the course of the 21st century, the sea level is expected to rise around 70 cm along the southern and western coasts, around 60 cm in Northern Norway and around 40 cm in the innermost reaches of the Oslo Fjord and the Trondheim Fjord (Havnivåstigning – estimater av framtidig havnivåstigning i norske kystkommuner, 2009) [Rising sea levels – estimates of future rising sea levels in Norwegian coastal municipalities, 2009]. These local variations are attributed to different degrees of post-glacial rebound along the Norwegian coast with the least rebound on the outermost parts of the south and west coasts. The specified values have an estimated uncertainty of -20 to +35 cm.

Uncertainty is particularly associated with the rate at which the Greenland and Antarctic ice will melt. Simplified models and knowledge about former warm periods indicate that it is unlikely that the sea level will rise less than 0.5 metres during the 21st century. It is unlikely, but by no means impossible, that the rise in global sea level will exceed one metre by 2100. Only accelerated melting of the ice on Greenland and in the Antarctic can result in a sea level rise of more than 0.5 metres this century.

Table 5.3 shows estimated limits for changes in sea level, including the effect of post-glacial rebound for some of Norway's largest coastal

Table 5.3 Low and high estimates of expected sea level rise and storm surges (100-year return level) in the years 2050 and 2100, including the effect of post-glacial rebound. The changes are relative to the year 2000. NN1954 corresponds to the datum origin on land maps.

	2050				2100			
	Change in sea level (cm)		Storm surge (cm) relative to NN1954		Change in sea level (cm)		Storm surge (cm) relative to NN1954	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Tromsø	10	32	229	251	43	98	267	322
Trondheim	-1	21	246	268	22	77	274	329
Bergen	15	37	178	200	53	108	221	276
Stavanger	17	39	143	165	58	113	189	244
Oslo	-1	21	189	211	21	76	216	271

cities. In addition, the table shows how high a storm surge can be expected to rise relative to the datum origin on land maps. The latter is expressed as a 100-year return level based on observed storm surges for the last 50–100 years. Equivalent values for all Norwegian coastal municipalities are available at *www.klimatilpasning.no*.

5.5 Use of the different climate projections

As mentioned in the introduction to this chapter, there are many causes of uncertainty associated with future climate trends. This yields a spread among different climate projections, and it is not possible to quantify the relative probability of the individual climate projections. Therefore, users of climate projections must assess various issues in light of risk, vulnerability or other possibilities.

The division into low, high and mean projections for temperature, precipitation and sea level are meant as an aid for users of climate projections. The results and calculations presented are based on all available climate projections for Norway. All projections for temperature and sea level estimate an increase. This is also the case for annual precipitation in Norway. However, for individual seasons, especially in summer, the low projection and in some places the mean projection predicts reduced precipitation.

The committee recommends that possible consequences and measures are assessed based on the scenario(s) that project the greatest challenges. Normally, the high projection will entail the largest challenges because it predicts the greatest changes compared with the current climate, but this should be carefully assessed. Risk of drought and forest fires, for example, ought to be assessed against the low precipitation projection, whereas it is recommended that consequences and measures associated with the risk of floods be assessed on the basis of the high precipitation projection.

Furthermore, we cannot ignore the possibility that the actual climate trend may be below the "low" or above the "high" projection. For assessments of issues where the consequences of climate change may be especially serious or extensive, we should therefore be aware that climate changes may exceed the range covered by the low and high climate projections. Based on current climate change and our existing knowledge, it is deemed to be more likely that the future trend in temperatures will be near (or above) the high rather than the low projection. Model results further indicate that the divergence from medium temperature projections is typically larger on the upper side. Some of the climate projections indicate that warming may be many degrees higher than the figures for the high projection. Nevertheless, there are no calculations that suggest significantly less warming than the low projection. This is attributed to the fact that there are more positive than negative feedback loops in the climate models. One way to take into consideration the risk that climate change will fall outside the range of the high and low projections is to estimate threshold values for the times when challenges will occur and possible measures will have to be implemented.

Comprehensive assessments of consequences for society should not be based on contradictory projections. However, it is important to point out that there is no consistent relationship between low, mean and high temperature and precipitation projections, nor between the projections for the different seasons. In other words, it is possible to combine a high temperature projection with both low and high precipitation projections. The issues that we face are crucial for determining which climate variables we should assess.

Existing climate models do not provide clear quantitative indications that all climate conditions are changing. This applies, for example, to wind and icing conditions, short-term precipitation and lightning. However, the climate models are in constant flux, and the committee recommends that the results from new model calculations be reviewed every five to ten years with the aim of improving the climate projections and making them more detailed. The committee also recommends that observations of climate variables are regularly analysed. This is a necessary condition for identifying and interpreting changes. For individual climate variables, such as short-term precipitation and wind, an assessment should be made of whether the existing observation network is sufficient.

Section III
Nature and society in a changed climate

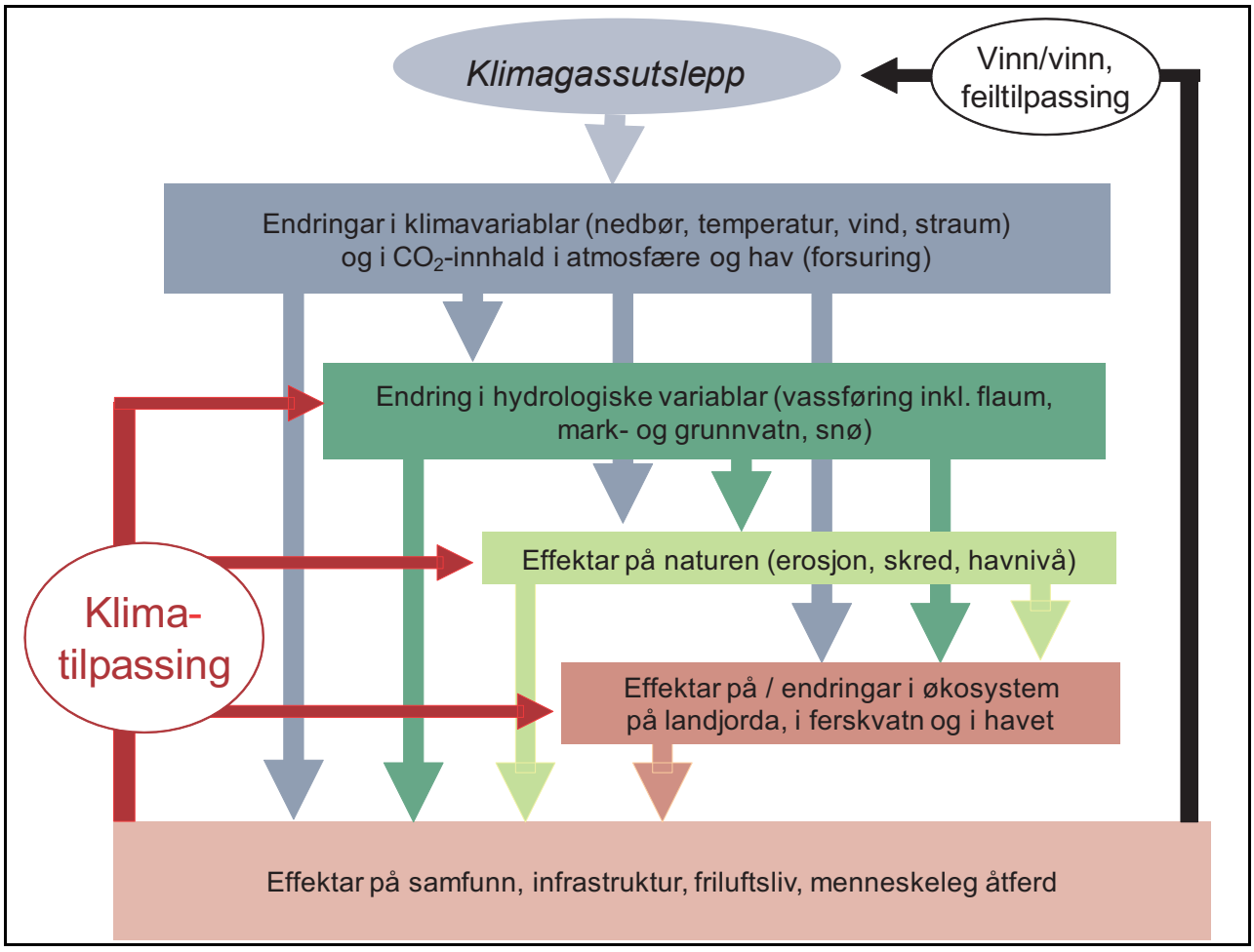
Chapter 6
From climate change to impact

Box 6.1 General comments on nature and society in a changing climate

The climate changes described in Section II will have an impact on nature and society. Climate change threatens many of the values important to society, and some of these will be lost. The impact of climate change will force both nature and society to adapt.

In this Section, we review the consequences for nature and society with particular emphasis on the natural environment, human health and safety, infrastructure and buildings and the economy. The review of the various areas will form the basis for a comprehensive assessment of the Norwegian society's vulnerability and adaptive needs.

Greenhouse gas emissions cause changes in temperature, precipitation, wind, ocean currents and the CO_2 content of the atmosphere and the oceans. These climate changes impact society directly, as well as indirectly through the natural environment. Changes in heating and cooling



Figur 6.1 The relationship between greenhouse gas emissions and the impact on nature and society

needs for homes and protection against precipitation are examples of direct effects of climate change, whereas damage resulting from floods and landslides/avalanches are examples of indirect impact through the natural environment. Changes in fish stocks – and thus the chance to harvest fishery resources – are examples of indirect effects.

The natural environment, ecosystems and society are not only impacted by the climate, human activity has an impact as well. Therefore, overall vulnerability to climate change is a result of both human activity and climate change. Overconsumption of natural resources makes the natural environment more vulnerable to climate change, thereby making society more vulnerable too. Likewise, land use and pollution may increase the vulnerability to climate change. In other words, the effects of climate change on society largely depend on how we manage the natural environment.

Adaptation to climate change may affect the climate, e.g. through measures that increase greenhouse gas emissions. For example, increased need for cooling requires investments in cooling systems, which require energy, causing increased greenhouse gas emissions. In some cases, adaptation may involve exploiting the opportunities that arise in connection with climate change. The production of oil and natural gas as a result of an ice-free Arctic is one example of the type of opportunity that may present itself. This can be regarded as a maladaptation in the sense that it is a measure that contributes to a temperature increase and amplifies the negative effects of climate change.

6.1 Society's vulnerability to climate change

The UN Intergovernmental Panel on Climate Change (IPCC 2001) defines vulnerability to climate change as the extent to which a system is susceptible to or unable to cope with adverse effects of climate change. The committee has based its work on an interpretation of vulnerability to climate change, where vulnerability is a result of how exposed and sensitive society is to climate change (the character, magnitude and rate of the changes) and of its adaptive capacity. Adaptive capacity is defined as the capacity of a system to adapt to climate change, to take advantage of the opportunities, and to cope with the consequences. Society's degree of exposure to climate change and its adaptive capacity will vary with the local situation and with time.

In order to be able to measure vulnerability, we must start by identifying relevant climate changes and the ways in which the natural environment and various areas of society are exposed to them. The idea that society is affected by the "weather" is not new, and therefore it is natural to begin by considering how an area of society is exposed to the present climate and then estimate how exposed it will be to future climate changes. If a sector or an area of society is vulnerable to climate change, this will give rise to a need for adaptation.

The committee bases its assessment of the adaptive capacity of the various sectors of society on four factors:

- *Organisation:* The capacity of the sectors to plan and implement adaptive measures is affected by the organisation and distribution of authority. Legislation and requirements, e.g. requirements for risk and vulnerability analyses (RAV analyses ROS in Norwegian), and systems for following them up also play an important role. The ways in which information and competence-building are organised also affect the adaptive capacity.
- *Resources:* The capacity to implement measures is affected by the economy, technology, access to expertise and human resources. The efforts to adapt to the current weather conditions are used here to assess factors related to expertise and human resources. In addition to these factors, a maintenance backlog has been found to be an important factor affecting the adaptive capacity of infrastructure and buildings.
- *Knowledge base:* The total knowledge from research and surveys has an important effect on the adaptive capacity. The monitoring mechanisms for relevant trends in the natural environment and society and measurement of relevant climate variables are part of the knowledge base.
- *Prioritisation:* The adaptive capacity of various sectors is related to the level of priority that is given to adaptation. In this context, the assessments of priority are mainly concerned with acceptance, understanding and the importance attached to risk. In addition, existing efforts to promote adaptation may also have some effect on the ways in which sectors prioritise adaptation. Insight into, and understanding of, climate-related issues and climate change are factors that have an important effect on adaptive

capacity, but they are difficult to measure and/or assess.

In addition, there will be some areas where there are only limited prospects of counteracting negative impacts of climate change. This is especially true in the case of the natural environment. For example, there will be species that are incapable of adapting in step with climate change and species that have few habitats into which they can disperse in order to maintain viable populations.

Adaptation does not just involve reducing vulnerability, but also our ability to understand and exploit the opportunities offered by climate change. This is also discussed in the sector review but the committee assumes that new opportunities for economic growth will be exploited by business and industry through ongoing processes of innovation and restructuring.

The adaptive needs will vary in different sectors. Adaption may involve anything from avoiding building in areas that may be affected by rising sea levels in the future to making use of new types of grain that are adapted to altered climate conditions. The committee has identified measures for improving the adaptive capacity in the reviewed sectors. It is important to emphasise that these measures are not exhaustive, nor are they meant to replace the assessments that the sectors themselves are conducting of their vulnerability to climate change and adaptive needs.

6.2 A changing society

This report discusses how adaptation can be integrated into social planning in order to make society less vulnerable to climate change. According to the projections referred to in Section II of this report, climate change will begin to be noticeable in earnest in the second half of this century. We must also expect that society will change considerably over the next 40–50 years.

There are few, if any, reliable projections of social development towards the end of the century. However, there are certain trends that provide a basis for predicting what society may be like during the second half of this century. By the end of the century, it is expected that Norway will have a population of between seven and nine million (Brunborg et al. 2008). There will be a smaller working population than at present, and the population will also be older. In addition, the committee assumes that there will be sustained economic growth and prosperity leading up to the end of the century, but at a somewhat slower rate than at present (Storting White Paper No. 9 (2008–2009)). The combination of demographic and economic trends together with a sustained, slight decline in the average number of working hours (Vista Analyse 2010) provides grounds to believe that people in 2100 will generally have more leisure time than in 2010. However, partly in light of the current financial crisis, the committee wants to stress that such long-range projections carry significant uncertainty related to trends in the global economy.

There is also reason to believe that the economic structure will continue to evolve, with a sustained shift away from primary and secondary industries towards service industries, including health and social services (Storting White Paper No. 9 (2008–2009)). The expected increase in people's leisure time relative to working hours provides reason to believe that the tourism industry will play a more prominent role in the future Norwegian economy (Vista Analyse 2010).

Society will most likely still be dependent on critical infrastructure for water, energy, communications and transport throughout the next century. Furthermore, the main features of the transport pattern are expected to persist. At the same time, analyses indicate good opportunities for reducing emissions from the transport sector (Vista Analyse 2010).

The committee assumes that significant emission reductions will have been achieved internationally by 2100, which will curb global warming. So far the global emissions curve for greenhouse gases is above the level known as the two-degree target. If Norway and other countries do not succeed in reducing global greenhouse gas emissions, climate change will probably be so extensive that society will face major changes. Internationally, this development will be so grave that the global community will have major problems preventing dramatic consequences. In a four-degree scenario, it is estimated that about one billion people will face problems gaining access to freshwater (UK Government 2009). There is no scientific basis for determining the consequences of, and vulnerability to, climate change based on a "business-as-usual" scenario for greenhouse gas emissions. Thus, in the discussions of impact, vulnerability and adaptive needs, the committee assumes a temperature increase somewhat higher than the two-degree target, but that will nonetheless entail that Norway and other countries have reduced their greenhouse gas emissions considerably.

General trends in social development are consistently too broad to function as a basis for analy-

sing consequences and adaptive needs in the individual sectors in this report. The analyses of adaptive capacity at this level are therefore based for the most part on the current situation and the ways in which the sectors function at present. However, projections of social development form a backdrop for the discussions of future adaptive needs.

Chapter 7
Natural environment

Climate change will have a major impact on ecosystems and increase the overall strain on the natural environment. The natural environment is affected in various ways by human activity through land and resource utilisation, transport and pollution. These activities affect ecosystems separately and in combination, and in some cases they are mutually reinforcing. This may cause changes in the conditions for growth and reproduction of organisms, resulting in loss of species. A main objective is therefore to counteract the reduction of natural diversity, both out of consideration for the natural environment as such and to ensure sustainable utilisation of the resources we depend on.

The natural environment determines the conditions for the existence and development of humans and all other species. The natural environment provides us with clean air, clean water, raw materials in the form of food and mineral resources, experiences and energy – in other words, it is an essential basis for health, welfare and economic growth in our society. At the same time, humans determine the conditions for nature through technological and physical encroachment, economic utilisation and management. So far, neither Norway nor other any country has been able to achieve economic development without putting pressure on the natural environment. Anthropogenic climate change is an example of this.

In addition to its value to humans, the natural environment has an intrinsic value that we have a duty to safeguard. Both of these considerations are reflected in Norwegian and international legislation for the preservation of biodiversity. Biodiversity encompasses all forms of life on earth. The preservation of biodiversity requires that every country assumes responsibility for the unique nature within its borders. Norway has several nature types and species that we have an international responsibility to protect. Many species and nature types in Norway are currently endangered, and climate change can exacerbate the threat.

The natural environment is influenced directly and indirectly by climate variability, and it is vulnerable to changes in external conditions. Climate change and human activity influence the reproduction and survival of species and the composition of ecosystems. Climate change increases the need for environmental management based on consideration for ecosystems, so-called ecosystem-based management.

7.1 Vulnerability to climate change

7.1.1 How is the natural environment impacted by the present climate?

The natural environment adapts continuously to variations in the climate. This takes place through changes in the distribution of species, through natural selection and over generations. For example, we know that natural climate variability during the 20th century has affected the size and distribution of fish stocks in the Norwegian fisheries.

The natural environment is exposed to a number of stress factors, and the vulnerability of the ecosystems is a result of their integral impact. Ecosystems are being destroyed and species go extinct with the current climate conditions despite the adoption of political objectives to counteract this development. Globally, it is estimated that the loss of biodiversity is up to 1 000 times faster today than what can be characterised as a natural loss (MEA 2005). This is related primarily to factors other than the climate conditions: According to the Norwegian Biodiversity Information Centre land-use changes and development are the greatest threats to biodiversity in Norway. Other important influences include pollution, harvesting, transport and the spread of alien species. In Norway, a total of 3 886 species are on the Red List of threatened species from 2006 (Kålås, Viken & Bakken 2006), and 285 of these species are critically endangered. As many as 85 per cent of the red-listed species are endangered by land-use

Box 7.1 Changes in the North Sea

Throughout the 20th century, significant changes have been observed in the production and distribution of plankton and fish as a result of long-term natural climate fluctuations. During the cold period of the 1960s and 1970s, there was a substantial increase in abundance of cod and haddock. The subsequent warming in the following decades caused a steady decline of all boreal plankton and fish species. The decline in fish stocks is not solely due to increased temperature; it is also attributed to overfishing in relation to the climate-induced reduction in the productivity of the North Sea. After the turn of the millennium, many of these fish stocks have therefore been in a critically poor state. A similar change has been observed with regard to zooplankton species. The amount of copepods (Calanus finmarchicus), the most important zooplankton prey for larval and early juvenile fish in the northern North Sea, has declined significantly during the same period and the distribution area has shifted northwards. New temperate and warm-water species of zooplankton have also been observed to move northwards. New fish species that have arrived in the North Sea during the recent warmer period include sardine and anchovy, which are more adapted to temperate zooplankton species. Most of the seabird populations have declined drastically along the coast of Western Norway. The lack of fish fry in the spring is probably a contributing cause, since eider that live on mussels and not fish fry during the critical period during spring, are not impacted to the same extent.

changes, while six per cent are considered to be endangered by climate change. Even though the impact of climate change is expected to increase, it is imperative to look at climate change in the context of other influences.

Large populations with high genetic variation and resilient ecosystems have been a prerequisite for nature's ability to adapt. The rate at which changes occur is also important for their adaptation capacity. Species with a long regeneration time, such as mammals, are more vulnerable to rapid changes. We have already registered effects of climate change, especially in the alpine and arctic regions (IPCC 2007).

7.1.2 How will the natural environment be impacted by climate change?

One challenge of a changing climate is the fact that changes may manifest themselves faster than nature is able to adapt. According to the UN Intergovernmental Panel on Climate Change (IPCC 2007), around 20 to 30 per cent of the world's species will be in danger of extinction if the temperature increases by more than 2.5 °C.

Climate change throughout the 21st century will not be the result of anthropogenic climate change alone; natural climate variations will also have an impact. The regional change in temperature over the coming decades may level out, or the climate may even become somewhat cooler, and the northwards migration of species may be temporarily reversed. In this case, during the subsequent period, around the middle of this century, there may be a potentially dramatic increase in temperature when the increasing anthropogenic changes and the natural fluctuations again move in the same direction. Such abrupt change could cause irreversible changes in the marine and terrestrial ecosystems, and we would have no empirical data to predict the consequences of this or know how to adapt.

Climate change represents a threat to many species indigenous to Norway. At the same time, species diversity may generally increase in Norway due to climate change because of the arrival of new species. However, greater species diversity, which may arise in certain ecosystems, does not necessarily mean an increase in biodiversity. This is because biodiversity can be reduced as various ecosystems lose some of their distinctive character. One example of an ecosystem that may acquire greater species diversity, but less biodiversity due to climate change, is freshwater areas in Norway, which are characterised by relatively few, but distinctive, species.

Climate change can also influence the natural environment indirectly through the effects of pollution. Increased precipitation, in particular, may result in more runoff and erosion and thus in the release of environmental toxins. This in turn has a negative impact on the natural environment, see Chapter 9.5 on pollution and waste for more details.

7.1.2.1 Terrestial environment

Mountains

Mountains and tundra comprise the areas above and north of the forest belt.

Climate change causes the tree line and vegetation zones to creep upwards, which in turn affects species in the mountains. For alpine species, there is a risk that there will no longer be any suitable natural habitats to migrate to and that some species will become extinct. This applies to the arctic fox, wild reindeer and alpine plants. Competition from new species will also pose a threat, such as the red fox, as it migrates to alpine areas and competes with the arctic fox. The tree line moving ever higher reduces the number of continuous alpine areas (DN 2009). This will happen at the same time as pressure increases in alpine areas due to development and other human activity. Some of the species for which Norway has a particular international responsibility, such as wild reindeer, are dependent on large, continuous alpine areas.

It is expected that climate change will result in the melting of glaciers in Norway. Estimates indicate that the volume of the glaciers in Norway may be reduced by 30–40 per cent by 2100 and that only the largest glaciers will remain (Nesje et al. 2008, Laumann and Nesje 2010). This means that the glaciers, which are important landscape elements in Norwegian nature and important for wild reindeer, will eventually disappear. In addition, the increased glacial melting will change the flow of water and the water temperature in glacial rivers, which will consequently change the ecology of these rivers.

The life cycles of small rodents may be significantly impacted by climate change due to changes in snow and freezing cycles. A collapse of the life cycles of lemming and mice, for example, will have major consequences for the ecosystem, as they play a vital role in the food chain, both as grazers and as prey for endangered species such as the arctic fox and snowy owl. In addition, a warmer climate in the summer may make animals more vulnerable to parasites, insects and disease.

Palsa mires are a type of mire only found in alpine or arctic tundra. Palsa mires have mounds or strings with ice cores and frozen turf, called palsa. Prolonged periods with a warm and damp climate cause the palsa to melt. This is a very rare nature type in Europe, and it is now endangered by climate change (Hofgaard 2009).

Forests

Forests and other tree-covered areas comprise 38 per cent of the land in Norway and have represented an important natural resource for centuries. The ecosystem and species in forests have been greatly affected by past and present human activity.

It is expected that the growing season will be extended due to climate change, and this will result in increased volume growth for Norwegian forests and more thermophile species in larger areas, as well as a change in the types of dominant trees in an area in the long term (DN 2009). However, there will be regional differences, and different types of trees may also react differently. A wetter climate and a longer growing season may result in more moss on the forest floor in some areas of the country. This may represent a problem for the establishment of seedlings of forest trees and other species (Framstad 2009).

Climate change will have an impact on wild animals, with regard to both their distribution and growth rate. This applies in particular to herbivores, which will be affected by a change in primary production. Carnivores will be affected primarily by the impact on their prey.

Climate change will have an impact on migratory birds – on when they migrate and possibly also on their migration routes. A change has already been observed in when migratory birds arrive in the country (Husby & Stueflotten 2008). The distribution area for bats and certain bird species may also change as a result of a change in temperature. With an expansion of the natural habitat northwards and new bat species, there could be an increased risk for the spread of rabies (Hansen et al. 2007). An increase in the deer population may result in an increase in the distribution of other species, such as ticks.

A drier summer climate in some parts of the country may result in an increased risk of forest fires, particularly in Eastern Norway. However, it is still uncertain to what extent this will have a major impact on the natural dynamics in forests, where forest fires are a natural process.

Logging and other human activity may have an impact on the climate vulnerability of different forest species. Fragmented areas entail less opportunity for relocation in response to climate change, and monoculture systems are less resilient to the impact of insect attacks, which are expected to increase due to climate change.

Other terrestrial nature types

Climate change leads to longer growing seasons, increased primary production and more rapid regrowth. This affects the cultivated landscape in Norway, which is also endangered by lack of use and care and subsequent regrowth. Climate change also increases the need for management measures in certain particularly valuable cultivated landscapes that are already overgrown due to lack of use (Höglind and Norderhaug 2008).

Wetlands represent the nature type that is disappearing fastest on a global scale (MEA 2005), and climate change exposes these systems to significant and irreversible changes (IPCC 2001). In Norway, wetlands, especially bogs, have also been exposed to major human encroachment, such as drainage for agricultural purposes, forestry, harvesting of firewood and peat moss, as well as other development. More precipitation results in further erosion of wetlands in many areas with such encroachment. Climate change represents a new factor that is threatening wetlands, in addition to other threats. This applies in particular to Southern and Eastern Norway, and to certain types of wetlands, such as palsa mires. Increased precipitation in other parts of the country will lead to an increase in wetland areas.

Climate change also results in improved conditions for alien species (see box) in Norway (Fjershaug et al. 2009). Alien species are a major threat to biodiversity today, and many of them are on the so-called Black List (Gederaas, Salvesen and Viken 2007). These species are declared unwanted in Norway (Ministry of the Environment 2007).

Freshwater

The effects of climate change on the freshwater ecosystem are many and complex (DN 2009), and they will have impact on production, biomass, life cycles and the species composition. Primarily, ecosystems will be affected directly by increased temperatures and precipitation, and indirectly by drainage changes and consequently the supply of nutrients and acidification. The ice-free season will be longer, the water temperature will increase, and the thermal vertical stratification in the lakes will increase.

Changing temperatures will alter the distribution of various species and affect thermophile species differently than species that thrive best in cold water. Species that barely manage to complete a single life cycle in a year today could potentially manage to complete several life cycles per year. Especially species near the bottom of the food chain could spread northwards and to water at higher elevations. For important fish species such as salmon, trout and arctic char, temperatures exceeding 20°C could be critical. It is conceivable that summer temperatures could become so high in certain rivers that salmon and trout stocks could disappear completely. Regulated rivers with low residual flows may be particularly exposed. Hydropower reservoirs in rivers make it possible to increase the water flow in order to lower the water temperature during droughts. While this would be favourable for fish stocks, it would require an amendment of the licence terms.

The impact may be less critical for trout that live in lakes. Northern areas and rivers with glacial meltwater that are too cold for salmon could be more suitable for this fish species if temperatures rose. Changes in the ice cover represent another stress factor for various fish species due to increased temperature. Some lakes that currently freeze during winter may become completely free of ice due to climate change. For example, low winter survival rates for salmon have been linked to ice cover reduction (Finstad 2005). Also a change in the patterns for ice formation from snow in the mountains may impact the growing season for fish (DN 2009).

In addition, changes on land could lead to significant indirect impact on life in freshwater. An increase in temperature and precipitation may result in more loose organic material in the water, such as pollution from agricultural activity, and this will change the amount of light that penetrates lakes. Together with changes in wind speeds and the air temperature, humus could affect the vertical layering of temperature and thus primary production and the composition of plankton species. At the same time, changes to the ice cover of rivers and streams affect how terrestrial animals can utilise the watercourse.

Climate change can also lead to a change in geochemical processes in the soil, which will also change the chemical composition of the water. Norwegian rock and soil have very low lime content. Hence, Norway is particularly vulnerable to increased acidification of sensitive rivers and lakes and increase in the supply of nutrients to coastal marine ecosystems. Acidification is harmful to freshwater fish, such as the trout stock. In addition, extreme events such as storms and floods may result in increased pollution and amplify the effects of such pollution (DN 2009).

Box 7.2 Alien species

The introduction of alien species is one of the greatest threats to the global natural environment. Species that are introduced to new habitats suppress the indigenous species, and they can cause irreversible changes to the ecosystem. The introduction of non-indigenous organisms is considered the second most important cause of biodiversity loss after the destruction of natural habitats. The 2007 Norwegian Black List is an ecological risk assessment for a number of alien species in Norway, where 93 species are listed as being a high risk.

An alien species is a species, subspecies or lower taxon, including populations that have been introduced outside of their current or historical natural distribution areas. This includes any part, gamete, seeds or eggs that can survive and propagate.

Introduction in this context is understood as relocation with *human assistance*, directly or indirectly, of a species outside of its distribution area. This relocation may take place within a country or across national borders.

Alien species differ from "new" species in that the latter are introduced naturally, for example when climate change expands their natural habitat. Wild boar is an example of a borderline case in this context. Wild boar is currently an alien species that has been introduced in Sweden, but it may emerge as a "new" species as they could spread naturally from Central Europe. Correspondingly, we see that fish species that are normally found in temperate and subtropical sea areas are increasingly being observed in the North Sea, for example sardine, anchovy and, to some extent, more exotic species such as European bass and John Dory.

Other examples of alien species that could spread even further due to climate change – all of which have been evaluated as having a high risk on the Black List:

- Waterweed (affects water quality and changes the living conditions for a number of freshwater species and is the cause of significant biodiversity loss, and it could establish itself further north than today as a result of climate change).
- Pacific oyster (spreading along the coast of southern Norway and may can displace mussels and flat oysters and destroy beaches; they currently only reproduce during hot summers).
- Chinese mitten crab (can cause significant damage to fishing nets and fish farms, only a few occurrences in the Oslo Fjord today, could spread to the Trøndelag coast if the water temperature increases by two degrees).
- Giant hogweed (this species creates dense patches and displaces all other species in their habitat, very difficult to eradicate, most common in Southern Norway today).
- Spanish slugs (can significantly harm plants, thrive in the coastal climate of Southern Norway, but have been found as far north as Bodø) could spread northwards as a result of climate change.

Sources: Cross-sectoral national strategy and measures against harmful alien species, the Norwegian Biodiversity Information Centre, Institute of Marine Research, NIVA, DN and NINA.

7.1.2.2 Marine and coastal environments

The Norwegian coastal and sea areas cover an area in excess of two million km^2, more than five times the area of Norway's land mass. The North Sea, the Norwegian Sea, the Barents Sea and coastal areas include a broad range of ecosystems, interests and resource utilisation. The Norwegian coastal and sea areas are rich in resources and are among the most important sources of marine food resources in the world.

Sea areas

With its great depths, the Norwegian Sea is a key area for the production of copepods in the northeast Atlantic. From this core area, plankton spread to the border areas where they represent an important food source for larvae and fish fry for the large boreal fish stocks, such as herring, cod and haddock. Fish stocks in the North Sea and the Barents Sea therefore depend on the nutrient base of the Norwegian Sea. The southernmost habitats for the boreal species are in the North Sea, while those in the Barents Sea have

their habitats in the northernmost areas. If the copepods continue to migrate northwards in the Norwegian Sea and establish themselves in the Arctic Basin as a result of the ice melting, then a corresponding displacement of the boreal fish stocks that depend on copepods can be expected. This means that the southernmost reaches for boreal fish species will move northwards and that the indigenous species, such as cod, haddock, herring and mackerel, will migrate northwards along the Norwegian coastline. As a result, these species will be less abundant in the North Sea. However, it is expected that, in the 21st century, several temperate and subtropical fish species, such as sardine, anchovy, European bass and tuna, will be common in the North Sea. It is uncertain how this will impact the overall production of the North Sea's ecosystem.

If copepods and other important crustaceans establish themselves with a core area in the Arctic Basin, the fish will follow them and provide a basis for the establishment of large boreal pelagic fish stocks, such as herring, blue whiting and mackerel. Therefore, we can expect increased productivity in the Barents Sea as a result of climate change. The arctic ecosystem will be the loser. With increasing temperatures, fish species such as capelin and polar cod will most likely disappear from parts of the Barents Sea, since they primarily feed on the arctic zooplankton species such as amphipods, whose natural habitat is along the ice edge. Whether these species will be able to establish themselves further north, with summer feeding in the Arctic Basin, and with spawning grounds off the coast of Novaya Zemlya and Svalbard, is uncertain. This will depend on how quickly they are able to adapt to major changes in their habitat conditions. Climate change may therefore also entail an overall increase in commercial fish stocks, but that the species composition in our seas will change.

Ocean acidification

The increase of greenhouse gases in the atmosphere also affects the seas, since a large proportion of CO_2 is absorbed by seawater, causing acidification. Ocean acidification will result in major changes in the seas' ability to precipitate calcium carbonate, on which calciferous organisms depend. This problem increases at great depths with high pressure and low temperatures. It implies that Norwegian waters, and especially the polar regions are particularly exposed and will be impacted before more temperate regions. This will have an impact on phytoplankton species, such as calcareous algae, zooplankton species, such as pteropods, and benthic organisms, such as deep-water corals on the continental shelf. Because the organisms that are found in the deepest waters will be affected by the change in the formation of calcium carbonate first, deep-water coral is one of the indicator organisms. In 1990 the critical level for the precipitation of calcium carbonate in the Norwegian Sea was measured at a depth of 2 600 metres; in 2000 it had risen to 2 400 metres. Calculations show that the limit for precipitation of calcium carbonate will rise to a depth of 400 metres in 70 years. This means that it will be possible to observe the evident effects of acidification on corals as early as in 2025, and that 70 per cent of the deep-water corals will be exposed to erosion of their calcium carbonate shells by 2099 (NorACIA 2009).

Norway has the world's largest deposits of deep-water corals (also known as cold-water corals). These reefs are found along the entire Norwegian coastline, and they are among Norway's most species-rich nature types. The world's largest deep-water coral reefs were discovered off the coast of Røst in the summer of 2002, and they were protected in 2003. Deep-water coral reefs grow at greater depths than the tropical coral reefs, and they are important habitats for many species of fish. Whether shellfish such as crab, lobster and shrimp are affected by the change in saturation concentration of calcium carbonate is uncertain, as the shells of these species consist primarily of hardened protein. However, we do know that the actual hardening of the lobster shell is dependent on calcium carbonate.

Although the effects of acidification on marine organisms are still unclear, it is nevertheless difficult to envision any positive effects of acidification. If shellfish such as copepods and krill prove to be sensitive to the acidification we will face in the 21st century, then we must be prepared for significant damage to our marine ecosystems and reduced production of harvestable marine resources.

Coastal areas

Climate change along the Norwegian coastline will reflect the changes that are expected to occur in the North Sea and Barents Sea. Coastal areas and the continental shelf are important spawning grounds for many fish stocks, and coastal currents carry the vulnerable eggs, larvae and fry northwards. There are many individual popula-

tions of coastal cod and fjord cod along the Norwegian coastline. Especially in the south these populations have declined significantly over the past decades, but certain populations are critically low in Northern Norway as well, as is the case in Porsangen. It is somewhat unclear to what extent this is due to climate change. In the south, climate change in combination with significant pressure from fishing may be a likely cause. With increasing temperatures since the 1970s, an increasing number of exotic species have been observed along the Norwegian coastline, such as European bass, swordfish, sunfish and John Dory. It is not likely that there will be a substantially greater frequency of such exotic species in the future. By contrast, the southern, more temperate species such as hake and tuna may become more common along the coast and fjords.

Increased sea temperature in coastal areas may result in an increase in sea lice. Climate change may also contribute to a worsening of the situation for wild salmon in Western Norway – and it may result in improved conditions in the north for sea lice in the future. As with all other species, fish are dependent on a high genetic variation in order to adapt to change themselves. Escaped farmed salmon that mate with wild salmon will reduce the genetic variation of different salmon stocks and thus make the stocks less resilient to climate change.

The runoff of nutrients from agricultural areas and other areas on land increases with changing climate. This may result in more frequent algal blooms, and these algae may be toxic at times. Runoff can also result in an increase in the sediments or pollution in coastal areas, which may have significant consequences for the ecosystem. The increased runoff and sediments, combined with higher summer temperatures, are already considered to be the cause of so much sweet tangle dying along the Skagerrak coast and in western Norway (Moy et al. 2008).

Seabirds along the Norwegian coast are also vulnerable to climate change. They are influenced by complex systems in the sea, and it can be difficult to differentiate what is climate-related. Seabirds are completely dependent on fish as prey, such as sand eel in the North Sea, herring in the Norwegian Sea and capelin in the Barents Sea. These fish are in turn dependent on copepods or other crustacean species, which could also move their core distribution area northwards with increasing temperatures. These climate-related migrations of small zooplankton therefore impact all levels of the food chain up to the sea mammals on top.

In addition to the exploitation by commercial fisheries and aquaculture, the Norwegian coastal ecosystem faces increased pressure from competing activities. Recreational fishing has to some extent resulted in increased pressure on local fish resources along the southern coast and in part also in Western Norway. Tourist fishing is divided between the coast of Western and Northern Norway. Recreation along the coast besides fishing, such as holiday homes, leisure boating and international cruise traffic has also increased significantly in the past 30 years. This has increased pressure on the coastal ecosystem in several ways, from pollution to the disruption of nesting seabirds. In the future, increased energy production may also impact the coastal ecosystem. Examples are farming of sweet tangle for the production of bio ethanol, establishment of wind turbines and possible petroleum activities in vulnerable areas.

7.1.2.3 Arctic areas

In the past 20–30 years, the Arctic land areas have warmed up more than other areas in the world, and the sea ice has been reduced by 10 per cent during the same period (ACIA 2005, IPCC 2007). Even greater temperature changes are expected in the Arctic in the next hundred years compared with mainland Norway, with subsequent major consequences for species and ecosystems. Even though it is expected that many of the effects will be the same as further south, they will be more prominent here. In general, the species diversity is declining in the north, and changes in distribution and species composition are expected (Loeng et al. 2010). Increased temperatures will result in a northwards displacement of the distribution for many arctic species, and in the long term they may have difficulty surviving due to the lack of a suitable habitat (ACIA 2005). This applies especially to species that depend on ice, such as polar bears, ringed seal, ivory gulls and auks. In Northern Norway, the expansion of conifer forests will have significant effects on the ecosystems (Loeng et al. 2010). Birch forests and willow will spread upwards in the mountains. Deer species, such as reindeer, are herbivores and will likely benefit from higher production, but they could be negatively impacted due to a higher icing frequency.

Large areas of the Arctic have permafrost, and parts of these areas are expected to thaw this century, but exactly how much is unclear (Førland et

al. 2009). In Svalbard many of the freshwater deposits are shallow ponds on permafrost. When the permafrost thaws, these ponds may drain completely and disappear (Loeng et al. 2010). Climate change is otherwise expected to affect the freshwater system somewhat differently on Svalbard than in mainland Norway, especially in low-lying areas, as more precipitation is expected to fall as snow on Svalbard, which results in a shorter ice-free period and lower production in the lakes.

Warming and less sea ice will likely result in increased activity and the transport of environmental toxins to the Arctic region. Environmental toxins that are currently stored in snow and ice could be released when the snow and ice melts, and increased precipitation could increase the amount of organic environmental toxins and mercury that is deposited in the area. Climate change may therefore have serious indirect effects through changes in the pollution loads.

Svalbard, especially the eastern areas, is currently subject to strict restrictions with regard to traffic. It may pose a challenge to maintain these restrictions in light of increasing tourism and more cruise ships, but it is just as important, perhaps even more so.

In conjunction with the melting, the arctic marine ecosystem could disappear completely from the Barents Sea. To what extent it will be possible to maintain parts of this ecosystem in the Arctic is unclear. This will probably depend on whether capelin and polar cod establish themselves in the Arctic basin. In this case, it is uncertain whether the capelin will be able to maintain their spawning grounds as far south as the coast of Finnmark County, where they currently spawn. Regardless, arctic sea mammals such as ringed seal and polar bears, which currently live in a close relationship with sea ice, will come under pressure. The same applies to seabirds associated with the arctic food chain.

7.1.3 Adaptive capacity

The natural environment is, in principle, different from most of the other areas discussed in this Official Norwegian Report due to the fact that the natural environment is not man-made. Climate change adaptation will therefore not be possible in the same way as in other sectors, which largely concern adapting the infrastructure or social conditions impacted by climate change.

There are also great differences in the extent to which individual species are able to adapt to climate change and at the same time withstand other stress factors. Many endangered species that have small populations and low genetic variation will have less capacity to adapt and are therefore vulnerable. Another factor is whether species are able to migrate. This applies to species that have little ability to increase their range, have fragmented habitats, or a combination of the two. One example is wild reindeer, which will face problems with increased temperatures, at the same time as their habitats are being diminished due to the fragmentation of the mountain areas.

In Norway, the arctic and alpine ecosystems are considered particularly vulnerable to climate change (DN 2009). Species will have fundamental difficulties in finding new and suitable habitats when the climatic zones shift and they have no place to migrate in order to maintain their living conditions. Arctic species such as polar cod, capelin, walrus, ringed seal, polar bears and arctic seabird species such as ivory gulls and auks, as well as alpine species such as arctic fox, wild reindeer and alpine plants will be particularly affected. A number of alien species that currently cannot survive in Norway's cold climates will have improved living conditions due to climate change and will as a result survive and spread northwards. These species may have a significant impact on species that are native to Norway, and they may have a major impact on the natural environment and natural resources. It will be difficult for species to adapt to changes that occur too fast. It is particularly the time factor associated with anthropogenic climate change that impairs the species' adaptive capacity. Excessive exploitation of resources will make it more difficult for a species to adapt to climate change.

In order to improve the natural environment's adaptive capacity, society must make arrangements for the best possible conditions for the adaptations that take place in the natural environment. The natural environment is influenced by activities in many different sectors and management areas. The adaptations involve a comprehensive approach to management of the natural environment in order to minimise the negative effects of climate change, or to exploit the positive effects with regard to national and international environmental goals.

Organisation

The Ministry of the Environment has the primary responsibility for the government's environmental and climate policy, and coordinates the various

sector authorities' follow-up of environmental policy. The Ministry of the Environment is responsible for legislation related to the natural environment, including the Nature Diversity Act, Salmonoid and Fresh-water Fish Act and Wildlife Act. In addition, the Ministry heads work on comprehensive management plans for the Norwegian ocean region, and so far such plans have been prepared for the Barents Sea and the Norwegian Sea. The Ministry of the Environment also has a directorate function for municipal and regional planning, and has the authority to issue planning instructions to the county governor. The Ministry's underlying agencies, including the Norwegian Directorate for Nature Management, the Climate and Pollution Agency and the Norwegian Polar Institute, also have administrative responsibility for the natural environment.

The Ministry of Fisheries and Coastal Affairs, together with the Ministry of the Environment, is responsible for sustainable management of the marine environment. The Directorate of Fisheries is responsible for tasks as the executive agency. The Ministry of Fisheries and Coastal Affairs, together with the Norwegian Coastal Administration, is responsible for national preparedness for acute pollution along the Norwegian coast. The Institute of Marine Research is responsible for monitoring the marine environment and living marine resources in the Norwegian economic zone, and also to a certain extent, the ocean outside this zone. In cooperation with the International Council for the Exploration of the Sea (ICES), the Institute of Marine Research issues recommendations on the total quotas for fish stocks in the north-east Atlantic.

The Ministry of Agriculture and Food, which is responsible for food and agriculture policies, also plays a key role in relation to the natural environment through its responsibility for land-use management, farming and forestry, livestock husbandry and reindeer husbandry.

The Norwegian Directorate for Nature Management and the Climate and Pollution Agency have specialist authority to issue instructions and management responsibility with respect to the county governors, who receive their instructions concerning the environment through their annual official assignments. The county governor is tasked with pursuing national environmental goals through guidance, coordination and supervision with respect to the efforts of the municipalities and sectors in the environmental area. As a result of the administrative reforms, the county authorities have taken over some of the county governor's duties in the environmental area as of 2010 (Recommendation No. 30 (2008–2009) to the Odelsting). This includes, for example, duties related to the regional water management and management of harvestable, non-endangered species of game and freshwater fish. These agencies report annually on the expectations for how these tasks will be solved.

Much of the practical management affecting the natural environment is carried out by the municipalities, which have an independent responsibility to observe the current laws and guidelines. The municipalities manage land and decide how land in the municipality is to be used. Most municipalities have conducted a biodiversity study, and some municipalities have been made responsible for the management of protected areas. Municipalities also decide on motor traffic permits in uncultivated areas.

How the municipalities safeguard the natural environment varies. Some municipalities have surveyed vulnerable nature areas, marked off these areas in the land-use section of the municipal master plan and issued regulations to maintain the value of these areas. However, many municipalities have stated that they do not utilise existing thematic data in land-use planning, either because they are not aware of the data or they do not have adequate resources available to organise the data so that it can be functional. Assessments regarding land-use in general have also been handled differently by the municipalities, for example, in connection with the review of planning matters and exemptions in the one-hundred metre belt along the coast. There is also great variation in how municipalities manage their authority related to motor traffic in uncultivated areas; some municipalities are more liberal in permitting motor traffic, while others are more restrictive. This applies, for example, to protected areas. An assessment of the local management of protected areas showed significant differences between areas and municipalities (DN 2008). This assessment showed that a lack of competence, coordination and capacity posed challenges for the management in some areas, while the management functioned well in other areas. The execution of administrative tasks could have a great influence on climate change adaptation, for example, how species are given an opportunity to adapt naturally through the provision of adequate protected areas.

All sectors that have activities related to the natural environment are responsible for observing the current laws and regulations. Some sectors have a high level of expertise and awareness

of this responsibility, while others have given less priority to establishing such competence. This may have consequences for how adaptation considerations are managed in matters that concern the natural environment.

A primary objective of the administration is to protect the structure and function of the ecosystems. The various species and natural habitats must, therefore, be managed in context based on the principles of ecosystem-based management. Ecosystem-based management has been developed on the basis of the Malawi Principles, laid down in the Convention on Biological Diversity. These principles indicate how such management should be carried out.

The Ministry of the Environment has assigned the task of promoting the development and implementation of comprehensive ecosystem-based management of the coastal and sea areas to the Directorate for Nature Management. This means that while the various business sectors, fisheries, shipping, the petroleum industry, etc. are responsible for their areas and must have an ecosystem-based management system for their activities, the environmental authorities have an overall responsibility for viewing the impact of the various sectors in context. The Norwegian Directorate for Nature Management is also responsible for promoting an ecosystem-based management of land areas.

Regulations and requirements

Norway's national environmental goals provide strict guidelines for management of the natural environment. Report No. 26 (2006–2007) to the Storting states: *"The environment will be managed in a way that maintains the diversity of habitats and landscape types and ensures that there are viable populations of naturally-occurring species: this will ensure that biodiversity can continue to evolve"*. This includes, for example, protection against the encroachment of endangered nature types, that species or populations are not eradicated or endangered through harvesting, that the ecosystem is protected from harmful organisms that do not naturally belong in Norwegian nature, and that the populations of endangered species are maintained. The most important statute regulating the management of biodiversity is the Nature Diversity Act (Act no. 100 of 19 June 2009 relating to the management of biological, geological and landscape diversity). Some important principles that are established as sections of this Act include the precautionary and critical level principle, and the ecosystem approach and cumulative environmental effects, discussed in more detail in Chapter 3. Achieving the objectives of these Acts will, to a great extent, facilitate the natural environment's opportunity to adapt.

Through various international agreements, Norway has committed to a number of goals and strategies related to management of the natural environment. The Conference of the Parties to the Convention on Biological Diversity in 2002 and the Johannesburg Summit the same year adopted a resolution that the loss of biodiversity must be reduced significantly by 2010. In 2003, the fifth Ministerial Conference on the Environment in Europe also adopted a resolution to stop the loss of biodiversity in Europe by 2010. Norway endorsed this objective. Norway's report to the Conference of the Parties to the Convention on Biological Diversity in 2009 does not indicate that Norway has achieved this goal.

The Water Regulations, which implement the EU Water Framework Directive in Norway, shall ensure a comprehensive and ecosystem-based management of all water. The regulations state, for example, that water must be managed as a whole, from mountain to fjord; surface water, groundwater and coastal waters must be viewed in context, and the management of water volume, water quality and the ecology of the water must be viewed as a whole. This presupposes coordination between the various sectors that use and have an impact on water and the respective authorities. Management plans stipulating that climate change must be taken into consideration must be developed for all the water regions. This means that climate change projections should be used when assessing the impact and strain. Measures that are planned to safeguard the environmental status of water must be evaluated so that they are as robust as possible with regard to climate change, and monitoring programmes must be designed so that they can detect climate change. A common European guide has been prepared that provides guidelines for the management of catchment areas in a changing climate (European Commission 2009).

The OSPAR Convention (Oslo/Paris Convention for the Protection of the Marine Environment of the north-east Atlantic) regulates the marine environment in the north-east Atlantic, especially with regard to pollution of the sea and protected marine areas. Marine fish resources are also managed at an international level. The International Council for the Exploration of the Sea (ICES) plays an important role here. Other fisheries coo-

peration is discussed in greater detail in Chapter 10.2.

Management of the natural environment involves many sector authorities, and there is a great need for cooperation between these authorities. The organisational framework is in place both nationally and internationally, but there is varied compliance with requirements and guidelines. The failure to achieve goals in accordance with the existing regulations impedes climate change adaptation in the natural environment.

Resources

The national environmental objectives cannot be achieved in their current form, and, with climate change, it must be expected that additional resources will be required in the form of funding and expertise in various sectors to ensure climate change adaptation in the management of the natural environment. Safeguarding the natural environment is often near the bottom of the list of priorities at local, regional and national levels (Lindseth 2006). There may also be dilemmas and conflicts of interest related to safeguarding national environmental interests, and often, priorities are made at the expense of environmental considerations. It is also challenging that it is still very difficult to put a value on nature and its diversity, and thereby the cost of lost nature. This complicates the municipalities' and various sectors' prioritisation of nature in competition with industrial and developmental interests, such as holiday homes.

Management of the natural environment is part of the responsibilities of many different sectors. These are sectors that do not necessarily have any scientific expertise, so prioritisation of the natural environment does not automatically occur. Since the Environmental Protection in the Municipalities Reform was discontinued, few municipalities had their own environmental affairs coordinators, and many municipalities stated that a lack of resources and expertise limited their ability to assess scientific questions regarding nature. It is the view of the committee that this could also have a negative impact on climate change adaptation in the sector.

Knowledge base

Sound surveys of natural diversity are a necessary starting point in order to be able to identify and monitor the effects of climate change on the natural environment and natural diversity. In Norway, most of the municipalities have conducted surveys of nature types and biodiversity, but the there is considerable variation in the scope and quality of these surveys (Gaarder et al. 2007). The surveys conducted as of 2007, were considered to have captured less than 20 per cent of the actual figures for valuable areas, and at that time 45 per cent of all the surveys did not meet the environmental protection authorities' documentation requirements. Both the figures and quality have increased since then, but there has been no new study of this situation.

There is also a great need to monitor the impact of climate change on nature. Some monitoring has been established both on land and at sea to track the developments in nature, but many of these monitoring systems are not designed to detect the effects of climate change, and many of them are not suited for this work either. There is, therefore, a need to adapt the existing monitoring systems so that climate change is taken into consideration, for instance, by introducing climate gradients and registering climate variables, and establishing new monitoring systems for selected

Box 7.3 Environmental Protection in the Municipalities

Environmental Protection in the Municipalities, the "MIK reform", was a reform initiated by the Ministry of the Environment and the Norwegian Association of Local and Regional Authorities (KS) in 1992 to promote and integrate the principles of environmental protection and sustainable development in municipal planning and administration. This reform meant that earmarked grants were made available to allow every municipality to employ an environmental affairs coordinator. In 1997, these earmarked grants were incorporated into the block grant from the government, and municipal environmental protection became an integral part of the municipalities' activities. When this scheme was discontinued, the number of environmental protection positions in the municipalities declined fairly rapidly, illustrating one weakness of this type of economic measure. Although the financial support scheme lasted for several years, the positions disappeared fairly rapidly after the earmarked grants were discontinued (Harvold et al. 2010).

areas and nature types. Long-term series are particularly important in a climate context, and it is therefore important that they are maintained in the future.

Most studies of the vulnerability of nature in Norway are based on a 2°C global warming scenario. In this scenario, the projections predict a 4.6°C increase in the annual average temperature over the next century in Norway. Few analyses have been performed to study the vulnerability in a scenario with higher temperatures, but there is reason to believe that the consequences will be more extensive than previous studies have indicated. Most of these studies have focused on individual species or simple systems. There has been little research into how climate change impacts the *entire* ecosystem, and what impact the combination of other factors together with changes in the temperature and climate will have on species and ecosystems. A tipping point is reached when a small change in an important variable, such as the temperature, results in a sudden and unexpected significant change in a natural system. However, we know little about where tipping points for dramatic change are. The northern regions and alpine areas are particularly vulnerable to climate change, and there is a need for greater focus on these areas. The new High North Research Centre for Climate and the Environment (Fram Centre) in Tromsø must be expected to contribute to a greater focus on research on the impact and the opportunities for adaptation.

Ocean acidification is potentially a very serious problem for the marine ecosystem. There are no known adaptation measures for this and the only possible way to prevent ocean acidification is therefore to reduce greenhouse gas emissions. Research on the impact on marine organisms is only at a very initial phase.

Priorities

The Norwegian Directorate for Nature Management has started to work on climate change adaptation by investigating the possible consequences of climate change on Norwegian nature (*Effects of climate change on ecosystems and biodiversity*, DN Report 2-2006). The Directorate has also started working on mapping and developing strategies for climate adaptation in the management area (*Climate change – nature management measures,* DN Report 2-2007). Various types of adaptations or measures are discussed and evaluated here within the performance areas of sustainable use and the protection of biodiversity and outdoor recreation. This includes planning work, administrative decisions, physical measures, amendments to laws and regulations, information and advice, sector cooperation, monitoring and research and development (R&D).

The Directorate for Nature Management has also established a database for the ecological consequences of climate change in Norway. The database contains results and references to research on the effects of climate change on the Norwegian ecosystem for use by various administrative levels and researchers.

The other agencies under the Ministry of the Environment have also prepared strategies for their adaptation efforts.

The committee has found that establishing knowledge and distributing information on the effects of adaptation and adaptation strategies are prioritised in environmental management. In the same manner as other considerations in environmental management, the prioritisation of adaptation considerations for the natural environment may be downgraded in conflict with other interests. This appears to be particularly challenging at the local level.

7.2 Socio-economic consequences

Human existence is entirely dependent on a number of fundamental natural resources and processes, such as the production of oxygen and organic material through photosynthesis, food, water, wood, building materials and medicines. This output is often referred to as "ecosystem services" to describe the benefits humans receive from nature (MEA 2005). These services are often taken for granted, but their importance ranges from invaluable to great: some are absolutely vital, such as photosynthesis, while others are of great importance to food production and the economy.

It is, therefore, difficult to measure the value of these ecosystem services. Nevertheless, an attempt has been made to calculate the loss should these services be weakened or disappear completely.

A study prepared for the United Nations and European Union estimates the global annual lost natural capital in the range of EUR 1 300 to 3 100 billion (NOK 11 000 to 25 000 billion, or almost 30 Norwegian state budgets) annually (TEEB 2009). These changes are irreversible. This capital is lost forever.

In Norway, extensive amounts of deep-water coral have been surveyed over time on the Nor-

wegian continental shelf. Around the middle of the last century, large amounts of coral were destroyed by activities such as bottom trawling; in this century, ocean acidification represents the greatest threat. The global ecosystem services from this coral are valued at roughly USD 170 billion, almost NOK 1 000 billion, annually. According to The Economics of Ecosystems and Biodiversity (TEEB) study, a coral reef the size of a football pitch delivers ecosystem services worth up to NOK 7 million annually. Around half a billion people, and more than a quarter of all fish species in the seas, are dependent on the services provided by coral reefs. Ocean acidification and the subsequent effects on the coral reefs may, therefore, have great economic consequences.

In a special report on climate (TEEB 2009b) it is pointed out that it would be economically beneficial to invest in the restoration and protection of forests, mangroves, river areas and wetlands, because of their potential in helping to adapt to climate change.

In the ongoing TEEB study, the economic value of 10 biomes and 22 ecosystem services is estimated, and these estimates are global. There are no calculations of what value these ecosystems represent in Norway.

7.3 Adaptive needs

Climate change and various forms of human activity affect the condition of ecosystems and the biodiversity in Norway. Species, ecosystems, nature types and landscapes are in danger of being lost as a result of the increased overall impact.

General considerations

Climate change will be amplified in combination with other negative impacts such as encroachment, fragmentation, overgrowing due to discontinued or changed use, pollution and the spread of alien species. Climate change adaptation may also impact other areas, such as land-use and measures to reduce greenhouse gas emissions. The natural environment might also be exposed to increased negative impacts as a result of adaptations that occur in other sectors.

It is therefore important that climate adaptation measures are developed in the context of other measures, and that they are based on the same principles as environmental and climate policies when assessing measures on the basis of the precautionary and critical level principle, as well as the ecosystem approach and cumulative environmental effects. Win–win measures that reduce both climate vulnerability and greenhouse gas emissions should be given special priority.

A changing climate may also trigger new opportunities and resources, and may result in increased pressure and greater economic activity in areas that currently are not particularly exposed to encroachment. There is a potential for conflict with the interests of natural diversity here. This applies to agriculture, where a change in land-use due to climate change and the intentional or unintentional introduction of alien species can have a negative impact on indigenous plants and animals. Arctic regions may experience increased business activity and traffic as a result of less ice, leading to a greater impact on the ecosystems. In some cases, it is virtually impossible to counteract the effects of climate change, while it is possible to do something about other influential factors that have the same effect, for example by introducing strong restrictions on the use of the areas. Such measures function as adaptation.

Ecosystem-based management

In the committee's opinion, further development of ecosystem-based management of the natural environment will be a necessary adaptation measure. This entails a comprehensive approach to the management of nature and natural resources through the management of human activity and means, among others, by ensuring that a common goal has been defined for all the interest groups. This requires that all the relevant sectors are involved in the management plans and their follow-up. For example, in this connection it will be important to establish international agreement on the status of endangered species (Red List) and unwanted alien species (Black List) for the various ecosystems when the climate is changing.

In addition, it will be important to focus on what is referred to internationally as ecosystem-based adaptation (World Bank 2009). Ecosystem-based adaptation entails adopting a starting point based on how functional ecosystems can be utilised as adaptation for multiple sectors, in other words, benefit others with regard to addressing the effects of climate change. Wetland systems that contribute to a substantial delay in and counteract floods are one example. Securing and restoring these areas may be a win–win measure that reduces climate vulnerability, protects the wetlands and binds CO_2 in functional ecosystems that protect the biodiversity.

This type of climate change adaptation may be relevant in areas near watercourses vulnerable to flooding, in areas that may be exposed to sea level changes and in areas where there is a heightened risk of landslides or avalanches. Instead of implementing physical protection measures, such as flood and erosion protection, which results in additional and more extensive encroachment, land use can be changed. Future damage can be prevented if vulnerable areas are not used, or by establishing and preserving resilient ecosystems in these areas.

For ecosystems it may be particularly difficult to differentiate between development trends caused by climate change and those caused by other factors. Therefore, it is necessary to have a network of marine and land-based protected areas that are spared to a great extent from human impact. Comparing the developments in these reference areas with developments elsewhere increases our opportunities to identify climate effects.

Cross-sector cooperation and coordination

In a number of areas, adaptation related to the natural environment entails the involvement of sector areas other than those solely related to environmental management. By adjusting the release of water in regulated watercourses, we can influence both water temperature and streamflow; measures in agriculture can counteract increased runoff due to increased precipitation; in forestry we can secure migration corridors when logging; regulation of tourism in the Arctic can reduce the risk of increased wear and erosion that is anticipated due to less ice and greater access; regulation of fishing will have an impact on seabirds in areas where climate change results in a reduction of the food supply. Alien species are spread in connection with many different sectors, such as tourism, plant and timber imports, transport, etc., and efforts to overcome this must take place in the various areas. The Ministry of the Environment is currently responsible for coordinating the work to ensure that the authorities responsible for the various sectors implement environmental policies, and it is also important that these policies are followed up in the context of adaptation. We see that climate change and adaptation challenges are highly cross-sectoral in their nature and that there is a great need for inter-sector cooperation.

Land-use management

A great deal of environmental management concerns land-use management. Terrestrial and aquatic environments will face new challenges to maintain their natural diversity in a changed climate. Alpine and arctic areas that are particularly vulnerable to climate change, as well as other influences, should be assessed in accordance with new, national guidelines for development, including construction and use. In addition, protection and isolation of biologically important areas should be considered so that species and ecosystems can adapt to the anticipated climate change by moving or adapting through natural selection. This includes preventing the fragmentation of alpine areas and ensuring that there are adequate areas for endangered species, as well as maintaining and establishing new border areas and migration corridors for species that are vulnerable to climate change.

Valuation of nature, prioritisation and funding schemes

Management of the natural environment, and consequently climate change adaptation, in relation to the natural environment are mainly carried out at a local level. Since ensuring prioritisation of measures to achieve national environmental goals appears to be a challenge, there is a need to investigate other systems for valuation of nature and ecosystem services in order to enable comparisons across the sectors, and the funding schemes must be studied to assess new financing mechanisms that promote adaptation and sustainable environmental management, such as subsidies, grants or funds.

Mapping

To ensure an adequate expert knowledge base for the natural environment, for example as a basis for planning, it will be necessary to expand the mapping of biodiversity to encompass the nature types that are considered important, and in this context, the nature types that are evaluated as being vulnerable to climate change in particular.

Monitoring

Monitoring is necessary to identify the effects of climate change. It will also be very important to create ecological scenarios for the various ecosystems based on the most relevant climate scena-

rios. Studies of key species and key systems and further development of ecosystem models will be important with respect to climate change adaptation. Such key species should be considered as possible indicators for use in monitoring.

Monitoring data will also be important for future generations of researchers to obtain new knowledge regarding nature and climate effects. More studies will provide an improved picture of the significance of climate change for the natural diversity in Norway. Comprehensive and continuous monitoring is nonetheless decisive for systematic identification of the effects of climate change. It is very important that the long-term series of measurements we have for biological variables in certain areas are continued in order to document the changes that actually occur, and the monitoring needs to be improved in several areas. The establishment of time series and continued monitoring activities are often initiated by different institutions without any overall coordination. Further development of monitoring activities for both terrestrial and marine ecosystems will require additional national and international coordination, preferably based on the existing national mapping and monitoring programme. In addition, the development of physical and biological modelling should be an integral part of the planning of ecosystem monitoring.

Knowledge and expertise

Research on the effects of ocean acidification should be a high-priority task. In particular, it will be important to investigate whether important key organisms, such as copepods, which spend the winter at depths of 400 to 2 200 metres, are affected by acidification. These depths are areas that will be affected first by changes in the conditions for precipitation of calcium carbonate as a result of an increase in the CO_2 absorption in the sea.

We must also generate more knowledge on the effects of climate change on nature and ecosystems, as well as the opportunities for adaptation measures to counteract negative impacts.

Like many other areas, expertise is decisive with respect to environmental management and the sectors that carry out activities that affect the natural environment. Authorities at all levels are completely dependent on good specialist expertise in order to develop adaptation strategies to climate change. At the municipal level in particular, there is a need for expertise related to climate and climate change adaptation.

7.4 The committee's recommendations

In order to reduce the vulnerability of the natural environment to climate change, the committee recommends:

Mapping and monitoring

- A review of current mapping and monitoring of ecosystems and climate effects to clarify the need for changes or supplementary programmes.
- Priority must be given to further developing methods for monitoring nature. Monitoring must focus on the needs resulting from climate change, such as developing and using relevant indicators.
- A comprehensive operational monitoring system for the marine ecosystem must be established.

Research-based knowledge creation

- Foster research on ecosystem effects, especially changes in species composition, biodiversity and productivity of key species.
- Improve the knowledge base for the development of ecosystem-based management.
- Improve research related to the tipping points for dramatic changes.
- Develop better valuation systems for nature and ecosystem services for use in the management.
- Improve knowledge of the effects of ocean acidification on marine organisms.

Management regimes

- A management system and expertise must be developed so that ecosystem-based management can be used as a basis in all the relevant sectors and at all the administrative levels.
- Improve the cross-sector coordination of the adaptation efforts to ensure a comprehensive approach.
- Review and adapt regulations to ensure consideration of the natural environment, including the drafting of regulations that promote the most resilient fish stocks.
- Improved protection of natural areas to safeguard both the natural diversity and carbon stores through resilient and well-functioning ecosystems, also reducing climate vulnerability.

- Protected areas must be given priority and arranged so that they allow species to migrate and thus help counteract genetic exhaustion.
- Combat unwanted alien species more effectively.
- Improve the policy instruments for ensuring consideration of endangered species and nature types that can come under greater pressure as a result of climate change.

Chapter 8
Human health and safety

Health and safety are fundamental to our perception of living in a safe society, and represent the building blocks of the Norwegian welfare society. Society invests a great deal of resources to ensure good health and safety for individuals and local communities. Great resources – both financial and human – are quickly mobilised when events occur that threaten life or health. Inability to meet health and safety challenges has major political consequences. They are the basis of both the health sector and civil protection efforts. Society also places great emphasis on both the health sector and civil protection functioning equally well regardless of geography. Where you live should not, in principle, have any consequences for your health or safety.

The principle of collaboration during incidents connects health and safety. According to this principle, the goal is for society's resources to be mobilised quickly and efficiently in response to adverse events. Health services, civil protection and emergency preparedness are also organised so that they have the capacity to respond to many different types of events.

The health sector in particular, and civil protection in general, are dependent on physical infrastructure. The infrastructure is highly exposed to climate change, and, as we will see in Section III, several infrastructure sectors are vulnerable to climate change. This can affect both the health sector and civil protection.

Many health challenges and conditions that test civil protection are associated with climate-related conditions. Climate change will intensify many existing challenges as well as create new challenges. This applies, for example, to new diseases that spread to Norway or natural events that we do not normally have to deal with. Efforts in the health sector and civil protection attach importance to being prepared and actively using scenarios to train for different types of events. Risk and vulnerability analysis is also incorporated into the management system, the purpose of which is to contribute to an overview of the risk situation and prepare the authorities for different types of events. It is decisive for our health and safety that climate change is included as an element in these assessments.

8.1 Health

Climate change to the extent that is described in Section II can influence public health in several ways. A warmer, wetter climate could increase incidents of infectious diseases, for instance, by providing improved living conditions for disease carriers such as mosquitoes and ticks. The pollen season will be longer and more intense, which would worsen the situation for people with allergies, entailing increased social costs. Climate change may also worsen health indirectly because a warmer climate contributes to more illnesses due to air pollution, and increased precipitation puts pressure on drinking water supplies. Positive effects of climate change include lower risk of asthma triggered by cold and reduced mortality during winter.

There is little or no factual data to suggest the occurrence of a catastrophic health scenario in this century. It is not very probable that malaria or dengue fever will spread throughout Norway, and there is little reason to fear frequent widespread heat waves resulting in high mortality rates. Therefore, it is the committee's view that climate change will have a moderate overall impact on the health situation in Norway. We must nevertheless be prepared for a broad range of infectious diseases and allergic reactions to new plants.

Norway has a highly developed health system that is well-equipped to meet the negative impacts of climate change. The health sector has adequate resources, is well-organised, has high emergency preparedness and is a high political priority. At the same time, there is low awareness of climate change and adaptation in the sector. The committee therefore sees a need for more knowledge, research and monitoring in certain areas.

8.1.1 Vulnerability to climate change

8.1.1.1 How is health impacted by the current climate?

Climate-related diseases and disasters are already part of the current overall disease and disaster situation in Norway. In recent years we have observed changes in climate-related infectious diseases. For example, the number of reported cases of the tick-borne Lyme disease increased from 103 in 2002 to 346 in 2008, while the number of reported cases of the serious disease tick-borne encephalitis (TBE) rose from 4 in 2004 to 14 in 2007 and 11 in 2008, most likely as a result of an increased tick population and distribution. This is due to an increase in the cervidae population (moose, roe deer, red deer), regrowth of the landscape and longer growing seasons. In addition, there has been a marked increase in the amount of birch pollen since the mid-1980s.

8.1.1.2 How will health be impacted by climate change?

Climate change is not expected to have a significant impact on mortality rates in Norway. It is likely that climate change will cause increased incidents of pollen allergy (as well as greater intensity for average allergy sufferers). There will probably be more incidents of tick bites and acute gastrointestinal infections. It is possible, and perhaps likely, that we will experience a greater prevalence of serious conditions such as the long-term after-effects of Lyme disease, serious infections and sores from bacteria in swimming waters. However, the current levels are very low, and the summary of knowledge in Ottesen (2010) does not provide any basis for claiming that the prevalence as a result of the increases would reach a serious level.

The health of the Norwegian population is generally good. Life expectancy is often used as an indicator of a population's health. A newborn boy today can expect to live until age 78.5, and a girl can expect to live until age 83. This is on level with the rest of Europe. Life expectancy in Norway has increased by around five years over the past 20 years. Increased life expectancy is one cause of the ageing population, in addition to the higher birth rates since 1945. Ageing can potentially render the population more susceptible to disease, but increased life expectancy also shows that people are living longer because they are healthier.

Generally, good public health will initially have a positive effect on how climate effects influence the health sector. Simply put, Norwegians are relatively well-equipped to meet health challenges.

Ambient temperature and mortality

Both cold and warm weather affect our health. Surveys referenced in Nafstad (2010) show that the mortality of a population increases during very hot and very cold weather.

It is estimated that between 22 000 and 45 000 more people died than normal during the European heat wave in 2003 (Kosatsky 2005). Hot weather in general, and especially in the form of sudden heat waves, appear to have a fairly instant effect on mortality rates, while the effect of cold weather is more gradual. In general the most vulnerable individuals, often the very old or sick, are most exposed to these effects. In a hotter climate, it is expected that mortality related to hot weather will increase, while there will be fewer cold weather-related fatalities. However, studies show that the outdoor temperatures that result in the lowest mortality vary according to the local climate (Curriero et al. 2002).

It is difficult to calculate the net effect of climate change on mortality. This effect will depend on how fast the changes occur and what type of preventive measures are implemented. Nafstad (2010) suggests that the net effect might go either way: reduced or increased mortality rate. A major European study of the relationship between climate change and health, Watkiss et al. (2009), finds that most model calculations suggest a lower mortality, but that there is so much uncertainty here that an increased mortality rate is almost just as likely.

Pollen allergy

A longer growing season might also result in increased prevalence and an extended pollen season in Norway.

It is believed that more than 20 per cent of the Norwegian population suffers from pollen allergy to some degree – or around one million people. An extended pollen season would result in problems for allergy sufferers throughout longer periods of the year. In addition, the key pollen types, such as grass and mugwort (Artemisa vulgaris), will probably increase in volume and activity. A warmer climate could also result in the introduction of new species that produce allergenic pollen. This applies in particular to the establishment of common ragweed (*Ambrosia artemisiifolia*), which has spread widely in Central Europe. In hot years, it is already able to pollinate in the southernmost regions of Sweden. The pollen of common ragweed is a very strong allergen on a global basis. It results in a severe allergic

reaction in the nose and eyes, and it is twice as likely to result in asthma as other pollen allergies.

Other allergies

Higher outdoor humidity results in higher indoor humidity as well. An increase in indoor humidity and temperature may increase the prevalence of house dust mites, which are a significant allergen globally. The significance of this is not known in Norway.

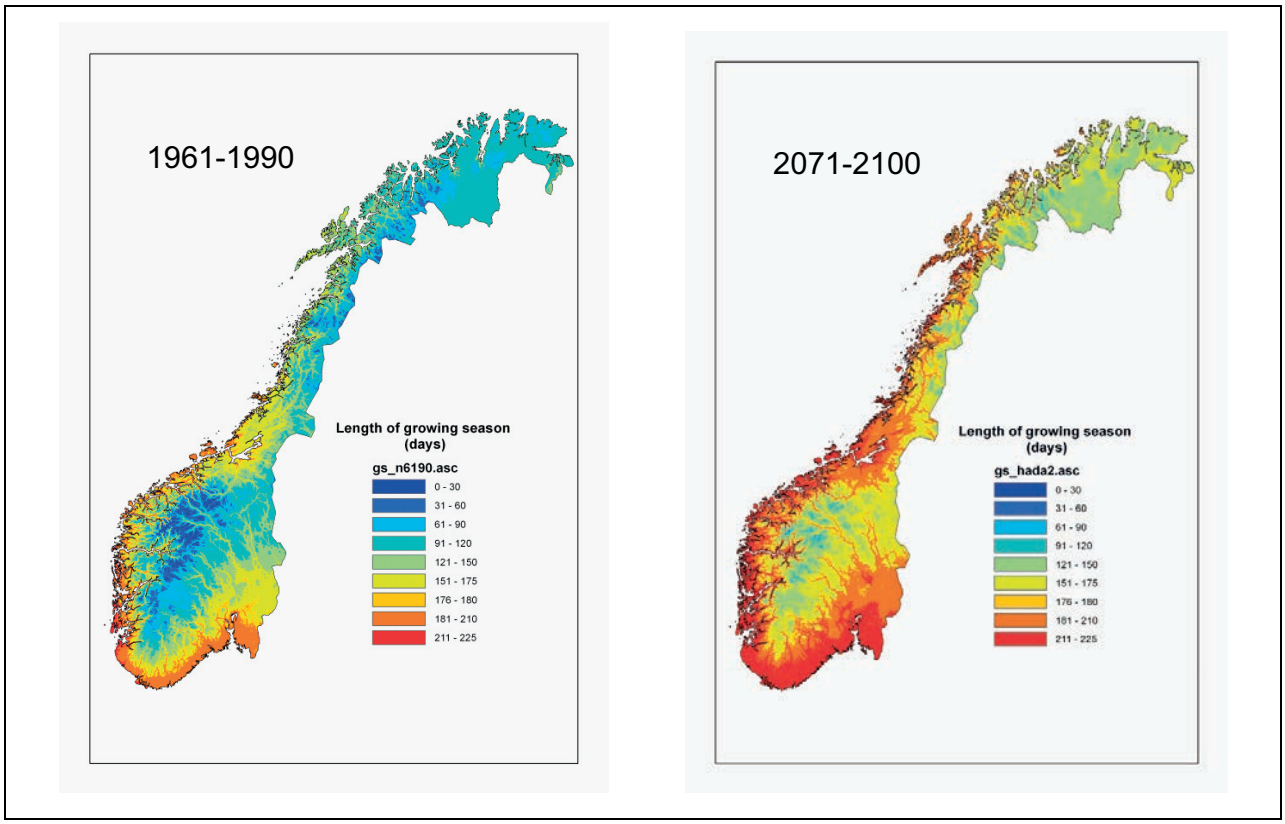
Climate change could increase the risk of humidity issues in Norwegian indoor environments. Population studies indicate a correlation between humidity problems in buildings and the prevalence of respiratory problems (WHO 2009, referenced in Nygaard and Schwarze 2010). High concentrations of mould spores or components in indoor air may aggravate asthma. Humidity-related worsening of respiratory problems and allergies could, therefore, become a more widespread problem with the estimated climate change.

However, there are potential positive effects of climate change for patients with respiratory problems. Higher temperatures reduce the negative effects of cold air for patients with asthma and allergies, and they could also make these patients less susceptible to upper respiratory infections.

Air pollution influences and is influenced by climate change. An increase in ozone at ground level is expected with higher temperatures. This will likely increase the prevalence of asthma, allergies, COPD and respiratory problems, especially in Southern Norway. In addition, the amount of suspended dust in the air may be influenced by climate change, and the composition of the suspended dust could change. The health consequences of this are uncertain. It is also important to bear in mind that air quality in Europe is improving in general.

Water quality

Climate change may have consequences for the quality of drinking water. This is discussed in greater detail in Chapter 9.2 Water supply and



Figur 8.1 The map on the left shows the length of the growing season from 1961 to 1990. The distribution of ticks today corresponds to 176 or more growing days, marked on the map by an orange to red colour. The increase in the length of the growing season for the period from 2071 to 2100 (map to the right), according to the Hadley A2 2071–2100 model, shows that a growing season length of 176 days or more will cover most of the low-lying areas in Norway, with the exception of the northernmost regions (Hanssen-Bauer et al. 2009).

sewerage. Pollution and reduced drinking water quality as a result of runoff and overflow problems could lead to more health problems. The most common diseases transmitted by drinking infected water are gastrointestinal infections. Other diseases, such as hepatitis from the hepatitis A virus, can also spread like this.

Higher temperatures provide good growing conditions for cyanobacteria, previously known as blue-green algae. Overfertilisation is the primary cause of the recent increases in cyanobacteria. Increased precipitation and the leaching of nutrients from the soil to water systems will further encourage this growth. Many cyanobacteria produce toxins and may, therefore, have a negative impact on health in connection with drinking or swimming. In addition, several species produce substances with a strong smell and taste that give the water an unpleasant odour and flavour. An increase in the temperature of saltwater and freshwater may provide better living conditions for microorganisms. Bacteria in the *Vibrio* family, which are usually found in brackish and sea water, may cause diarrhoea and serious infections in wounds. Some of the species in this family could become more common in Norway if the water temperature in Norwegian waters remains at 20 °C or more over extended periods of time, which will probably be more likely for parts of the Oslo Fjord and in the south. Cercarial dermatitis ("Swimmer's itch") is a problem when freshwater temperature exceeds 20 °C. With the expected climate change, the temperature of several water sources will exceed 20 °C.

Vector-borne diseases (Lyme disease, malaria, dengue fever, etc.)

One health hazard attributed to higher temperatures, both nationally and internationally, is the prevalence of vector-borne diseases, i.e. diseases transmitted by a carrier – such as mosquitoes, ticks or snails. These diseases will spread because of an increase in the distribution, population and period of activity of these vectors with higher temperatures. There is international concern about the spread of diseases such as malaria, schistosomiasis, dengue fever and various forms of mosquito or tick-borne encephalitis. Some of these are relevant for Norway.

Milder winters, warmer summers, longer growing seasons and a more humid climate will expand the natural habitat for ticks in Norway. At the end of this century, it is expected that ticks will be found in most areas where people live in Norway, in contrast to the current coastal distribution (Figure 8.1). This may result in more cases of tick-borne diseases, such as Lyme disease, and the currently far less common diseases anaplasmosis, tick-borne encephalitis (TBE), babesiosis and tularaemia. Lyme disease is the most common vector-transmitted disease in Europe. Left untreated, around ten per cent of the Lyme disease cases will develop into advanced forms that manifest themselves by local paralysis, inflamed joints, rashes and symptoms that affect the heart and/or central nervous system. In Norway only such advanced stages are reported. In 2008, almost 350 cases were reported, but this infection is probably underreported. According to Ottesen (2010) around 20–30 per cent of the ticks in Norway may be infected with the borrelia bacteria, which causes Lyme disease. Tick-borne encephalitis is another consequence of tick bites. In Norway, this disease has been very rare, with only 44 cases during the period from 1998 to 2009, all of which were infected along the coast from the southern areas of Vestfold County to Aust-Agder County. There is reason to believe that the prevalence will increase, but it is difficult to predict to what level. Sweden currently reports up to 200 cases annually.

Diseases spread by alien species that are normally associated with more tropical environments may gain a foothold in Norway with a warmer climate. For example, the Asian tiger mosquito has spread very quickly to all continents since the 1980s. The Asian tiger mosquito is spreading quickly in southern Europe and can transmit at least 22 disease-causing viruses to humans, including dengue fever, yellow fever, Chikungunya and Ross River fever. The first European outbreak of Chikungunya was reported in Italy in 2007, and the risk of dengue fever establishing itself in Europe is imminent. This means that more people may be infected by dengue fever when travelling abroad. According to IPCC's estimates (Schaffner 2009), with the current climate, the Asian tiger mosquito can establish itself in the outermost part of Western Norway, but as early as in 2030 it will be able to establish itself in large sections of coastal Norway, from the Oslo Fjord area to the southern parts of Nordland, County. However it is not very likely that dengue fever will establish itself in Norway.

Malaria was naturally present in northern Europe, including Southern Norway, up until the 20th century. The malaria mosquito still exists in Norway and currently feeds primarily on livestock in less populated areas. In recent years, around 30

people annually have brought malaria home with them from abroad. This figure has declined steadily since 1997 when there were more than 100 cases. The number of infected persons may, nevertheless, increase as a result of the expansion of malaria-infested areas in warmer climates. The probability of the malaria mosquito becoming a carrier of malaria in Norway is, however, small, and it is therefore not likely that malaria will spread in Norway.

Food-borne infections

Intestinal infections from food are among the most common types of infection, and higher temperatures increase the risk of such infections. A Canadian study (Fleury et al. 2006) found that salmonella, campylobacter and EHEC infections increased by between 1.2 and 6.0 per cent for each degree Celsius above the average level. The increase is partly dependent on environmental conditions and partly dependent on a change in social behaviour, with more outdoor activities in more primitive conditions with regard to hygiene, such as barbecue parties, camping, staying in mountain cabins, picnics, etc. where food is often not stored or treated optimally. It is therefore reasonable to expect that an extended summer season in itself could result in a higher prevalence of such summer infections.

Mechanical injuries

Extreme events such as storms, landslides, avalanches and floods entail a health risk in the form of mechanical injuries to people. More frequent and more intense weather events may result in an increased risk of accidents. Areas that have historically been safe with respect to landslides, avalanches, floods, etc. may become more exposed as a result of climate change.

According to the Norwegian Geotechnical Institute (NGI)'s slide database, around 2 000 people have lost their lives in landslides and avalanches in Norway in the past 150 years. Avalanches have claimed most lives, but clay landslides, rock slides and boulders have also claimed lives. Only a few deaths due to storms and floods on the mainland have been reported in the past 20–30 years (Aamodt 2010). Changes in slide frequency and the types of areas that are prone to slides, and especially avalanches, may increase the risk of landslide and avalanche-related accidents. The same effect may apply to floods and flood-related slides.

8.1.1.3 Adaptive capacity

Organisation

The Ministry of Health and Care Services has the overall administrative responsibility for health and care services in Norway. The Ministry manages the health and care services through a comprehensive body of laws, annual grants and with the help of government agencies, organisations and enterprises. The responsibilities for treatment, research and monitoring, which are important to climate-related diseases, are generally clearly defined. It is the view of the committee that the comprehensive organisation of the health sector from the central to the local government levels enhances the sector's adaptive capacity. The Norwegian Food Safety Authority has the supervisory responsibility for food safety through its responsibility for supervision and regulations covering the entire production chain for both the marine/aquatic and land-based food sectors.

The topography and climate of Norway pose challenges in terms of emergency medical transport. Disruptions in transport, for example, difficult flying conditions for airborne ambulance services or roads with reduced navigability, may mean that patients arrive later at the hospital. The specialist health service is in the process of implementing changes to the organisation of their emergency medicine units, in which they are being moved from many local hospitals and centralised at fewer hospitals. This means longer travelling distances for the patients. More frequent and intense natural disasters in the future could increase the risk of stops and delays. At the same time, emergency medical transport is developing rapidly, and the ambulances in use are well-equipped. It appears that this reorganisation in itself will not necessarily have a negative impact on the capacity of the sector, and that the new organisation may function well despite more frequent disruptions in transport.

Regulations and requirements

The health sector is managed through a comprehensive body of laws, and the Communicable Disease Control Act contains provisions concerning emergency preparedness in the event of outbreaks of new and previously rare diseases. The municipalities and health trusts are obligated to prepare emergency preparedness plans for the health sector. This emergency preparedness obligation is another organisational measure that pro-

vides an element of safety with regard to the sector's ability to cope with climate change.

However, the committee would like to stress that the health sector and services are increasingly dependent on external suppliers to deliver and perform their services. This applies primarily to the supply of power, electronic communications, and road and rail transport. Power disruptions are a growing problem for almost all social sectors, but they can have particularly serious consequences in the health sector. Chapter 9. Infrastructure and buildings, shows that climate change may increase the risk of disruptions. It is vital that the health sector has emergency preparedness in place for such situations, for instance that hospitals have adequate emergency generator capacity. Drinking water is also regulated through regulations and standards.

In order to ensure food safety, inspections and safety procedures have been introduced throughout the entire chain from the land (or fjord) to the table. The committee believes the inspection of food in Norway is generally good. However, it may still be necessary to establish additional inspections in order to prevent increased risk. In Sweden, for example, food that has been inspected and found free of salmonella in the production country has later been found to contain salmonella.

Flow of information and competence building

Information and training within the health sector and among the general population are well-developed in Norway. Norway already monitors the distribution of the castor bean tick, and the population in general appears to be increasingly aware that they must protect themselves and remove any ticks that may have attached themselves.

Alien species are increasingly being observed in Norway. The Norwegian Biodiversity Information Centre registers all unwanted species in Norway in the "Alien Species Database", including the species that represent a health hazard, and it publishes the "Norwegian Black List" and factsheets for these species. This is an important tool in order to stop or limit unwanted species today, and it will also be important to monitor the development of species in a warmer climate.

Pollen alerts may take place within the framework of the current notification service, so that new and old allergy sufferers can take precautions. However, it is not very likely that these measures will eliminate pollen allergy as a growing health problem.

Doctors are obliged to report more than 50 contagious diseases, many of which are climate-related, to the Norwegian Surveillance System for Communicable Diseases (MSIS) at the Norwegian Institute of Public Health. These figures are then reported to the World Health Organisation (WHO). The monitoring of these diseases is, therefore, good. All data is publicly available at *www.msis.no*. Norway also cooperates closely with the European Centre for Disease Prevention and Control (ECDC), which is tasked with strengthening Europe's defence against infectious disease.

Resources

Viewed in an international context, the resource situation in the Norwegian health service is very good. After the US, Luxembourg and Monaco, Norway is the country that uses the largest amount of resources on health per person (WHO 2010). The committee regards the current resource situation and the expected resource situation in the future to be adequate to meet needs incurred by climate change.

Knowledge base

Internationally there is a great deal of research, mapping and monitoring with respect to health and climate change. In Norway, the report prepared for this study is the first comprehensive work that reviews and assesses the health impact of a changed Norwegian climate. This is a start, but, in the committee's view, research, mapping and monitoring need to be improved in several areas. This applies in particular to monitoring. Above we have pointed out the risk of the spread of vector-borne diseases. In addition, a warmer climate could result in the establishment of more allergenic plants. It is important that the spread of species is monitored closely, so that Norway is able to implement measures that limit or stop the spread of these species and/or measures that prevent them from causing health problems for the population.

Priorities

Health has high priority in Norway. The understanding in the health sector and the general public, as well as the willingness to make resources available in the event of new health risks, are all high. The handling of the swine flu outbreak in 2009 showed that the authorities make significant resources available when the population faces a

health risk. The committee therefore feels that the willingness to adapt in the health sector is high.

Adaptation in other sectors

Many of the effects described above are handled primarily by other sectors. This applies in particular to the quality of drinking water. The supply of drinking water in Norway is improving, and UV radiation is increasingly being used to disinfect drinking water. UV disinfection of drinking water eliminates the threat of many of the diseases mentioned above. Many large water treatment plants have switched from chlorine disinfection to UV disinfection in recent years, so that most of the Norwegian population now receives UV treated drinking water (Lund, Utkilen and Krogh 2010). Vista Analyse (2010) believes that this development will continue so that eventually almost the entire Norwegian population will receive drinking water disinfected by use of UV. Thus, both microbes and parasites that can withstand chlorination will be eliminated. Of course, this requires that the plants are run correctly, and that other requirements are in place so that the UV radiation is effective. A future increase in colour and reduced visibility in the water will require that a number of smaller waterworks also improve the pre-treatment of their water to ensure that UV disinfection continues to be a satisfactory hygienic barrier in the future.

There is technology available that removes cyanobacteria, toxins, and the substances that make water smell and taste bad from water, but the cost is considerable – both in terms of the initial investment and operation. Lund, Utkilen and Krogh (2010) believe that this type of technology does not appear to be required under the current climate conditions.

8.1.2 Socio-economic consequences

The socio-economic assessment of the health impact of climate change focuses primarily on the fact that climate change may affect mortality rates. Based on international experience, Vista Analyse (2010) estimates that climate change by the end of the century could change the annual mortality rate in Norway by around +/- 300 lives or less. At the end of the century, this corresponds to a socio-economic impact of between NOK 15 billion in costs if the mortality rate rises and a gain of NOK 15 billion if the mortality rate falls. Pollen allergies entail great costs for society today in the form of expenses for consultations with medical doctors, medicines, increased absence due to sickness and reduced work capacity. Allergy afflictions also result in a significant non-material welfare loss in the form of reduced quality of life for sufferers. Given the large proportion of Norwegians who suffer from some form of serious pollen allergies, even a small increase or exacerbation of the pollen season may well entail great costs for society.

Most of the health hazards from climate change could be prevented or modified by well-functioning health services together with good water treatment facilities. On the basis of the summary in Ottesen (2010), Vista Analyse (2010) concludes that the health service will be able to handle climate change-related health hazards within the framework of the existing budget and with the existing use of resources. The existing budget and use of resources refers to the levels at the point in time when these health injuries occur.

8.1.3 Adaptive needs

In light of the information on which the committee has based its assessments, the committee finds that the current health service and health emergency preparedness are adequate to handle climate change. The committee does not see a need for greater measures within this sector, but has noted that there is limited knowledge of the links between climate and health in Norway.

In the opinion of the committee, there is a need to improve the knowledge base, especially related to the monitoring of new diseases and species that can spread disease or exacerbate existing health problems. In the event that malaria, dengue fever, swimming-related infections and other serious infections establish themselves and spread in Norway, it will be important that the health service has the expertise and equipment to meet these challenges. It is also important that we maintain a critical level of expertise on serious diseases in Norway.

The risk of infectious material entering the water pipes may increase in the future, but how much it will increase and what the consequences will be in the form of occasional gastrointestinal infections, for example, is unknown. In addition to the need to increase the replacement rate in the water supply and sewerage system, there will be a need for increased knowledge on the risk of infection through penetration, i.e. the health consequences of leaky pipes.

Mortality rates during heat waves and hot summers can probably be reduced by better air conditioning in buildings, information on the importance of rehydrating, etc. Air conditioning will probably be particularly important in retirement homes and nursing homes. These are measures that the committee feels should be assessed sometime in the not-too-distant future. It should also be considered whether an increased risk of power disruptions for health institutions as a result of more frequent and more extreme weather events changes and increases the need for emergency power.

Even though pollen allergies can hardly be seen as a serious health hazard for most people, it is an annually recurring affliction that is costly for society. In addition, pollen allergies aggravate other afflictions, such as asthma. With increased prevalence and people who can afford to pay, it can be expected that the pharmaceutical industry will intensify its research to develop good medicines to combat the problem.

The committee's proposed measures in the health sector are related to obtaining more knowledge, research and monitoring so that the sector is optimally prepared to meet future challenges.

8.1.4 The committee's recommendations

In order to improve adaptation in the health sector, the committee recommends:

- Improving international cooperation and national efforts to monitor the spread of vectors that can transfer diseases such as malaria and dengue fever. Monitoring of the spread of allergenic plant species must also be improved.
- Research on:
  - heat and heat waves, the ways in which they affect mortality rates and the significance for society.
  - links between climate and pollen allergies, ways in which the individual can prevent allergies and medical treatment of allergies
  - links between health consequences and deficiencies in the water supply and sewerage system.
- Maintaining expertise on tropical diseases and infections in the health service.

8.2 Civil protection and emergency preparedness

Climate change will challenge our capacity to prevent and deal with the consequences of natural disasters. More frequent, more intense and unexpected weather situations, more days of heavy precipitation and a higher volume of precipitation may increase the risk of floods, landslides, avalanches, and other natural events, exposing individuals and society to an increased risk and greater negative impact. This will pose challenges for safety and emergency preparedness efforts by the authorities in many sectors, such as the supply of power, transport and the municipalities.

Civil protection involves social planning with a view towards creating a safe and resilient society. A resilient society is capable of maintaining important social functions and safeguarding lives, health and fundamental necessities for the population in different types of crises. With regard to civil protection and emergency preparedness, the heightened risk of climate-related events poses challenges in maintaining important functions and activities.

During the review of Storting White Paper No. 22 (2007–2008) relating to civil protection, climate change was identified as a factor that could entail increased civil protection challenges. The committee shares this view. However, the committee finds that the sector has a good foundation, as it possesses relevant knowledge and experience. In order for society to benefit from this in the face of a changed climate, the committee finds that the expertise related to climate change adaptation must be improved, and that the adaptation efforts must be given priority and more resources.

Systematic identification of what risks and what types of negative impact climate change may entail, and analysis of the vulnerability of the individual sectors and society as a whole, will be key elements of any adaptation effort. Risk and vulnerability analysis will form a necessary basis for assessing measures to prevent or reduce damage caused by adverse events. These analyses will also form the basis for emergency preparedness planning and other tools to handle events if they should nevertheless occur. The committee would like to emphasise the need to ensure systematic work on risk and vulnerability analyses and that climate change is integrated in this work.

Society is increasingly dependent on a reliable supply of electricity, telecommunications, drinking water, etc. Safety may be challenged if the supply of such services is disrupted. Therefore, planning and operation of infrastructure services are an important part of any civil protection efforts. The more resilient Norwegian energy and telecommunication networks are to climate-related events, the better the level of civil protection will be.

8.2.1 Vulnerability to climate change

8.2.1.1 How is the sector impacted by the present climate?

Each year, strong winds, intense precipitation, floods, storm surges, etc., result in small and large-scale events that impact negatively on individuals and society as a whole. The storm "Narve", which hit several municipalities in Finnmark in 2006, resulted in the evacuation of 1 100 people from Melkøya in Hammerfest (Husabø 2010). The six-day power outage in Steigen in 2007 reminded us that society is vulnerable to prolonged power supply disruptions. It was not possible to provide many of the services we take for granted, such as heating, water supply and telecommunications, as normal. There was, for example, a problem ensuring that the elderly and sick were kept warm and received necessary help (NSBR 2008).

In years with prolonged dry periods, larger and more frequent forest fires arise. The fire in Froland in Aust-Agder in 2008 is regarded as the largest forest fire since 1945. A total of around 2 600 hectares burned, around 1 900 hectares of which was productive forest. According to figures from the insurance company Skogbrand, the forest-related damage to the 12 properties that were affected was assessed at NOK 21.5 million. In addition, a number of holiday homes burned down, and fires in power masts resulted in power disruption in a number of places. This fire started during a very dry period in the early summer, and there were major forest fires in Råde and Konnerud at the same time (*Forest fire preparedness and the handling of recent forest fires in Norway*, DSB 2008).

Even though natural events such as landslides, avalanches, erosion and floods do not necessarily threaten life and health directly, they may entail other types of negative impacts on society. Moreover, the indirect consequences of such events may be just as serious as the actual event; for example, if closed roads prevent emergency response vehicles from responding promptly, or repair crews are unable to reach sites in order to repair damage to inoperative grid lines.

The scope of the damage caused by weather events is largely related to the intensity of the weather and whether society has the capacity to prevent and handle the strain. This is discussed in the paragraph on adaptive capacity.

8.2.1.2 How will the sector be impacted by climate change?

The most important consequence of climate change with respect to civil protection is related to the impact of severe weather. Natural disasters such as landslides, avalanches and floods are already a challenge to society today and can be expected to increase in the future.

Search and rescue work following natural disasters such as avalanches is demanding, and an increase in the number of such events will result in greater challenges for rescue services. The report *"What If" – Status, challenges and measures for the voluntary rescue service* (Voluntary Organisations' Rescue Professionals Forum 2007) discusses the future challenges for the rescue services. The report concludes that climate change will necessitate improvements to the rescue services in the future in order for them to be able to respond to an increased frequency of natural disasters. The report states that there has been a steady increase in the number of rescue operations over a number of years. It also states that if this trend continues, the number of rescue operations could double by 2030.

Climate change can increase the incidence of drought during summers in parts of the country, which may in turn exacerbate the problem of forest fires. In the report *Effects of climate change on cultural relics and sites* (Directorate of Cultural Heritage 2010), the Directorate of Cultural Heritage points out that droughts do not only result in a greater risk of forest fires, but also a greater risk of fires in wooden houses with cultural heritage value.

More emergency events as a result of changed climatic conditions may increase the risk of the infrastructure systems not managing to fulfil their intended functions. This can create problems for the population, business and industry and the authorities. The various infrastructures are mutually interdependent, for example, telecommunications depends on a reliable power supply. This is discussed in greater detail in Chapter 9, Infrastructure and buildings.

Part of the infrastructure represents what is referred to as critical infrastructure. This infrastructure comprises the networks that form the basis for all social activity and are absolutely essential to meet the needs of the authorities, business and industry and the public. In addition to the power grid and the telecommunications networks, this infrastructure also includes the transport networks for goods and people (roads,

air, rail and sea), and the water and sewerage networks. Therefore, the loss of one of these networks could have major consequences. Events occur regularly that prove how vulnerable society can be to critical infrastructure disruptions. After the volcano eruption in Iceland in the spring of 2010, flights were grounded in large parts of Europe. This created a very difficult situation for the health service, for example, as air ambulances could not take off, and because patients, medical equipment and medicines could not be transported fast enough to and between hospitals.

8.2.1.3 Adaptive capacity

Organisation

In Norway, civil protection work is based on the principles of responsibility, proximity and similarity, cf. Storting White Paper No. 22 (2007–2008).

- The *responsibility principle* entails that the agency that is responsible for a specific area in a normal situation is also responsible for handling extraordinary events within this area.
- The *similarity principle* means that the organisation used during a crisis should be as similar as possible to the organisation used on a day-to-day basis.
- The proximity *principle* means that a crisis should be handled at the lowest possible organisational level.

This means that the authorities at all levels are responsible for preventive measures, emergency preparedness preparations, and handling extraordinary situations within their areas of responsibility. At a general level this means that the ministry that is responsible for a sector on a day-to-day basis is also responsible for handling a crisis situation within its own area of responsibility, and each minister maintains his constitutional and parliamentary responsibility.

Although civil protection tasks are organised as a sector responsibility, Norwegian emergency preparedness is based on coordination of resources and management when adverse events occur. This applies, for example, to efforts to save lives and protect health, where the management of the rescue services will also manage the efforts of participants who are not part of the organised rescue services on a daily basis. During operations and clean-up after a major acute pollution incident, the operational management in the Norwegian Coastal Administration may manage resources from its own agency and from external sources.

The government has emphasized cooperation and coordination in order to ensure comprehensive and coordinated emergency preparedness and crisis management at the central, regional and local levels (Storting White Paper No. 22 (2007–2008)). In recent years, a number of royal decrees have been adopted with the purpose of strengthening the Ministry of Justice's coordination role (Royal decree of 16 September 1994 on the Ministry of Justice's coordinating function in the emergency preparedness sector and Royal decree of 24 June 2005 on the Directorate for Civil Protection and Emergency Planning's (DSB's) coordinating responsibility and responsibility for coordinating supervision). The Ministry of Justice's coordination role includes tasks such as the preparation of general guidelines, and facilitating and being a driving force for the sectors' civil protection efforts. The Ministry of Justice must also clarify responsibilities in grey areas and make fundamental decisions in the civil protection and emergency preparedness area (Storting White Paper No. 39 (2003–2004): Civil protection and civil-military cooperation). The coordinating responsibility also entails that the Ministry of Justice must supervise the work of the ministries in the area of civil protection.

The Directorate for Civil Protection and Emergency Planning (DSB) supports the Ministry of Justice in carrying out its coordinating and supervisory roles. DSB manages cases that fall under the legislation related to fire and electrical safety, hazardous substances, product safety and the Norwegian Civil Defence. DSB is also the administrative agency for the county governors' civil protection efforts. As a government support resource, the Civil Defence assists the emergency and rescue agencies in connection with major accidents and events. This also applies to long-term and complex events. The Ministry of Justice is also the managing agency for the National Police Directorate and the two main rescue coordination centres, both of which have important duties in the area of civil protection.

At the regional level, the county governor is responsible for coordinating civil protection efforts in the county and being a driving-force for civil protection and emergency preparedness efforts, as well as playing an advisory role. The municipalities are the local foundation for national emergency preparedness, and they are responsible for the safety and protection of the population in their geographical areas. The organisation of civil protection efforts at the local and regional

Box 8.1 Forest fire cooperation

Following the 2008 forest fire in Froland, a working group was established to review the handling of the fire. In its report, the working group proposed a reinforcement of emergency preparedness and monitoring during periods of extreme fire hazard (*Forest fire emergency preparedness and handling of recent forest fires in Norway*, DSB 2008). The working group stressed the need for a warning and reporting regime that would allow accurate and timely forest fire hazard warning, and pointed out the need for using more resources at an early stage than normally indicated by the severity of a fire. The working group also stressed that if a municipality could not comply with the regulations on its own, and make sure that it was prepared to handle forest fires, then the municipality must seek binding cooperation with other municipalities. In a changed climate where forest fires may occur more frequently, this type of cooperation between municipalities will be even more important.

levels is discussed in greater detail in Chapters 13 and 14.

With regard to forest fire efforts, the Act relating to the prevention of fire, explosion and accidents involving hazardous substances and the fire service requires the municipalities to prepare risk and vulnerability analyses. These analyses are to provide a basis for determining how the fire service can be adapted so that they are able to handle such fires. Major fires will often require more personnel and equipment resources than the individual municipalities possess. Both the Norwegian Civil Defence and Armed Forces are important reinforcement resources for the municipalities in the area of forest fire preparedness, in addition to other municipal fire brigades.

Even though the responsibility for safeguarding civil protection is divided among many parties and government agencies, the committee feels that the sector generally has clear authorities and a clear distribution of roles. However, the committee feels that climate change increases the need for even better coordination and cooperation between the authorities at central, regional and local levels. Experience from handling severe weather in recent years (for example, the storm "Narve" in Central and Northern Norway in 2006, and "Loke" in Western Norway in 2005) demonstrates the complexity of handling extreme weather events that affect large geographical areas. Major events will require the ability to cooperate across agency and organisational borders and may necessitate joint prioritisation of resources and coordination of information. In document No. 3:4 (2007–2008), the Office of the Auditor General states that it is necessary that the Ministry of Justice plays an active role in the civil protection efforts in order to improve general cooperation.

In the report "Extreme weather events", Vestlandsforsking points out that sound crisis management helps reduce the scope of damage. Cooperation across organisational and geographical borders, for example, by the Norwegian Armed Forces and Civil Defence providing assistance to the police and municipalities, is highlighted as an important factor for successful crisis management (Husabø 2010).

Requirements and regulations

It is essential that the responsible authorities are aware of how climate change will affect civil protection efforts within their areas of responsibility. In the opinion of the committee, all civil protection efforts must be based on risk and vulnerability analyses (RAVs). These analyses will provide a solid basis for the selection of measures to reduce the risk of undesirable incidents events (prevention) and for preparations to meet the challenges entailed by such incidents (emergency preparedness). The risk and vulnerability analysis requirement has been formalised in many areas through statutory and regulatory requirements, for example, in the Act relating to the municipal emergency preparedness duty, civil protection measures and civil defence, which enters into force on 1 January 2011, and which stipulates requirements for cross-sector risk and vulnerability analyses. The Planning and Building Act also stipulates requirements for conducting risk and vulnerability analyses for all new development areas and that all areas that are exposed to risk can be indicated as buffer zones in plans.

Risk and vulnerability analysis will be a suitable methodology to assess new or changed risk as a result of climate change. The goal of the analysis process must be to provide knowledge of the impacts entailed by climate change, assess how probable they are and what type of consequences they may have, and to assess what can be done to

prevent or reduce the damage caused by these effects. The committee believes it is important to stipulate the requirement that the consequences of climate change must be part of the risk and vulnerability analysis in the administration. If it is not possible or useful to implement preventive measures, then there must be requirements for the preparation of emergency preparedness plans for how to handle adverse climate-related incidents.

The Directorate for Civil Protection and Emergency Planning's (DSB's) official assignments for the county governors constitute a good example of how an expectation of climate assessments in the risk and vulnerability analyses can be expressed in practice. In the assignment for 2010, the Directorate states, for example, that the county governor must ensure that climate change is one of the considerations that form the basis for risk and vulnerability analyses for individual counties. The assignment also assumes that climate assessments will be an integral part of the county governors' follow-up of the municipalities. The county governor shall ensure that the climate change considerations are assessed and followed-up in municipal plans and that climate change is one of the topics that must be assessed in risk and vulnerability analyses.

The committee has also noted that in its discussion of the need for improved cooperation in civil protection (document No. 3:4 2007–2008), the Office of the Auditor General highlights the need to prepare comprehensive risk assessments. Even though risk assessments related to climate change are not addressed specifically in the Office of the Auditor General's study, the committee believes climate change increases the need for risk and vulnerability analyses and improved cooperation.

The government supervises the municipalities and counties in a number of areas to ensure that activities are in compliance with laws and regulations. Supervision is also used as a tool to verify whether the government's own activities are being carried out in compliance with laws and regulations and in accordance with the political expectations. For instance, the Directorate for Civil Protection and Emergency Planning (DSB) supervises the work of the county governors in the area of civil protection. On behalf of the Ministry of Justice, the Directorate also supervises the ministries' work in the area of civil protection. Climate change adaptation is now included as a topic in the Directorate for Civil Protection and Emergency Planning's (DSB's) supervision of the county governors.

Flow of information

The National Emergency Planning College (NUSB) is the central training institution for civil protection and emergency preparedness and is a subordinate agency under the Directorate for Civil Protection and Emergency Planning (DSB). Since 2008, NUSB has offered municipalities and counties courses on "Climate change adaptation in social planning" and "Civil protection in land-use planning".

The Directorate for Civil Protection and Emergency Planning (DSB) is also responsible for the Norwegian Fire Academy, which is the national training institution for municipal fire and chimney sweep personnel. The Norwegian Civil Defence's emergency preparedness and expertise centres provide training in emergency preparedness and rescue of own personnel and other parties in the rescue services.

The committee finds that it is important that the established training opportunities for climate change adaptation and civil protection continue and are developed further. Climate challenges should be integrated in all risk and vulnerability analysis training, emergency preparedness planning, etc. Climate-related scenarios must also be relevant topics for emergency preparedness training at the local, regional and national levels.

Resources

Society provides a significant amount of resources when accidents and other serious incidents occur. The lifesaving efforts by the rescue services are governed primarily by what is practically possible and appropriate to do, and not by financial concerns. However, the Norwegian authorities also deploy resources for incidents that do not represent a direct threat to life and health, even though it may be costly. In the aftermath of major floods, landslides, avalanches, forest fires, etc., it has been common practice that the central government has contributed significantly to cover the extraordinary costs that the municipalities have incurred.

With regard to the capacity for work related to civil protection, the committee finds that the knowledge, expertise and training the parties possess to respond to incidents today will largely enable them to handle the challenges represented by climate change. For rescue services, a landslide is a landslide regardless of whether it was caused by climate change or not. The fact that such incidents occur more frequently, become more intense and

occur in places where they have not previously occurred will probably pose challenges in terms of capacity, in the sense that the personnel and equipment might not be adequate.

Traditionally, these services depend on a great deal of volunteer work when disaster strikes. Voluntary organisations account for a significant share of the combined resources in the Norwegian rescue services. Voluntary organisations are also very concerned about climate change and what consequences it will have. See the discussion concerning the Norwegian Red Cross in Chapter 11.1, Local communities.

A great deal of willingness to help is also mobilised, in addition to the organised volunteers. There are many examples of farmers with slurry tankers who have volunteered and contributed greatly in the efforts to extinguish heather and forest fires. In addition to voluntary efforts, mobilisation of resources in the form of personnel and equipment from the Civil Defence and the Armed Forces will play an important role in handling major events.

It is harder to find funds and other resources for preventive and damage-limiting work than for efforts in response to extraordinary events. Adaptation in the area of civil protection will essentially involve compensating for the increased risk and negative impact caused by climate change. There will be an increased need to protect structures against floods, landslides and avalanches, reduce the backlog in maintenance of critical infrastructure, perform a comprehensive survey and analysis of risk, etc.

Knowledge base

There are limited studies of the relationship between climate change, natural disasters and climate change adaptation. The IPCC is currently working on a special report on this topic.

In Norway, there have been some studies of the sector's work on climate-related issues, for example, the study "Exit war, enter climate" (Husabø 2008). In the national vulnerability and emergency preparedness report for 2007 (NSBR 2007), there is a discussion of current natural disasters, with a special discussion of major rock slides. The report does not mention climate change directly, but it does, however, address adaptation-relevant matters. An internal review has also been conducted vis-à-vis the Directorate for Civil Protection and Emergency Planning's (DSB's) climate change adaptation. These reports and studies all provide an account of the status of the adaptation efforts or the efforts related to adaptation-relevant conditions. It is important to identify needs for further work in this sector.

In the practical work on prevention and emergency preparedness planning, the parties will use much of the same knowledge as is used in other sectors. Basic map data, projections, etc. are important in order to obtain an overview. Defects and gaps in this knowledge base are just as relevant for civil protection and emergency preparedness as for the other sectors. This is discussed in greater detail in Chapter 16.3.

Priorities

In a national risk perspective, the challenges posed by climate change must compete for attention and priority with many other possible events, such as international terrorism, major accidents, cyber attacks, critical infrastructure failures, etc. Previously, civil protection has been an area in which the activities have concentrated primarily on the nation's ability to defend itself against outside attacks. The report "Exit war, enter climate" (Husabø 2008) discusses the process of reordering priorities from a military focus to an increased civilian focus with regard to civil protection. The report points out that the Directorate for Civil Protection and Emergency Planning (DSB) understood at an early stage that climate change would be a major challenge for civil protection. It concludes that even though the change of focus from military threats to natural disasters is evident, the process is far from completed.

A survey conducted in connection with an internal assessment in the Directorate for Civil Protection and Emergency Planning (DSB) (Climate efforts in DSB's areas 2010) shows that climate vulnerability and climate change are rarely on the agendas of the Directorate's departments. The evaluation report states that it is likely that these activities still need to be improved before adaptation efforts become a natural and integrated part of the follow-up of the specialist areas.

The committee is not aware whether similar investigations or evaluations of other national organisations, for example, the National Police Directorate or joint rescue coordination centres, have been made. It is part of the Ministry of Justice's general responsibility to ensure that climate challenges are given clearer priority on the agenda in the work on civil protection.

Husabø (2010) points out that it appears that assessments following extreme weather incidents place more emphasis on improving the ability to

handle future situations than preventing them. Some of the improvement potential for civil protection lies, therefore, in improved utilisation of the empirical knowledge gained from severe weather events in preventive efforts.

8.2.2 The impact of climate change on the Armed Forces

Climate change may affect the Armed Forces and their activities in several ways.

Climate as a condition for planning and carrying out military operations

The weather has always been a key condition in the planning and execution of military operations. Firstly, planning is important to avoid exposing troops to unnecessary risk and strain due to weather conditions. Secondly, the weather can be decisive for the ability to perform a military operation and its outcome.

The Armed Forces have routines for assessing weather, road and light conditions that can affect operations. These routines exist primarily to ensure that the risk of extreme conditions is adequately assessed. The risk of avalanches has been one area that the Armed Forces have focused on, especially in the wake of the accident in Vassdalen in Nordland in 1986.

For the Armed Forces, one of the consequences of climate change will be that they will become even better at safeguarding their troops through the development of procedures.

Increased need for assistance from the Armed Forces for civilian society

The ways in which the Armed Forces support civilian society are mentioned in several reports and Storting White Papers. For example, in the context of the new total defence cooperation, Storting White Paper No. 22 (2007–2008) states *"… at its core is the mutual support between the Armed Forces and civilian society with regard to prevention, emergency preparedness and impact management for the entire range of crises, from peace to security policy crises and war"*.

The contribution of the Armed Forces' efforts is based on the assumption that they can make available the resources and expertise that have been established for solving their primary tasks. The Armed Forces already provide support to the police and civilian society when important social interests and lives and health are at risk. This may be in connection with assistance during forest fires, major floods or rescue operations. Police assistance is regulated by special assistance instructions. Municipalities and other authorities may receive assistance in connection with major accidents, crises and natural disasters.

The coastguard is in a unique position since its primary task is the civilian border patrol of Norway's territorial limits. Together with the Directorate of Fisheries and cooperatives, the coastguard is also responsible for performing fishery inspections. In addition, it represents a very important resource for the rescue services at sea, especially in the northern regions. Gradually, as ice-free regions north of Svalbard are used for fishing, there will be a need for a greater range for both the coastguard and the rescue services.

In all probability, the need for support from the Armed Forces in civilian society is set to increase, as climate change is expected to cause more natural disasters and other serious adverse incidents. The Armed Forces have rescue services, personnel and equipment from which other emergency preparedness authorities require support. This can range from assistance from the Home Guard for local landslides, avalanches and flood events to regional transport and communications support during extensive extreme weather. For example, in Sweden the Armed Forces' telecommunications network was the only communications network that worked in the affected areas during the storm "Gudrun" in 2005.

Adaptation requirements for the Armed Forces' own property, buildings and equipment

The Armed Forces have many properties and own a significant amount of hi-tech and costly equipment. The Armed Forces have the same need as other sectors to ensure that routines for planning, building, inspection, maintenance, etc. are adapted to climate change.

Need for an increased presence of the Armed Forces in the Arctic regions?

Ship traffic represents important challenges with regard to risk and vulnerability in the northern areas due to the risk of accidents leading to loss of life and/or environmental pollution. There are many indications that ship traffic in the northern areas has increased, and there is reason to believe that climate change will contribute to a further increase in ship traffic (Molenaar and Corell 2009). More activity in the north will also necessi-

tate an increased presence by the Armed Forces to enforce sovereignty and to exercise authority.

The Armed Forces provide resources to civilian society in the area through, for instance, coastguard services, surveillance and rescue services. Due to the great distances involved, a military presence with vessels and aircraft in the north is a requirement in order to reach the sites in need of assistance in a timely manner. Other infrastructure is limited or absent, and because of a limited volume of traffic, the efforts cannot be based on "vessels of opportunity". The special local climatic conditions (cold temperatures, darkness, ice, polar low pressure, summer fog, etc.) also increase the challenges.

8.2.3 Adaptive needs

The committee finds that climate change increases the need for better coordination and cooperation between the various authorities in the area of civil protection as well. In order to increase the capacity to handle forest fires, for example, it is important to establish sound cooperation schemes between the municipalities. This will help ensure adequate resources for extinguishing efforts, especially in the initial phase of a fire.

The committee finds that there is a need for routines to ensure that the administration evaluates the lessons learned from responding to extreme weather and natural disasters related to the climate. Experience from such events is an important basis for both preventive measures and the handling of future incidents.

There is a need for clearer requirements for risk and vulnerability analysis for climate change at all administrative levels. Tools and methods must be developed further for analyses that integrate this as an analysis topic.

It is the committee's opinion that civil protection efforts require more resources. Reference has been made above to studies that underline the reduction of the county governors' capacity. The committee assumes that the need for increased resources will also apply to other authorities that work with civil protection.

The necessary establishment of expertise on climate and civil protection must be ensured throughout the administrative structure.

In order to ensure that adaptation efforts are safeguarded in an appropriate manner, the committee believes that climate change adaptation must be a priority topic for the supervision of civil protection efforts in the administration. The Directorate for Civil Protection and Emergency Planning's (DSB's) supervision of county governors already includes this topic, and this should also be the case for the supervision of other sectors of the public administration. In order for the State to be able to supervise climate change adaptation in the municipalities, such supervision must be authorised by law or regulations.

8.2.4 The committee's recommendations

In order to improve adaptation in the civil protection and emergency preparedness sector, the committee recommends that:

- A comprehensive review of vulnerability, organisation, resources and competence must be conducted in the sector in light of the new challenges posed by climate change.
- Regulations and guidelines for risk and vulnerability analysis must be reviewed and adjusted as needed so that adaptation will be taken into consideration.
- Supervisory authorities at various administrative levels must be given the authority to include adaptation as a topic for supervision in all contexts where it is relevant.
- Based on the review of the sector's needs for expertise, a plan must be developed for competence building.

Chapter 9
Infrastructure and buildings

All infrastructure is affected by climate, and through direct exposure to the weather, will be exposed to climate change and changes in precipitation and temperature. The vulnerability of infrastructures varies, but the need for maintenance will be a major common challenge in connection with climate change. At the same time, different types of infrastructure are mutually dependent, further increasing their vulnerability.

Society and individuals depend on access to electricity, transport and communication, water, waste management services and shelter. Because of their importance to society, sectors such as power supply and water supply and sewerage are often referred to as "critical infrastructure". The vulnerability of infrastructure and buildings is therefore significant for society's overall vulnerability to climate change.

Infrastructure includes roads, airports, ports, railways, energy and telecommunication networks, water supply and sewerage, waste management and buildings. The various infrastructures are mutually dependent. For example, power supply is essential for the functioning of all the other socially important infrastructures, and a functioning telecommunications network is necessary for a stable power supply. In the event of any disruption in power supply, there is a dependency on the transport system to perform repairs. This mutual dependency increases vulnerability to climate change and makes society even more vulnerable.

However, vulnerability to climate change varies between different infrastructure areas. The committee finds that power supply has a relatively high adaptive capacity, which counters the fact that the sector is highly exposed to climate change. The overall vulnerability is, therefore, relatively low. The adaptive capacity in the water supply and sewerage sector is, in the opinion of the committee, low, and the vulnerability is correspondingly high. The assessments of the transport sector and buildings provide a more complex picture of adaptive capacity and vulnerability.

The variations in vulnerability are largely related to the service life of the infrastructure. Buildings, water supply and sewerage networks, and roads and railway sections that are built today have a long service life and must be designed for various loads far into the future. The electronic communications sector is characterised by a short service life for the cable network and a capacity to adapt quickly. Therefore, vulnerability in this sector is fairly low, despite the fact that it is exposed to the effects of climate change. The time perspective requires solid climate projections, calculation methods and cost–benefit analyses for the planning of new infrastructure.

There are some common challenges for all infrastructure when facing climate change. A backlog in maintenance is a shared challenge for large portions of the infrastructure and buildings. Climate change will increase the need for maintenance and increase the challenges related to the maintenance backlog, which is particularly true for transport, buildings, water supply and sewerage. Because of an ageing grid, there is also a great need for reinvestment and improvements in the power supply sector. The infrastructure is not adequately adapted to climatic conditions at present due to the maintenance backlog. The combination of the maintenance backlog and climate change significantly impairs the adaptive capacity and may result in substantial costs for society.

Infrastructure generally has high investment costs. The maintenance backlog may be an obstacle to adaptation since the sector must spend its time and capacity on repairs rather than long-term planning. Climate change therefore increases the need to eliminate the maintenance backlog, which means that the adaptation costs will increase.

9.1 Transport

The transport sector is exposed to the climate. Precipitation, precipitation intensity, cloud cover,

temperature and wind all place severe restrictions on the transport sector. Climate change may have both positive and negative consequences for the infrastructure for land, sea and air transport. On the one hand, increased precipitation, precipitation intensity, temperature changes and more frequent floods, landslides and avalanches will increase weathering, the scope of damage and the number of traffic disruptions. On the other hand, less snow and ice may improve navigation on land and at sea, as well as access to airports and ports during the winter.

Society is dependent on a well-functioning transport system. Correspondingly, disruptions in transport systems have major consequences for society and quickly gain political attention. The decentralised settlement pattern in Norway entails that the availability and navigability of roads, railways, the sea and the air are of great significance to individuals, emergency and preparedness services and other functions in society. The location of business and industry makes Norwegian businesses very transport-intensive and vulnerable to disruptions and reduced accessibility. Business and industry are dependent on reliable deliveries and are thus more dependent on the transport system. Therefore, vulnerability in the transport sector has a great impact on the overall vulnerability of society.

There is much awareness of climate-related conditions and generally good preparedness for weather-related events in the transport sector. Climate change adaptation initiatives have already been taken in several areas of the transport sector. The National Transport Plan is the transport agencies' most important strategy document. It provides a common platform for developing the transport sector's ten-year plans, and is an important basis for adaptation efforts.

Maintaining safety and accessibility in a changed climate with optimal use of resources is a goal. Climate change creates increased uncertainty concerning what impacts the infrastructure must be able to withstand. If this uncertainty results in the use of higher than necessary safety margins, this will lead to unreasonably high costs for the sector. Increasing the knowledge about climate change, and thus reducing uncertainty, is therefore an important aspect of the adaptation efforts.

The transport sector's vulnerability to the climate is related primarily to the maintenance backlog. With the exception of aviation, the infrastructure for transport currently has a significant maintenance backlog, and it is, therefore, not adequately adapted to climatic conditions at present. Stronger negative climate impacts will exacerbate this problem and increase the vulnerability.

In the committee's opinion, a significantly greater focus on maintenance is a prerequisite for reducing this sector's vulnerability.

9.1.1 Land transport

The infrastructure for land transport includes almost 100 000 km of public roads and 4 100 km of railway lines. While the railways are managed by the Norwegian National Rail Administration centrally, the Norwegian road network is managed by the Norwegian Public Roads Administration, county authorities and the municipalities.

Land transport is highly exposed to climatic conditions. Temperature conditions, precipitation and events such as floods and landslides affect the efforts in this sector to secure the accessibility of the roads and railways.

Climate change will intensify many of the challenges facing land transport today. In the committee's opinion, land transport has a relatively high adaptive capacity at the national level, since the sector has a clear management system and significant resources at its disposal. Nationally, the sector is very aware of climate change, is used to tackling challenges related to harsh weather, and has allocated resources to survey the need for climate change adaptation. This contributes to improving its adaptive capacity. However, the resources available for realisation of adaptive measures must be seen in the context of the maintenance backlog. The maintenance backlog represents a significant adaptation shortfall. Significantly increased resources must be allocated for this to enable climate change adaptation in this sector.

9.1.1.1 Vulnerability to climate change

How is land transport impacted by the current climate?

In recent years there have been more frequent floods, landslides and avalanches, some of which have had major consequences for the transport network. For example, large volumes of snow, combined with very cold weather, created problems for the railways and passengers last winter, and a sudden spring thaw resulted in major damage and traffic disruptions in Northern Norway in May 2010. Even though these events cannot be directly linked to climate change, these

cases clearly demonstrate the sector's climate vulnerability and what type of challenges the climate will represent in the future. There is also an opinion in this sector that parts of the transport network do not hold a satisfactory technical standard (NTP 2010–2019).

How will land transport be impacted by climate change?

Roads and railways are exposed to climate change in a number of different ways. Road and railway transport are exposed to natural events that can reduce traffic safety or otherwise threaten life and health, which may result in major material damage, impede accessibility and increase costs.

Greater precipitation volumes will result in an increased strain on the drainage systems. An increased risk of floods, landslides and avalanches entails a traffic safety hazard and may increase the frequency of disruptions. Existing flood protection, drainage and landslide protection may also prove to be inadequate. Slope stability may decrease as a result of increased precipitation and changes in erosion and the groundwater level. "Wet" slide types, such as debris flows and mudslides, will probably occur more frequently.

In the winter, increased precipitation will come in the form of more snow on alpine stretches in the first half of this century. In addition, there is a risk that more intense snowfall may significantly affect road navigability. More wet snow can increase the problem of trees falling over and blocking rails and roads, and damaging the tracks and power lines. Higher elevated areas may become more exposed to fluctuation above and below the freezing point, i.e. alternating between freezing and thawing. This will increase the risk of frost damage and weathering on the rail network. It may also affect the roads' bearing capacity, traffic safety and the need for road salt and grit.

Rising sea levels and storm surges may create problems linked to wave erosion and overflow, which may result in erosion damage and traffic disruptions. This can also increase the risk of water flowing into underground tunnels with low-lying entrances. Increased amounts of water will also expose road fill and bridge foundations to more strain and erosion.

Disruptions and problems in other sectors; for example, the water supply and sewerage or power supply sectors, also create problems for transport. In the introduction to Chapter 9, this is referred to as a mutual dependency between the infrastructure sectors. Sound coordination is important to counteract problems today as well. In a changed climate, such problems could worsen, and coordination will become even more important.

Climate change will also have certain positive effects on transport networks on land. Less snow will reduce the need for ploughing and winter maintenance, and more roads and railway stretches could stay open in the winter. The number of avalanches that close roads could be reduced in some parts of the country. The shorter periods of snow and ice cover on the roads will also reduce the risk of accidents. With higher winter temperatures, the number of rail breakages as a result of extreme cold could be reduced. A longer growing season will increase overgrowth along roads and railway lines, but higher tree lines can reduce the problem of blowing snow at higher elevations and have a stabilising effect on avalanches.

Adaptive capacity

Organisation

In 2010, the road network consists of 10 800 km of national roads, 44 000 km of county roads and 40 000 km of municipal roads. The Norwegian Public Roads Administration is the road authority for the national road network and develops strategies, prioritises measures and manages the combined national roads budget for development, operation and maintenance. In addition to being responsible for the national road network, the Norwegian Public Roads Administration assists the county authorities with the management of the county road network through a joint roads administration. The county authority and municipalities are responsible for most of Norway's roads. This decentralised ownership and the fact that a great number of suppliers are used for development, operation and maintenance increases the risk of a fragmentation of the responsibility for development and operation. Harvold et al. (2010) points out that this fragmentation makes the sector's adaptation efforts more complicated.

The Office of the Auditor General points out (report 3:16 2008–2009) that too few resources have been used for owner's inspection in many road contracts. Climate change will entail a greater need for such inspection and clearer requirements when entering into operation and maintenance contracts with contractors. This applies to all administrative levels.

The Norwegian National Rail Administration owns and operates the railway infrastructure, such as tracks, signals and interlocking systems,

platforms and stations. The Norwegian National Rail Administration is also responsible for managing rail traffic and distributing the rail capacity between the various railway companies.

The Norwegian Railway Authority is the executive control and supervisory authority for rail traffic, which also includes light rail and metro in Norway. The authority is an independent agency under the Ministry of Transport and Communications. There are currently 13 railway companies that operate on the Norwegian rail network. The largest of these companies is NSB, the Norwegian State Railways.

Highway standards and specifications provide the basis for planning, capacity design and building the entire public road network in Norway. However, there are no formal requirements that they must be used for municipal and county roads. The government aims to issue regulations in areas where it is important to follow up national goals. Currently regulations for tunnel safety, the use of road data and safety requirements for bridges, ferry terminals and load-bearing road constructions have been given priority. These regulations are to define shared minimum standards for the national, county and municipal roads in Oslo. The government may issue additional regulations if this is found to be necessary. An internal committee in the Norwegian Public Roads Administration is currently preparing a recommendation to the county authorities concerning the minimum standards based on the highway standards and specifications. Initially this recommendation will have guideline status, but, in the future, it may become part of a regulation if this is considered appropriate. The Norwegian Public Roads Administration's sector responsibility includes transferring knowledge that can ensure the correct construction, operation and maintenance solutions, primarily to the county administrations. Adaptation efforts in this sector can be strengthened by including knowledge on the effects of climate change in the highway standards and specifications, and using these standards and specifications.

It is not enough to use historical data as a basis in a situation with a changing climate. Requirements that are not adapted, for instance, to increased precipitation, may result in under dimensioning. This can in turn cause increased repair and maintenance costs. In the Norwegian Public Roads Administration's project "Climate and Transport", the regulations have been reviewed to ensure that climate change considerations are taken into account.

The individual municipalities prepare standards and design specifications for municipal roads, but far from every municipality has done so. Municipal road standards and specifications are based partly on the Norwegian Public Roads Administration's highway standards and specifications. The lack of expertise and capacity at the local level to take the consequences of a changed climate into account (see Chapter 13 for further details) and a lack of regulations makes it especially challenging to adapt local road building to climate change. However, there are good opportunities in expert environments that can contribute to knowledge sharing in the various specialist areas. The "Road Forum for Cities and Towns" is an example of such an arena for the exchange of experience, joint professional development and competence building. For instance, in 2009, the Forum published a new operation and maintenance standard. It is currently being assessed whether it could be relevant for the Road Forum to develop recommended highway standards and specifications for municipal roads. Information from the Road Forum is disseminated and made available via NKF (Norwegian Association of Municipal Engineers). The committee believes that it is important that such networks are maintained and develop their professional activities, as they can make important contributions to addressing insufficient competence and capacity for work on climate change in the municipalities.

The Norwegian National Rail Administration prepares and manages technical regulations, which include requirements for development, operation and maintenance of the infrastructure. An analysis of what changes are needed for adaptation is underway here as well; for example, changes to the capacity-design basis for increased streamflow or changed wind loads.

Resources

Society spends vast resources on roads. Compared with roads, there has been relatively little focus on the development and modernisation of the railway network in the post-war period, even though both goods and passenger traffic have increased in recent years. The government has signalled an increase in railway investments, particularly in and around the largest cities. Compared with the National Transportation Plan (NTP) 2006–2015, the budgets for the current plan

Box 9.1 Emergency preparedness

Emergency preparedness requirements are key for both roads and railways. The Norwegian National Rail Administration introduced a successive emergency preparedness system for severe weather in 2002. These routines have been implemented throughout the entire rail network and entail more frequent inspections of the rail sections during heavy precipitation and that the lines can be closed in extreme cases. The Norwegian Public Roads Administration also started a focused effort to establish a tiered emergency preparedness system after the flood in Trøndelag in 2006. Further development of tiered emergency preparedness for both roads and railways is accomplished, for example, by better utilisation of weather and climate data. This takes place in cooperation with the Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Meteorological Institute (met.no), which are developing FøreVar, a map portal for weather and natural event data based on the SeNorge.no portal. This emergency preparedness scheme focuses primarily on heavy precipitation and how this can affect avalanches. Over time this will include several types of severe weather and incidents on the road and rail networks.

Box 9.2 Slide protection

The Norwegian Public Roads Administration has a professional forum on landslides and avalanches, in the form of an internal professional group for slide expertise across departmental divisions. Slide incident protection plans are prepared regionally, and investments for protection measures are prioritised based on a model which includes traffic volume, detour alternatives, landslide and avalanche statistics and the frequency of closures. Work is also underway to develop a landslide and avalanche risk model that aims to describe the risks, regardless of previous landslides and/or avalanches.

Slide protection is also a prioritised topic in the railway sector. The Norwegian National Rail Administration has a special committee to coordinate the work on slide protection. Routines have also been incorporated for mapping and systematic risk assessments of crossings with regard to slide risk, using cost–benefit assessments. Inspections, clearing and securing rock outs are carried out on an annual basis. This is resource-intensive work that the Norwegian National Rail Administration wishes to replace with permanent solutions. Work is being carried out to develop procedures and work processes that will include climate change considerations. Protective measures should be designed with a view towards possible changes in the frequency and type of slide events. As part of this work, a risk assessment of slide-prone areas started in 2008–09.

period NTP (2010–2019) have increased by 39 per cent for roads and 58 per cent for railways.

County and municipal roads are funded through the block grants to the respective counties and municipalities. Through their investments in the road network in 2010, which are higher than originally planned through the National Transport Plan (NTP), the county authorities have shown political willingness to prioritise the road network. With regard to municipal roads, it is the committee's impression that they are being given less priority, and that the municipal capacity and resources are being primarily spent on day-to-day operations and short-term maintenance. For municipal roads, it appears that a lack of resources is a general obstacle to good road maintenance and even more so to adaptation.

Climate change adaptation in the form of increased maintenance requirements and changed requirements for new facilities will incur higher costs. It is, therefore, necessary to ensure that these costs are included in all estimates for the sector's future financial requirements.

The road and railway sectors possess substantial technical expertise. For example, the Norwegian National Rail Administration has started compiling a competence plan that comprises line personnel, clearing teams and specialists in areas such as geology, geotechnics and hydrology. The committee believes projects and specific protection efforts related to the current climate challenges for roads and railways are helping ensure the basic competencies required to meet the climate challenges of tomorrow.

Expertise is also increasing through international cooperation. One example is the EU-funded ROADEX network – an international cooperation

between northern European road administrations on the exchange of information and research.

Maintenance backlog

There is a substantial maintenance backlog for both roads and railways due to lack of resources. The maintenance backlog increases the vulnerability to climate effects. This applies to the entire railway and road networks, but it applies in particular to the municipal roads in the road sector.

In the report "State of the Nation" (2010), the Association of Consulting Engineers (RIF) graded the infrastructure based on its condition and maintenance requirements. National and county roads were given a score of 3, on a scale from 1 to 5, with 5 as the best. Based on the estimates from Schjølberg et al. (2009) and NTP 2010–2019, the maintenance backlog is estimated to be around NOK 12 billion for county roads and NOK 19 billion for national roads based on the classification prior to 2010. These estimates are for the cost of bringing the road network back to its original standard. If the road network is to be brought up to the current standard requirements and needs, then the costs would be far higher. Because of the high degree of uncertainty concerning the figures and calculation methods, the Norwegian Public Roads Administration conducted a new review in 2010–2011.

The municipal roads were also given a score of 3. The costs to improve only the municipal roads that are in "very poor condition" are estimated at NOK 11–13 billion. This is the lowest ambition. The costs for improving unsatisfactory roads, in addition to those in very poor condition, will be NOK 22–26 billion.

The railways were given a score of 2. The improvements required to achieve an acceptable technical standard are estimated at NOK 20–30 billion. Essentially, Norway has the same rail network today as 40–50 years ago. The signal and safety systems, power supply, etc. have undergone improvements, but many of the facilities have reached or are about to reach the end of their service life. The National Transport Plan (NTP) stresses that there is a significant need for renewal of railway facilities, and that this is a requirement for maintaining the railways' competitiveness. In the NTP 2010–2019, the Ministry of Transport and Communications stipulates an annual ceiling for maintenance, which is an increase of 56 per cent compared with the ceiling in the plan for 2006–2015. Slide protection measures are also funded through the operation and maintenance budget.

According to the strategy department of the Norwegian Public Roads Administration, the Ministry of Finance's guidelines for conducting socio-economic analyses are in need of review and revision. The way analyses are conducted today can lead to solutions in which high operating or maintenance costs in the future may be prioritised over solutions with more resilient capacity design.

The significant maintenance backlog for both roads and railways means that the infrastructure is currently not adapted to climatic conditions. In the opinion of the committee, this represents an adaptation deficiency that poses significant challenges for the work to adapt the roads and railways to future climate change.

Knowledge base

Road and railway sector investments are costly. Changes in requirements, standards and criteria for capacity design may entail significant additional costs. Standards, criteria for capacity design and security measures require accuracy and significant documentation. Mapping and monitoring of different natural conditions and natural hazards are necessary in order to provide this documentation. In addition, it is important to have documentation of actual events on the road and rail networks.

The data included in the knowledge base for climate change adaptation is obtained primarily from other agencies and sectors, such as the Norwegian Meteorological Institute (met.no), the Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Mapping Authority. The transport sector is completely dependent on this knowledge base being updated, adapted for application and maintained. Cooperation across the various agencies is a prerequisite for climate change adaptation.

Priorities

There are several indications that climate change adaptation is a priority area in the road and railway sector at the national level. For example, the R&D project Climate and Transport 2007–2010 under the leadership of the Norwegian Public Roads Administration, represents a significant adaptation initiative for Norway. Both NTP 2010–2019 and the Norwegian Public Roads Administration's Action Programme 2010–2013 define several goals that contribute to adaptation: prioritisa-

tion of maintenance, improvement of existing roads rather than building new roads, development of alternative contract types to reduce operating and maintenance costs, etc. In addition, there is the annual NOK 1 billion grant for slide protection, which will contribute to climate change adaptation.

The Norwegian National Rail Administration started a more goal-oriented climate change adaptation initiative in 2008. The goal of the "Robust Railways" programme is to reduce the number of adverse events in the rail network. The report includes, for example, work related to mapping landslide and avalanche hazards and protective measures and preparedness for more extreme weather. The Norwegian National Rail Administration also participates in the Norwegian Public Roads Administration's R&D project "Climate and Transport". The discussion of climate change adaptation and specification of measures in the Norwegian National Rail Administration's Action Programme for 2010–2014, such as an increased focus on maintenance, is an expression of willingness with respect to climate change adaptation. According to the technical staff at the Norwegian National Rail Administration, the management is supportive and seeks results from work associated with adaptation.

In the committee's opinion, adaptation is generally given fairly high priority in the road and railway sector at the national level. Increased traffic safety, increased focus on slide protection and better maintenance are the main priorities in the National Transport Plan (NTP) 2010–2019. The effects of climate change have such a great impact on these areas that adaptation considerations must be included in order to ensure a successful follow-up.

9.1.1.2 Adaptive needs

Climate change adaptation is necessary to ensure future accessibility, navigability and safety of road and railway transport. A fundamental prerequisite for this is an improvement of the technical standard of the infrastructure, so that the maintenance backlog is eliminated. On some sections, in both the road and rail networks, this backlog is so critical that operational problems due to a poor standard force short-term, rather than more forward-looking, solutions. Slide protection is important for safety along roads and railways today, and it will be even more important in a changed climate. In addition, it is important that both existing and new knowledge and experience from ongoing projects are systematised, incorporated into regulations and procedures – and distributed to the authorities at all administrative levels. Specialist expertise must be safeguarded and developed by ensuring adequate recruitment to the relevant disciplines. Training programmes must include subjects that cover the effects of the climate and climate change.

All of this requires increased resources for knowledge, expertise and professional guideline materials for both roads and railways. This also includes further development of preparedness plans and slide protection plans for the road and railway networks.

It is especially important to strengthen the knowledge base. There is a need for more research on rising sea levels and storm surges, the effect of inclement weather combinations and persistent severe weather. Improved forecasts are required for projecting wind pattern and storm frequency developments. Knowledge of the correlations between the weather and landslides/avalanches must be improved.

In order to adapt to intense precipitation incidents, there is a need for measurements and short-term precipitation projections with a time resolution of one hour or less and a greater geographical resolution. Coordination and harmonisation of data from different weather stations has started and will provide better data, which will be of great importance to climate change adaptation. There is also a need for better hydrological data, both streamflow observations with a short time resolution and measurements of runoff, as well increased knowledge of the significance of runoff from melted snow.

Both research results and measurements must be adapted to the users. In order to adapt the road and rail networks to climate change, the sector is dependent on a research environment and other agencies that can supplement data and analyses with top-level expertise within their areas of responsibility. This includes the need for an update of intensity-duration-frequency tables (IDF curves) and flood frequency analyses for small catchment areas. There should be a focus on developing internet-based communication solutions and keeping the eKlima portal, etc., updated with the latest knowledge. The further development of mapping portals for better utilisation of climate data, master data and documented events is included here. The national database for landslides and avalanches is also included in this type of coordinated solution for access to information.

There is also a need to develop better cost assessment methods that include estimates for the loss of regularity, less predictable traffic and delays as a result of climate change.

9.1.2 Sea transport

The sea has always been important to Norway, both as a source of resources and as a means of national and international transport. The Norwegian merchant navy consists of almost 1 900 vessels. This makes Norway the fifth largest shipping nation in the world. Norway has Europe's longest coastline with around 25 000 km from the Swedish border in the south to Russia in the north, including fjords and inlets. Sea transport along the Norwegian coastline is increasing and will most likely continue to increase in years to come.

The maritime infrastructure in the form of waterways, navigation guides (lighthouses and markers), harbours and the infrastructure in harbours (quays, etc.) are important requirements for sea transport. Safe and functional harbours provide the foundation for an efficient, safe and competitive industry.

9.1.2.1 Vulnerability to climate change

How is sea transport impacted by the climate?

For shipping traffic, demanding climatic conditions and complicated manoeuvring conditions in narrow waters are well-known challenges. Sea transport is exposed to wind and wave conditions, currents, fog, polar low-pressure systems, etc. Along the coast, wind, particularly in combination with local wave and current conditions, cause the most demanding situations. Section II shows that there is significant uncertainty related to wind conditions. This makes it more difficult to predict the conditions for sea transport in the future. However, sea transport will likely be less exposed to climate change than other forms of transport.

How will sea transport be impacted by climate change?

The maritime infrastructure is exposed to rising sea levels and increased storm surge levels and generally harsher weather effects. Sea level rise may affect the function and usability of the infrastructure, and more severe weather effects and storm surges may result in greater challenges for the operation of the infrastructure and more frequent damage. Even under the current climate conditions there are waters and harbours that are not accessible several days a year due to safety considerations. Any worsening of wind, wave or current conditions could further reduce availability. Climate change will increase the strain and weathering on lighthouses, markers, breakwaters and quay installations. Overflow and disturbances behind breakwaters can be expected to increase. Erosion and sand movements on the sea bed could become an increased problem. Vessels may experience difficulties with access to harbours and sailing heights under bridges with higher sea levels. The Norwegian Coastal Administration sees the risk of larger vessels being forced to sail farther from the coast during harsh weather due to navigability considerations in narrower waters and poor visibility. However, there will be a need to pilot smaller vessels in protected waters near the coast. This may constitute a greater strain on the Norwegian Coastal Administration's pilot services and the environment, and it could require the establishment of safer waterways nearer the coast in the long term.

Other changes in sea transport may include transport in new waterways in the Arctic as a result of less ice. This is discussed in more detail below.

Adaptive capacity

Organisation

The Norwegian Coastal Administration reports to the Ministry of Fisheries and Coastal Affairs and is a specialist agency for sea transport, safety at sea, harbours and emergency preparedness for acute pollution at sea. The Norwegian Coastal Administration is responsible for pilot services; vessel traffic services (VTS); lighthouse and marker services and navigation notifications; improvement of waterways; and the construction and maintenance of fishing harbours. The Norwegian Coastal Administration is also responsible for the central government's preparedness for acute pollution.

The Norwegian Maritime Directorate reports to the Ministry of Trade and Industry and the Ministry of the Environment. The Directorate is the authority responsible for Norwegian registered ships and foreign ships that call at Norwegian harbours and is required to ensure proper safety for life, health, vessels and the environment. Through advisory services, follow-up and supervision, the Directorate shall contribute to Norwegian ships and ship-owning companies maintaining high standards with regard to safety and the

environment and ensuring that seamen on-board Norwegian ships have good qualifications, working and living conditions. Another important task is to ensure that foreign ships in Norwegian waters and harbours observe international regulations.

The Ministry of Trade and Industry is responsible for business policy in Norway, including the policies for the maritime sector. The Ministry is responsible for work on international regulations and agreements, bilateral agreements and marketing for the maritime industries. The Ministry of Trade and Industry is also responsible for following up the Government's maritime strategies.

Most of the public harbours in Norway are owned by the municipalities, but there are some state-owned fishing harbours. There are also many private harbours, both large petroleum harbours and supply base harbours for the petroleum activities in the Norwegian economic zone. Pursuant to the 2010 Act relating to harbours and fairways, municipalities have a general administrative responsibility for safety and navigability in the municipality's entire maritime zone, within the area in which the municipality has planning authority. The Norwegian Coastal Administration has a veto right in land-use planning cases within the Norwegian Coastal Administration's area of responsibility. Many municipalities organise harbour operations as intermunicipal companies. Municipalities have overall responsibility for the management and administrative operation of their own harbours (infrastructure, zoning measures, emergency preparedness, etc.).

Regulations and requirements for sea transport must be viewed in the context of the fact that shipping is a global industry with free competition. The regulations and regulatory work are primarily handled through international organisations, primarily the International Maritime Organization (IMO), which is the UN's shipping organisation. The IMO has been established to develop international regulations for safety and environmental considerations for shipping. In the opinion of the Norwegian Maritime Directorate, the IMO's focus on climate change is satisfactory, and the Directorate has stated that it does not see a need for any special national measures beyond this. The IMO is working, for example, on the development of a binding polar code for ship traffic in polar regions based on the voluntary "Guidelines for ships operating in polar waters". The Norwegian Maritime Directorate has a leadership role in this work, which includes safety and environmental aspects. This work is expected to be completed in 2012.

There is increasing transport of crude oil and oil products along the Norwegian coast from north-west Russia. According to the Norwegian Maritime Directorate, the standard of the vessels that transport oil from north-west Russia along the Norwegian coastline is good. This is related, for example, to the stringent requirements for oil tankers that deliver oil to Europe (Bambulyak & Frantzen 2007, NSBR 2009). The quality of foreign vessels that pass along the coast of Norway varies. In the future, the continued safety of vessels, cargo and crew will be dependent on these requirements being reviewed and possibly amended in accordance with changes in the risk picture for navigation in the High North.

The national government's preparedness for acute pollution of the sea and coastline is primarily aimed at preventing and limiting damage as a consequence of incidents and accidents at sea. Evaluation of accidents show that there are defects in the current emergency preparedness scheme. After the loss of the Server on 12 January 2007 (Norconsult 2008), the Norwegian Coastal Administration's handling of the accident was considered satisfactory; however, inadequate administrative routines were identified, and the need to strengthen preparedness related to the limitation of damage in littoral zones was emphasised.

After the Full City ran aground in July 2009, the Intermunicipal Committee against Acute Pollution (IUA) received orders from the Climate and Pollution Agency to amend the non-conformity identified during the inspection and to review its own emergency preparedness plan, as well as routines for updates and training. The Climate and Pollution Agency concluded that the intermunicipal preparedness against acute pollution needed to be strengthened.

Climate change may increase the risk of accidents, and this requires even stricter requirements for the preparedness of both the central government and municipalities, and for clear procedures for the division of responsibility.

Resources

It is a primary objective of the transport policy to ensure that more freight is transferred to sea transport. In the National Transport Plan (NTP) a decision has been adopted to invest around NOK 1 billion annually on infrastructure for harbours and waterways during the period from 2010 to

2019. This is a significant increase compared with the NTP for 2006–2015.

A significant maintenance backlog has been identified at several of the Norwegian Coastal Administration's traffic control centres and in the infrastructure for navigational aid. The maintenance backlog for navigation facilities is estimated at NOK 1.6 billion. Maintenance and replacement of equipment are necessary to maintain high operational safety (NTP). Much of the infrastructure along the coast is damaged and worn. For example, 344 of the 778 breakwaters (507 locations) that the Norwegian Coastal Administration is responsible for, were assessed as damaged in some way. Both the risk of increased damage and the consequences of infrastructure with an unsatisfactory technical condition will probably be greater in a changed climate.

Knowledge base

As for land-based transport, familiarity with changes in climate variables is an important part of the knowledge base for climate change adaptation in sea transport. Improved forecasting of wind conditions, sea levels and storm surges and changes in wave heights require close cooperation with specialist agencies and relevant research environments. Improved knowledge of weather forecasting in the northern maritime areas is also included in this. In addition, there is a need for improved knowledge of environmental risks, such as the effect of increased sea temperatures on the risk of alien organisms spreading to Norwegian waters. There is also a need for new surveys and the updating of maps, especially in the High North, where an increase in shipping and other maritime operations is anticipated.

Priorities

Work on climate change adaptation has not been formalised by the Norwegian Coastal Administration or the Norwegian Maritime Directorate. The Norwegian Coastal Administration's action programme for 2010–2019 includes matters related to securing the infrastructure. Adaptation is mentioned as a goal, but the plans have not been specified. However, in the Norwegian Coastal Administration's appropriation letter there are several assignments that support climate change adaptation. These include improvements to clear the maintenance backlog for infrastructure and navigation facilities.

Climate change is an important part of the technical foundation for updating the management plan for the Barents Sea. This is now being revised and is expected to be completed in 2011.

It is the committee's general impression that there is increasing awareness of climate change, particularly the significance of maintenance. However, the committee finds that adaptation should be given greater priority and be more formalised in this sector.

9.1.2.2 Sea transport in the High North and Arctic

Currently the use of the North-west and North-east Passages is insignificant, but the Arctic ice front is receding to the north and the ice cover is becoming thinner and weaker. Projections indicate that the sea ice in the Arctic Ocean may disappear completely during the summer by the end of this century. This situation will mean ice-free routes in the Arctic Ocean through the North-west and North-east Passages (Buanes et al. 2009a). This creates new opportunities for sea transport in polar waters. This represents a reduction in travelling distance of 40 per cent for ships sailing from Asia to Europe through the North-east passage. The savings in time and fuel represent significant economic value for the shipping industry (Innbjør 2008), at the same time as CO_2 emissions will be reduced. Their proximity to the Arctic will probably be a competitive advantage for Norwegian operators in the industry and may increase the use of harbours in Northern Norway.

Increased maritime activity in the north as a result of less ice in the Arctic, and a possible increase in petroleum activities, will provide the authorities with significant new challenges with regard to safety at sea. This comes in addition to the environmental consequences.

Nevertheless, observations of ice conditions indicate that there is, and will continue to be, a great deal of variation in sea ice from year to year in certain Arctic regions, for example, near the Canadian Archipelago. The scope of these variations is challenging for planning and risk assessments of Arctic sea transport. However, all sea transport through the Arctic must pass through the Bering Strait, which is regarded as a bottleneck (Molenaar and Corell 2009).

There is a general lack of maritime infrastructure (mapping data, navigation facilities, etc.) in the Arctic, with the exception of along the Norwegian coastline and in north-west Russia. This

makes navigation difficult and increases the risk of accidents. Exploiting the opportunities for increased sea transport also requires that harbours and infrastructure are developed in the north. This development will be demanding, and it will be very costly for society.

Challenges related to safety at sea and preparedness are significant in the High North, for instance due to limited and/or insufficient infrastructure, vulnerable natural environments, great distances, special climatic conditions, lack of Arctic expertise and suitable equipment on board vessels.

Open seas during summers could result in a commercial potential for sea transport in the Arctic and near Svalbard. However, this will also entail high risk of destruction of very vulnerable nature. The arctic ecosystems are marginal and very vulnerable. Biological activity is lower in a cold climate than in warmer areas, and the decomposition of pollutants, such as oil, takes significantly longer in the Arctic than in warmer regions. Discharges will therefore be more serious and have more long-term consequences in the Arctic.

A 2009 study of civil protection and preparedness in the High North pointed out that even though the probability of running aground is relatively low, the risk is still regarded as fairly high, as the consequences of an accident would be very serious (NSBR 2009). Exploitation of the opportunities provided by an ice-free Arctic and longer navigable periods around Svalbard can be a dilemma, since climate change will most likely exacerbate the challenges with respect to safety at sea and emergency preparedness in the High North. How well the oil spill preparedness functions will depend, to a great extent, on the weather during a response operation. In the opinion of the Norwegian Coastal Administration, it will be possible to effectively limit damage by oil protection measures around 60 per cent of the time, in view of the weather conditions in the North Sea. Wind and wave statistics for Lofoten and the Barents Sea indicate similar results. This means that changes in the direction of more extreme weather conditions may have a negative impact on oil spill preparedness in Norway (Parliament White Paper No. 14 (2004–2005)).

Activities in and around the Svalbard archipelago have increased, especially along the glacial apron, and they may continue to increase as a result of the area becoming accessible for greater parts of the year. Navigation conditions in the Svalbard region are challenging since weather and ice conditions can change rapidly, there are great variations in depths within a limited area, and there can be significant discrepancies between the actual glacial apron and what is shown on charts. In particular, there is a lack of good sea charts of the coastline that was previously covered in ice.

The Norwegian Maritime Directorate has the legal authority to regulate the cruise ship traffic near Svalbard pursuant to the Ship Safety and Security Act that applies to Svalbard and Jan Mayen. The Directorate does not have the authority to verify whether vessels that pass through the Norwegian economic zone on their way to the Arctic have navigational expertise in these waters. This is referred to as "innocent passage". Nevertheless, the Coast Guard can intervene if there is an indication of an oil discharge, for example.

Increased shipping in the Arctic will increase the demand for vessels with reinforced hulls for icy conditions. This may result in new opportunities for the Norwegian shipyard industry.

9.1.2.3 Adaptive needs

The main topics associated with climate change adaptation for sea transport are improving safety and preparedness and securing the infrastructure. There is a need to reinforce the overall infrastructure for shipping, such as new sea charts, oil spill preparedness and improved harbour facilities. In order to reduce the negative effects of any accidents or discharges, there is need for a better clarification of matters such as maritime law and liability in connection with any accidents and discharges.

Climate change will require better regulated traffic, organisation of alternative shipping routes and marking new waters. Expanding proper berths and emergency ports of refuge will be necessary to improve safety and limit damage at sea.

There is a need to reinforce existing constructions, (lighthouses, markers, breakwaters and quay facilities), and to raise particularly exposed quays due to higher sea levels and the risk of higher extreme waves in some areas. The need for maintenance dredging may increase due to increased erosion and sand movement on the sea floor.

There is a need to reinforce the knowledge base for climate change adaptation for shipping as well. There is a need for better knowledge of changes in sea levels and storm surges, wave heights and wave impacts, and changes in wind

speeds and wind patterns. There is a further need for more knowledge regarding the effects of a warmer climate on the spread of organisms in ballast water and fouling. The current so-called "biogeographical regions", where the probability of the spread of organisms is given based on the existing sailing patterns and temperature regimes, may be changed in the future. New groups of organisms and new biogeographical regions can be expected, and this may result in undesired species spreading to Norwegian waters.

The sea charts for the areas in the High North are inadequate. Improvement of the sea charts around Svalbard has been planned due to the increase in traffic. The melting of land ice will also result in new land areas being exposed. The need for updated maps is increasing. As the ice is gradually receding and constantly uncovering new areas along the coast, it is important that these maps be updated regularly.

International cooperation will be especially important with regard to arctic sea charts. Cooperation with Russia and other Arctic states must be continued and strengthened. This is discussed in greater detail in Chapter 11.3, International affairs.

9.1.3 Aviation

All Norwegian airports will be affected by climate change, but to varying degrees and in different ways. Climate affects both air traffic and the physical infrastructure.

Many Norwegian airports are located near the coast on flat or reclaimed land near the sea or open water. Twenty airports are just 3 to 15 metres above sea level, making them vulnerable to impacts from higher sea levels and large waves. Safety zones and lighting facilities at several airports could be exposed to erosion, but the airports' infrastructure can also be vulnerable as a result of climate change. Therefore, wave and erosion protection for safety zones at airports near the sea is a major resource-intensive challenge. Rocks that are washed up onto runways may also pose a problem.

However, the committee believes that Norwegian aviation has an orderly and well-organised management system with clear distribution of responsibilities. Airspace and runways are continuously monitored from traffic control towers and by means of friction measurements. The risk to life and health due to changed climatic conditions is, therefore, regarded as limited. Airports may be closed for shorter or longer periods of time if weather and snow conditions threaten safety.

The high degree of risk aversion in aviation also reduces vulnerability in this sector. The committee's impression is that climate change adaptation has high priority, and that the sector has adequate resources for handling the challenges.

9.1.3.1 Vulnerability to climate change

How will aviation be impacted by climate change?

Climate change will result in a number of challenges for aviation related to both airports and air traffic. Wet runways reduce the braking effect, and increased precipitation can make it more important and more demanding to drain runoff water.

More frequent temperature variations around 0 ^{o} C will be an additional challenge in some places as regards controlling the friction conditions on runways. Increased precipitation in the form of snow in the first half of this century will place higher demands on winter maintenance and ploughing, and it may disrupt traffic while runways are being cleared. Higher winter temperatures may result in more problematic snow conditions at airports in the north and at higher elevations. For airports in areas that may receive less snow in the future, the need for winter maintenance will be reduced correspondingly. The Svalbard airport is constructed on permafrost. Melting of this permafrost would undermine the stability of the ground.

Changes in wind speed and direction, turbulence and possibly more frequent episodes of extreme low-pressure systems will affect air traffic.

Adaptive capacity

Organisation

The Ministry of Transport and Communications is responsible for the framework conditions for aviation in Norway and administers the Civil Aviation Act. The Civil Aviation Authority is an independent administrative agency under the Ministry of Transport and Communications, and is the authority responsible for Norwegian civil aviation. The Civil Aviation Authority ensures that the parties in Norwegian civil aviation comply with the Civil Aviation Act. The Regulations for Civilian Aviation (BSL) are a series of regulations pursuant to the Civil Aviation Act. These regulations include requirements for the operation, design and management of the physical infrastructure. The Civil Aviation Authority

issues rules, performs access control and supervises airlines, workshops, flight schools, aircraft, licence holders and airports.

Established in 2003, Avinor is a wholly state-owned limited company, and ownership of the company is managed by the Ministry of Transport and Communications. The company was formerly a public enterprise called the Norwegian Civil Aviation Administration. The company is responsible for planning, developing and operating the Norwegian airport network. Avinor is also responsible for aviation safety and aviation navigation services in Norwegian airspace.

The National Transport Plan (NTP) is a fundamental strategy document for Avinor.

Other strategically important documents for Avinor's operations include the Strategy Plan and the Activity Plan 2010–2013 ("§"10 plan"), which covers adaptation to climate change.

According to figures from the Civil Aviation Authority, more than 30 companies have an approved licence and/or permit to operate commercial air transport of passengers and goods, or other aviation activities (aerial photography, flight training, etc.). In addition to Avinor's airports, there are four private airports with regular traffic. The Norwegian Armed Forces are responsible for substantial aircraft and helicopter traffic, and there are also a number of aviation clubs and privately operated aircraft.

Resources

For Avinor climate change adaptation is not a separately defined focus area, and the costs associated with adaptation measures are not specifically calculated. Projections of the climatic conditions are nevertheless included as part of all the activities. For example, climate change projections are taken into consideration when assessing the required dimensions of new lighting facilities or safety zones surrounding runways (S&L project). The need for additional similar projects is being discussed. Any such projects will include climate projections.

Avinor states that reduced punctuality and regularity due to poor visibility during the period leading up to 2100 may be mitigated by the development and deployment of new technology. Several of these measures have already been implemented. For example, several comprehensive projects have been carried out to improve work processes related to the measurement and notification of runway conditions. In addition, there is continuous research on navigation and approach technology. A new internet-based wind shear and turbulence warning system that provides light aircraft and helicopter pilots with access to detailed meteorological information via Avinor's website has been implemented. Scheduled traffic also has access to meteorological data through e.g. NAIS (Norwegian Aeronautical Information System).

In the safety zone and lighting installation project (S&L project), Avinor concludes that a small amount of wave erosion damage in the safety areas surrounding runways can be accepted. Initial investments will be formulated so that they take climate change into consideration, but as long as it does not interfere with safety, punctuality or regularity, they will be kept at a reasonable level.

The committee finds that the Norwegian aviation sector has the resources required to handle climate change adaptation.

Knowledge base

The ability to make good decisions in connection with new buildings, repairs and renovations can be improved by better data and more precise climate models. There is a particular need for more knowledge on any changes in the wind conditions and criteria to determine the capacity of wave energy when designing airports using land reclaimed from the sea. Increased knowledge in these areas is essential since a small change in the climate assumptions may have a substantial impact on the project costs.

Priorities

A high degree of risk aversion reduces the sector's vulnerability. The committee is of the impression that adaptation is given high priority.

9.1.3.2 Adaptive needs

A more varied climate will pose greater challenges for aviation. The industry needs to maintain safety, punctuality and preparedness under changed climate conditions, especially with regard to drainage and friction on the runways. Improved knowledge is required in order to ensure the optimal, cost-effective prioritisation of investments in preventive measures against climate-related damage, such as in connection with wave erosion.

Climate change will also increase the need to develop equipment, procedures and regulations.

- While aviation does not have the same maintenance backlog as other infrastructure, it is

important to limit damage and prioritise maintenance. As the owner, Avinor finds that the craftsmanship of building and construction work may be deficient. This indicates a need to strengthen professional training, increase the expertise requirements for contractors and/or stricter requirements for the owner's follow-up.

9.1.4 Socio-economic costs for the transport sector

Climate change may result in some financial savings for the road sector, but additional and new costs may arise at the same time. Overall, less snow and higher temperatures may yield lower costs. At the same time more precipitation and more frequent lashing rain may result in increased expenditure as a result of increased rock fall frequency, weathering of surfaces, and increased operating and maintenance costs related to the drainage of floodwater. The annual operating and maintenance costs will likely increase in some parts of the country and be reduced in others. When assessing the scope of the financial costs, it should also be considered that the standards of new roads will be improved over time. With better road standards, climate change will do less damage, and the economic costs of climate change in the sector will be lower than they would have been.

Based on this, Vista Analyse (2010) has estimated that the operating and maintenance costs in the road sector will provide at best, national annual savings of around NOK 150 million in the second half of the century. In the worst case scenario, there may be an increase of NOK 500 million annually.

More frequent episodes of extreme weather may result in more damage of a more serious nature. The estimates are sensitive to the assumed frequency of these types of episodes. The greatest costs in the transport sector as a result of climate change will likely be related to the loss of regularity, less predictable traffic and delays in the transport system. An important initial research task will therefore be to develop methods to improve the estimates for these variables, and thereafter the associated costs.

Similar to the road sector, the railway sector in Norway has increased its investments in slide protection and measures to reduce the risk of landslides and avalanches. The railway sector is characterised by a significant maintenance backlog and capacity problems in key regions. Without improvements, even fairly moderate changes in the climate conditions (cold, temperature variations, driving rain, and snow) will result in more disruptions and/or reduced navigability. This has a significant impact on the costs incurred by passengers. Additional costs for operations and infrastructure as a result of climate change are expected to be around NOK 0–100 million per year towards the end of the century.

Climate change will result in financial savings for shipping due to less ice, and increased costs if wave heights and winds increase. Harbours and breakwaters will incur costs related to rising sea levels. However, the sea will rise so slowly this century that the harbours will probably be able to adapt to the changes in the sea level as part of the normal renewal and maintenance procedures in the sector. The repetition interval for incidents with a potentially damaging effect is expected to decline. This will result in more frequent episodes in which damage costs are incurred, but Vista Analyse (2010) finds that they will be limited to less than NOK 10 million per year on average. It is anticipated that reduced regularity will also be the greatest cost here. Value creation in the industry may increase due to the potentially shorter transport time to East Asia in the summer. It may also lead to a greater demand for harbours and harbour services in the northern regions. This effect is not stipulated.

Aviation has dimensioned the safety zones for the expected climate change based on a repetition interval of 20–50 years. From 2050 and beyond, certain airports may experience more frequent splashing from waves as a result of rising sea levels. According to Vista Analyse (2010) the costs may be high, but they have not been calculated, because the future airport pattern is not known. Furthermore, the costs associated with disruptions and reduced regularity as a result of climate-related closures are expected to be the most significant. For example, the closure of Arlanda airport in Stockholm, Sweden, for one day has been calculated to result in a cost of SEK 150 million. However, with our current knowledge, there is no basis for estimating the future frequency of airport closures as a result of climate change.

9.1.5 The committee's recommendations

In order to improve adaptation in the transport sectors, the committee recommends:

Securing the transport infrastructure

- Integrate climate considerations into all planning processes, reports and analyses of the transport system.

- Conduct surveys and labelling of vulnerability for particularly vulnerable assets or stretches relative to various types of events.
- Maintain a strong effort to protect roads and railways against landslides and avalanches, and include considerations regarding climate change and the efforts to develop the National Database for Landslides and Avalanches.

Improving management regimes

- Make adaptation a management responsibility in the sector's management structures.
- Review and revise the current regulations, follow up amendments with courses and information. Give priority to the development of recommended road standards for municipal roads.
- Review function contracts and contract forms and develop methodologies for service life assessments and cost–benefit analyses.

Resource management

- Give priority to clearing the maintenance backlog and improving the ongoing maintenance.
- Integrate climate change considerations into existing plans for inspection, maintenance and renovation.
- Develop better analytical methods for including future maintenance costs in the basis for the decision.

Improving emergency preparedness

- Improve and develop the work on proactive emergency preparedness systems with emphasis on adaptation to weather conditions and weather-related events on the road and rail networks, including increased use of weather prognoses and systems for transport information.
- Safeguarding ship traffic by improving traffic monitoring and control. Develop a better basis for reducing acute accidents by improving anchorages, ship grounding sites and places of refuge.

Improve the knowledge base and the dissemination of knowledge

- Assess and, if necessary, supplement the current system for measurement of important climate variables, cf. Chapter 16.3, and improve the coordination of existing databases.
- Develop the knowledge base by improving the documentation of adverse events related to weather conditions.
- Continue the cooperation among government transport agencies, the Norwegian Water Resources and Energy Directorate (NVE) and other organisations on online map databases for data on weather and weather-related events in the transport network.
- With a special focus on the High North, improve maritime monitoring, develop the system for automatic identification (the AIS system) and improve the system for data exchange and integration.

Special measures for shipping in the High North:

- Give special emphasis to developing regulations, monitoring and control systems, and expertise in mastering the special challenges that derive from an increase of ship traffic in the Arctic Ocean.
- Meet requirements as a result of increased maritime activities in the High North by giving harbours, rescue services and emergency preparedness in northern Norway special priority.
- Attach great importance to developing cooperative relations and cooperation forums with Russia and other nations that have interests in the Arctic.

9.2 Water supply and sewerage services

Climate change will increase the risk of disruptions in the water supply and sewerage services. A disruption in the water supply will quickly affect private households and the business community, and a disruption of sewerage processing can have serious consequences for health and the environment. It is therefore essential for the entire community that the water supply and sewerage sector adapts to climate change.

The water supply and sewerage sector currently has a significant maintenance backlog, creating an adaptation deficiency. Fragmented areas of responsibilities, lack of resources and prioritisation entail that this sector is the infrastructure sector that has been evaluated as most vulnerable to climate change.

The adaptive capacity of the water supply and sewerage sector can be enhanced by amendments to the legislation and review of the economic framework conditions. Measures to improve the handling of stormwater runoff are also of key importance.

9.2.1 Vulnerability to climate change

9.2.1.1 How are water supply and sewage impacted by the climate?

Around 2 600 municipal or intermunicipally-owned sewerage works handle sewage from 83 per cent of the population, while the remaining 17 per cent have their own sewerage works or share small private solutions (SSB 2008).

About 1 600 waterworks supply water to 90 per cent of the population, while the remaining 10 per cent have their own wells or small shared installations. Of these waterworks, around 1 000 are either municipally or intermunicipally-owned, about 500 are private waterworks and around 100 are waterworks for holiday homes. As much as 90 per cent of the water supply comes from surface water sources, while 10 per cent comes from groundwater sources (Norwegian Institute of Public Health 2008). As much as 41 per cent of the water production from municipal waterworks goes to households, 26 per cent goes to industry and agriculture, while 33 per cent is lost due to leaks in the distribution system (SSB 2008).

The water supply and sewerage infrastructure can be broken down as illustrated in Figure 9.1:

- water source (groundwater or surface water) and associated catchment area
- water treatment plant
- water distribution system (pipe networks, tunnels, elevated tanks, pumping stations)
- sewage transport system (pipe networks, tunnels, pumping stations)
- sewage treatment plant, including sludge treatment plant
- recipient of treated sewage

The figure shows how the water supply and sewerage infrastructure is connected to the natural environment through the use of natural resources and the return of treated sewage water to recipients, and that the infrastructure is of vital importance to critical social functions.

In times of heavy precipitation or flood situations, the distribution network for drinking water may be exposed to increased risk of contamination, as pipes and cisterns may be submerged. If there are any vulnerable areas in the distribution system, such as leakage points on pipes or leaky ventilation valves in cisterns, polluted water can penetrate the water supply system if the water pressure inside the pipes is reduced; for example in connection with repair work. There may also be a problem of fouling inside the distribution network as a result of more organic material in the water sources.

The pipeline network for stormwater runoff and shared pipes for sewage and stormwater are designed on the basis of knowledge about the precipitation conditions at the point in time when they were designed. However, several municipalities and water supply and sewerage works now experience problems related to more frequent cases of flood damage, water damage and sewage back-up in buildings as a result of intense precipitation situations. This may be caused by underdimensioning, increased urbanisation which in turn results in an overload of the sewerage system, or frequent and extreme precipitation periods. An increase has also been observed in problems linked to poor quality of the untreated water in the drinking water sources as a result of increased temperatures, precipitation and runoff. This illustrates that the water supply and sewerage sector are currently not adequately adapted to climatic conditions.

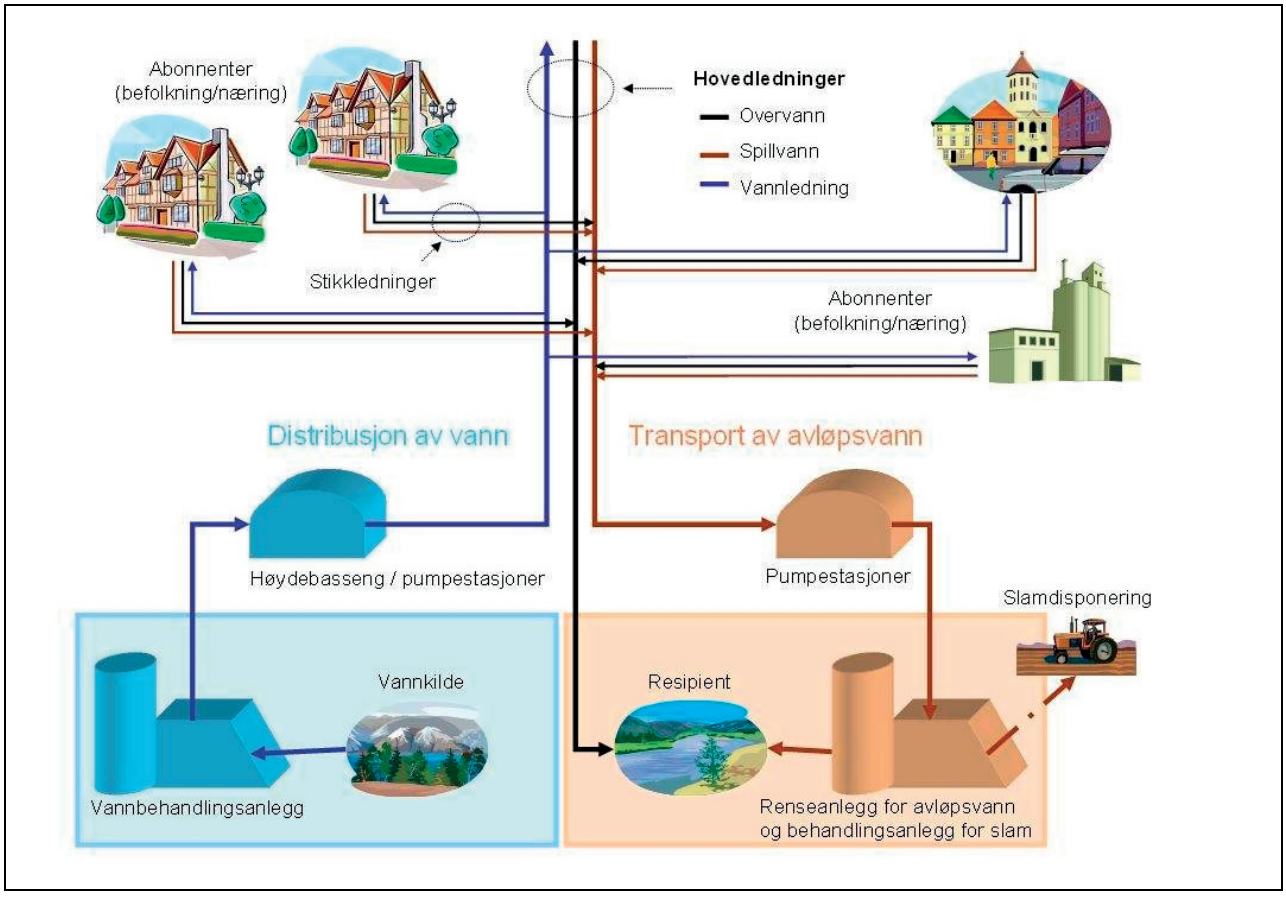
The traditional method for handling stormwater runoff is to drain it through the sewerage system. This is an efficient way to drain water, but it can result in a great strain on drain pipes and treatment plants during periods of heavy precipitation. Stormwater is seldom so polluted that comprehensive treatment is required, as is the case for traditional sewage. Large quantities of stormwater in the sewerage network therefore entail that large quantities of unnecessary water pass through the treatment plants.

The sector also faces challenges related to a low rate of renewal and a maintenance backlog for the infrastructure. The renewal rate for sewerage pipes in Norway was 0.45 per cent annually in 2008 (SBB 2008). This means that it will take over 200 years to renew all the sewerage pipes. At the same time, the quality of many pipes is such that they should be replaced sooner, some of them after only 20–30 years (RIF 2010).

9.2.1.2 How will water supply and sewerage be impacted by climate change?

Climate change will affect snow conditions, runoff, flood conditions, erosion and landslides and avalanches. This will add to the challenges that the water supply and sewerage sector are currently facing, as well as pose new challenges. Many water supply and sewerage plants are located in or near watercourses and coasts, and they will also be exposed to floods, flood slides, rising sea levels and spring tides (Harvold et al. 2010).

Sewerage works must in general handle large amounts of water, and in flood situations, pumping stations, water treatment plants and sewage treat-



Figur 9.1 Schematic diagram of the water supply and sewage infrastructure (Norwegian Water)

ment plants could be disrupted. Similarly, rising sea levels and higher spring tides will have a negative impact on water supply and the sewerage infrastructure along the coast. An increasingly unstable climate with more extreme conditions may also cause problems such as water shortages and frost damage to the infrastructure as a result of drought or long-term ground frost. A greater number of freeze/thaw periods with associated ground frost movements in areas where this currently does not occur may also result in more pipe ruptures.

Higher temperatures, combined with greater precipitation intensity and runoff may have negative effects on drinking water quality. More erosion and runoff from areas around the water sources may, depending on the area type and activities around the water sources, lead to an increased prevalence of infectious matter, environmental toxins, nutrients and organic matter in the water. In Eastern Norway there have been observations of bacterial growth that may be cause for concern. More nutrients in water sources may also increase the risk of toxic algae blooms (cyanobacteria); see 8.1, Health, for more details.

There is already a risk that drinking water may be contaminated when distributed, for example, because drinking water and sewerage pipes share the same trench for practical and economic reasons. Contamination may be transmitted from a leak in a sewerage pipe into a leaky drinking water pipe if the water pressure is reduced during repair work, for example. Increased precipitation will also increase the risk of drinking water pipes becoming immersed in sewage-contaminated water.

Increased precipitation volumes and intensity will create problems for drainage systems that are not adequately designed for larger volumes of water. Greater quantities of water may also lead to more damaging incidents with sewage back-up in buildings and basements, which is already a large problem in several municipalities. Increased discharge of contaminated sewage through overflow and leakage points in the sewerage network may result in contamination of the local environment and water sources. In addition, it may result in an increased risk of contamination entering drinking water pipes. The distribution network's limited capacity for stormwater runoff may also lead to a worsening of the flood situation in densely populated areas. The situation may be particularly challenging in the event of extreme amounts of precipitation combined with rapid snow melt.

Increasing urbanisation, with a significant increase in impervious surfaces, dramatically changes stormwater runoff patterns. Watercourses and areas that previously absorbed stormwater have, in many cases, been sealed off. Therefore, most cities in Norway will face even greater challenges in handling stormwater in a changing climate.

The mitigation of peak storm runoff in connection with new buildings and planning, requires that provisions are made for the removal of as much stormwater runoff as possible from the pipe network, retaining water on surfaces or leading it down into the ground, i.e. primarily leading it to places other than drains (through infiltration, vegetation, open water routes, etc.). The strain on the public pipeline network and the risk of flood damage may be reduced by handling stormwater locally through infiltration on the surface where precipitation falls or by delaying the runoff in reservoirs. Open storm drainage is also effective. This is a surface runoff system in which stormwater can be drained away without causing unacceptable damage if the pipeline network is overloaded, clogged or damaged.

Calculations made by the Climate and Pollution Agency (Klif) show that without compensating measures, the amount of contamination from the pipe network and treatment plants and flood damage in densely populated areas could increase (Norwegian Pollution Control Authority (SFT) 2008). This could result in various forms of environmental damage, such as significant increases in contaminated discharges from overflow, treatment plants and stormwater, flooding of basements and building areas below ground level, aesthetic losses and environmental damage to watercourses in towns, in addition to increasing the risk of disease transmitted by drinking water.

9.2.1.3 Adaptive capacity

Organisation

Most water supply and sewerage systems are owned by the municipalities or municipally owned companies. These services are included as part of the municipal services. Municipalities are responsible for 41 000 km of water supply pipes, 35 000 km of sewerage pipes, including shared pipes for stormwater runoff and sewerage, and 17 000 km of pipes for stormwater runoff for the distribution of water and transport of sewage (SSB 2008). In addition, there is the private network of supply pipes to and from buildings and the pipeline network for shared waterworks and small shared solutions. The stipulated buyback value of the water supply and sewerage infrastructure exceeds NOK 500 billion, and the pipeline network represents the largest share of this (Norwegian Water 2003).

Responsibility for the water supply and sewerage system is fragmented at the national level. Several ministries and the underlying directorates are responsible for regulations related to water supply and sewerage. The Ministry of Health and Care Services is responsible for the quality of drinking water through agency management of the Norwegian Food Safety Authority, the Ministry of Petroleum and Energy is responsible for the regulations relating to the exploitation of water resources, the Ministry of Local Government and Regional Development is responsible for the supply regulations and certain functional requirements for the operation of pipe networks, and the Ministry of the Environment is responsible for the discharge requirements for sewerage works and for the regulation of water and sewerage fees.

Requirements and regulations

In some areas no national authority has been assigned responsibility. This applies, for example, to the handling of stormwater runoff. In addition, there are certain conditions in the water supply and sewerage sector that are not currently regulated, such as what obligations and rights apply to the relationship between the municipalities/water supply and sewerage operations and their customers. Damage due to backwash from public sewerage networks is currently a matter between the municipalities and the insurance companies. Insurance companies demand reimbursement (recourse) from the municipality after payments are made for damage for which the municipality is liable. Many municipalities have liability limits in the terms and conditions that they stipulate for inhabitants. To what extent the municipalities can disclaim liability pursuant to the law has been tried in court (see e.g. Rt. 2007/431). The municipalities have been partially successful with their case. 2007-03-19. Rt. 2007 431. Norwegian Supreme Court – Decision (see box).

The example from the case involving the City of Stavanger indicates that there is a need for clarification of the liability of the municipalities and customers when faced with extreme weather events as a result, for example, of climate change. Municipalities are currently entitled to include a clause in contracts limiting their liability in the event of sewage back-up caused by special (weather) conditions.

Box 9.3 "The Stavanger Decision"

The case concerns a compensation claim pursuant to Section 24a of the Pollution Control Act for water damage to a residence following backwash from a municipal sewerage pipe. The reason for the backwash was that the sewerage pipe was not designed to handle the amount of rainwater that was generated by a downpour in Stavanger in the summer of 2003.

The municipality of Stavanger had included a provision in its terms and conditions for connection to the municipal water supply and sewerage network that the municipality is not liable for flooding following precipitation that exceeds the premises that were made at the time when the municipal sewerage pipes were designed. The main question to be considered by the Supreme Court was whether this liability waiver entailed that the municipality was without liability.

The Supreme Court decided that the reservation made in the terms and conditions for connecting to the water supply and sewerage network meant that the municipality was indemnified. The Court emphasised that the preparatory works for Section 24a of the Pollution Control Act indicate that the regulations were not absolute and that the homeowner, like other homeowners in Stavanger, must have been aware of the fact that there were municipal regulations for connection to and use of the public sewerage works. In addition, the limitation of liability in question could not be regarded as unreasonable pursuant to Section 36 of the Contracts Act. The Supreme Court stressed that each individual customer had the opportunity to obtain insurance coverage and to take precautions to prevent, or limit, damage.

At present there are no specific capacity design requirements for sewerage and stormwater pipes, but the association Norwegian Water (Norwegian Water 2008) has recommended minimum design return intervals for separate and shared sewerage systems. It is, however, up to each municipality to decide what extreme amounts of precipitation they should design for in each new development or improvement of the existing network; in other words, what risk is acceptable.

The climate change adaptation guides for sewerage works from the Norwegian Pollution Control Authority (2007) and Norwegian Water (2008) refer to the fact that other countries have introduced national recommendations for the design of sewerage works for a future climate. Even though it is difficult to transfer these forecasts to Norwegian conditions, as we must use the anticipated increase in extreme precipitation here, they may be of some value for Norway. For example, in Denmark the capacity design criteria are based on the current climate multiplied by a factor of 1.2 to 1.5 to account for climate change. The Norwegian Meteorological Institute is the professional body that the municipalities can contact if they require advice concerning extreme precipitation. The adaptation guides also recommend that the rising sea levels and storm surge changes be considered in planning work.

Treatment requirements are stipulated pursuant to the Pollution Control Act and the Pollution Regulations, and they vary according to the size of the discharge and conditions where the treated sewage is discharged. The pollution authority for sewerage is divided between the central government and the municipalities, where the county governor is responsible for around 400 large sewerage works in Norway, and the municipalities are responsible for around 2 500 other sewerage works for smaller, densely populated areas.

The quality requirements for drinking water are regulated through the Drinking Water Regulations. There are also a number of other statutes and regulations that regulate water supply services, including regulations related to the consumption of water, emergency preparedness, dam protection, fire water supply, etc.

Work pursuant to the European Union's Water Directive, which Norway has implemented through the Water Regulations, should ensure comprehensive water resource management through common environmental goals for water resources, which in turn ensure good water quality. The management plans prepared by the county authorities through the water area committees will have a significant impact on what measures will be required in the water supply and sewerage area in the years to come.

The Planning and Building Act stipulates that water supply and removal of sewage must be secured before a property or building can be used. Furthermore, parties have an obligation to connect to the public water supply and sewerage network if there are pipes in the vicinity of the pro-

perty. Similar requirements for existing housing are not possible.

The Technical Building Regulations pursuant to the Planning and Building Act contain functional requirements for the design of the private part of the water supply and sewerage pipelines (supply pipes etc.) in order to ensure that large amounts of water from heavy precipitation are taken into consideration. There is a requirement that stormwater should be infiltrated or handled locally to the greatest possible extent in order to ensure the water balance in the area and to avoid overloading the sewerage works. Other requirements regarding both private and public sewerage networks are stipulated in the Pollution Regulations.

Municipalities can fund water supply and sewerage services by collecting fees from customers, cf. the Act relating to municipal water supply and sewerage fees. The fees must not exceed the necessary costs the municipality incurs in this area (at cost). Many municipalities have their own service terms and conditions for water supply and sewerage with a limited municipal liability in connection with delivery of the services. These are private agreements between the municipality and the customers.

Municipalities do not have a direct legal responsibility to supply water to their inhabitants. However, they do have a general responsibility to ensure sanitary conditions in the municipality through the Municipal Health Services Act and the Environmental Health Protection Regulations (Harvold et al. 2010) and certain provisions in the Fire Safety Act and the associated Fire Water Supply Regulations. Municipalities do not have a legal obligation to provide sewerage services to their inhabitants either. However, the building, operation and maintenance of sewerage works have traditionally been regarded as municipal tasks.

The Planning and Building Act grants the legal authority to regulate areas as special buffer zones. In the municipal land-use plans, open storm drainage can also be included as buffer zones, and supplementary land-use regulations may be established for these zones.

Resources

The water supply and sewerage sector has a costly infrastructure that needs to be planned for the longest possible service life. For example, it is suggested that pipeline facilities should have a service life of at least 100 years. This creates special challenges in a situation with uncertain climate projections.

Funding is a key challenge for work on adaptation in the water supply and sewerage sector. Measures for more advanced water treatment, protection of flood-prone facilities and facilities that are affected by rising sea levels, local handling of stormwater runoff and conversion from shared pipes to separate pipes will be costly. The water supply and sewerage sector is a so-called self-cost industry, where the services are funded primarily through the water and sewerage fees that are collected from customers pursuant to the Act relating to municipal water supply and sewerage fees from 1974 and supplementary provisions in the Pollution Regulations. This gives municipalities the opportunity to collect fees to make the necessary investments and to operate and maintain the municipal water supply and sewerage works. The owner of the water supply and sewerage facility, which is the municipal council for the municipal installations, annually stipulates the size of the fees.

Only measures that are necessary for performing water supply and sewerage services can currently be funded by the water supply and sewerage fees. This limitation means that only the costs that are normally associated, directly or indirectly, with responsible commercial operation of the water supply and sewerage sector can be included in the basis for the fee. The distinction must be made on a discretionary basis. Replacing sewerage pipes and the development of treatment plants, etc., are core activities that are clearly included here. The challenge is to make a distinction between measures to deal with stormwater runoff that are necessary out of consideration for the water supply and sewerage services and other measures to deal with stormwater runoff in the municipality.

Many municipalities have made efforts to keep the fees at the lowest possible level, and this has resulted in a renewal rate that has been too low for the existing infrastructure. In 2009, the average household paid a total of NOK 5 500 for water supply and sewerage services (SSB 2008). There will be a need to clarify what can be funded by this fee scheme.

The water supply and sewerage sector is facing major challenges with respect to recruiting and retaining personnel with water supply and sewerage expertise. Studies of pension cohorts compared with the number of new graduates shows that over the next 5–10 years we may see the number of engineers with water supply and sewerage expertise in Norway halved (Lindholm and Moen 2006). The recruitment challenges are

Box 9.4 Box Climate change adaptation for water supply and sewerage and treatment of stormwater runoff in the City of Oslo

The main challenges facing the Agency for Water and Sewerage Works (VAV) are related to climate change and escalation of the current challenges. Climate change emphasises the need to establish general stormwater strategies in Oslo since these are inter-agency challenges that require inter-agency cooperation. Such a general plan must include facilities for open solutions and local infiltration, plans for open storm drainage and how to avoid too many impervious surfaces. The VAV has a current master plan for sewerage that runs from 2000 to 2015. The plan does not discuss climate change to any great extent. A revision of the *Master plan for sewerage,* including the climate change challenges, is planned for the early autumn of 2010.

Climate change is particularly important with regard to stormwater runoff. VAV currently requires that all developers handle stormwater locally. If infiltration is not possible, it is only permissible to release a limited amount into the public pipe network. The remainder must be delayed on the developer's property. By reducing the amount of stormwater that enters the public pipe network, the flow in the pipe network is reduced and delayed during heavy precipitation.

The Agency for Water and Sewerage Works' (VAV's) pipes were designed to last +/- 100 years. When designing the dimensions of these pipes, the climate and runoff patterns for this period must be taken into account. With regard to the capacity design rules, VAV uses Norwegian Water's recommended return interval as described in the guide for climate-adapted handling of surface runoff. VAV also uses updated IDF curves and flood frequency analysis to find the return intervals for floods and flooding. "Known" problem areas are modelled, and measures are proposed; for example, for areas with frequent basement flooding. VAV has not yet changed its design practices regarding extreme precipitation, and clear advice regarding expected future changes in extreme precipitation is needed. There is a particular need for precipitation projections with a short-term temporal resolution.

Water supply and sewerage measures that are relevant in the City of Oslo include re-opening of streams, cisterns that retain stormwater runoff and runoff from shared systems, separation of sewerage and stormwater runoff and increasing the dimensions of sewerage pipes.

Inter-agency challenges in Oslo include preparation of open storm drainage in urban areas, avoiding impervious areas and green roofs.

Intermunicipal and international projects are important for local efforts

Oslo participates in the "Cities of the Future" project, in which climate change adaptation is one of the main topics. "Prepared" is a European Union project on water supply and sewerage challenges and climate change, where Oslo is one of 14 participating cities, in addition to 21 research partners. "Skint" is an interregional project in which, for example, the Norwegian Institute for Water Research (NIVA) and the Geological Survey of Norway (NGU) participate. The project links groundwater, stormwater runoff and archaeology in cities with a mediaeval heritage in the planning phase for new developments. A national guide on how to handle groundwater and stormwater in city areas with cultural heritage assets is to be prepared as part of this project.

The purpose of the "Midgardsormen" project is to install a new sewerage system in the central parts of Oslo.The "Midgardsormen" project has been established to meet the requirements for the urban development in Bjørvika, and it will address the environmental challenges in the Bjørvika area today and in the future. "Midgardsormen" will be one of the city's most important and extensive environmental measures.

"Strategy 2010", a project by the Water Supply and Sewerage Council in cooperation with the Inner Oslo Fjord region, involves water supply and sewerage cooperation among ten municipalities in the Inner Oslo Fjord and focuses on improving the water quality in the fjord. "Strategy 2010" focuses on climate change, population trends and measures to ensure good sewage transport and management.

There is an urgent need for increased monitoring of short-term precipitation. As a basis for design criteria, for example intensity-duration-frequency curves (IDF curves), historical time series of short-term precipitation are used. The uncertainty in the calculations is reduced as the number and length of such time series increases. In addition, there is a need for knowledge about the effect of climate change on extreme precipitation in Norway. This information will help create a basis for climate-adapted handling of stormwater runoff. There is also need for more knowledge regarding measures and technical solutions that can prevent the damaging effects of climate change.

present regardless of climate change, but adequately qualified personnel are an absolute requirement for successful adaptation.

Maintenance backlog

The sector faces challenges related to a low renewal rate and a maintenance backlog for the infrastructure (RIF 2010). The renewal rate for sewerage pipes in Norway was 0.45 per cent annually in 2008 (SSB 2008). This means that it will take more than 200 years to renew all the sewerage pipes.

Knowledge base

In addition, climate change will also require the establishment of research-based knowledge for the development of models to determine the correlation between climate change and the development of chemical and microbiological water quality in Norwegian drinking water sources. There is also a need for water treatment methods to handle rapid fluctuations in water quality and new types of contaminants in water sources.

In many municipalities there is a need to survey the water supply and sewerage networks and determine which parts are vulnerable to climate change. There is also a need to develop better monitoring and management technology for water supply and sewerage works and methods to protect the existing water supply and sewerage infrastructure against floods and rising sea levels. Norway has no good national overview of pipeline networks, and there are no national, common data models.

In addition, there is a need for knowledge on the effects of rising sea levels on the water supply and sewerage networks.

Norwegian Water (2010) stresses that much of the new knowledge on climate change adaptation in the water supply and sewerage sector has been generated in recent years, and that many activities are being carried out. It is a major challenge for the municipalities to assimilate this new knowledge. Increased cooperation between different agencies in the municipalities is necessary, and there is a need for a forum to exchange knowledge in general, which can be used as a basis for comprehensive climate change adaptation.

Priorities

The climate projections in Section II indicate that climate change may have consequences for all the water supply and sewerage works in Norway. Municipalities and other owners of water supply and sewerage works in Norway must implement adaptation measures in the coming years, and the adaptation efforts will continue for a long time. Climate change may impair the adaptive capacity, since many municipalities will have to give priority to repairs following heavy precipitation incidents or floods rather than to systematic prevention and renewal.

Some municipalities and water supply and sewerage works that have faced the greatest climate-related challenges so far have implemented measures to meet known challenges. Bergen and other participants in the "Cities of the Future" project are an example of municipalities that have started adaptation efforts in a number of areas in the water supply and sewerage sector. However, this is not the case for the majority of Norwegian municipalities and water supply and sewerage works.

Box 9.5 Cost calculations for adaptation in the water supply and sewage sector in Sweden

In Sweden cost assessments have been made in the background reports used in the compilation of "SOU 2007:60 Consequences of climate change and extreme weather events".

These calculations indicate investment requirements for water supply adaptation measures of at least SEK 4.25 billion during the period 2011–2040, but it is emphasised that it is likely that the actual costs will be higher. In addition, there are higher operating costs and costs related to measures in sparsely populated areas (SOU 2007:60).

In the sewerage area, Sweden estimates that an additional investment of SEK 10–20 billion is required for the sewerage network over the next 25 year period as a result of heavy precipitation. The general renewal requirement for the sewerage network during the same period is SEK 50 billion. In addition, there are costs related to investments that private homeowners must make, as well as costs attributed to rising sea levels and other climate effects in the sewerage sector (SOU 2007:60).

9.2.2 Economic consequences

Climate change will increase the need for maintenance and renewal of the water supply and sewerage infrastructure.

Table 9.1, provided by Vista Analyse (2010), provides a summary of the socio-economic costs and savings as a result of climate change in the water supply and sewerage sector.

Based on the table and analysis in this chapter, it can be concluded that despite a reduction in the maintenance backlog in the sewerage system, the sewerage and drainage systems will most likely not be adapted to cope with the precipitation volumes and precipitation patterns towards the end of

Table 9.1 Socio-economic costs and savings as a result of climate change in the water supply and sewerage sector (Vista Analyse 2010)

	Adaptation measures	Unsolved problems	Socio-economic costs
Water supply	Increased requirements for treatment plants through statutes and regulations. Costs will be transferred to the user. Water quality and supply reliability are taken into account.	Leaks from pipeline networks diminish the capacity of the sewerage system and the associated treatment plants. Increased risk of contaminant penetration in water pipes as a result of contaminated water in trenches.	Health – insignificant, but users may experience periods with reduced drinking water quality. Increased costs for the sewerage network – not calculated. Dependent on the existing capacity of the sewerage system and the degree of leakage in the water supply.
Sewerage	New facilities will be designed in accordance with the expected increase in precipitation. Some of the current backlog will be eliminated. Environmental considerations with respect to discharges will be taken into account by the pollution authorities – costs in connection with the improvement of sewerage works.	Maintenance backlogs result in an increased risk of structural damage when the precipitation exceeds the limits that parts of the sewerage system have been designed for.	External effect on buildings as a result of increased groundwater levels and the penetration of water, as well as sewerage backwash. Insurance payments, difference between 2008 and 2007, multiplied by the expected increase in real capital throughout the century, a total of around NOK 0.5 billion.
Stormwater runoff – drainage	New facilities will be dimensioned and designed for future climate change. The current backlog and defects in parts of the sewerage systems will continue.	Increased risk of local flooding and the associated damage as a result of inadequate drainage. Increased risk of damage to buildings and other infrastructure.	Shorter periods between floods and flooding with cost consequences. Costs for transport infrastructure and other traffic arteries. Claims settlement for inadequate drainage of buildings, NOK 0.05 billion.
Reduced frost damage			Insignificant savings, reported insurance payments are currently between NOK 17 and 98 million.

the century. Costs that can be quantified are primarily damage to buildings, and they are estimated to amount to NOK 0.5 billion annually (Vista Analyse 2010). An underdimensioned sewerage network will also result in more frequent flooding, causing secondary problems, such as traffic disruptions. There are no figures to enable calculation of the scope of this, nor is it possible to quantify potential drinking water supply problems on the basis of our current knowledge.

9.2.3 Adaptive needs

Great efforts are required to make the water supply and sewerage sector more resilient to climate change. It is important to begin as soon as possible by using climate projections as the basis for planning in municipal areas, in master plans for water supply and sewerage and in emergency preparedness plans, including RAV analyses for the water supply and sewerage.

Extreme precipitation and meltwater volumes and floods will represent an increasing challenge for cities and densely populated areas. To remedy these situations, open storm drainage and local measures to deal with stormwater runoff must be organised in connection with land-use plans and building applications. In addition, there is an increased need to renew the pipe network by increasing dimensions, by separating shared systems, by building cisterns that delay stormwater runoff and counteract higher flood peaks, etc. There may also be a need to make provisions so that treatment plants can handle increased volumes of sewage water to reduce the negative impact on the aquatic environment.

To alleviate the pressure on the sewerage system, handling of stormwater should be carried out naturally in urban areas as far as practically possible. This can, for example, be accomplished by establishing green areas (such as green roofs), natural drainage and other local measures. These measures can also contribute to facing other consequences of climate change, such as an increased need for cooling in urban areas. In addition, they can contribute to functional ecosystems that preserve biodiversity, and they will be able to adapt to climate change.

In addition, there is a need to protect existing water supply and sewerage infrastructure against damage as a result of floods, rising sea levels, spring tides and landslides/avalanches, and to avoid new water supply and sewerage works being located in areas exposed to natural hazards.

There is also a need to ensure the quality of drinking water through measures to limit the contamination of water sources, improve the water treatment at water works, improve monitoring of the water quality and limit the risk of contamination in the pipe network.

Need for clarification of authority and conditions

There is a need to clarify the municipalities' responsibilities in the water supply and sewerage area in order to increase the renewal rate and adaptation measures in the sector. This should clarify, for instance, the inhabitants' rights and obligations related to the water supply and sewerage services, including the municipalities' opportunity to disclaim liability for damage to buildings as a result of backwash.

However, the municipalities have a general responsibility to safegurd the sanitary conditions through the Municipal Health Services Act and the Environmental Health Protection Regulations (Harvold et al. 2010) and certain provisions in the Fire Safety Act and associated Fire Water Supply Regulations. It is still not completely clear how far the municipalities' responsibilities extend into the water supply area (VA-jus 2009).

In the sewerage area, the municipalities are responsible under the Pollution Control Act and the Pollution Regulations for ensuring that the sewerage conditions are satisfactory, and through the Planning and Building Act and regulations pursuant thereto, the municipalities are also responsible for handling stormwater locally. There is a need to appoint a national level authority with responsibility for stormwater runoff.

There is a need for more detailed government recommendations on what climate projections for rising sea levels, spring tides, floods and landslides/avalanches the municipalities should use as a basis in their planning work for water supply and sewerage. There is also a need for government guidelines on designing the dimensions of shared systems and systems for stormwater runoff, based on precipitation intensities and return intervals. In addition, there are unclear responsibilities between road owners and the owners of sewerage and stormwater pipelines as regards stormwater runoff from roads. Regarding funding of measures, there is a need to clarify what type of stormwater runoff measures can be funded through the water supply and sewerage fees and how to secure the funding of other stormwater runoff measures.

In order to facilitate the best possible framework and prerequisites for planning for the muni-

cipalities and their inhabitants in the face of climate change, the authorities should make sure that the responsibilities are clarified and the regulations are amended in the aforementioned areas. This includes clarifying the responsibilities of road owners and the owners of sewerage and stormwater pipelines with regard to stormwater runoff from roads.

Need to strengthen the knowledge base and expertise

New knowledge and new technological solutions are required to improve adaptation in the water supply and sewerage sector. There is a need for a better overview of the current resiliency of the various parts of the Norwegian water supply and sewerage sector and what practical and economic consequences climate change may have for the sector, as well as the scope and costs of adaptation measures in the sector.

Further R&D work is needed on the impact of climate change on drinking water, related to both quantity as well as microbiological and chemical quality. Better knowledge of short-term precipitation through increased monitoring is necessary, and R&D activities are also required to improve knowledge of the impact of climate change on extreme short-term precipitation. Such knowledge must be used as a basis for climate-adapted capacity design criteria in the water supply and sewerage sector.

There is a need for measures to increase the municipalities' expertise, including increased recruitment to study programmes that are relevant for work in the water supply and sewerage sector.

9.2.4 The committee's recommendations

In order to improve climate change adaptation in the water supply and sewerage sector, the committee recommends:

Monitoring

- Increasing, improving and coordinating the collection of short-term precipitation data in urban areas.

Research-based development of knowledge

- Strengthen research and the development of technology necessary to upgrade the water supply and sewerage sector to handle climate change.
- Initiate R&D activities that will provide increased knowledge on the impact of climate change on extreme short-term precipitation.

Analysis of the infrastructure

- Initiate a survey of how resilient the water supply and sewerage sector currently is by studying the practical and economic consequences of climate change and estimating the scope and cost of necessary adaptation measures in the sector, including a report on the consequences for the fee scales in the water supply and sewerage sector.

Knowledge systems and dissemination of knowledge

- Improve the guidelines on how the municipalities can handle stormwater runoff in their planning, including guidelines on how open storm drainage can be arranged as buffer zones in the land-use plans.
- Help improve the educational programmes on offer and increase recruitment to the water supply and sewerage sector.

Management regimes

- Clarify responsibilities for stormwater at the national level by designating an authority to be in charge of dealing with surface runoff.
- Draft national government guidelines for the capacity design of water supply and sewerage systems so that the expected climate change is taken into account.
- Clarify the legal basis for the water supply and sewerage services, so that the owner of the water supply and sewerage system cannot disclaim liability for damage to the customer's property as a result of inadequate system capacity and sewage backwash.
- Clarify the municipalities' opportunities for funding in the water supply and sewerage area, and consider a legislative amendment that will clarify that the handling of stormwater in regulated areas can be funded by the water supply and sewerage fees.
- Clarify the customers' rights and obligations in the water supply and sewerage area.
- Consider amendments to the Planning and Building Act and the Technical Building Regulations so that there will be an opportunity to demand measures for handling stormwater in the vicinity of existing settlements.

9.3 Power supply

Norway's power supply is primarily based on renewable energy, such as hydropower, and it will thus be impacted directly by climate change through changes in the production potential. At the same time the expected increase in temperature will mean Norway requires less heating, but more cooling.

It is a prerequisite that the power supply also functions under extreme weather conditions. The power supply system is, therefore, designed to withstand the forces of nature. At the same time, weather conditions are a major cause of the faults and disruptions that do occur in the distribution, regional and national grids. Unless the adaptive capacity of the power supply system is improved, the expected increase in extreme weather events will increase the risk of damage.

The infrastructure for the production and supply of electrical power is part of what is often referred to as the vital infrastructure. Society is entirely dependent on a stable power supply in order to function. Significant disruptions in the supply of power will have major social consequences and may threaten life and health.

The power sector is exposed to climatic conditions at present and will be exposed to the effects of climate change. However, the committee believes that the adaptive capacity in the power sector is high. The systems that currently handle safety and emergency preparedness must also integrate climate change considerations. It is important that future developments, improvements and continuous maintenance of existing plants take climate change into consideration, as required by the regulations.

9.3.1 Vulnerability to climate change

9.3.1.1 How is the power supply impacted by the present climate?

The power supply is currently exposed to climatic conditions. Around half of all the faults and disruptions in the distribution grid are caused by impacts due to weather conditions. Lightning is the primary cause of disruptions, but indirect climate-related conditions such as vegetation growth and fallen trees, wind, snow and ice can also result in disruptions.

In general, the infrastructure in the power supply sector is well-adapted to the current climatic conditions. There is a slight maintenance backlog, but emergency preparedness for weather-related events is good. However, a large part of the power grid was built in the 1960s, 70s and 80s, and major reinvestments and improvements will be required in the future. Power plants are built with a long service life, and they are expensive to modify if inadequate consideration was given to climate change in the design phase. The equipment has long order lead and delivery times, rendering the plants vulnerable. Local emergency preparedness is decisive for both preventive work and for solving problems quickly when they occur.

Requirements are stipulated that companies must be able to quickly restore a normal supply when damage or breakdowns occur.

The power supply infrastructure, such as dams, are designed and certified for different loads (strains), including so-called normal loads due to normal climate variations and abnormal loads as a result of rare or extreme events. Many of these loads come from climate effects in the form of precipitation, temperature and wind. Examples are flood water levels and flood streamflow, pore pressure, ice pressure and ground frost pressure, and exposure to waves. Abnormal loads may, for example, be the result of landslides or avalanches onto dams or into reservoirs.

9.3.1.2 How will the power supply be impacted by climate change?

Climate challenges are primarily related to a higher frequency, strength or intensity of weather events. Areas may be exposed to a change in climate variables, exposing them to events that they are not, or are only to a very limited extent, exposed to today. In addition, rising sea levels and storm surges may result in challenges in new areas.

Below are some examples of how climate change can increase the need for maintenance and the risk of damage to power plants, such as dams, power stations, transformers and power lines.

Increased maintenance requirements

- The risk of more frequent alternating freezing and thawing periods may result in greater problems with frost bursts in parts of Norway that currently have a stable winter climate and where the power infrastructure is not constructed for these conditions.
- Increased humidity and more precipitation will result in increased weathering of concrete and stone structures. A combination of increased

humidity and higher temperatures may amplify the problems with rot in woodwork (power masts, buildings).
- A longer growing season and faster growth will increase the challenges associated with vegetation near lines.
- More humidity and periods with prolonged drought can cause ground movements. This will increase the pressure on underground pipes and cables, which may in turn shorten their service life and increase maintenance requirements for cables and pipes.

Increased damage frequency

- More thunderstorms will increase the problem of disruptions.
- Ice and snow on power lines in parts of the country that currently do not have this problem and where the lines are not designed for this. Without any climate change adaptation, this will increase the problem of disruptions.
- High temperatures (hot summer days) expand metal, resulting in so-called power line sag. This means that power lines stretch and can come into contact with vegetation. Together with increased vegetation growth and increased probability of summer droughts in southern Norway, this may result in more frequent disruptions and cause forest fires that can potentially damage power plants.
- More precipitation increases the probability of major floods, flooding and landslides/avalanches. This increases the risk of damage to power plants and can entail that the need for remodelling of dams and spillways will increase.
- Slides in new areas will increase the exposure of infrastructure with limited prior exposure.
- Rising sea levels result in increased storm surge levels and low-lying plants will be more exposed.
- Less ground frost in areas that currently have stable ground frost may weaken the stability of masts and forests in storms.

Climate change may also entail possible positive consequences in the power sector, since increased precipitation results in an increased potential for power production. An increased average annual inflow is expected in Norway, but with regional and seasonal variations as illustrated in Section II.

Most studies indicate that climate change can lead to an increase in the average annual inflow to power plants and thereby increase the production potential for hydropower. The inflow will particularly increase during winter. Estimates of changes in the power production as a result of climate change vary between different studies, depending on the climate projections used and how far into the future one looks. For example, Mo et al. (2007) find that the Norwegian hydropower production will increase by 2.3–17.1 per cent in the period 2071–2100, compared with 1961–1990, while a recent study from the Norwegian Water Resources and Energy Directorate (NVE) indicates an increase of 5.5–18.2 per cent for the same period, but with 1970–99 as the reference period (Seljom et al. 2010). Statistics Norway (2005) has calculated that power production in Norway will increase by 7.3 per cent in 2040. Calculations by Mo et al. (2010) give an increase in hydropower production in the Nordic countries of about 10 per cent for the period from 2021 to 2050 compared with 1961–90. There is broad support for claiming that increased inflow will increase hydropower production in existing plants, but there is uncertainty as to how large this increase will be.

Climate change provides increased access to biomass and a potential opportunity for increased bio energy production. The sector analysis of the land-based primary industries in Chapter 10.1 mentions an increase in agricultural production and increased forest growth. This suggests a potential for the increased production of bio fuel. How much of this potential will be used for energy purposes is uncertain. This will depend on the development in the energy prices and the demand for different energy sources for different purposes.

Higher temperatures mean that heating requirements will be reduced, while cooling requirements will increase. It is expected that heating requirements will be reduced by more than the increase in the cooling requirements, implying that the energy demand in Norway will likely be reduced (NVE 2010).

A key part of the licence processes is to find solutions for the development of renewable energy that provides greater advantages than disadvantages for society as a whole if a licence is granted. In those parts of Norway where climate change results in increased inflow, it can be debated whether the power producer or nature and public interests should benefit from this water. For example, it could be relevant to consider increasing the minimum water flow in favour of vulnerable ecosystems in a river.

Changes in climate and hydrology, more wind power and a changed power market could make

increased hydro peaking of hydropower plants more relevant. Hydro peaking entails sudden changes in the streamflow in rivers and water levels in reservoirs. In some reservoirs and rivers this may result in increased erosion and undesirable impacts on nature and user interests and requires increased preparedness. In addition, hydro peaking operations entail increased maintenance costs due to increased wear and tear of the turbines.

Climate change could result in a need for new power lines in the interests of safety and preparedness considerations, and a greater need for transmission capacity related to increased production of hydropower and other renewable energy. In connection with increased grid development, especially in areas that are particularly vulnerable to climate change, these vulnerabilities must be considered to ensure maximum consideration of the natural environment and society.

9.3.1.3 Adaptive capacity

Organisation

Clear administrative structures and orderly distribution of responsibilities among the various parties will serve to strengthen the adaptive capacity in the sector.

The Ministry of Petroleum and Energy, represented by the Norwegian Water Resources and Energy Directorate (NVE), has the principal management role of electrical power resources and stipulates the regulatory framework for the Norwegian energy system with respect to production, trading, transmission and energy consumption. This role includes the power system, quality of deliveries, and safety and preparedness of the power supply sector. Through the enforcement of regulations, guidelines, assistance and supervision, the NVE is responsible for ensuring good safety and emergency preparedness in the power supply sector. The NVE is also responsible for reviewing licence applications in matters that concern the encroachment of watercourses, power production and power lines.

The Ministry of Justice, represented by the Directorate for Civil Protection and Emergency Planning (DSB), has two roles: as the authority for electrical safety, the Directorate shall protect against electricity hazards; in addition, it shall follow up other authorities' safety and preparedness tasks.

The NVE and the DSB control a number of instruments to ensure that the power supply infrastructure is appropriately dimensioned for the relevant climate load. The instruments can basically be divided into direct regulation, economic regulation, supervision and information work.

Industry players in the power sector comprise more than 300 public and private companies organised in various ways with respect to generation, transmission and trading of power. Depending on what type of activity is carried out, the companies are often referred to as production companies, grid companies, power companies or vertically integrated companies, and in some cases they are referred to collectively as power companies. In addition, there are companies that only work with the brokering of power contracts and companies that are subcontractors to power companies.

Power companies vary in size and organisational structure, and they are generally characterised by a large component of public ownership, where the national government, county authorities and municipalities are on the ownership side. Statkraft is the largest company generating electricity in Norway, with a market share of around 30 per cent.

- The State owns a large portion of the national grid through Statnett SF.
- Municipalities and county authorities own most of the regional grids and the local distribution grids.
- Grid companies own, and are responsible for, the power grid, which transports power from the power supplier to where it is to be used. Grid companies have a monopoly on the transmission of power within their geographical region.

Emergency preparedness should counteract damage as a result of natural events, technical breakdowns, deliberate vandalism and other extraordinary circumstances. The Norwegian Water Resources and Energy Directorate (NVE) supervises the owners of dams and power plants to ensure that they fulfil their safety and emergency preparedness obligations. The Norwegian Water Resources and Energy Directorate (NVE) is also responsible for ensuring that the environmental requirements stipulated in licences are observed, as well as revision of the terms and conditions in old watercourse licences.

Regulations and requirements

As the emergency preparedness authority, the Norwegian Water Resources and Energy Directorate (NVE) is responsible for coordinating emer-

gency preparedness planning within the entire power supply sector and managing the power supply under extraordinary circumstances, such as natural disasters. In the Directorate for Civil Protection and Emergency Planning's (DSB's) regulations for power plants, which were revised most recently in 2006, the requirements for the capacity design of power lines in order to withstand the expected climatic and other natural influences were made more stringent. As the authority for electrical safety supervision, the Directorate for Civil Protection and Emergency Planning (DSB) carries out annual inspections of all grid companies. The Directorate for Civil Protection and Emergency Planning (DSB) focuses, through its supervisory activities and, possibly, administrative decisions, on maintenance requirements for plants based on electrical safety considerations, not supply reliability considerations. The Norwegian Water Resources and Energy Directorate (NVE) is responsible for managing electrical power resources, and supply reliability is one of the key considerations that NVE must take into account.

Since dam bursts may pose a risk to human life, dam safety is given special attention. The regulations for dam safety comprise all dams that can potentially injure a third party. There are approximately 1 700 hydropower dams in Norway, and around 750 of these dams represent a risk to human life if they should burst (NVE 2010). The regulations for dam safety stipulate that dams must be assessed every 15 to 20 years, depending on their consequence class. The purpose of this reassessment is to identify any changes in the loads, such as the size of floods, wind waves, ice pressure, etc., and changes in the regulatory requirements. The design flood magnitude should, for example, be recalculated so that any changes over the past years are identified, including changes as a result of climate change.

It appears that the requirements and expectations that are stipulated in statutes and regulations provide satisfactory legal authority for continuous climate change adaptation in the sector, and to ensure that future changes in the climate are taken into account. It is important that the Norwegian Water Resources and Energy Directorate (NVE) and Directorate for Civil Protection and Emergency Planning (DSB), as the supervisory authorities, ensure that the industry familiarises itself, and complies, with the regulatory framework with regard to climate change considerations as well.

The review of licence applications is an important instrument to ensure good adaptation within the scope of the direct regulatory authority of the Norwegian Water Resources and Energy Directorate (NVE). This authority is based on several Acts, including the Energy Act, Water Resources Act, Watercourse Regulation Act and the Industrial Licensing Act. It is a requirement for a company to be awarded a licence to own and operate a power plant that important safety requirements are satisfied in connection with the construction, commissioning and continued operation. For example, the Energy Act grants the licensing authorities very broad authority to stipulate conditions, provided there is a justifiable correlation between the conditions and the subject matter of the licensing. In licensing applications, the supply reliability must be taken into consideration, and this is also often grounds for reinvestment and improvement applications.

Through the review of licence applications for hydropower plants, conditions can be stipulated for river management and implementation of measures that can reduce the risk of damage as a result of floods, erosion, sea level rise, etc. Climate effects should be a key topic in the impact assessments that are required in connection with the licence applications.

The Directorate for Civil Protection and Emergency Planning's (DSB's) regulations pursuant to the Electrical Supervision Act (Regulations relating to power plants) contain requirements that power plants shall be engineered, built, operated and maintained so that they safely fulfil the function they are designed for, without any risk to life, health or material assets. This means that the plants must also be able to withstand future climate effects.

Knowledge of expected climate change should, therefore, be part of the review basis for the formulation of regulations and requirements in licence processes and other contexts. There are already strict requirements for licence applications, impact assessments and power system assessments today, but climate change must be given more attention in this context.

Refinement and revision of all the regulations related to the energy sector is important to ensure that the power supply infrastructure is less vulnerable to climate change and that the safety requirements are adapted to climate change. Further development of technical standards for plants will also be a key issue. In certain areas, standards committees have been established to prepare industry requirements that will apply to different

components and constructions. For the Norwegian Water Resources and Energy Directorate (NVE) and the Directorate for Civil Protection and Emergency Planning (DSB), it will be important to influence this work so that the authorities' requirements are implemented in these standards.

NVE sets a revenue ceiling for each company. This is supposed to mirror the cost conditions in the delivery area, based on climate, topography, settlement, etc. The regulations are to ensure, for example, that the companies do not receive unreasonable revenues due to the fact that they have a monopoly on the services they deliver. Grid companies have criticised the way in which the Norwegian Water Resources and Energy Directorate (NVE) regulates their revenue. The trade organisation Energy Norway has stated that the Norwegian Water Resources and Energy Directorate (NVE) is impeding timely further development and renewal of the power supply grid through the revenue ceiling. The organisation has claimed that the revenue system prevents the companies from achieving their climate goals and to be reliable with regard to the delivery of power, and that companies do not invest more than they absolutely have to.

In the opinion of the Norwegian Water Resources and Energy Directorate (NVE), the current regulation of the grid companies' revenue, together with other laws and regulations, provide adequate incentives for efficient operation, exploitation and development of the grid. The committee does not have any grounds on which to base an assessment of whether the revenue ceiling regulations contribute to the necessary renewal and improvement of the grid. Nevertheless, the committee finds that the need for a reinforced grid that can handle the effects of a changed climate may give cause to re-evaluate this.

Flow of information

In order to improve access to information in all matters that should be considered when planning and operating a power system, grid companies are obliged to carry out power system studies. The purpose of this is to facilitate the coordination of planning between production and grids and between the licence areas. An important part of the power system study is the scenario descriptions, where the future development of production, consumer demand and grid capacity are evaluated. The use of this scenario methodology will ensure that important social drivers are included in power system planning. There will be a need to include climate effects as important variables for future studies.

Resources

The power sector has significant financial resources and relevant expertise. These are seen as satisfactory to meet the adaptive needs.

It is costly to build power plants, and it is both difficult and costly to make subsequent structural or land-use changes. For physical plants that may be affected by a changed climate for a shorter or longer period, the adaptation requirements should be part of the process and evaluations from the planning phase.

Climate change may necessitate more remodelling and development. For example, more frequent slides lead to more sediment, which in turn increases the maintenance requirements for plants. Climate change such as increased floods, landslides/avalanches and precipitation can also result in more damage to dams and intakes, pipe trenches, river courses, turbines, transformers and grids. An important point is that it will pay off to invest in robust technology.

Knowledge base

Increased risk due to climate change must be studied further by the sector to ensure a resilient power supply in a changing climate. As part of the requirement for improved knowledge of a future climate and how this can affect the power supply, there is a need for analysis of the risks and vulnerability and further research on possible direct and indirect consequences. This applies, for example, to:

- mapping the possible effects of lightning frequency and which regions of Norway might be most exposed
- effect of rising sea levels and storm surges on power facilities
- possible consequences of new flood and slide regimes and the challenges for power plants in and near regulated and non-regulated watercourses and slide-prone areas
- icing problems in a future climate
- clarify how changes in wind and wind directions will influence the power supply installations
- forest clearing in connection with distribution routes
- need for changes in maintenance (salt crystallisation, weathering, lashing rain, etc.), and

whether this will affect how and where we build
- interaction with other infrastructure areas (such as roads and telecommunications)
- opportunity to use underground cables for the distribution grid in areas that will be particularly exposed to wind, snow/ice and rain
- determining the measurement parameters for (inadequate) maintenance of components and constructions in the supply grid
- assessment of whether changes in the licence terms and river management regulations will be necessary to optimise power production and reduce the adverse effects of floods, for example in a future climate, or to counteract the negative effects of minimum flows on natural diversity

Priorities

A study under the direction of the Norwegian Water Resources and Energy Directorate (NVE) in 2009 confirms that climate change adaptation is on the agenda of many energy companies (NVE 2009). Nevertheless, there are differences between the companies. Six out of ten companies in the energy industry believe that climate change may entail safety challenges, but only 24 per cent currently have specific plans for adaptation. The rest of the industry is waiting to see how the situation develops. The largest companies have the highest level of awareness. Nearly the entire industry (99 per cent) is aware of climate change. There is a relatively large group (31 per cent) that think that climate change will not represent any particular challenge to their own activities.

Safety and preparedness are high on the agenda of both the authorities and the industry. Disruptions have significant socio-economic consequences, and they are also of great significance to a number of functions vital to society. It should also be mentioned that, in the event of any incidents in the grid, the company, in addition to direct earning losses due to the fact that they cannot sell their product to customers, will also have their stipulated revenue ceiling reduced. If the fault is also a breach of regulatory requirements, then the company may be fined or sanctioned for this. Climate-related conditions already have a strong focus today, and this is a good point of departure for adaptation.

Other conditions that affect the adaptive capacity

In connection with reinvestments and improvements to the power grids, the grid companies must place greater emphasis on climate studies in their planning, in order to take into consideration safe operations and maintenance under all weather conditions, including in a changed climate. The choice of routes is important with a view toward reducing climate effects and simplifying self-inspection and maintenance.

9.3.2 Socio-economic consequences

As previously mentioned, there is reason to believe that climate change will increase the need for maintenance of power sector infrastructure, such as the power lines, production plants, etc. This results in added costs for the power sector. However, there is also reason to expect more precipitation and inflow to the reservoirs, which will in turn generate more power and larger revenues for the sector. The overall socio-economic consequences for the sector are the sum of the positive consequences for production and the negative consequences for the infrastructure.

As is evident from the analyses above, it is uncertain how much climate change will affect power production. Based on a literature review, Vista Analyse (2010) estimates that the economic consequences will be a 7–22 per cent increase in production in the second half of this century. The value will be dependent on the price of power at that point in time. Vista Analyse finds that clean power will have an added value in the future and estimates a relatively high price of NOK 0.50–0.60. In general, the price of hydropower will be determined by the stringency of the future climate policies in Europe. In addition, the price in Norway will be determined by the transmission capacity to the Continent. By multiplying the price and increased production, Vista Analyse (2010) finds that the production revenues for hydropower may increase by between NOK 5 and 16 billion annually.

Vista Analyse has also tried to estimate the costs related to increased maintenance. It appears that this will be a small amount of NOK 0.01–0.5 billion annually. This amount must be seen in the context that Norway has a resilient supply system. In 2008, only 0.14 per cent of the production did not reach the consumers. Half of this, around 0.1 TWh, was due to natural events.

9.3.3 Adaptive needs

Climate effects must be an integrated and important part of an energy company's risk management. At the same time, changed climate-related negative impacts and adaptive needs require a great deal of attention in the future. Planning and development of grid reinforcements, for example, has a long-term perspective and must be fairly robust with regard to changes in the framework conditions.

There is a need for greater awareness of relevant future climate change and to further chart climate challenges in the sector. A focus on cooperation between management, R&D institutions and the industry may make mapping climate risk as operationally beneficial as possible for energy companies.

The Norwegian Water Resources and Energy Directorate (NVE) and the Directorate for Civil Protection and Emergency Planning (DSB) will need more resources to follow up the energy companies' work on their own risk assessments and follow up their work on adaptation plans to reinforce the sector's adaptive capacity. There is also a need to strengthen adaptation expertise in the power industry. The Norwegian Water Resources and Energy Directorate (NVE) has a particular responsibility to promote this.

The need for increased knowledge on the impact and consequences of climate change must be met with a focus on R&D activities, by looking at what climate change means with respect to wind, lightning, floods, landslides and avalanches for example. Additional effects on the infrastructure are also important to the power industry.

The current laws and regulations provide adequate legal authority for continuous climate change adaptation in the sector, but the supervisory authorities must ensure that the industry familiarises itself and complies with the regulations related to the consequences of climate change as well. The government authorities must also incorporate topics related to climate change into guides and guidelines and actively use advisory services as a means of creating activity in the industry.

Investments may be required in order to exploit increased hydropower potential. The Norwegian power industry should assess the need for investment in various parts of the power supply sector to optimise the potential inherent in increased inflow. The need for grid development and grid reinforcement must also be assessed in this context. At the same time, this should be considered in connection with an upgrade of security adapted to a changing climate and the opportunities to maintain biodiversity.

9.3.4 The committee's recommendations

In order to improve climate change adaptation in the power sector, the committee recommends:

- Improving research on all climate effects that can impact the power supply system, including changes in the frequency of lightning strikes and thunder.
- The Norwegian power industry should assess the need for investment in various elements of power plants in order to optimise the potential inherent in increased inflow. The need for grid development and grid reinforcement must also be assessed in this context. At the same time, this should be viewed in the context of upgrading the security adapted to a changed climate and an increased need for a contiguous protected area.
- Improving the expertise with regard to adaptation in the power sector. As the authority in charge of emergency preparedness, the Norwegian Water Resources and Energy Directorate (NVE) has a special responsibility to implement measures that increase the energy companies' awareness of climate change and adaptation.
- As the supervisory authorities within their respective areas, the Norwegian Water Resources and Energy Directorate (NVE) and the Directorate for Civil Protection and Emergency Planning (DSB) must ensure that the sector familiarises itself and complies with the regulations related to the consequences of climate change as well. They must also assess the need for incorporating climate-change-related topics into their guidelines.

9.4 Functions and services for electronic communications

Functions and services for the electronic communication of information (the electronic communications sector) are exposed to climate change that may cause disruptions or damage to cables and other facilities, or indirectly through damage that results in disruptions of the power supply. More frequent and more intense weather as a result of

climate change could, therefore, further expose the sector.

A modern society is dependent on functioning electronic communications services. The electronic communications sector is vital in order for all other social sectors to function and maintain the delivery of goods and services upon which the population depends. Therefore, vulnerability in this sector affects the vulnerability of society as a whole.

Despite the fact that the sector will be exposed to the effects of climate change, the committee finds that the sector's vulnerability is limited. Due to the rapid technological developments in the sector, the electronic communications infrastructure has a relatively short service life, and it is characterised by a rapid ability to adapt.

9.4.1 Vulnerability to climate change

9.4.1.1 How will the electronic communications sector be impacted by climate change?

The electronic communications network is generally designed to withstand, and if possible, avoid, known environmental impacts such as floods, wind, etc. Planning regulations and guidelines should ensure that redundancy is incorporated into important electronic equipment, communication lines and power and cooling units and that they are physically protected. Many of the most crucial installations are located in underground facilities.

The electronic communications sector is particularly exposed to thunder, strong winds (which knock down aerial lines), floods (submerging facilities, damaging cable networks, etc.) and landslides and avalanches (which damage power lines, cables, etc.). Icing on lines can also be a problem.

For the electronic communications sector, the main challenges associated with climate change are an increased risk of

- power supply instability
- breakdown of electronic communications cables
- physical damage to electronic communications facilities
- access issues for repair crews and emergency preparedness equipment

The power supply and supply of electronic communications services are mutually dependent. The facilities that support the telecommunications network must have power to function. Power must be delivered to the base stations for the mobile telephony network in order for them to work. The customers are also dependent to a great extent on power so that telephones and other equipment can function. In the same manner, the management and control of both the production and distribution of electrical power depend on electronic communications.

Large and important facilities in the telecommunications network are equipped with emergency power so that it is possible to operate for up to four days in the event of a major disruption. Regional and local exchanges in the fixed network and base stations in the mobile network are not normally equipped with emergency generators. Some of them are equipped with back-up batteries that can support operation for a few hours in the event of a power failure. The impact of climate change on the stability and reliability of the power supply thus also greatly affects the supply of electronic communications.

Physical damage to the electronic communications structure must normally be repaired on site. During difficult weather conditions, the problem of closed roads or the reduced operation of other types of transport arteries can create problems for repair crews. In addition, many facilities are located in fairly inaccessible areas, such as mountain-top stations (base stations, radio relay installations, etc.). During long periods of bad weather, fault repair after power failures, icing, etc. may take time, because it is difficult to access the site. Fault repair of subsea cables is particularly time-consuming, because such work is dependent on good weather (cable laying vessels, long cable runs).

9.4.1.2 Adaptive capacity

Electronic communications are distributed by an infrastructure that basically consists of a transmission network and an access network. The transmission network (including transmission network exchanges) represents the transmission "highways", while the access network (including regional and local exchanges) represents the "pathway" to each individual user.

In the electronic communications sector, there are currently more than 200 companies that provide electronic communications services. They do not all have the same amount of infrastructure and equipment. Many companies lease this from major suppliers, such as Telenor, NetCom and Ventelo Networks.

The Ministry of Transport and Communications is responsible for the framework conditions in the electronic communications market, while the

Norwegian Post and Telecommunications Authority is the agency under the Ministry that is responsible for important supervisory functions in the telecommunications markets. The supervisory functions include inspection and technical supervision.

The Act relating to electronic communications (Electronic Communications Act) and the associated regulations do not stipulate any emergency preparedness requirements for the network beyond the general provision that it must function in times of peace, crisis and war. The telecommunications providers must accordingly safeguard the critical communication requirements of enterprises that are required to handle functions critical to society.

The industry itself is interested in ensuring the longest possible uptime, because a network that is down also means lost revenues. In order to re-establish the network as quickly as possible after a disruption due to floods, fire, power supply breakdown, etc., the individual providers have established emergency stores of materials such as cables, electronics and power generators. The committee finds that these circumstances contribute to the sector being less vulnerable to climate change.

9.4.2 Adaptive needs

The electronic communications sector is constantly changing, and new technology is under continuous development. This means that the electronic communications infrastructure has a shorter service life than many other types of infrastructure. The electronic communications infrastructure will most likely be completely different in 40 years. Due to the continuous development in this sector, it will, therefore, be less vulnerable to climate change and have fewer adaptive needs, despite being exposed to climate change.

In the long term, there will likely be a need to develop measures that provide greater delivery reliability during disruptions. Today, for example, base stations are equipped with generators that keep them running for a couple of hours. In the future, the sector must be prepared for more frequent and longer lasting disruptions. This will require generators or other solutions that can withstand somewhat longer disruptions. There may also be a need to adjust the requirements for cabling etc. However, the committee finds that there is no need to implement measures at this point in time due to the rapid replacement rate in this sector.

9.5 Waste and pollution

Climate change will have consequences for pollution and may increase pollution both on land and in the sea. The leaching of environmental toxins that are bound up in the environment will occur more rapidly as a result of increased precipitation. Increased runoff and erosion are expected to increase pollution from nutrients and particles in watercourses and the sea and increase the formation of sludge in the habitats of important species. Increased erosion and leaching may also contribute to more environmental toxins, such as mercury, seeping out from the ground into rivers, lakes and fjords. A higher frequency of intense periods of precipitation may increase the risk of overflow discharges from sewerage systems, and it may reduce the effectiveness of treatment plants or render them inoperable. Higher temperatures in freshwater, coastal and sea areas will affect the transport, circulation and effect of nutrients and environmental toxins alike. Climate change will likely also affect the concentration and spread of air pollution.

For the time being there is little knowledge about the correlation between climate change and pollution. For example, in the UN climate panel's 4th assessment report (IPCC 2007), there is limited mention of the effects of climate change on pollution. The committee therefore has limited means of assessing vulnerability and adaptive measures. In the committee's opinion, there is a need for more knowledge on the links between climate change, pollution and the impacts on nature and society.

The studies that the committee has reviewed indicate that climate change may increase the release and spread of environmental toxins. ACIA (2005) has studied the links between climate and pollution in the Arctic. The study concludes that warming will likely increase the amount of contaminants transported to the Arctic. Two studies were conducted on climate and pollution as part of the Swedish climate change adaptation research (SOU 2007:60). These studies concluded that air pollution will likely increase due to climate change. In Norway research has been conducted at the Climate and Pollution Agency (Klif), previously the Norwegian Pollution Control Authority (SFT), in connection with their climate adaptation strategy (SFT 2009). In its strategy, the Climate and Pollution Agency (Klif) points out that the knowledge they currently possess indicates that climate change will entail significant challenges in their area of responsibility, but that the develop-

ment will take place gradually, and that there is still significant uncertainty as to the scope.

Different contaminants are also discussed in other sections, such as Chapter 7, Natural environment, Chapter 9.1, Transport, and Chapter 9.2, Water supply and sewerage. The subject of this section is waste and waste management in particular, but other forms of pollution at a more general level will also be discussed.

Society produces a vast amount of waste and is dependent on a functioning waste management sector. According to figures from Statistics Norway, the total amount of waste in Norway was close to 11 million tonnes in 2008. Waste management may result in various health and environmental problems. The waste management sector is strictly regulated and followed up closely by the supervisory authorities. In the committee's opinion, this sector is well equipped to meet the challenges of climate change.

The most important adaptive measures will be to ensure that higher temperatures and greater precipitation do not increase the contamination of leachate from the waste disposal sites. The existing, regulated disposal sites maintain a high standard and make it possible to verify the content of the leachate. The committee finds that there is reason to expect that climate change will increase the risk of contamination from discontinued disposal sites.

9.5.1 Vulnerability to climate change

9.5.1.1 How is the sector impacted by the present climate?

Waste disposal can contaminate the environment when chemicals, nutrients and heavy metals leak through leachate. This type of leakage may continue for a long time after the waste has been disposed of. The disposal of waste can also contribute to greenhouse gas emissions. In 2009 the emission of methane from disposal sites accounted for around 2 per cent of Norwegian greenhouse emissions (Environmental Status in Norway).

There are problems associated with old waste disposal sites. They can contain all types of waste, but disposal sites that contain hazardous waste; older industrial sites and other ground that is contaminated with environmental toxins; contaminated sediment in harbours, fjords and watercourses; and contaminated areas associated with discontinued mines in particular may result in the discharge of environmental toxins. Some waste also ends up directly in nature when it is dumped illegally, buried or emptied into the sewer. This is a source of spreading contaminants to the ground, groundwater, surface water and organisms, and it may result in acute contamination or serious long-term contamination. In today's climate, heavy precipitation and flooding may also lead to an increased risk of hazardous waste going astray.

9.5.1.2 How will the sector be impacted by climate change?

Climate change will have consequences for the pollution situation in Norway; for instance, as an additional strain on an already strained system and because the spread and effects of environmentally hazardous chemicals will change. Increased precipitation may, for example, lead to more rapid leaching of environmental toxins that are bound up in the environment. Higher temperatures in freshwater, coastal and sea areas will affect the transport, circulation and effects of nutrients and environmental toxins. Large amounts of ice melting may release contaminated substances. This is an area where we have little knowledge today.

Most of the discontinued disposal sites have been surveyed and classified by the Climate and Pollution Agency (Klif) in connection with their contaminated ground efforts. Increased precipitation means that this must be re-evaluated. Climate change that results in increased total precipitation and more frequent intense precipitation periods will increase the permeation of water through the waste disposal sites. This may increase the leakage of environmental toxins from disposal sites and the amount of contaminants in the leachate. A greater number of days with heavy precipitation may expose discontinued disposal sites to a heightened risk of slides and unstable soil conditions and thus an increased risk of contamination.

More frequent intense weather and floods will increase the amount of waste that must be handled specially. An increase in the number of rainy days will mean that the ground is saturated with water for longer periods of time. This will reduce the infiltration of rainwater and may result in increased and more frequent surface runoff. This means that for each period of precipitation a smaller portion of the precipitation will be infiltrated down into the ground and thus lead to larger floods, even if the amount of precipitation in a single incident is not more intense than before. Therefore, there are several reasons why the climate effects may result in more contamination from

overflow and more frequent and larger damaging floods in the sewerage pipeline networks, and thus greater damage to basements, storerooms, infrastructure, etc.

Increased erosion and leaching may also contribute to more environmental toxins seeping out, for example, mercury from the ground into rivers, lakes and fjords.

For agricultural areas, longer periods without frost or snow cover, more freeze–thaw episodes and rain on frozen ground without snow cover will contribute to increased runoff. With temperature increases and a higher CO_2 content in the atmosphere, a longer growing season may result in greater use of fertilizers and pesticides. This may also heighten the risk of more runoff. In Chapter 10.1, it is pointed out that climate change may result in an increased pest problem in agriculture and thus a greater need for spraying with pesticides. Thus the discharge of harmful and environmentally hazardous substances may increase. All these factors also increase the emission of nitrous oxide (SFT 2009).

Increased precipitation will result in a greater strain on the sewage treatment plants. This could reduce the treatment efficiency of the plants and result in a higher nutrient content in the discharge from treatment plants. This alone may result in an annual increase of up to 20 per cent in pollution discharges (SFT 2009). In order to counteract this, it is extremely important to prevent the penetration of stormwater runoff into the sewage treatment plants.

9.5.1.3 Adaptive capacity

Municipalities are responsible for collecting and treating waste from households, while industrial waste is the responsibility of the individual enterprises. Municipalities are also responsible for receiving and providing receiving stations for hazardous waste from households. Most of the infrastructure related to the treatment of residual waste is owned by the municipalities and consists of waste disposal sites, facilities for the biological treatment of waste or incineration facilities.

The municipalities' handling of household waste is self-financing and funded by user fees based on the full-cost principle. Full-cost reimbursement is required, i.e. the municipalities can neither subsidise nor profit from waste treatment. Waste recycling facilities are normally owned by private enterprises. The recycling of materials in industry takes place by converting waste to raw materials for industrial production.

The county governor is the pollution authority for most waste facilities, such as receiving facilities, waste recycling and treatment facilities, car-scrapping sites, disposal sites, incineration plants and waste from ships. The county governor reviews discharge applications from waste disposal sites and inspects the plants to ensure that the licence conditions are met.

The Climate and Pollution Agency is responsible for overall management of the county governors' work in this area. The Agency directs the county governors and functions as the appeals board for decisions by county governors. The Climate and Pollution Agency (Klif) is the authority directly responsible for the disposal sites for hazardous waste. The same applies to in-house disposal sites for which the Agency has granted a combined discharge permit for the entire enterprise.

Pursuant to the Pollution Control Act, anyone who operates a disposal site or other facility for the treatment of waste that may result in contamination or appear unsightly must have a permit. In 2002, new and stricter disposal site regulations were introduced, and in 2009, it became unlawful to dispose of biodegradable waste such as paper, woodwork, textiles and food waste. The number of disposal sites has been greatly reduced in recent years. In 1992, there were 330 waste disposal sites, while there were 89 in 2008 (SSB). The Climate and Pollution Agency (Klif) finds that the disposal sites hold a high environmental standard.

There are currently no authorities responsible for ensuring adequate capacity for the treatment of all waste in Norway.

9.5.2 Adaptive needs

The committee believes that both the authorities and players require a greater awareness of what climate change may entail for the sector. It is important to map the risk of increased discharges that are hazardous to health and the environment from the waste management sector as a result of climate change. Risk and vulnerability analyses in which changed climatic conditions are included as parameters must be important management tools for the planning, operation and subsequent use of infrastructure.

Increased runoff and erosion are expected to increase pollution from nutrients and particles in watercourses and the sea and increase the formation of sludge in the habitats of important species. Higher summer temperatures in the sea may eradicate species that are temperature-sensitive and

affect the foundation for growth. This may have effects on the marine environment. One example of extensive changes is the significant decrease in sweet tangle growth along the Skagerrak coast and in Western Norway. It has been suggested that the increased discharge of nutrients and particles is one of the main reasons why sweet tangle forests have not regenerated, since the increased nutrient and particle levels favour other species (hair algae), which drive away and prevent sweet tangle from establishing itself. The sweet tangle dies in years with high sea temperatures. Agriculture is the greatest source of nutrient discharges around Skagerrak, while a rapidly growing aquaculture industry contributes to large local discharges of nutrients in Western Norway. On a regional scale, however, the discharge of nutrients from the aquaculture industry in Western Norway is still unproblematic, and the sweet tangle has not been weakened due to this.

9.5.3 The committee's recommendations

In order to prevent climate change from increasing the adverse effects of waste and pollution, the committee recommends.

Research

- Strengthening research on the impact of climate change with respect to the spread of pollution.

Management regimes

- Review the databases of registered areas with polluted ground in order to undertake a new risk assessment that takes climate change into consideration.
- Formulate recommended requirements for leachate at disposal sites.
- Ensure that there is sufficient infrastructure for the treatment of waste generated during floods and persistent bad weather.
- Improve the handling of stormwater runoff, which is discussed in greater detail in Chapter 16.1, and/or increase the capacity of the treatment plants.
- Improve the emergency preparedness for acute pollution.

9.6 Buildings

The climate in Norway has always dictated the criteria for the planning, design, location and maintenance of buildings. The built environment is vulnerable to several types of natural disasters, including events caused by extreme weather. Moisture problems as a result of more frequent and more intense precipitation will be the greatest threat in a changed climate. Historical buildings are particularly vulnerable because they have special needs for maintenance and because they are often unique and irreplaceable. For the cultural heritage authorities and society in general, the loss of heritage features and sites constitutes the loss of an important foundation for fellowship, knowledge, experiences and the creation of value.

Buildings represent major investments in society's infrastructure. As of January 2008, there were 3.8 million buildings in Norway. Around 40 per cent of these buildings were homes. About 80 per cent of the buildings that exist today will still be standing in 2050. The goal of adaptation should be to maintain or increase the current service life. This means that new buildings must be equipped to withstand future climate change, and the quality of the existing buildings must be maintained. A major maintenance backlog hinders adaptation. Regulations and standards exist and are adequate, but the lack of compliance, maintenance and expertise in the construction industry weakens the adaptive capacity. Historical buildings are particularly vulnerable.

Climate change will necessitate adaptation of buildings, such as stricter requirements for how cladding is mounted, ventilated and drained in order to function as an efficient climate barrier, and other measures to prevent the penetration of moisture. In a changed climate, buildings will be more vulnerable to design faults and geographical location, and the maintenance requirements will increase.

The built environment in Norway has the potential to be much more resilient to the climate than it is today, provided existing knowledge is incorporated into planning processes and renovation projects in the public and business sectors, as well as among homeowners.

9.6.1 Vulnerability to climate change

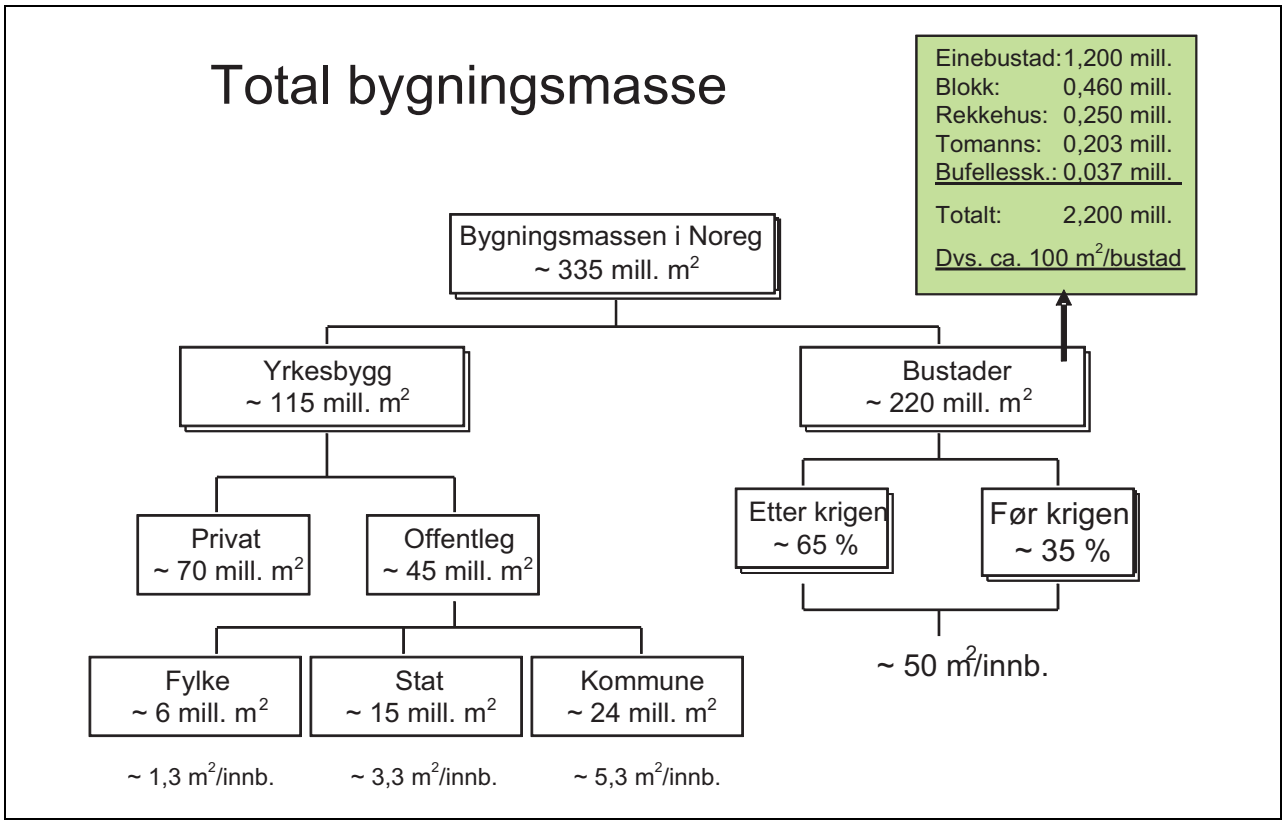
9.6.1.1 How are buildings impacted by the climate?

Settlements in Norway reflect the fact that the country has a varied climate and topography. Local climate conditions affect the service life of materials and structures in certain areas. Along with usage criteria and varying architectural sty-

les, climate has been an important premise in determining Norwegian building techniques. How climate affects buildings depends on their use, size, design and construction, as well as the materials used and location. The directional orientation and the design of the roof angles, placement of the building in the terrain, choice of materials and construction methods will determine how climate-adapted a building is. Moisture and insect attacks are examples of factors that lead to a biological breakdown of the buildings due to fungi and algae growth on exterior surfaces. Frost bursts, salt crystallisation and collapse due to snow loads, are other examples of effects on the built environment that can be directly related to the climate. The risk of frost deterioration of porous building materials, such as old brickwork and plaster, depends on how much water is absorbed by the materials when freezing. Roof snow loads are associated with the amount of precipitation, temperature and air humidity, wind and wind direction during and after a snowfall, design, construction and materials used in the roof, heat loss through the roof structure, as well as the local geography and topography.

As much as 76 per cent of all damage to buildings is caused by the effects of some form of moisture (Lisø and Kvande 2007), and this indicates that the built environment in Norway, despite our experience with adapting to shifting climatic conditions, is not adequately adapted to the current climatic conditions. Moisture-related damage in buildings is caused by moisture penetrating the construction. Precipitation and wind may trigger damage, but incorrect orientation and built-in faults are the most common causes of moisture damage. Buildings may also deteriorate as result of regulations not being observed, design faults, inadequate knowledge and/or as a result of poor communication between the parties in the building process.

Adding insulation to old buildings often increases the risk of rot damage. One of the reasons why many older buildings have managed to avoid damage is precisely because they have leaked heat and the walls have dried out. In combination with a more humid climate, adding insulation may make buildings more vulnerable to rot. Therefore, it will be important to develop and disseminate knowledge on how older buildings can be insulated whilst still preserving their antiquarian value and ordinary building physics.



Figur 9.2 Summary of the buildings in Norway (Multiconsult 2003)

9.6.1.2 How will buildings be impacted by the future climate?

Increased precipitation, exposure to moisture and changes in the wind patterns are the key climate variables that determine a building's vulnerability. The effect of moisture is reinforced by rising sea levels, increased and more intense precipitation and increased floods, landslides and avalanches in a changed climate.

Climate change may reinforce many of the climate variables that currently affect buildings. In addition, a change in precipitation patterns may lead to the spread of problems that have been associated with specific geographic areas to areas where the problems did not previously exist.

Climate change will entail increased impacts from lashing rain, i.e. a combination of rain and wind. There may be significant regional variation with respect to the prevalence of these effects.

Øyen et al. (2010) estimate that 2.4 million of the existing buildings will be at risk of rot damage in 2100. For example, almost all of the existing buildings in Oslo will move from the "moderate rot risk" category to a "high rot risk" category in 2100. In Hordaland county, currently about 190 000 buildings, or well over half of the buildings in the area, have a potentially high rot risk. This figure will increase to around 220 000 in 2100. The risk of rot in exterior wood constructions above ground is dependent to a great extent on local climate conditions. More parts of the country will be exposed due to climate change.

More extreme events, such as storm surges, landslides, avalanches and floods, will entail a risk to buildings in exposed locations. Some locations that are already exposed may become even more exposed, and new locations may become exposed. Rising sea levels in combination with storm surges will increase the risk of floods in coastal settlements

Historical buildings in a changed climate

A significant proportion of the buildings in Norway are older buildings worthy of preservation. Currently in Norway, there are about 6 000 protected buildings, around 5 500 buildings in museums, around 1 000 listed churches that are treated in practice as if they were protected, and a large number of buildings that are regulated for preservation pursuant to the Planning and Building Act. Around 375 000 buildings, primarily built before 1900, do not have any formal protection, but are registered in the Directorate for Cultural Heritage's SEFRAK register of historical buildings. A number of these buildings are worthy of preservation.

Most protected buildings are owned by private individuals. There are no statistics on buildings that are regulated for protection, but these buildings will also primarily be privately owned.

The government has defined the following national targets for cultural relics and sites, which the Storting has adopted through Storting Proposition No. 1 (2009–2010).

1. The annual loss of cultural assets and sites worthy of preservation must not exceed 0.5 per cent by the year 2020.
2. Protected and cultural relics and sites worthy of preservation must be safeguarded and maintained with an ordinary level of maintenance by 2020.

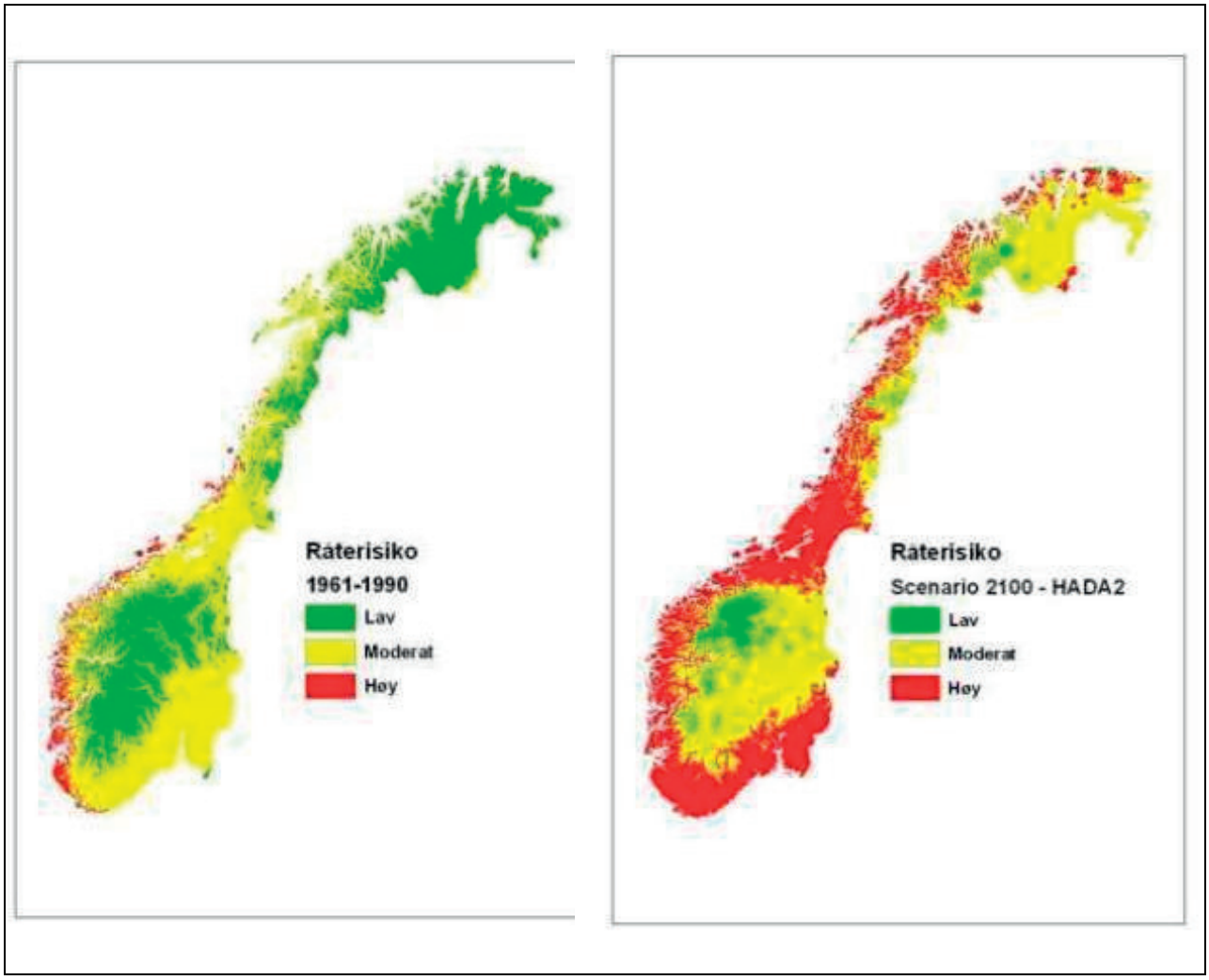
In the long term, climate change may mean that it will be more difficult to meet these targets.

The risk that climate change poses with respect to our building heritage will partly be related to the direct effects of a warmer, wetter and more extreme climate. The first consequences will likely be related to intervention in connection with energy saving measures, which often require new designs (Directorate for Cultural Heritage 2010).

In Norway, climate change will directly affect our building heritage, primarily through increased precipitation combined with higher temperatures. Climate change will increase the risk of rot damage to wooden buildings that make up around 80 per cent of the protected buildings in Norway (Directorate for Cultural Heritage 2010). The risk of rot in wood will likely increase the most along the western and northern coasts, where the increase in precipitation will be the greatest. A greater risk of rot is also expected in the inland areas due to higher temperatures and more precipitation in the spring and autumn.

In areas with permafrost, Svalbard in particular, the thawing of permafrost could destabilise building foundations and increase the risk of landslides and avalanches in settled areas. Our coastal building heritage, especially in areas that are most exposed to rising sea levels, will be endangered by more frequent storm surges and gradually rising water levels.

The Nordic cooperation project "Effects of climate change on cultural relics and sites", led by the Directorate for Cultural Heritage, has prepared future climate projections for a selection of Nordic world heritage sites. These sites include the Bryggen wharf in Bergen, which will be expo-



Figur 9.3 Potential rot risk in Norway today and in 2100. Large parts of the country will end up in the high rot risk classification in the future (based on Scheffer 1971, Lisø et al. 2006 and Øyen et al. 2010).

sed in the future to both a significant increase in precipitation and rising sea levels.

Increased deterioration of cultural buildings necessitates more supervision and maintenance for the prevention of damage, and more moisture and rot damage necessitates more repair work. The need for resources in sectors that manage buildings or building environments will likely increase with respect to funding, expertise and knowledge. Good workmanship and knowledge of the correct use of materials and traditional building techniques are important. Open-air museums must expect an increased need for maintenance as a result of climate change.

Climate vulnerability for historical buildings is similar to the vulnerability of other existing buildings, but there is an additional dimension, since these buildings cannot be replaced. Since it is not desirable to encroach on or make changes to protected buildings and other architectural heritage of great value, there are limits to the adaptation that is possible in this area. Our adaptation efforts must take into account the special requirements related to the maintenance and repair of cultural relics.

9.6.1.3 Adaptive capacity

Organisation

The committee believes that standards, guidelines and regulations, including the Regulations under the Planning and Building Act (TEK 10), provide a good framework for climate change adaptation in the construction industry. However, a lack of compliance, training and verification with respect to the building regulations weakens the adaptive capacity. The current information systems are not effective, and the players in the industry, which are often small businesses, do not receive the

information and training with respect to building standards etc. that they require.

The building sector has a very broad range of players, from very large contracting companies to a large number of sole proprietorships.

The Ministry of Local Government and Regional Development is responsible for policies and overall governance of the construction industry. In addition, the Ministry of the Environment is a key player at the ministerial level as the administrator of the planning part of the Planning and Building Act. The key players at the agency level are the National Office of Building Technology and Administration, the Norwegian State Housing Bank and Standards Norway. Government authorities stipulate requirements and standards, provide financial incentives, and offer support for information and competence building.

At the administrative level, the municipalities are responsible for local planning, supervision and verification of building applications. As the authority responsible for planning at the regional level, the county authority can influence planning in the municipalities, and the office of the county governor has an opportunity to influence municipal planning by functioning as the appeals board in building matters. The Ministry of Local Government and Regional Development and the Ministry of the Environment are key ministries through their administration of the Planning and Building Act and follow-up of land-use planning in the municipalities.

All public players also have roles as clients and owners, and some ministries own substantial assets, such as the Ministry of Education and Research (universities and colleges) and the Ministry of Defence with the Norwegian Defence Estates Agency, and therefore they play an important procurer role. Of the research institutions in this area, SINTEF Building and Infrastructure plays a key role.

As the planning, approval and supervisory authorities for matters pursuant to the Planning and Building Act, the municipalities have a considerable responsibility to contribute towards ensuring that the buildings maintain a high standard and protect the users from harm and inconvenience. The new Building Regulations introduced stricter requirements for the supervision of all building matters. Through their supervisory activities, the municipalities have an opportunity to identify and follow up violations of the regulations that may subsequently lead to damage. The municipalities do not have a satisfactory overview of the condition of the buildings, and the buildings are not generally established as separate companies. In addition, there are no internal leases between the different municipal agencies that use the building either.

Stricter requirements for risk and vulnerability analyses strengthen the municipalities' incentive to obtain competence early in regulation processes and when preparing analyses (Harvold et al. 2010). To a certain degree, the municipalities have incorporated requirements related to the climate, and this includes the revision of the Planning and Building Act. As a rule, this has been associated with climate-related events, such as the storm in Western Norway in 1992. In Bergen, the landslide at Hatlestad terrace in the autumn of 2005 resulted in changes to the municipal requirements, entailing a greater focus on assessing the risks and vulnerability associated with building sites.

The local processes related to reviewing and changing the routines and practices after extreme events depend on local initiatives and expertise within the current municipal framework (Aaheim et al. 2009). In order to facilitate preventive adaptation, all the municipalities should review their routines and practices in this area. There is a need for updated knowledge of the extent to which RAV analyses are used as active tools in the public sector at different levels and in the construction industry, and what can be done to strengthen the risk-based planning. Geological and geotechnical competence must be incorporated early in the process in order to ensure that buildings are built on sites that will remain suitable for construction in a changed climate.

Requirements and regulations

Buildings are regulated primarily through the Regulations relating to technical requirements for buildings (Technical Building Regulations) and the Planning and Building Act. These regulations have recently been revised and updated. Although climate change considerations are not referred to directly in the current regulatory framework, Storting Proposition No. 1 (2009–2010, Ministry of Local Government and Regional Development) stresses that the new building regulations will take into account the need to adapt new buildings to tougher climatic conditions and more extreme weather at a general level. The building section of the new Planning and Building Act will strengthen supervision to ensure compliance with the regulations and local requirements. This is not directly related to climate, but will nevertheless

play an important role as a legal policy instrument for climate change adaptation. The committee believes that the combination of Technical Building Regulations and the Planning and Building Act provides a good foundation for climate change adaptation.

General requirements for the municipal implementation of risk and vulnerability analyses are an important measure in the new Planning and Building Act, and this will have a major impact on development planning, especially with respect to the location of buildings and the review of building applications in the future. It will be an important signal at all the administrative levels (national government, county and municipality) that climate change adaptation is a political priority and becomes a basic strategic focus area for development of the built environment.

The research project "Climate 2000" (Lisø and Kvande 2007) primarily studied guidelines and methods for climate-adapted construction with a view towards new buildings. The existing buildings represent substantial value. There is a need for regulations for existing buildings (BE 2010). In this context it should be assessed whether future climate change will trigger a need for more extensive regulations for existing buildings. Regardless, the regulations must take into account the special challenges that apply to buildings worthy of preservation.

Climate change means that constructions defined as having an acceptable level of safety in the current climate may well be exposed in the future. In order for buildings to maintain the current standards, it will be necessary to introduce stricter requirements for new buildings being constructed today, as buildings have long service lives and increased maintenance levels. As emerges from the Government's action plan for buildings, further extension of the life of buildings is a goal. This will also increase the requirements for climate change adaptation.

It is the opinion of the committee that the regulations are of decisive importance with respect to how vulnerable buildings are to climate change adaptation, and that a lack of follow-up makes the sector more vulnerable.

Flow of information and competence building

Good systems for the dissemination of expertise and information to players are vital to ensure that adaptation considerations are better integrated into the building processes.

Studies carried out by SINTEF Building and Infrastructure indicate that the annual costs related to the building repairs due to the building process in Norway amount to around 4 per cent of the annual investment costs for new buildings. In addition, the studies show that a national focus on the reduction of building damage through systematic knowledge sharing and feedback could result in savings of 7 to 11 per cent of the net annual building production. The Ministry of Local Government and Regional Development points out that emphasis will be placed on reaching as many people as possible with information and knowledge on climate change adaptation of buildings.

Nevertheless, the authorities' current focus on climate change adaptation is not regarded as adequate for the needs of the building industry for practical and goal-oriented information on the adaptation of buildings to future climate change (BE 2010). Work in this field is currently fragmented. There is a lot of expertise and knowledge, but it is not easily accessible to the players in this industry.

Measures and development work in the construction industry tend to focus on promoting adaptation to the current climatic conditions, especially improved protection against moisture damage, which is the greatest single building damage problem. For example, climate indices and systematic division into climate zones for use in climate adaptation are not extensively used today, although these methods are available. The committee believes that one reason for this is inadequate dissemination of updated expertise in the industry. There are few systematic further and continuing education measures, and competence requirements are rarely stipulated, where the market itself would provide the necessary development of competence. The use of a non-local workforce when building new houses reinforces the need for greater knowledge and knowledge sharing. The lack of establishment thresholds for many building tasks makes the construction industry vulnerable to unprofessional players.

SINTEF Building and Infrastructure's Building Research Series includes guides that classify the various climate zones, but input received by the committee indicates a varying degree of use by the different players. Inadequate knowledge of climate development weakens the adaptive capacity for climate change, since building projects do

not take changes in the local climatic conditions into consideration in connection with new buildings. Given that this knowledge is available, major players will probably be in a better position to incorporate this expertise into their systems than small players. This applies to both the municipalities and commercial players in the industry. The challenge may be to get them to use this knowledge if it is not required. Small companies and municipalities may require a great deal of help and support to meet the challenges of climate change.

Resources

The construction industry consists of many private enterprises that operate according to commercial principles. Many public players own buildings and are clients in relation to the industry. The public players, especially the municipalities, have limited resources, particularly for following up and supervising building assignments and the maintenance of existing buildings.

The specialist expertise and traditional knowledge possessed by the executive players in the industry will be important resources for facing a changed climate. The consequences of taking adaptation into consideration will vary greatly according to the local climate conditions. In order for future buildings to be adapted to the future climate, the efforts must not be linked too strongly to one specific climate projection; rather, the available knowledge on climate developments must be used continuously and supplement traditional knowledge to develop resilient strategies over time.

Maintenance

A maintenance backlog will increase the damaging effects of climate change since the structures will not be equipped to handle increased precipitation. Multiconsult and PwC have estimated that the maintenance backlog in the municipal sector alone is between NOK 94 and 142 billion (Multiconsult and PwC 2008). Estimates from 2003 indicate a maintenance backlog of NOK 340 billion for commercial buildings and NOK 210 billion for private homes (Bjørberg 2003). Combined, these calculations indicate a maintenance backlog of NOK 550 billion, or more, if more recent estimates for the municipal sector are used as the basis. It is important to note that the maintenance backlog refers to a defined quality level, and that this backlog increases when the defined quality level is raised. Buildings which are not being maintained in accordance with the stipulated quality levels will be less resilient as regards increased exposure to climate effects in a changed climate. The report "Well-maintained buildings provide more for everyone" (NOU 2004:22) concludes that "systematic maintenance at a professionally correct level is profitable and will, over time, result in lower management costs than the opposite. Postponing maintenance in order to save money is, therefore, a short-sighted measure and results in higher costs in the long run".

In the action plan "Building for the future" (Ministry of Local Government and Regional Development 2009), maintenance and restoration are referred to as an area with great environmental potential. The plan discusses climate change adaptation, but it has not operationalised any relevant focus areas and measures in this area. The plan recommends the establishment of comprehensive environmental accounts by building new buildings rather than demolishing or rehabilitation, based on the benefits and costs in a life-cycle perspective. The need to make buildings capable of withstanding climate change is mentioned as a supplemental factor, not as an integrated part of such accounts. The report also states that in several areas, management appears to focus on "damage control and sudden spurts of activity", undermining the authorities' financial and political freedom of action. The situation indicates that there is room for improvement in many municipalities' management of properties.

Historical buildings have a special status, as they involve irreplaceable assets, and since there are special requirements that apply to their restoration and maintenance. Projects are underway to develop knowledge on the consequences of climate for historical buildings, and an assessment must be made as to what follow-up requirements they will entail with respect to funding, competence, knowledge and increased maintenance requirements.

In the opinion of the committee, the maintenance backlog increases the vulnerability of the buildings in the face of a changed climate.

Knowledge base

Good knowledge on facilitating building processes and climate-adapted solutions has been developed for new buildings. In particular, the research programme "Climate 2000" (Lisø and Kvande 2007), led by SINTEF Building and Infra-

structure, has provided new knowledge on climate change adaptation for the built environment over the past decade. SINTEF Building and Infrastructure is still issuing publications based on the Climate 2000 programme, and it has published a number of instructions and guides. Experience shows, nevertheless, that the use of this knowledge varies greatly.

Norway has one of the best building damage registration programmes in Europe, and it is important to make use of the lessons learned so far. SINTEF Building and Infrastructure has charted building damage through comprehensive field studies for more than 50 years, on assignment for both the construction industry and insurance companies. Detailed information on these assignments has been stored in an electronic building damage archive. Together with the building research series, this archive represents one of the most important sources of knowledge on damage types and causes in Norway.

The Climate 2000 programme addressed adaptation to the present climatic conditions. Now it is important to develop and use this knowledge to adapt to the future climate. There is a need to strengthen knowledge on the possible effects of climate change at the national level for the construction industry. It is essential to ensure constant updating and renewal of the knowledge base as the effects of climate change manifest themselves to prevent economic and other negative impacts of climate change on buildings. The need for a research programme should be evaluated against other ways of solving long-term knowledge needs that can ensure continuity in the development of knowledge, including whether there is a need for a new joint knowledge centre for climate change adaptation for buildings, and, if so, what the target groups, functions and forms of affiliation would be for such a centre.

Priorities

New design and architectural trends determine the requests of the construction industry's customers. Changes can be both positive and negative with respect to climate change adaptation. In recent years, the focus in the mass market has been to improve interior solutions rather than the general quality (Eriksen et al. 2007). This is negative for adaptation, which requires robust solutions. Poor adaptation to local conditions and the choice of the least expensive and simplest solutions within the regulatory requirements, rather than opting for more climate-adapted materials and solutions, also make the buildings less resilient to changed climatic conditions.

Buildings placed too close together as a result of increased urbanisation, or a deliberate concentration policy due to environmental considerations, may exacerbate problems concerning the handling of surface runoff and damage to buildings, as discussed in greater detail in Chapter 16.1. The interests of safeguarding natural diversity as expressed in the Nature Diversity Act may also increase the pressure on land areas and further affect the municipality's ability and willingness to locate new buildings in a climate-adapted manner.

Considerations other than climate change adaptation will take precedence in many decision-making processes by both public and private players. In the opinion of the committee, this weakens the adaptive capacity for climate change.

9.6.2 Socio-economic consequences

Vista Analyse (2010) calculates climate costs and gains based on four types of impact: more maintenance, increased claims payments from insurance companies, reduced heating requirements and increased cooling requirements.

A study carried out as part of the Climate 2000 programme shows that a 10 per cent increase in wind speed during a storm will more than double the costs related to wind damage to homes.

9.6.3 Adaptive needs

Adaptation to the current climatic conditions acts an indicator of the ability to adapt to climate change in the future. Many buildings are already vulnerable to the climate today. The socio-economic costs are already substantial, and they will only increase with time. Including adaptation as a factor in the

Table 9.2 Estimates of annual effects for buildings for the period 2070 2010 (Vista 2010)

Effect category	
Increased maintenance	4.5 – 10
Increased claims payments, water damage	0.3 – 0.75
Reduced heating requirements	-5 – -6
Increased cooling requirements	0.5 – 0.6
Total	0 – 5.5

planning processes today will probably be less expensive than the costs entailed by a wait-and-see attitude. Strengthening the maintenance of existing buildings will reduce climate vulnerability. There is a need for a better system for promoting renovation and maintenance, not only by the public authorities, but also through measures aimed at private players and homeowners.

There is a need to develop expertise and knowledge, improve dissemination of knowledge on building techniques and ensure a functioning planning regime that encompasses all stages, including maintenance and the improvement of existing buildings. The low-energy committee has proposed a focus on competence-building in the construction industry. Adaptation efforts can also benefit from such a focus, provided these considerations are taken into account.

In the opinion of the committee, strict requirements must be stipulated for more resilient building techniques in the future. A general improvement in quality will be necessary for the construction and operation of buildings, as well as the dissemination of knowledge on climate change, the consequences and adaptive needs to the public sector, the construction industry and individual homeowners. There must also be stricter documentation requirements for materials that are tested and approved for local climate impact. Zoning plans and building and improvement guidelines must take into consideration the current climatic conditions and projected climate scenarios for the future to a far greater extent. This work is currently underway through amendments to the Planning and Building Act.

Climate change will result in increasing challenges related to the handling of stormwater on and around buildings and an increased need for cooling in buildings. Green adaptation strategies for individual buildings and built environments may be part of the solution to these challenges. Green adaptation strategies for buildings involve the use of vegetation for cooling or handling stormwater in built environments. Norway has already implemented green strategies for the adaptation of buildings to a limited extent. There are no national guidelines on this topic, even though the intention is stated in the Planning and Building Act. The standardisation of green roofs has been initiated internationally, but Norway is not participating in this work.

New or revised guidelines in the building research series for existing buildings, differentiated solutions and guidelines that take into consideration the local climatic conditions are measures that can be implemented quickly. These measures may also help improve current and future climate change adaptation. There may also be a need to update the building damage registry.

A higher adaptive capacity is dependent on long-term efforts to further develop standards, building details, textbooks and educational material concerning guidelines and knowledge related to climate-adapted buildings. Development and implementation of the climate change adaptation field, and a greater focus on climate design of buildings (energy, climate and environment), must to a greater extent be incorporated as part of the training in building and construction trades. For example, a framework must be developed to ensure further and continuing training for both teachers in secondary and vocational schools, and for employees in the industry. In order to meet climate change in a sustainable and robust manner, there is a need to

Box 9.6 Swedish estimates for how buildings will be impacted by climate change

SOU (2007) indicates that more than 300 000 buildings in Sweden are in areas with a high risk of landslides, avalanches and erosion. Buildings valued at between SEK 30 and 100 billion will be at risk this century, unless measures are implemented. According to the Swedish studies, the flooding of settlements can cause damage in excess of SEK 100 billion. Costs related to preventive measures are assessed to be significantly lower in many cases. For certain parts of Sweden, it has been assessed that relatively cost-intensive measures must be implemented as soon as possible to prevent damage to exposed settlements.

Box 9.7 Green roofs

One example of a green roof is Haraldrud Gjenvinning in Oslo, which now has the largest green roof in the Nordic region. The sedum plant species used to cover roofs absorbs 50 per cent of the roof water, and the roof binds both dust and CO_2. The building is therefore better adapted to increased precipitation, and the green roof has a positive effect on heat regulation in the building.

develop strategies for increased use of green knowledge in the local adaptation efforts, including the handling of stormwater, management of groundwater and cooling of buildings.

Municipal expertise regarding climate change adaptation and buildings' climate vulnerability must be improved so that the new prerequisites regarding supervision can contribute to better climate change adaptation in planning, the building process and completed buildings, and so that the municipalities will be able to formulate local climate requirements and advice to the players (Harvold et al. 2010). The Ministry of Local Government and Regional Development (2009) also emphasises this, with reference to the need for increased supervision: "Increased supervision from the municipalities will require more resources in the municipalities".

The national authorities must assess whether Norway participates to an adequate degree in international forums for training and the exchange of experience, and whether it participates in international forums to a great enough extent to influence the formulation of international standards that will be normative for the industry.

9.6.4 The committee's recommendations

In order to improve climate change adaptation in the construction industry, the committee recommends:

Research-based development of knowledge

- Establishing a separate strategic research programme in the Research Council of Norway for the construction industry with a main emphasis on the consequences of climate change.

Knowledge systems and dissemination of knowledge

- Identify and design policy instruments that help disseminate knowledge about climate change and adaptation to all parties in the industry. The Building Research Series from SINTEF (the Foundation for Scientific and Industrial Research at the Norwegian University of Science and Technology) may be one such policy instrument, but may not necessarily be sufficient.
- Make greater use of the Norwegian Climate Change Adaptation Programme, the Norwegian government's information platform, to reach out to the construction industry with information, even if it is currently aimed at parties in the public sector, especially in the municipalities.
- Facilitate continuous updating of a national database for building quality (www.byggkvalitet.no).
- Prepare a national strategy for utilising green environmental knowledge in the local adaptation efforts (cooling of buildings, handling of stormwater).
- Increase the resources for preventive advice to house builders and homeowners.
- Make better use of known climate data in the planning, design and erection of buildings.

Management regimes

- Include climate monitoring in the Directorate for Cultural Heritage's environmental monitoring programme and establish a separate preservation programme for buildings of cultural and historical significance that are particularly vulnerable to climate change.
- Establish clear competence requirements for all parties that conduct economic activity in the construction industry, and require that companies systematically provide continuing and further education for employees.
- Propose the preparation of regional climate indices or climate zones in order to clarify the requirements that should to be set for the building stock and for use in municipal land-use planning.
- Introduce stricter national requirements for documentation of building materials, including requirements related to the materials' properties and requirements that derive from climate change.
- Introduce stricter requirements for more robust construction practices and requirements for the use of life-cycle analyses in the construction and operation of buildings.
- Strengthen incentives for increased maintenance of municipal buildings, e.g. by assessing changes in the requirements for municipal accounting and providing advice about the organisation of municipal property management.
- National authorities ought to participate to a greater extent in international forums for the development of international standards for adapting buildings to climate change.

Chapter 10
Business and industry

Norwegian businesses and industries are exposed to climate change that directly, or indirectly, impacts activities in particular industries and individual enterprises. It is also exposed to the consequences for other sectors of society. This particularly applies to infrastructure which is vital to the enterprises' ability for value creation, such as communications, power supply, premises and equipment.

Norwegian business and industry comprises more than 350 000 enterprises (Statistics Norway: Establishments and enterprises 2010). Their activities cover primary industries such as agriculture, secondary industries such as manufacture of machinery and equipment, and tertiary industries such as retailing and entertainment. Private-sector enterprises employ 1.6 million people and are responsible for more than 70 per cent of the economic growth in Norway. Naturally, it is difficult to make general statements regarding climate impact on such a large and varied group of enterprises.

Climate change will have a direct impact on industries that base their activities on natural resources, such as agriculture and forestry, fishing, aquaculture and the petroleum industries. It will also affect typical outdoor industries such as tourism. These industries will be discussed in some detail in this chapter. The committee has chosen to discuss industries that it is natural to look at in relation to infrastructure in Chapter 9, such as the construction industry and the power sector. The shipping industry, which will face unique opportunities and challenges as a result of the reduction in Arctic sea ice, has also been discussed in Chapter 9.

Businesses and industries are vulnerable to impact in other areas of society, above all in regards to infrastructure and buildings. Coffee shops, furniture factories and fish farms all depend on functioning power and communications infrastructure, premises and equipment being in working order, employees being able to get to work and receiving goods and services from suppliers and delivering them to customers on time. It will be vital to ensure that climate-related incidents such as power outages, damage to the transport network, grid disruptions and damage to buildings do not affect Norway more seriously than other countries, making business and industry less competitive. Resilient infrastructure and buildings are therefore essential to prevent climate change impact from diminishing value creation by businesses and industries. These consequences are discussed in more detail in Chapter 9.

The industries that will be indirectly affected through impact on buildings or infrastructure will not be discussed further here, with one exception: the insurance industry has a special place due to the impact that climate change will have on the industry's market. The insurance industry is also an excellent example of how the private sector can play an active role in society's adaptation. By taking on the risk of unforeseen losses from other players in society, insurance can potentially play an important role in reducing vulnerability. The insurance industry can also actively promote adaptation to climate change, for example in buildings, assuming the right framework is put in place. Insurance is discussed in Chapter 10.4.

The construction industry is another example of how both society and businesses are mutually dependent in their adaptation efforts. By realising investments in practice, the construction industry will be a key player in adaptation. In order to exploit this role, the right framework must be created, and political signals must reach enterprises so that they can find good solutions that promote adaptation. The construction industry is discussed in more detail in Chapter 9.6.

Climate change may pave the way for new activities and areas of wealth creation. In some areas, however, exploiting those new opportunities may bring businesses into conflict with other considerations, primarily environmental ones. In some cases this will require strategic political decisions and prioritisations.

In Norway, safeguarding jobs is high on the political agenda. The authorities are quick to react

when jobs at cornerstone enterprises, or in important industries, come under threat. Government efforts to save jobs at Årdal, Skien and in the construction industry are examples of this. The political willingness to intervene will support the ability of business and industry to adapt to climate change.

Adaptation in the private sector must be viewed in the context of the fact that enterprises are continuously developing and are quick to adapt to change. The structure of the Norwegian economy has changed radically over the past century and is likely to continue changing even more rapidly over the next one. Two-thirds of new Norwegian enterprises survive for less than five years. The majority of the current Norwegian enterprises will therefore have been replaced by new ones in 2050 – let alone 2100 – and the ones that do still exist will probably have changed both their range of products and technologies several times over the course of the century. As such, business and industry will constantly be adapting. It is therefore particularly important to create a good regulatory framework for innovation and adaptation, which makes it possible to adapt operations to a changing climate and to make use of the opportunities that it provides.

10.1 Agriculture, forestry, reindeer husbandry and other wilderness-based sectors

The activities of the onshore primary industries are dependent on plant production, which at our latitudes fluctuates with the annual sunlight and temperature cycle to a greater extent than in many other parts of the world[1]. But other climate variables, such as humidity, precipitation, surface runoff, wind and various combinations of these climate variables, also have a major impact on the productivity of plants and animals. As these industries are directly dependent on climatic conditions, in principle they are highly exposed to the impacts of climate change.

The primary industries provide the raw materials for the timber and food processing industries, and having active agricultural, forestry and wilderness-based industries is beneficial in terms of tourism, cultivated landscapes and local communities. It is expected that climate change in Norway will allow for greater agricultural production and will probably also increase aquaculture production. In many parts of the world, agricultural production is expected to decrease as a result of climate change. In view of this, agriculture in Norway may become more important to food production and food security in the future. See Chapter 11.3 for a more detailed discussion of this.

To achieve our goal of maintaining active and sustainable primary industries in the face of changing climatic conditions, we must take climate change into account when formulating policies and tools and developing new research-based expertise. Among other things, adapting to climate change will require plant varieties and technology that are better adapted. Adaptation also requires management regimes to take into consideration the impact of the climate on the ecosystems that provide the basis for the industry. Raising awareness of the consequences of climate change among enterprises and developing their expertise will also be a prerequisite for proactive adaptation to a changing climate.

The committee's overall assessment is that the primary industries, in spite of their dependence on climatic conditions, are moderately vulnerable to climate change. This is partly due to the expected increase in the growth potential of plants, but also to the good management framework, access to resources and sound knowledge base. It is the view of the committee that the sector can successfully adapt within the existing institutional and economic framework. However, there is a need to develop new technologies and increase the understanding of adaptation within the primary industries. Regulations and subsidy regimes should also be reviewed in order to assess whether they promote or obstruct adaptation.

10.1.1 Vulnerability to climate change

10.1.1.1 How are the industries impacted by the present climate?

Agriculture

In 2009, there were around 58 000 full-time-equivalent workers in the agricultural industry. The pro-

[1] The following industries are included here: agriculture, forestry and wilderness-based sectors. Agriculture comprises crop production, animal husbandry, horticulture and greenhouse production. Forestry comprises traditional timber production and the management of natural resources and ecosystems in forests. Wilderness-based sectors refers to grazing, freshwater fishing and reindeer husbandry, as well as hunting. Other wilderness-based sectors will be discussed under living conditions and Sámi culture and commercial activities (e.g. in Chapters 11.4 and 11.2).

duction value of the food industry, excluding fish products, but including the food-processing industry, was around NOK 118 billion in 2007, and the industry had approx. 40 000 full-time equivalents. Increasing efficiency and constant structural change are two of the key developments in Norwegian agriculture. There are around 177 000 agricultural properties with farmland in Norway, around a quarter of which were independent farms in 2008. The trend is towards larger units and more leasing of land. Around 1.03 million hectares of agricultural land is actively farmed.

Even with the current climate, farming activities and technology have to adapt to considerable challenges in the form of torrential rains, floods, drought, ice cover on the ground, frost damage during the growing season and other climate-related challenges. The extent to which insects and fungi damage agricultural production already varies in response to precipitation, humidity and temperature. The agricultural industry is therefore continuously developing its expertise and technology and adapting in order to optimise its production to the local climatic conditions. Annual crops can more easily adapt to changes in the conditions through breeding and the appropriate selection of varieties than crops with long generational intervals.

The way in which animal husbandry is structured is thought to be one of the most important reasons for the good animal health in Norway. High levels of expertise and effective systems for monitoring animal health play an important role. Infection pressure is kept under control by the wide geographical spread of production and by periods during which grazing land is not used. Furthermore, Norway's cold climate plays a direct role by eliminating a number of infectious agents. However, in recent years the trend has been towards a heavy concentration of animal husbandry in a few regions; for instance, Jæren has the highest density of domesticated animals in Europe. This increases the risk of infection spreading rapidly in the event of an outbreak of a new domestic animal disease in one of these regions.

Forestry

Forestry and the forest industry employed just over 25 000 full-time equivalents in 2007. The forest industry's total production value was around NOK 47 billion, including around NOK 14 billion of exports. The total area of productive and non-productive forest land in Norway is close to 124 000 km^2. Of this, about 80 000 km^2 is productive forest, i.e. it produces more than around 1 m^3 per hectare per year. The non-productive forest comprises up to 17 000 km^2 of non-productive forest on firm ground and 6 000 km^2 on marsh land below the conifer tree line overgrown with trees. The remaining 21 000 km^2 consists of mountain birch forest above the conifer tree line and in Finnmark.

In the current climate, the forest industry's methods of production and forest management have to adapt to significant climate-related challenges. These include insect and fungi attacks that vary with temperature and humidity, operating conditions that vary with frost, snow cover and precipitation, and damage due to frost, wind, snow breakage and drought. Even with the current climate, summers with prolonged warm spells can produce two generations of bark beetles, leading to significant increases in the population size. Warm summers, combined with drought conditions, weaken the trees' resistance against such pests.

One important climate-related challenge facing the forest industry is that it must use varieties that are adapted to, and capable of surviving in, the current climate when planting new forests, although the trees will not be harvested for another 60–120 years, when the climatic conditions will be different. New varieties are therefore being bred for gradual introduction as the climate changes, in order to enable adaptation to the future opportunities afforded by climate change. The Norwegian Forest Seed Centre's 2010–2014 strategy for breeding forest plants includes adaptation to the climate as one of the main goals for all forest tree breeding programmes in Norway.

Reindeer husbandry

In Norway, reindeer husbandry has its origins in the Sámi population. Sámi people herd reindeer in the mountains and wilderness in Finnmark, Troms, Nordland and Nord-Trøndelag counties, and in parts of Møre og Romsdal, Sør-Trøndelag and Hedmark counties. Reindeer are also herded in rural communities, organised through cooperative societies, in the northern part of the Gudbrandsdalen valley and in the Valdres valley. In total, reindeer husbandry takes place in almost 140 municipalities in Norway, over an area that constitutes around 40 per cent of Norway's land area, or around 140 000 km^2 (Storting White Paper No. 39 (2008–2009)). The grazing lands are the most important resource for reindeer husban-

dry. The fact that reindeer need different kinds of grazing land over the course of the year means that reindeer husbandry is highly dependent on access to land.

Differences between local climates, topographies and grazing conditions can result in the production variations in reindeer herds between areas, and between years within the same grazing area. While summer grazing conditions have the largest impact on the dress weight of reindeer, factors such as snow levels and conditions also affect the herd's regeneration levels. If there is little snow on the winter grazing lands, the plants that the reindeer graze on are more accessible. If there are ice layers in the snow and/or on the ground, it is harder for them to reach the vegetation. Large amounts of wind-packed snow and/or ice layers in the snow cover can completely or partially prevent reindeer from getting to their winter food.

Traditional reindeer husbandry is based on the natural migration and movement patterns of the reindeer as they seek the best grazing land during different times of the year. Nevertheless, as a nature-based industry, reindeer husbandry has a long history of adapting itself to the climate and natural climate variations. Social developments are resulting in a variety of interventions that are reducing and fragmenting the area available for reindeer husbandry. This in turn limits the possibility of using alternative areas when the climate makes it difficult to use the current core areas for grazing, putting even greater pressure on reindeer husbandry. There are also other challenges increasingly affecting the industry, such as growing predator populations, the development of tourist facilities and increased traffic, as well as, in some cases, imbalances between what the grazing areas can sustain and animal density.

Hunting and fishing

Hunting is an additional source of income for landowners, who can lease out hunting rights and sell the meat. The state also owns large areas of land with hunting rights that it leases out. One important part of Norwegian agricultural policy has been to encourage landowners to make commercial use of their uncultivated land, allowing them to supplement their income by building mountain cabins, leasing out hunting and fishing rights, and so on. The wilderness-based sector also includes harvesting berries, mushrooms and other wild plants that have commercial value. This industry is based on what can be found in the countryside during the various seasons, and it cannot therefore be said to be particularly exposed in the current climate.

10.1.1.2 How will the industries be impacted by climate change?

All industries based on biological resources will be directly exposed to the effects of climate change. In general, higher temperatures will increase the spread of plants and trees both northwards and to higher altitudes. This will affect genetic diversity and the balance between species. If the climate does not change too quickly, species may be able to naturally adapt to the new conditions. Higher temperatures and greater humidity may also affect harvesting conditions, logistics, storage and, in some cases, processing methods. Those conditions may also increase the risk of damage caused both by pests and directly by the weather itself. This may in turn have a significant impact on the quantity and quality of what is produced, and consequently on the wealth created by the industries.

Agriculture

A moderate temperature increase is expected in Norway, and combined with sufficient access to water this may result in increased production. However, this will depend on farmers starting to use plants and varieties that can benefit from the extended growing season. Higher temperatures and a longer growing season may also allow the introduction of new crops that require a warmer climate, such as more autumn-sown cereals and cereals for human consumption in areas where the short growing season currently prevents it. The number of daylight hours will however limit what can be produced without the use of artificial light, even if rising temperatures prolong the growing season. This limit is most relevant in Northern Norway.

Increased precipitation may make harvesting more difficult, both because it may negatively impact crop quality, and because it may increase the problem of damage caused by vehicles. More precipitation and a higher number of intense precipitation events, combined with less snow cover and shorter periods of ground frost, will increase erosion and surface runoff. This causes both the loss of valuable topsoil and deterioration in water quality as a result of greater runoff of particles and fertilizers from farmland. It can also be expected to exacerbate operating problems and winter

damage, particularly where there are poor drainage systems. Inadequate maintenance of drainage systems significantly increases the vulnerability of agriculture to climate change.

Higher temperatures and more precipitation may lead to increasing damage caused by existing and new pests, viruses and fungal diseases. This will both be directly through increasingly intense attacks by larger numbers of pests and indirectly through improved conditions for vectors, allowing them to spread the pests more effectively. Higher temperatures, humidity and longer growing seasons may also lead to a greater variety of weeds that are also able to make use of the longer growing season. This may create challenges in terms of pest and weed control, and the need for chemical weed killers and pesticides may increase with a changing climate.

There have been few studies on the effect of climate change on diseases in domestic animals, partly because it is hard to isolate the effect of climate change from the effects of other changes. However, it is likely that a warmer climate will have an impact on the health and welfare of domestic and wild animals alike. Temperature is a very important factor, and particularly winter temperatures above a certain threshold can allow more organisms to survive; see discussion in Chapter 8.1, Health. Greater humidity can also promote survival. Both vector-borne and parasitic diseases may pose increasing problems for Norwegian agriculture.

Wild animals can also become infected and spread infection, thereby making it harder to combat the diseases. Regrowth and other environmental factors may also tend to do the same. Both structural changes to agriculture that have resulted in regional concentrations of domestic animals and larger production units may increase the risk of diseases spreading. With a milder climate, animal diseases transmitted by vectors such as biting midges (bluetongue disease), ticks or mosquitoes will be the major challenges in relation to animal health.

Increased temperatures and plant growth may produce better grazing conditions in uncultivated land for domestic animals and extend the grazing season, but it may also increase the risk of diseases being acquired during grazing. More precipitation in autumn may shorten the grazing season by making the pasture more exposed to trampling damage. Heavy precipitation in the form of rain in winter resulting in ice cover on the ground may increase winter damage and surface runoff.

Forestry

In areas where lower summer precipitation does not produce a soil moisture deficit, the combination of a longer growing season and higher CO_2 content in the air will allow the forest to grow more quickly. This will also allow the forest to bind more CO_2 (Zheng et al. 2002). The productive forests will expand both to higher altitudes and northwards throughout the country. Higher temperatures will extend the distribution ranges of existing species and potentially allow the introduction of new species that prefer a warmer climate. In the long term, this may alter the balance between the various species of trees in Norwegian forests. There will be significant regional differences, with forests in Southern and Eastern Norway potentially facing drought stress, and during a transition period it appears that the growing season in the interior of Finnmark and Troms may become somewhat shorter (Høgda et al. 2001)

The largest threat to the health and vitality of Norwegian forests going forward will be increasing attacks by native pests such as fungi, insects, deer and rodents, as well as non-native organisms that may be able to establish viable populations in Norway as a result of climate change. The conditions may improve for existing species, enabling them to cause greater damage. Insects that may cause significantly more harm include species which are already present and causing damage in Norway today, but that would cross the threshold from one to two generations annually with higher temperatures. Other insects currently exist in Norway without doing serious harm, but which are serious pests for our southern neighbours, and with higher temperatures they may develop into more vital and harmful populations. There are also a range of species that would normally take some time to migrate, as specific habitats must develop in Norway for damaging populations to become viable. The last group are pests which do not currently exist in Norway, but that may be introduced with imported timber, and that would rapidly establish themselves in Norway if the climate were warmer.

Without ground frost for much of the year and with less snow cover, operating conditions will become more difficult using existing technology. Winter has traditionally been an important time for much of the Norwegian forest industry, due to soft ground conditions. Two or three fewer snow and ground frost months will make it more challenging to maintain this operating model without vehicles also causing more damage to the ground.

More intense precipitation incidents may also damage or wash away forest roads. This may in turn result in additional operating and maintenance costs and a less reliable supply of timber for the industry. Poorly-chosen routes can change natural drainage patterns and lead to a greater risk of landslides, particularly as regards steep slopes (Bakkehøi 2008), which means that it is important to carefully plan drainage. Climate change may also result in more damage caused by freeze–thaw cycles, changes in wind patterns, heightened fire risk due to drought and increased erosion as a result of more precipitation, with a risk of nutrients being washed out of the soil.

Reindeer husbandry

Reindeer husbandry is one of the industries in the Norwegian Arctic that has been studied the most in relation to climate change (Buanes et al. 2009). Due to the fact that it uses large grazing areas in the High North all year round, reindeer husbandry may be very seriously impacted by climate change in some respects. Climate change may pose major challenges for traditional reindeer husbandry by reducing access to pasture both qualitatively and quantitatively, thereby changing nutrient intake (Øseth 2010). The consequences of poorer grazing conditions are largely known. When winters are bad, the doe produces less milk, and the calves suffer.

Climate change will also heighten the risk of reindeer herds suffering stress due to insect attacks. It will be possible, and necessary, to change the way in which the reindeer husbandry areas are used, including changing the traditional migration routes and times. Climate change may also increase competition for reindeer husbandry areas from other industries. The impact on reindeer husbandry will vary from area to area, depending on regional and local conditions, as well as when and how the areas are used for herding. It is difficult to predict the overall effect of these various factors. The complexity of the problem is clear from the available research on the affect of climate change on northern deer populations (Weladji et al. 2002). If, for instance, the winter climate in the inland winter grazing areas in Norway becomes milder and more unstable, there is a heightened risk that ice layers will prevent the reindeer from being able to reach their grazing areas. In 1997, large numbers of reindeer were lost in Finnmark because of this. In addition, increasingly humid weather patterns may reduce the quality of the winter grazing, by allowing species that thrive in wet conditions to spread, at the expense of lichen-dominated vegetation types. By contrast, more precipitation may increase access to nutrients, and hence increase lichen growth rates, provided that the lichen is not ousted by other species. An increase in average temperatures, as well as wetter springs and autumns may have a positive impact on summer grazing lands by prolonging the growing season and increasing the growth rate of green pastures (Aaheim et al. 2009).

Climate projections also suggest that summers will become warmer. Higher temperatures increase parasite numbers on reindeer and can also raise the risk of new parasites and diseases (Aaheim et al. 2009). The positive impact of an earlier onset of spring is to some extent counteracted by warmer summers, as insect attacks may increase, affecting the survival rates and condition of the calves (Weladji 2003). It may also result in lower slaughter weights, which would have significant financial implications (SOU 2007:60). Any reduction in the amount of mountain grazing and snow-beds may further exacerbate the insect problem (SOU 2007:60). Increasing attacks by the larvae of the winter moth and autumnal moth (Operophtera brumata and Epirrita autumnata) have caused significant damage to birch forests, which in turn is changing the vegetation on the ground. This may affect reindeer grazing, but little is known about the matter.

Freshwater fishing in rivers and lakes

The vast majority of freshwater fishing in Norway is a marginal industry. The exception to this is salmon fishing, which has a turnover of several billion kroner each year (Storting Proposition No. 32 (2006–2007)). Salmon, trout and char populations may decrease as a result of climate change, and in some rivers the summer temperatures may become so high that salmon and trout populations will completely disappear; see the more detailed discussion in Chapter 7, The natural environment. Dammed rivers with low minimum waterflow may be particularly at risk. Salmon fishing in the sea and rivers are also traditional Sámi livelihoods that will be affected by changing conditions for the salmon; see the more detailed discussion in Chapter 12.2, Sámi culture and commerce. Meanwhile, higher temperatures in rivers and lakes will make it easier for species from further south to establish in Norway. Alien species may also be able to establish themselves in watercour-

ses. Increased mobility and alien species may pose a threat to Norway's freshwater fauna.

Hunting and trapping

In the long term, climate change will significantly alter the game animal habitats. Species living at the northern limits of their distribution ranges, such as red deer and roe deer, may extend their ranges and the populations may become denser. Wild reindeer herds will have increasing problems maintaining their populations, due to changes in vegetation, increasing competition from species occupying the fringes of their habitats and greater fragmentation of grazing areas. This is discussed in greater detail in Chapter 7, The natural environment.

Climate change will increase the probability of alien species such as raccoon dogs and wild boar being able to establish themselves in Norway, which may also displace native Norwegian species. If wild boar do establish themselves in Norwegian forests, it will be possible to hunt them, as is done in parts of Sweden. However, wild boar is not a desirable addition to Norwegian fauna as boar can cause a great deal of damage and displace native species.

A milder climate, with less snow cover, will make it harder for the large predators to hunt deer. Studies have shown that both lynx and wolves have lower hunting success rates in shallower snow (Nilsen et al. 2009, Wikenros et al. 2009). A study from Alberta, Canada indicates that snow depth also affects the age of the animals killed by wolves, with animal size increasing in parallel with snow depth (Huggard 1993).

Both animals that are hunted and plants that are harvested are integrated parts of the ecosystems in which they live. In Chapter 7, the committee pointed out that there are limits to the abilities of many species to adapt to rapid climate change. Hunting and other forms of harvesting in uncultivated areas are therefore directly affected by climate change. However, it will also be necessary to change the way in which uncultivated areas are used in response to changes in game populations and other wilderness resources. The underlying conditions for hunting and harvesting in the countryside will be altered, but to some extent society can mitigate the consequences of this through sustainable management reflecting the impacts of climate change.

10.1.1.3 Adaptive capacity

Organisation

Stakeholders in agriculture, forestry, reindeer husbandry and the wilderness-based sectors comprise a broad mix of enterprises, farmers, forest owners, reindeer owners, landowners and their associations, research institutes and the authorities. The Ministry of Agriculture and Food and the agencies that report to it, such as the Norwegian Agricultural Authority, the Norwegian Reindeer Husbandry Administration and the Norwegian Food Safety Authority, are the main authorities that govern the primary industries. In addition, regional and local authorities can decide on matters that affect their operational activities and regulatory framework.

It is a stated goal of agricultural and food policy (Storting Proposition No. 1 (2009–2010)) to maintain an active and sustainable agricultural sector throughout Norway, which is adapted to the current climate and produces low emissions of greenhouse gases. National policy places particular emphasis on ensuring that the future potential for increased production in Norway is exploited, due to both national and global considerations. It highlights the need for systematic measures to adapt to climate change if Norway is to increase food and biomass production.

National policy also aims to encourage and promote greater value creation and improved quality of life through the sustainable management of agricultural and rural resources. The agricultural industries in Norway play a key role in regional development policy. The management regimes that determine the geographical distribution of agricultural production are implemented through industrial policy and a wide range of other measures. Consequently, agricultural activities are not always carried out in the optimum location from a production and environmental perspective.

Financial, legal and information measures are used to promote desired developments and adaptations. Norwegian agriculture is managed within a regulatory framework that covers both farming and forestry. Each year, the government and the farmers' unions negotiate a financial framework as well as industrial and environmental policy measures for the industry. Important aspects of the financial framework for forestry are also specified in these agricultural agreements. This mechanism is the primary forum for discussions between the industry and its representative organisations and the national authorities.

The Norwegian Agricultural Authority is responsible for implementing agricultural policy and the annual agricultural agreements at the national level. County governors are responsible at the regional level. The Norwegian Food Safety Authority has the national and regional responsibility for ensuring food safety and animal and plant health. The Norwegian Reindeer Husbandry Administration and its regional offices implement policies and agreements on reindeer husbandry.

Municipalities are the initial point of contact for individual enterprises in the agricultural and forestry sectors. In recent years there has been a reduction in resources and expertise at municipal agriculture departments. Nationwide, the reduction has been approximately 30 per cent. The proposed 2009–2010 national budget highlighted that *"Although there is a great deal of variation between the various municipalities and counties, staffing has reached critical levels in some municipalities"* (Storting Proposition No. 1 (2009–2010)). This may weaken the ability of the agricultural authorities to monitor local adaptation to climate change within the agriculture industry, and may have a negative impact on the sector's adaptive capacity.

The Ministry of Agriculture and Food owns four research institutes that cover the sector's research needs, and which also support the authorities by providing maps and geodata, statistics and expert assessments relating to plant and animal health. The Norwegian Agricultural Advisory Service (Norsk Landbruksrådgiving) and the Forestry Extension Institute play an important role in transferring knowledge to the operational levels of the industry.

It is the committee's view that the agricultural sector has an overall structure that allows government agencies and research institutes to cooperate successfully. Together with close consultation with industry bodies on policy measures, this helps to ensure that the sector is in a good position to formulate a coordinated response to the challenges posed by adaptation. This includes coordinated efforts to build expertise in priority areas and clear and efficient implementation of systematic response measures and adaptations. However, the committee would also like to point out that a reduction in the expertise and capacity of municipal agricultural departments will weaken the sector's adaptive capacity.

Requirements and regulations

There are a range of regulations, requirements and guidelines that are relevant to adaptation to climate change in the agricultural, forestry, reindeer husbandry and wilderness-based sectors. Several of these regulations are based on international rules and requirements. The committee has not looked at the regulations individually. However, the committee believes that the regulations and control mechanisms governing the primary industries are highly developed, but that they need to be reviewed to ensure that adaptation considerations are adequately taken into account.

Approval schemes for the introduction of new plant breeds, rules relating to animal and plant health, import controls and other regulations have been developed to protect the primary industries in the current climate. Based on that, the committee believes that the regulatory frameworks and requirements that currently exist for the primary industries will be able to deal with adaptation to a changing climate. However, climate change means that it is necessary to review the nature of these frameworks in order to assess whether sufficient consideration has been given to adaptation. It will also be essential to gradually adapt these systems as the climate changes, new knowledge comes to light and the nature of the risks alters and/or increases.

Freshwater fishing is governed by the Act relating to Salmonids and Fresh-Water Fish, etc. and the Water Resources Act. Landowners hold the fishing rights, and have the authority to manage fishing activities locally. In dammed watercourses it will in some cases be possible to counteract the negative impacts of climate change by adjusting the water released through power stations and from reservoirs. It is possible to both regulate the temperature by altering the water layer from which water is released, and adjust the amount of water released. It will be necessary to review and amend the terms of the licence agreements in order to implement such measures.

To enable the continued harvesting of natural populations in these ecosystems, it will be necessary to introduce measures to prevent the further spread of alien freshwater species and to eliminate them where they have already established themselves.

The Reindeer Husbandry Act shall enable the sustainable use of the grazing resources for the benefit of the people who depend on reindeer husbandry for their livelihood and society at large. Reindeer husbandry shall be protected as an important foundation of Sámi culture, in accordance with Article 110a of the Norwegian Constitution and the human rights of indigenous peoples and minorities under international law.

Information flow

The unique cooperation between industries, the authorities, researchers and educational institutions within the primary industries in Norway is a strength that will help enhance the sector's adaptive capacity. Stakeholders and organisations in the primary industries, research institutes and the responsible authorities already share knowledge through regular contact, and maintaining that cooperation will play a very important role in adaptation.

The agricultural sector takes an integrated approach to management and research, with extensive collaboration between the institutions responsible for higher education – the Norwegian University of Life Sciences and the Norwegian School of Veterinary Science – applied research institutes, institutions with responsibility for knowledge-sharing, the Norwegian Genetic Resources Centre, the Norwegian Agricultural Advisory Service, the Forestry Extension Institute, the Norwegian Forestry Society and the breeding centres Geno, the Norwegian Forest Seed Centre and Graminor. This provides a good foundation for adaptation efforts. The Nordic countries already collaborate within several of these areas, and that cooperation is being further strengthened.

The committee therefore believes that the agricultural sector and reindeer husbandry sector have a system for building knowledge and exchanging information that works well, and for reindeer husbandry, traditional knowledge is an important part of that system. The committee also believes that the system has the ability to meet the challenges posed by adaptation; however, it will be a challenge to integrate new knowledge about adaptation into both vocational and higher education courses. This also applies to upper secondary education and further and continuing education for people in the industry, advisers and the authorities.

One of the features of the sector is that many enterprises are run by people who combine agriculture or forestry with another profession. This could entail that many agricultural and forestry enterprises are not run by people with specialist expertise in agriculture and forestry. If particularly demanding technical challenges result from climate change, it may be necessary to provide resources to improve research and knowledge sharing with the industries.

Resources

The committee believes that the agricultural sector is in a fairly good position in terms of resources for adaptation. Various challenges require major technological advances and research, which in turn require more resources and/or changes to priorities. Upgrading and maintaining the drainage system, for instance, and other measures to prevent damage due to more abundant and intense precipitation may lead to higher costs in the future. The committee is not in a position to quantify the level of these costs. Increased production may help to provide more resources.

The Norwegian forestry and agriculture sectors comprise many small enterprises. Individually, they do not have the resources to or tradition of purchasing research and investigation services. Schemes such as sales taxes, the Norwegian agricultural agreements and other government funding sources are used to compensate for this by financing knowledge development and information-sharing measures.

Innovation Norway is used to channel loans and subsidies for agricultural investments. The Norwegian Agricultural Advisory Service offers planning services in relation to farm buildings. These organisations thus help to ensure that the priorities and designs for building projects and other investments reflect the latest knowledge about changing climatic influences.

Adapting the facilities used in agriculture and forestry is a key element of adaptation. Breeding programmes are run by Graminor in the case of domesticated plants and the Norwegian Forest Seed Centre in the case of forest trees. There is only a small market in Norway for new plant varieties and breeds, so any increased investment in breeding plants for a changing climate will require better funding schemes with a larger share paid for by the government. Geno and other animal breeding enterprises are run on commercial principles, and they must be included in any comprehensive breeding strategy for the Norwegian primary industries, which must consider the question of the resiliency of domestic animals to the effects of climate change.

Current programmes to monitor damage to plants on farms and in forests will, to some extent, also uncover new, climate-related damage. By adjusting these programmes, it should be possible to identify relevant problems, but it has proved difficult to secure stable funding for them.

In view of the challenges faced by the primary industries in dealing with a changed climate, it

may be necessary to review the resources provided to these government subsidy schemes, either to reinforce or adjust them.

Knowledge base

Research

The level of the Norwegian education and research system, described above, is good within the research areas relevant to adaptation in the primary industries. We have a sound fundamental understanding of the interactions between climate variables, plant growth and other factors that influence the plant and animal products that form the basis of the primary industries. However, research has focused less on long-term consequences and adaptation. The main challenge within agricultural research therefore appears to be strengthening research into adaptation. Other challenges include the long-term timeframe and how to handle the uncertainties concerning how things will develop. It is worth pointing out that there is currently inadequate research into a wide range of impacts on the primary industries.

The so-called "tipping points", which may result in completely unforeseen reactions in ecosystems, may also have serious consequences for the primary industries. This is discussed in greater detail in Chapter 7, The natural environment.

Resource mapping

It is important to have a good understanding of what land resources are available and their properties, if we want to understand how climate will affect the use of those resources. Relevant national programmes have been set up to map the resources in our forests, agricultural land, uncultivated areas, grazing lands for domestic animals and reindeer, land cover, etc. Some of these programmes are long-term and cover all of Norway, while others are progressing at a rate which means that it will be some time before nationwide data is available.

Monitoring programmes are important in order to detect the effects of climate change, and because they allow the primary industries to adapt early. Norway has several monitoring programmes that track the progress of parameters and indicators relevant to documenting the situation for the primary industries. Measures have also been introduced to inspect imported plant and animal material in order to prevent unwanted organisms from entering the country due to imports.

Climate change, particularly more precipitation and shorter frost-free periods, will alter the operating conditions for farming and forestry. Technological progress tends to result in larger and heavier machines, which exacerbates the challenges associated with a wetter and warmer climate. Over the past 10 to 15 years, there has been a significant decline in technical research and training.

Priorities

The sector is by definition strongly focused on adaptation to the natural environment. In 2009 the Ministry of Agriculture and Food issued a report to the Storting that focused heavily on adaptation. It is the opinion of the committee that the political priority given to continuous adaptation increases the sector's adaptive capacity.

10.1.2 Socio-economic consequences

For the primary industries, climate change creates both new opportunities and new hazards. Vista Analyse (2010) points out that people brave enough to make quantified assessments, end up estimating in some cases large increases in harvests and tree growth rates. They estimate an increase of 15 to 30 per cent in crop yields, and of 20 to 40 per cent in tree growth rates, in the event of moderate, but not insignificant climate change. The implications of this for animal farming have not been discussed much in the literature, but it is clear that longer grazing seasons and more grass will be beneficial for red meat and milk, i.e. forage-based farming.

The fact that there is fairly close agreement between the estimates does not mean that we can be very certain that the increases will be of that order. There are significant unknown factors relating to the overall impact of climate change. The estimates do tell us that with our current knowledge, and based on the research material currently available, the balance of probabilities is that climate change will have a positive impact of the order estimated. However, the committee believes that there is not sufficient scientific evidence to quantify this any further.

10.1.3 Adaptive needs

It is the view of the committee that the basic prerequisites for successful adaptation to climate change in agriculture, forestry, reindeer husbandry and the wilderness-based sectors can be summarised as a need for accurate and up-to-date

information about the resources, relevant monitoring programmes, research-based knowledge about adaptation, traditional knowledge about adaptation, technological developments and adaptation of the management regimes.

The industries need to continuously adapt, both to limit the damage and to exploit the opportunities resulting from climate change. The committee believes that the land-based primary industries have the capacity to adapt to the degree of climate change on which the assessments in this report are based. Also see the discussion in Chapter 5, Future climate.

The committee therefore assumes that Norway will be in a good position to maintain or increase its level of plant production in the future. The climate and geographical conditions determine the kinds of plants that would be financially viable to cultivate. Meanwhile, it is expected that global demand for food and other biomass will increase. Climate change will provide new opportunities for farmers. To make full use of these opportunities, plant varieties, technology, knowledge and expertise must be developed in a way that responds to the new challenges created by climate change.

The potential increase in plant growth can only be exploited if we proactively adapt our domesticated plants and forest trees. To make use of the opportunities provided by a changing climate in terms of increasing the production of plants, continuous, systematic plant breeding programmes will be needed that take into account the significant uncertainties associated with changes in the most important climate variables.

Areas of research that must be given greater priority include:

- How existing and new pests will behave in a changed Norwegian climate
- How technology and production methods in agriculture and forestry can be adapted to a warmer and wetter climate with significantly longer frost-free periods.
- What contribution genetic resources (domesticated plants, forest trees and domestic animals) can make to successful adaptation, and how they will be affected by climate change.

The committee sees a particular need to increase our knowledge and understanding of the importance of genetic resources to adaptation in the primary industries. Mapping land resources will also make it possible to quantify both adaptation issues and opportunities for greater economic growth. It will therefore be necessary to both modify and strengthen the existing mapping programmes.

Proper monitoring programmes enable us to detect changes early and thereby react quickly. There is therefore a need to periodically review the monitoring programmes covering the primary industries' resources, their condition and the risk of importing new pests that affect forest trees, domesticated plants and domestic animals.

New knowledge and better-adapted technology can enable production methods that reduce the problems caused by climate change. It is therefore necessary to look at how to adapt the technologies on which the primary industries are currently based to the operating and production conditions that will result from climate change.

The genetic diversity of our domesticated plants and forest trees may be a source of solutions to future challenges with respect to food production and sustainable forestry. Genetic diversity is irreplaceable, and if it is not preserved in gene banks, in breeding populations or in nature, it may be lost forever.

If the new conditions are to be exploited by introducing species that are not native to Norway, this must only be done after thorough, research-based risk analysis and in accordance with the framework provided by the Nature Diversity Act and other regulations. Investment in plant breeding today may yield large returns in the future, and international cooperation gives access to knowledge about plant health outside Norway. This is essential to good contingency planning. Sharing knowledge about combating pests and cooperating on international standards in the field of plant health, also play an important role in building mutual understanding and preventing the spread of pests.

The use of genetically modified organisms (GMOs) as a tool to help us adapt to the consequences of climate change is currently a major topic of international debate, particularly in relation to resistance to plant pests. This may also enter the Norwegian agenda in the future, leading to a greater need to assess the risks associated with such organisms. We need to know more about the effects of climate change on the preservation of genetic resources at farms and in the wild, and to assess what these kinds of measures can contribute to adaptation efforts in food production. Information must be developed to help the authorities understand the effect of climate change on the health of Norwegian domesticated and wild animals. There will also be a need to focus more on measures to combat increased stormwater runoff and water pollution from agricultural land caused by higher precipitation levels.

The government's goal is for 15 per cent of agriculture to be organic by 2020 (Storting White Paper No. 1 (2009–2010)). In the short term, new pests and higher infection pressure may create major challenges for certain types of organic production. The concept of organic farming is based on the principle of adapting to local conditions and on resilient agro ecosystems. As such, organic farms can play an important role in preserving genetic diversity. Organic farms usually grow a number of different crops at the same time, which may reduce vulnerability to climate change that primarily affects one species.

For the forest industry, poorly adapted plant varieties will result in more serious damage. Adaptation in forestry may involve developing more resilient forests, for example by creating forests with a greater mix of tree species and multilayered forests, as well as by monitoring the health status of forests. There is a clear need for more research, to assess areas like the need for various measures, the risks associated with new species and the advantages and disadvantages of introducing new tree species. In order to reduce the risk of landslides in forests, good planning and drainage is necessary when building forest roads.

Reindeer husbandry has traditionally taken place on nature's terms, and it is therefore fundamentally vulnerable to external influences such as the climate, in addition to which it may come under pressure from other commercial interests and predators, etc. External impacts affect access to grazing areas, and the climate will also have a direct impact on the quality and quantity of pasture. This also affects how areas are used, migration routes and migration dates.

Reindeer husbandry will need to be managed to allow for greater flexibility. Flexible management will make it possible to successfully meet the needs that arise as a result of climate change. In view of the changing situation, there should be greater room for the authorities to exercise judgement than is the case under the existing laws and regulations. One example is the regulation of the migration from summer to winter grazing areas. Climate change may necessitate greater flexibility, so that migration can take place when the situation dictates, and not by a set date. For the industry to survive in a changed climate, it will be necessary to regularly review the regulatory framework in the context of changing circumstances. There is considerable uncertainty surrounding the combined effect of various climatic variables, and of how they will affect the various reindeer grazing areas. Research is needed into individual processes that are currently inadequately understood, and into the interaction of the various processes. Combining research-based knowledge with knowledge gained through experience may lead to a better understanding of how to adapt. It will become increasingly important to map and monitor the state of grazing areas and other areas used for reindeer husbandry, the areas the sector is particularly interested in preserving and how these areas are affected by climate change (both positively and negatively). The committee would like to highlight the need for a review of the management regimes in the light of new research, which includes a need to look at how they can be made more flexible, so that greater importance can be given to the traditional knowledge of the industry.

10.1.4 The committee's recommendations

To improve adaptation to climate change in the land-based primary industries the committee recommends:

Resource mapping

- Review the land resource mapping programmes (forest resources, soil types, grazing resources, land cover and land use) in order to ascertain the need for changes.
- The status of the industry's facilities and machinery should be analysed. There should be a particular focus on assessing the state of agricultural drainage systems.

Monitoring

- Review monitoring programmes (e.g. plant health, animal health, forest health, import control measures, land cover and cultural landscapes) to ascertain whether they are adequate in terms of identifying the needs for monitoring of impacts of, and adaptations to, climate change in the primary industries.

Research-based knowledge development

- Priority should be given to research programmes dealing with the impacts of climate change and adaptation in the primary industries, focusing on areas such as:
  - How existing and new pests will behave in a changed Norwegian climate.
  - How technology and production methods in agriculture and forestry can be adapted

to a warmer and more humid climate with significantly longer frost-free periods.
- What contribution genetic resources (domesticated plants, forest trees and domestic animals) can make to successful adaptation, and how they will be affected by climate change.

Technological development

- Investigation of the adaptation of production methods and technologies.

Knowledge development and sharing

- Knowledge-sharing systems must be improved, and must integrate the latest knowledge about adaptation to climate change.
- Access to people with the necessary academic and vocational training must be ensured by prioritising all levels of education.

Land-use management

- The management of agricultural land must take into account the fact that a changing climate may affect land values both for agricultural purposes and environmentally. The way in which agricultural land is managed must therefore also develop so that any potential to manage surface runoff and prevent damage in other areas is also exploited.

Management regimes

- Laws and regulations must be reviewed to ensure that they do not contain any stipulations that counteract adaptation to climate change. Stipulations must be then be added making adaptation to climate change a consideration that the authorities must take into account whenever relevant, which includes developing flexibility that allows autonomous adaptation and emphasises traditional knowledge in reindeer husbandry.
- Ecosystem-based management of harvestable resources should be further developed and made operational for industries that use natural resources. This involves using resources in a way that also takes into account what the ecosystem can sustain, which in turn is dependent on how the climate develops.
- Resources, including both productive areas and genetic resources, must be managed in such a way that their importance (value) in a different climate is also taken into consideration in decisions made now.
- The number of reindeer must be evaluated in the context of climate change, and the management of the areas used for reindeer husbandry must prevent further fragmentation, as fragmentation reduces adaptive capacity.

10.2 Fisheries and aquaculture

Like the land-based primary industries discussed in Chapter 10.1, the Norwegian fisheries are based on plant and animal growth that fluctuates greatly with the annual cycle of light and temperature at our latitudes. However, the vast majority of the plants in oceans, seas and lakes are drifting microscopic organisms (phytoplankton). The energy in these organisms can only be utilised by the fish stocks once it has passed through the plant-eating zooplankton. Phytoplankton and zooplankton production does not just fluctuate with the seasons: it also varies from year to year, from decade to decade and over longer time scales, as a result of variations in climate variables such as wind, currents, temperatures and salinity.

The use of the term fishing refers to marine fishing. Aquaculture includes the farming of fish that live in both fresh and salt water (salmon, trout), fish that only live in salt water (cod, halibut) and shellfish and bivalves. It also includes the harvesting of kelp in coastal waters by kelp-trawling. These resources are used by the food-processing and pharmaceutical industries.

The Norwegian fisheries and aquaculture generate significant export revenues, and Norway is one of the world's leading exporters of fish and seafood products. There is uncertainty linked to various aspects of climate change and the potential consequences for the marine environment. This is discussed in greater detail in Chapter 7, The natural environment. For example, ocean acidification may counteract the expected increase in the productivity of the marine ecosystem.

The fishing industry has very high adaptive capacity. The deep-sea fishing fleet has an extensive range, and can fish in much of the North Atlantic Ocean and even the Arctic Ocean. This gives it the flexibility it needs to respond to changes in fishery resources. The coastal fleet will be more exposed to climate change due to its more limited range. On the other hand, coastal fishermen have traditionally shown great flexibility by moving to areas where fish are to be found.

10.2.1 Vulnerability to climate change

10.2.1.1 How is the sector impacted by the current climate?

Norwegian fish and seafood exports have increased steadily over recent years. In 2004, exports totalled NOK 28 billion, and the sector's total turnover, including knock-on economic activity, was estimated to be NOK 86 billion (Sandberg et al. 2005). In 2006, revenues from farmed fish exceeded those from wild fish for the first time. In 2009, the total exports of fish and seafood products amounted to NOK 45 billion. This made Norway the world's second largest exporter of fish and seafood. By using the same relative figures as Sandberg et al. (2005) used for 2004, we can estimate that total turnover, including knock-on economic activity, amounted to just under NOK 140 billion in 2009.

The Norwegian deep-sea fishing fleet operates across a vast geographical area, which includes the area west of the British Isles, as far west as Greenland the North Atlantic, the North Sea, the Norwegian Sea, the Barents Sea and parts of the Arctic Ocean north of Svalbard. The ecosystems and climates of these areas are very different, ranging from temperate ecosystems to Arctic ecosystems in the northern Barents Sea.

It is normal for fishermen to experience significant fluctuations in access to resources, which is due partly to changes in the geographical distribution of fishery resources and partly to variation in the size and growth rates of fish populations. These fluctuations are due to natural processes in marine ecosystems at high latitudes, and are often driven by natural climate variations. Excessive fishing pressure and overfishing will not only reduce fish populations, it will also exacerbate such variations.

Over the past 30–40 years, the productivity and distribution of commercial fish populations in Norwegian areas have changed as a result of higher temperatures in the whole Atlantic Ocean. This has caused species that have traditionally been economically important, particularly cod and herring, to become more productive. From a climatic point of view, these species are adapted to subarctic seas. The past changes in ocean climate are still mainly due to natural climate variability, but nevertheless they give us an indication of what impact anthropogenic climate change may have over the coming century.

The Norwegian coast is one of the few areas in the world where natural species of kelp are harvested commercially for use in the food processing and pharmaceutical industries. Around ten per cent of the world's harvested wild kelp is obtained from the coast from Rogaland to Trøndelag counties. The distribution of kelp species is largely determined by water temperatures. Species such as tangle, sugar kelp and winged kelp occur naturally from south-western Norway and northwards, and this range is largely determined by climatic conditions. South of this belt the summer temperatures are too high. Along parts of the Helgeland coast and in Finnmark County, the kelp forests have for several decades been grazed down by sea urchins. This phenomenon has also been observed in other areas, including the west coast of Canada. It is unclear what causes the major increase in sea urchins.

The Norwegian aquaculture industry has experienced dramatic growth since the pioneer days of salmon farming in the early 1970s. In 2009, approximately 950 000 tonnes of salmon and trout, 20 000 tonnes of cod and approximately 1 500 tonnes of halibut were produced. The aquaculture industry operates along most of the Norwegian coast, from Southern Norway to Finnmark, but the core area runs from Hordaland County to Helgeland. This is due to a combination of the existence of suitable locations and an optimal marine climate for salmonids in this zone. The aquaculture industry faces major challenges in terms of combating disease and parasites. The development of vaccines has played an important role in this regard. The biggest challenge today is developing a sustainable method for controlling sea lice, which are a particularly big problem in coastal areas with high water temperatures.

10.2.1.2 How will the sector be impacted by climate change?

Higher sea temperatures may cause a shift in the spread of sea organisms, with both wild populations and farmed organisms making a general migration northwards. The overall productivity of the boreal species of fish is expected to increase in the northernmost fishing areas, while the productivity of the Arctic species will decline in the same areas. There are no known positive effects of ocean acidification.

Marine fishing

The shift northwards means that the Arctic areas, i.e. the northernmost parts of the Norwegian Sea and the Barents Sea, will become increasingly important fishing areas as the temperature increa-

ses. In addition, entirely new fishing areas north of Svalbard will become available as an increasingly large area of the Arctic Ocean becomes ice-free during summer. It will potentially be possible to fish traditional Norwegian species such as herring, cod, haddock, blue whiting and mackerel in the Arctic zone. Demersal fish, such as cod and haddock, will also spread east through the Barents Sea. This particularly applies to cod, and the cod spawning grounds off the coast of Finnmark County will become more important. Existing Arctic species in the Barents Sea such as capelin and polar cod will be pushed further north; see Chapter 7, The natural environment, for further details. The North Sea will experience a reduction in boreal species, while new temperate species such as sardines and anchovies will increase their numbers. Climate change will also lead to changes in the total productivity of the various marine ecosystems that are primarily governed by plankton production. Uncertainty remains as to what will happen to overall production levels, but initial research results suggest an increase in northern waters (Mueter et al. 2009), while the North Sea will probably not see a significant increase.

For centuries, fishing off the Lofoten Archipelago has attracted fishermen from the entire Norwegian coast. It is unclear how climate change will affect the distribution of coastal cod resources along the coast of Finnmark County, but an eastwards shift is to be expected, while the cod in the Barents Sea will increasingly be able to use the coast off Finnmark County as a spawning ground. An influx of more southern fish species is also likely. This will affect the livelihoods of the Sea Sámi population, other commercial enterprises and the general local population.

As temperatures rise, the southern limit for all kelp species will migrate towards the north along the coast due to excessively high summer temperatures. If kelp starts to be used as a raw material for the production of bioethanol, the demand for kelp can be expected to increase dramatically. It is therefore possible that kelp farming may develop into a new industry in Norway.

Overall, climate change over the remainder of the 21st century will probably increase fish resources in the Norwegian Exclusive Economic Zone, particularly in the north, whereas it is less certain that the North Sea ecosystem will become more productive. However, there are two factors that may counteract those predictions. One of them is associated with natural climate variability, which may dominate over anthropogenic climate change and result in a somewhat colder marine climate, with a temporary reversal of the northward migration of populations during the first part of this century. If that happens, there will be potential for a very sudden and dramatic increase in temperatures in the period around the middle of the century when the increasing anthropogenic change and natural variations once again pull together. The other major uncertainty factor is ocean acidification, a process taking place simultaneously with, and to some extent, independently of, climate change. Acidification creates a more hostile environment for calcifying organisms. The effects will probably be fairly uniform throughout the Norwegian fisheries, but may perhaps be felt first and most significantly in the north, where the cold waters absorb most carbon dioxide. Commercial fish populations will primarily be affected indirectly by acidification through the impact on calcifying prey at lower levels in the food chain and through changes in benthic communities. Our knowledge about the effects of acidification on marine ecosystems is still very limited.

Aquaculture

The traditional farming of fish for human consumption currently takes place at farms located in sheltered areas along the entire Norwegian coastline. Salmon and trout are the dominant species, but extensive development work is being done with the aim of farming additional species such as cod, halibut, wolf fish and mussels. Temperature is of vital importance to the aquaculture industry, as it affects factors such as growth rates, algal blooming and the spread of disease. In the long term, an increase in sea temperature therefore has the potential to result in significant structural changes in terms of the species farmed, the best production areas and location patterns.

With higher sea temperatures, the conditions for farmed species that are adapted to life in cold water will deteriorate, and their growth rates will decline. This may result in Southern Norway becoming less suited for farming species such as salmon and trout. High summer temperatures are the main problem here. In the long term, this may make northern regions better suited to the farming of those species. It may eventually become possible to farm species that prefer warmer conditions in Southern Norway.

Periods of significantly higher summer temperatures in the fjords may increase the risk of disease outbreaks both among farmed and wild

fish. This is partly because temperature stress reduces the disease resistance of fish. The nature of the risk from marine infectious agents (pathogens) will change. Some pathogens will disappear, while new ones will present themselves. The extent to which this will lead to larger problems, as opposed to different problems, remains unclear. However, with respect to sea lice, higher temperatures will probably exacerbate the problems faced by the aquaculture industry, as sea lice will be able to increase the number of generations they produce each year.

Aquaculture is responsible for releasing a significant amount of organic waste into Norwegian fjords and coastal waters. The microbial conversion of this material into chemical nutrients will significantly affect health at fish farms and in the surrounding ecosystems. Higher temperatures are expected to increase the transformation of the waste, but in addition to temperature, there are many other physical and biological factors at work.

In the longer term, shellfish may suffer as a result of ocean acidification. This may also affect the farming conditions for these species.

10.2.1.3 Adaptive capacity

Organisation

The Norwegian fisheries comprise the deep-sea fishing fleet and the coastal fishing fleet. In total, more than 10 000 people have fishing as their main occupation, in addition to those employed in associated onshore activities and the export industry. There are approximately 6 500 registered fishing vessels in total. In 2009, the deep-sea fishing fleet consisted of 235 vessels (over 28 metres), made up of vessels using purse seines, trawl nets, gill nets and lines, and it employed approximately 4 400 people on board the vessels and on shore. The deep-sea fishing fleet represents around two-thirds of the fishing industry as measured by first-hand value. In 2009, the coastal fleet consisted of a total of 6 275 vessels, comprising 409 vessels of between 15 and 28 metres, 760 vessels between 11 and 15 metres and 5 106 vessels under 11 metres.

The changes in the distribution and productivity of the various species may lead to major challenges in terms of their management, both at a national and international level.

The Ministry of Fisheries and Coastal Affairs is responsible for regulating the fisheries, which includes setting catch quotas for wild populations and production capacities for the aquaculture industry. Keeping catch quotas at a level that ensures optimum, but steady, access to fish resources through sustainable management will remain just as important in the future as it is today. The fisheries regulations should currently be based on ecosystem-based management principles, but it has yet to be determined how best to implement those principles in practice. Further developing the system of ecosystem-based management of fishery resources is a prerequisite for exploiting them in a way that is more resilient to climate change.

Globally, many fishery resources are overexploited. In many places, the major fish populations have been declining since the 1970s and 80s as a result of overfishing. On a global level, we cannot expect to be able to harvest more fish resources from the seas without first reducing fishing pressure. Large, resilient spawning populations are more productive, so it is important to allow them to rebuild from critical levels. In many parts of the world's oceans and seas, climate change may have a negative impact on fish production. This will increase pressure on the fishery resources there. Northern waters are expected to be among the areas where fisheries will benefit from greater production of commercial fish species as temperatures increase. That imposes on us a special duty to manage our share of the fishery resources sustainably.

Marine fish populations are distributed across the Exclusive Economic Zones of several countries and international waters, and their distribution, quantities and migration patterns vary. International cooperation, coordination and regulations are therefore needed.

- In the North Sea, Norway negotiates with the European Union on fisheries agreements.
- NEAFC (North East Atlantic Fisheries Commission) comprises Norway, the European Union, Iceland, Denmark (on behalf of the Faroe Islands and Greenland) and Russia, and regulates the resources outside the economic zones in the North East Atlantic.
- NAFO (Northwest Atlantic Fisheries Organization), which consists of the NEAFC countries, in addition to the US, Canada, Korea, Cuba, Ukraine, Japan and France on behalf of St.Pierre et Micquelon, negotiates agreements outside the economic zones in the North West Atlantic.
- The Joint Norwegian–Russian Fisheries Commission, established in 1975, is responsible for fisheries agreements between Norway and

Russia in the High North, and in Norway it reports to the Ministry of Fisheries and Coastal Affairs.

The committee has not assessed whether these existing international frameworks will be sufficient in meeting the requirements that a changing climate will bring in terms of cooperation on fishery resources in northern waters. However, the committee would like to stress that if stipulations in these frameworks are based on the current resource situation, they may lose relevance in 50 years' time.

The aquaculture industry must comply with various laws and regulations relating to sustainability. Within aquaculture, high production volumes are dependent on large amounts of feed, which consists mainly of wild fish bought on the global market, and particularly sardines and anchovies. Opinions are divided on how sustainable this will be in the future. The committee has not considered this question, but theoretically it is possible that farming salmon could be combined with farming of organisms that utilise the increased phytoplankton production from waste from salmon farming (e.g. shellfish). This may result in improved energy conversion and greater sustainability.

Resources

The fishing and aquaculture industries control significant financial resources. For the government, the sector is important because it provides employment, generates revenue and safeguards national interests in the north. Assuming that the productivity of the northernmost Norwegian waters increases, the financial resources will grow over the coming years. It is the committee's belief that this will provide a good foundation for the necessary restructuring processes resulting from climate change.

There is a great deal of expertise within the fishery and aquaculture industries. Cooperation between the authorities, industry and research institutes will increase their capacity to handle climate change.

Knowledge base

Our knowledge base on the effects of climate change on marine organisms is partly based on laboratory studies, particularly those done in conjunction with aquaculture research, and partly on the observed effects on the marine environment of long-term natural climate variability over the course of the 20th century. Over the past 15 years, great strides have been made in the field of physical-biological models, which puts us in a better position to quantify the effects of climate variability and climate change on growth and recruitment in fish populations. These models tend to focus on the effects of the underlying production of plankton in particular.

It will require significant resources to investigate the impacts of ocean acidification on marine ecosystems and how this affects the feeding conditions throughout the food chain. In contrast to our knowledge of the effects of climate change on marine life, our knowledge of the effects of acidification on marine organisms is very limited. It is less than ten years since the first ever laboratory experiments on acidification were carried out, and documenting what will happen organism by organism is a major task.

10.2.2 Socio-economic consequences

In the fishing and aquaculture industries, the literature again suggests a significant increase in production, although ocean acidification represents an unknown threat, and moving fish populations may require adjustments to management regimes and adaptation by individual enterprises.

10.2.3 Adaptive needs

Climate change will affect both the fishery and aquaculture industries, and adaptation to climate change will be necessary in order to maintain their financial viability. This will require sustainable management, knowledge development and possibly also technological innovations, for instance in aquaculture. Increasing attention will need to be given to international agreements on adjustment of the allocation of quotas to reflect changes in distribution patterns.

In the long term, higher sea temperatures will affect which areas are optimal for farming different species. Future decisions on where to locate fish farms must take into account climate change. It is therefore important to plan the future direction of the industry well in advance, as changes in which areas of the coast will be optimal for which species will require new land-use plans and environmental impact assessments.

Changes in the distribution of fish populations may cause major challenges with respect to allocating fish quotas between nation states. The allocation of quotas for Norwegian spring-spawning herring, which is currently one of the world's largest

fish stocks, is based on so-called zonal attachment, where the amount of time spent in the various countries' economic zones is used to calculate quotas. Blue whiting and mackerel, which spawn to the south of the Norwegian Sea, are two large populations that are increasingly using the northern part of the Norwegian Sea, and even western parts of the Barents Sea, as summer feeding grounds due to increasing temperatures in recent years. Recently, mackerel have also started using the areas west towards Iceland as feeding grounds, resulting in large, unregulated catches in Icelandic waters. Consideration should be given to introducing similar allocation principles to the ones that apply to Norwegian spring-spawning herring for other fish populations, particularly pelagic ones, as their natural distribution patterns change.

It is important to develop commonly accepted principles for solving such issues. One of the main principles that applies to quota allocation, "historic fishing rights", will naturally be of limited value as the climate and fish distributions change. Zonal attachment, which is based on the average time spent in different areas, is an example of a useful principle that could be applied. A need may arise for looking into how climate change requires adjustment to management regimes for fishery resources, at both national and international levels.

Climate change will create new challenges, and there is a need to fill large gaps in our knowledge as we move towards an ecosystem-based management regime for fishery resources that will adapt the fishing industry, regulatory framework, production technologies, etc. to changes in fish stocks caused by changes in sea temperatures, acidification and other alterations to the marine environment.

Modern deep-sea fishing vessels are long-range. Climate change will increase the need for access to servicing and other support functions in the north. Fisheries for new species in the south will require adaptation of vessels and equipment, as well as adaptation in the processing industry.

The harvesting of wild kelp along the coast will need to move northwards as the kelp forests farthest south suffer stress from excessively high summer temperatures.

It will also be important to reach international agreement on the status of endangered species (the Red List) and invasive, alien species (the Black List) in the various ecosystems as the climate changes. This must be done within the framework of established international organisations. Fishing and climatic impacts are the two most important factors that determine how fish stocks develop. There needs to be a move towards a greater emphasis on ecosystem-based management of fishery resources, which involves assessing the combined impacts of fishing, climate variability and climate change.

10.2.4 The committee's recommendations

To promote adaptation in the fishing and aquaculture industries, the committee recommends:

Resource mapping

- Improved mapping of the northernmost marine areas where ice cover has until now prevented it.
- Greater focus on monitoring climate-induced changes in the composition of ecosystems along the coast and in the southernmost Norwegian waters.
- Maintain existing data sets and develop additional ones for marine climate and marine organisms.

Research

- Develop ecosystem models capable of quantifying the impact of climate change on the productivity and distribution of marine organisms ranging from plankton to fish and marine mammals.
- Build knowledge about the combined effects of climate variability and climate change on fishery resources.
- Develop climate models for coastal and fjord areas with a sufficient level of detail to simulate changes in environmental conditions for the benefit of the aquaculture industry.
- Study the impacts of ocean acidification on fishery resources and their food base.
- Develop methods for ecosystem-based management of fishery resources.

Technological development

- Develop technology that makes the aquaculture industry less vulnerable to extremes in the marine climate and to diseases and parasites. Promote the development of multiculture farming in the aquaculture industry.
- Further develop energy-efficient catching methods, and develop vessels and methods that reduce the impact on benthic communities.

Management regimes

- Norway must help to strengthen international management regimes in order to prevent conflicts over marine resources as their distribution patterns and productivity change.
- Norway must promote adaptation to climate change in the harvesting of fishery resources through the established international channels of cooperation and, in particular, through bilateral cooperation with the other Arctic states.

10.3 Petroleum

Oil and gas production on the Norwegian continental shelf is significantly affected by the weather and climate. The technology used in Norway for both production and support functions is therefore designed to withstand significant weather-related impact.

The consequences of accidents during oil and gas production are serious both to the environment and to society. This creates special requirements in terms of safety at installations. Changes to the underlying climate may make it necessary to change those requirements. Designs based on a 30 cm sea level rise will, based on the projections used here, be insufficient towards the end of this century.

When assessing vulnerability to climate change, time is an important factor. It is expected that Norwegian oil and gas production will, in general, decline over the course of the century. The committee believes the time factor, combined with existing safety requirements for facilities and production processes on the Norwegian continental shelf, mean that the vulnerability of the petroleum sector to climate change is limited. Nevertheless, the committee would like to emphasise that it is essential that sizing and safety requirements for new facilities and extensions to existing facilities beyond 2050, are based on the projected climate.

The committee believes that the most important measures in this sector relate to knowledge development and monitoring, and that this work should start quickly.

Opportunities arising from climate change in the Arctic raise dilemmas about the relationship between commercial activities and the environment, with both increased activity in its own right and potential accidents having major consequences. One dilemma is that exploiting the opportunities resulting from climate change may increase emissions of greenhouse gases, which in turn will lead to more rapid global warming and greater climate change. From an adaptation point of view, this will make both humans and the environment more vulnerable to climate change. The recent incident in the Gulf of Mexico demonstrates what impact offshore oil production can have on the environment. It also demonstrates that we can never be entirely confident that accidents will not happen.

10.3.1 Vulnerability to climate change

10.3.1.1 How is the industry impacted by the present climate?

Petroleum facilities are currently highly exposed to climatic conditions, and they will also be impacted by climate change.

- Wind and waves are currently the most important design parameters. In the High North, polar low pressure systems, which cause strong winds to suddenly pick up, are a particular challenge, partly because they are hard to forecast.
- Waves exert dynamic loads on facilities, which can also be a major challenge.
- Sea level is another important design parameter, and since 1987 the rules have recommended including a safety margin to allow for a 30 cm rise.
- Air temperature is not currently a particularly critical, or challenging, design parameter for installations. In the event of future petroleum activities in the High North and Arctic regions, the air temperature will become a more important parameter.
- The sea temperature only has a marginal impact on structures, but it is an important design parameter for cooling water, gas transportation pipelines and, in some places, problems with wax blocking production flows from the sea bottom.
- Ice conditions may also be an important factor in the High North. Sea ice, icebergs and icing caused by sea spray and atmospheric humidity may create design challenges, and complicate emergency preparedness and operations in the northernmost Norwegian waters.

10.3.1.2 How will the industry be impacted by climate change?

In a changed climate, higher temperatures may lead to a slight increase in corrosion rates, but

this will also depend on changes in atmospheric humidity. Climate projections do not predict temperatures that would produce any such impact.

Higher sea temperatures may reduce the capacity of gas pipelines and reduce the efficiency of LNG plants (facilities that produce liquefied natural gas). Higher sea temperatures may also alter the fauna and flora in the vicinity of the facilities, which may in turn result in fouling. For so-called jacket structures (steel tubes welded together into a lattice) used on facilities in the North Sea, marine fouling may result in both higher wave and current loads by increasing the surface area of the structural elements. In the Norwegian Sea, only gravity base structures are used, and the marginal impact of fouling on these will be insignificant. If the temperature of the sea water used as cooling water increases, existing cooling water intakes may become too small in the future.

Any changes in the fauna and flora in the vicinity of the facilities may also cause living organisms to move. Microorganisms moving can block various systems and cause other non-conformities.

At some facilities, increased sea levels may change the evacuation criteria ahead of storms, and at others they may entail the introduction of procedures for evacuation in the event of high wave forecasts. Increased sea levels may also cause damage to facilities.

For onshore facilities, sea level rises and storm surges will result in the sea reaching further up on quays and other facilities in proximity to the sea. This may make it necessary to construct facilities on high ground or to limit their use.

10.3.1.3 Adaptive capacity

The Norwegian Petroleum Directorate estimates that the total discovered and undiscovered petroleum resources on the Norwegian continental shelf amount to around 13 billion standard cubic metres of oil equivalents (Sm^3 o. e.). A total of 5.1 billion Sm^3 o. e. of this has been produced, equivalent to 38 per cent of the total resources (Ministry of Petroleum and Energy and Norwegian Petroleum Directorate factbook 2009). There are currently tens of small and large companies with production licences, and in total, more than 500 production licences have been granted on the Norwegian continental shelf.

Three national government agencies are in charge of the petroleum sector, with the Ministry of Petroleum and Energy having overall responsibility for the management of petroleum resources on the Norwegian continental shelf. The Norwegian Petroleum Directorate exercises authority in conjunction with petroleum exploration and production activities, while the Petroleum Safety Authority Norway is responsible for technical and operational safety, emergency preparedness planning and working environments in enterprises in the petroleum sector.

Meteorological and oceanographic data and other external conditions are important parameters for the requirements that apply to the design and operation of individual oil and gas fields. The authorities require facilities to be able to withstand potential environmental loads, with the key parameters being wind, waves, sea level, currents, air and sea temperatures, as well as ice conditions.

In assessing how vulnerable the petroleum industry is to climate change, timescale is an important factor. That is particularly true with respect to rising sea levels.

The government expects a slight decline in oil production and an increase in gas production in coming years. There are still major petroleum resources on the Norwegian continental shelf, and new technology has already extended the life expectancy of many fields. The Ekofisk field remains one of the largest Norwegian oil fields, and according to plans, it will continue to produce until 2050.

New discoveries and the development of technologies to extend the production life of existing fields are two of the factors that will have a big impact on the timescale. New activities in the Arctic will result in completely different circumstances that the industry is not adapted to. The fact that the industry is designed to withstand the current climate does not mean that it will be resilient to the future climate.

The petroleum industry itself claims that it has a long history with responding as, and when, required by changing circumstances. During the development of a field, dedicated teams obtain the best possible information about climatic conditions and the natural environment, which is then transformed into physical and functional requirements that apply during the field's production life. The industry assumes that climate change will be gradual enough for it to be possible to predict, and thus take into account, changes in the design specifications for new fields. Technological progress means that alternative solutions adapted to the new climate may be available relatively quickly (around a ten-year response time).

The committee shares the industry's view that it has excellent adaptive capacity. The vulnerability of the sector is therefore considered limited, in spite of the sector being highly exposed to climate change. However, the committee would like to stress that vulnerability will increase in relation to new facilities and modifications to existing facilities that result in them being used for more than 30 additional years, if no measures are taken to ensure that the facilities can withstand the additional loads described above. The committee would also like to stress that its assessments are based on limited knowledge, and that there is greater uncertainty associated with its assessment of the vulnerability of the petroleum sector than with other sectors it has studied.

10.3.2 Adaptive needs

An improved understanding of what will happen to the climate is an important prerequisite for adapting to climate change in the petroleum industry. There is a particular need to know what, if any, changes there will be to wind and wave conditions. If winds become stronger and waves become larger, this may increase the stress on structures, resulting in a shorter lifespan than expected. Although this will not have a critical impact, it will require more frequent inspections and maintenance. If waves become a larger issue, this may also affect how companies operate and the use of mobile facilities.

More frequent storms may make it difficult to carry out maritime operations as planned, and create greater challenges for logistics activities, such as helicopter transport and deliveries. This may lead to more waiting time, but it will not have a critical impact on health and safety. It may, for instance, necessitate increased accommodation capacity on platforms and larger and more advanced supply and guard vessels.

In combination with higher sea levels, more frequent storms will make continuous operation challenging. For some facilities it may be necessary to change the evacuation criteria in the event of wave warnings and storms. In the worst case, this may lead to facilities being shut down, but the consequences of these measures will be commercial rather than technical.

To reduce exposure to climatic conditions, it is expected that the petroleum industry will increasingly make use of intelligent fields, where the production facilities are on the seabed and onshore. Such solutions have already been introduced on fields fairly close to shore. Work is being done to extend pipelines from facilities on the seabed, with oil–water separation, compression and reinjection taking place on the field.

Higher sea temperatures may require a slight increase in the amount of cooling water used, which in turn will increase costs, energy consumption and associated emissions.

Climate change in the High North, including the melting of Arctic sea ice, may make it possible to explore for and produce petroleum in completely new areas. The agreement on the maritime delimitation line between the Norwegian and Russian sectors will probably make the industry more interested in exploring the Barents Sea. Any accident resulting from petroleum or shipping activities in this area will have a significant impact on the natural environment and society at large. Increasing the activity level in these areas will also increase greenhouse gas emissions.

The report by the *"Technical forum of the monitoring and risk management groups of the inter-ministerial steering group for the integrated management plan for the Barents Sea and the sea areas off the Lofoten Islands"* (2006) discusses measures to enhance preparedness for acute pollution. It concludes that even if several measures have been taken to improve preparedness, it is "… *not possible to document that the nature and scope of contingency planning is such that it can effectively help to minimise the risk of harm to the environment and living marine resources*".

The report also points out that there is a need to develop a joint understanding of risk, as well as to further develop a comprehensive risk management model. The technical forum also believes that there is a need to develop methods for improving assessments of the impacts on society of acute pollution, and to improve methods of analysing environmental impacts and risks associated with oil spill emergencies on fish, sea birds, marine mammals and beaches.

In addition to the direct risk of damaging the vulnerable arctic natural environment, greater activity in the High North raises several other dilemmas. Climate change is due to increased greenhouse gas emissions due to human activities, primarily burning coal, oil and gas. It is hard to see how the need for sustainable adaptation to climate change is fulfilled by increasing the exploitation of fossil fuels, which in turn will exacerbate climate problems.

10.3.3 The committee's recommendations

To strengthen the petroleum industries' adaptive capacity, the committee recommends:

- Improving our understanding of the impact of climate change on the petroleum industries. Performing research into, and developing our understanding of, changes in climate variables that affect the petroleum industry; particular priority should be given to winds, waves and icing.
- Climate change considerations must be incorporated into the design parameters for new facilities or modifications/upgrades of existing facilities that will remain in service towards or after the middle of the century.
- A clear precautionary principle must be applied when assessing new or expanded petroleum activities. The potential damage that could be caused by a petroleum accident must be given particular emphasis when considering whether exploration and production should be allowed in the vulnerable High North.

10.4 Insurance

Climate change will affect the use of insurance policies and the market for insurance services. More frequent weather-related and natural damage will both change the risk pattern and stimulate demand for insurance.

The committee believes that current insurance policies are well adapted to the current climate. The industry is exposed to the effects of climate change, but also has the capacity to adapt, in part through international reinsurance.

Insurance plays an important role by taking on the risk of unforeseen losses from other players in society, and it can therefore potentially make a significant contribution to reducing vulnerability and making our society better adapted to the climate. A prerequisite for this is that the authorities create an appropriate framework and clarify government policy.

10.4.1 Vulnerability to climate change

10.4.1.1 How is the industry impacted by the current climate?

Insurance companies are affected by all climate change that results in harm to people, animals and assets. Climate-related accidents are mainly associated with precipitation, temperatures, runoff, lightning strikes and wind. Although climate-related damage has not increased as rapidly in Norway as in other parts of the world, Norwegian insurance companies are already experiencing an increase in such claims. Society is particularly vulnerable to water and moisture damage caused by increased levels of precipitation, which is exacerbated by buildings that are not properly adapted, underdimensioned water and waste-water pipes, short-sighted land-use planning and a failure to give proper consideration to topography and flood zones when locating buildings. In the past 20 years, payments on claims for stormwater runoff and sewer backwash have been three to four times higher than those relating to floods.

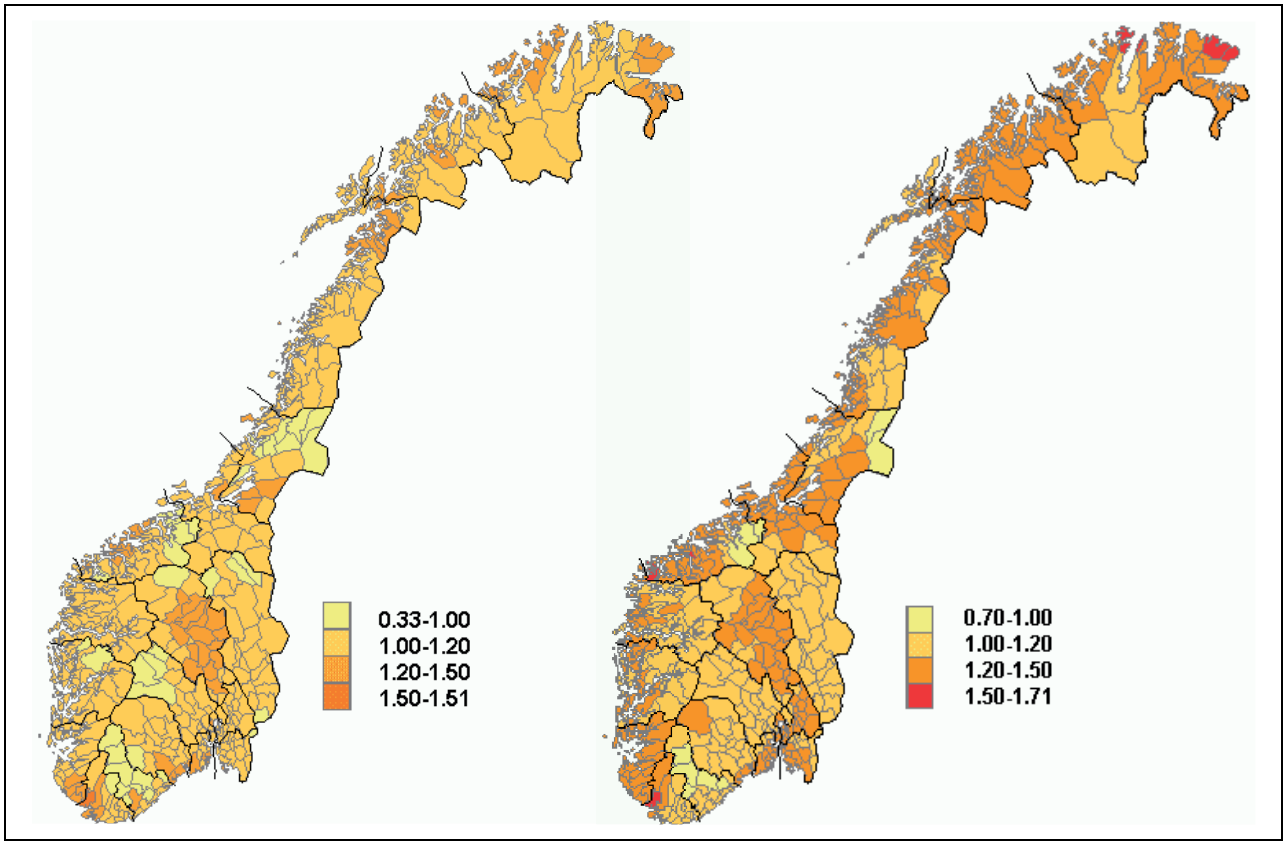
10.4.1.2 How will the industry be impacted by climate change?

Climate change will result in a greater need for various insurance policies, among other things related to health, primary industries, buildings and equipment.

Climate change may increase the risk of damage to human and animal health. More frequent landslides and floods may increase numbers of personal injuries and fatalities, and increased issues with poor water quality may increase the prevalence of water-borne infection and disease. Any increase in the prevalence and growth rate of moulds will increase the risk of respiratory problems and allergies, and vector-borne diseases, such as blue-tongue disease and infections caused by ticks, are expected to become more commonplace. See the more detailed discussion of these issues in Chapters 8.1, Health, and 10.1, Agriculture, forestry, reindeer husbandry and other wilderness-based sectors.

In the forestry and agriculture industries, more frequent droughts may increase the risk of forest fires and destruction of crops. If pests become more widespread, then damage may increase, including damage not currently covered by insurance policies. Forests will also become more vulnerable to damage if extreme weather events become more common. These issues are discussed in greater detail in Chapter 10.1.

More frequent floods and landslides and more precipitation will result in greater damage to material, buildings and equipment. Heavier precipitation with more thunder and lightning may increase the risk of fires, and result in more damage due to voltage spikes. If prevailing wind directions or storm patterns change, buildings and facilities may become more exposed. This



Figur 10.1 Percentage increase in the number of loss events due to water damage up to 2100 based on two different climate models and emissions scenarios (IPCC): Hadley-A2 (l) and Echam-B2 (r). Each colour code is an interval of change in the number of loss events (1.00–1.20 is equivalent to a 0–20 per cent increase).

may also apply to places that were previously not exposed to wind damage. Sea level rises, particularly in combination with storm surges and spring tides, may also increase damage to buildings and facilities close to the sea.

A survey of residential housing suggests that the regions that are most exposed to bad weather, such as Western and Northern Norway, are also the best adapted to the current weather. Throughout Norway, local building techniques have been adapted to local and historical weather conditions. Geographical areas that have historically had less rain and wind face a greater challenge in adapting their buildings and infrastructure to future climate change than areas that are already accustomed to severe weather conditions (Orskaug and Haug 2009).

In the future, greater precipitation intensity, combined with buildings that are not sufficiently adapted to local climatic conditions, may further increase the number of loss events due to water and moisture damage. A study by Gjensidige found that increased precipitation towards the end of the century may result in up to 50 per cent more water-damage incidents in certain counties (Orskaug and Haug 2009). However, there are large geographical differences, and the increase in the volume of damage is not necessarily proportionate to the increase in precipitation. For example, smaller increases in precipitation may have a greater impact in Eastern Norway, and conversely, Western Norway may experience less additional damage in spite of a larger increase in precipitation. This is because it is believed that buildings in Western Norway are designed for more precipitation than those in Eastern Norway, and are therefore better positioned to adapt to more precipitation. Orskaug and Haug (2009) have attempted to estimate the consequences of "moving" Bergen's current precipitation levels to Oslo. According to their analysis, this would lead to the number of water-damage incidents in Oslo more than tripling and the total volume of damage increasing sixfold.

There has not been any clear-cut increase in strong winds in Norway in recent years. Nevertheless, climate change may change wind patterns (Hanssen-Bauer et al. 2009), potentially

resulting in damage in areas where building techniques are not currently designed to withstand strong winds. There is a great deal of uncertainty as to whether climate change will result in stronger winds. Stronger winds can potentially have major consequences. A study carried out as part of the research programme Climate 2000 (Lisø and Kvande 2007), shows that a 10 per cent increase in wind speeds may result in the cost of wind damage to Norwegian homes more than doubling.

Another challenge is that certain kinds of climate-related damage may become more frequent and widespread. If they become so common that they cannot be defined as unforeseen, they will no longer be covered by insurance. There is also a possibility that reinsurance companies will pull out of certain areas, because the damage is no longer unforeseen. In this case, the risks and costs associated with these kinds of damage will be transferred from insurance companies to individuals. Repeated damage caused by stormwater runoff and sewer backwash may be one example.

The level of the direct impact on insured property will in many cases depend on vulnerability and adaptation in other areas. In general, climate change will exacerbate many of the challenges that already exist in other areas of society. This applies to inadequate land-use planning, capacity of water and waste-water pipes, poor building techniques and designs, consumer behaviour and market developments.

A survey of consumers in the Nordic countries carried out by the Nordic insurance companies in 2009, shows that consumers expect insurance companies to take responsibility by covering increasing damage due to climate change, without raising premiums. If the challenges associated with climate change create greater risks than the companies and their customers are willing to bear, this will come into conflict with society's need to protect itself against risk. Insurance currently acts as a safety net that plays a key role in providing both individuals and enterprises with financial protection against unforeseen events. A properly functioning insurance system is therefore vital to the financial security and stability of society.

10.4.1.3 Adaptive capacity

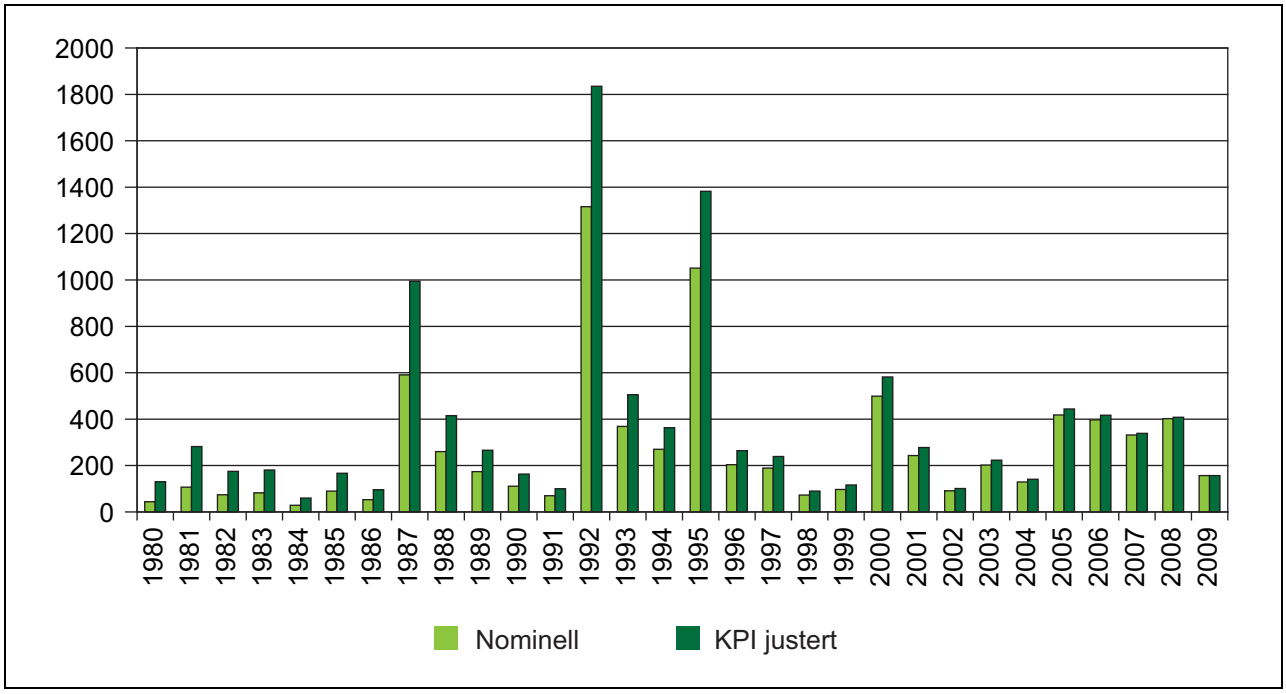
Organisation

Norway has a general insurance system that comprises the insurance companies, the Norwegian Natural Perils Pool and the Norwegian National Fund for Natural Damage Assistance.

The insurance companies cover loss events such as fire damage, water damage and burglaries, third-party liability and damage to cars and boats, and injuries and illnesses through travel, personal and pet insurance policies. Forests can be insured against fire, storms and damage caused by rodents and defoliating insects.

The Norwegian Natural Perils Pool is a distribution pool for all insurance companies that provide fire insurance in Norway, and covers natural damage caused by storms, landslides, storm surges, earthquakes and volcano outbreaks. The Norwegian system for insurance against natural damage is unique, and is considered one of the best in the world. Pursuant to the Act on Natural Damage Insurance (Act No. 70 of 16 June 1989), buildings and contents that are insured against fire are automatically insured against natural damage. This does not apply to forests, standing crops, goods during transportation, motor vehicles and trailers, aircraft, ships and small boats as well as oil and gas production equipment on the sea bed. One of the many reasons for the current natural damage insurance system is the principle of solidarity. Through the Act on Natural Damage Insurance, anyone who takes out fire insurance, whether as a business or private individual, pays the same rate for insurance against natural damage, regardless of the risk faced. As of 2010 the price is NOK 0.09 per NOK 1 000 of fire insurance cover. The own risk carried by the customer, the excess, is also the same, regardless of whether the customer is a private individual or business. As of 2010 the excess is NOK 8 000. Total compensation for each individual natural disaster is limited to NOK 12.5 billion. It is the committee's assessment that the Norwegian Natural Perils Pool helps to increase adaptive capacity by coordinating the response of all of the insurance companies in the event of natural disasters. This coordination gives the insurance industry a better overview and knowledge base for implementing measures, such as actions for recourse, which are more difficult for individual insurance companies to pursue on their own.

The Norwegian National Fund for Natural Damage Assistance provides compensation for natural damage in cases where this is not possible to take out through a normal insurance policy, pursuant to the Natural Damage Act (Act No. 7 of 25 March 1994). This applies to roads and arable land, for instance. There are just over 1 000 payouts each year. In the period from 2001 to 2008, an



Figur 10.2 Natural damage over the past 30 years – compensation paid out through the Norwegian Natural Perils Pool. Millions of NOK (Finance Norway).

average of NOK 85 million was paid in compensation annually. 60 per cent of this related to floods, 20 per cent to storms and storm surges and 20 per cent to landslides.

Insurance is a way of pooling the risks of all of the members of an insurance scheme, and the members cover the cost of all of the loss events. Insurance companies are currently able to manage their risk through higher insurance premiums, by differentiating insurance premiums based on risk (e.g. in the case of buildings: by construction method, location and preventive measures), by excluding certain kinds of losses or geographical areas or by requiring customers to pay a higher excess.

The insurance companies and the Norwegian Natural Perils Pool "reinsure" risks through the international reinsurance market. The reinsurance system works by reinsurance companies equalising all potential risks between different countries and regions. Good insurance systems are dependent on there being an international reinsurance market for the risk in question. Reinsurance companies may increase prices or exclude geographical areas, types of loss and asset classes, which will in turn have an impact on the insurance companies and consequently on insurance customers.

Regulations and requirements

The insurance industry can play an important role and be a resource in society's efforts to adapt to climate change. By differentiating prices based on resilience to climate change and by demanding that customers and repair contractors adapt, they can stimulate adaptation to climate change. Their ability to achieve this depends on the correct regulatory framework being in place. The example of the so-called "Stavanger Decision", which is discussed in more detail in Chapter 9.2, shows that there is a need to clarify the responsibilities of municipalities and individual customers in relation to extreme weather, including as a result of climate change. Municipalities are currently entitled to include a contractual clause limiting their liability in the event of sewer backwash caused by special (weather) conditions. Liability for compensation therefore falls upon the insurance company.

It is the view of the committee that this decision is a hindrance in the perspective of adaptation to climate change. The insurance policy covers the damage, but it does not eliminate the underlying cause. This kind of practice promotes a reactive approach to climate-related damage and hinders preventive adaptation to increasing amounts of water. The committee believes that this will discourage the proactive role that could be played by the insurance industry in relation to adaptation efforts.

The Natural Damage Act does not allow the price, excess or terms and conditions of insurance policies to be adjusted based on risk. The current system does not provide any incentive to implement preventive measures, with the exception of the scope for recourse action. As a result, insurance companies do not focus much on natural damage risk when selling insurance. The Norwegian Natural Perils Pool cannot change the mandate it has been given under the Act on Natural Damage Insurance unless authorised by the members of the pool or the government.

Resources

In principle, the insurance companies, including the Norwegian Natural Perils Pool, have significant resources comprising accumulated reserves and reinsurance policies. The committee has not considered a worst-case scenario with several simultaneous major disasters, but the maximum limit per natural disaster is currently NOK 12.5 billion. Over the past 20 years, Norway has had one major storm incident and one major flood, and total compensation paid for natural damage during the same period has been just below NOK 8 billion. Based on that, the committee believes the NOK 12.5 billion limit to be fairly robust.

However, Norwegian insurance companies depend on the capacity of the international reinsurance companies. Natural damage around the world will affect prices and capacity in the industry, and in the worst case scenario, it may become impossible to obtain reinsurance. Climate change may increase pressure on the industry, thus limiting its capacity.

In Norway, the vast majority of buildings, cars and other assets are insured, but the coverage level varies. For instance, damp and rot damage are generally not covered, which often means that the individual customer has to pick up the bill.

In the case of personal and animal insurance, there is far less coverage, both because some illnesses are not covered, and because more people choose not to take out insurance. This means that the costs of illnesses and injuries are to a greater extent borne by individuals. The same applies to forests, where many risks are not covered. Of productive forests, only half are currently insured against fire and only a third against storms.

Insurance premiums are set for a year at a time, which makes it possible to adjust prices in response to the level of losses. A fundamental principle of insurance is that the price is determined by the risk, taking into account preventive measures. The Act on Insurance Activity states that premiums shall reflect risk.

Knowledge base

Insurance companies currently have good statistical data and excellent analytical capabilities, which are vital for their ability to assess and price risk. Climatic conditions are an important factor in their analyses. The insurance industry currently collaborates with various research institutions, but as pointed out in Chapter 13, Infrastructure, in the future, it will not be sufficient to base assessments on analyses of the current climate or on historic records. As a result, there will be a need for improved understanding of climate projections, future climate impacts and adaptive needs.

Priorities

Natural damage insurance is a priority area both for the industry itself and for the authorities. For the industry, the cost of failing to adapt insurance products to a changing climate will be high, and for society there will be major consequences if insurance is unable to provide predictability and security. Internationally, there is a strong focus on insurance both as an industry and as a tool to help society adapt. In the United Kingdom, where flooding is the largest challenge, insurance companies are still obliged to provide insurance against floods provided that the government implements measures to prevent flood damage. This is a good example of cooperation between the authorities and the insurance industry, and is a much better option than insurances companies withdrawing insurance products from the market.

10.4.2 Socio-economic consequences

It is difficult to estimate the socio-economic cost of climate change in regards to insurance. The cost depends on many factors, and there is a significant degree of uncertainty. Therefore, Finance Norway cannot estimate the future costs, but Vista Analyse estimates that, during the period from 2070 to 2100, climate change will result in NOK 100–300 million of additional annual costs compared with current levels.

10.4.3 Adaptive needs

Insurance schemes in Norway are well-adapted to the current climate, and have further adaptive capacity through reinsurance schemes. Climate change

may create challenges for the industry, but also opportunities, with additional insurance needs increasing its turnover. Insurance is a key element of society's financial infrastructure. It is important to maintain the security it provides even if climatic conditions change. Insurance has the potential to be a tool that facilitates adaptation to climate change. This could involve requiring that climate change considerations be taken into account, and requiring that any necessary preventive measures be introduced before insurance is provided. Insurance can also play a proactive role after a loss incident. To a large extent, the reconstruction of buildings and replacement of property is organised by insurance companies. Insurance companies can also contribute to adaptation to climate change by demanding, both of customers and repair contractors, that adaptation measures are implemented in conjunction with repairs and rebuilding. They can, for instance, demand that authorised craftspeople be used to repair particular types of damage, require certification schemes for craftspeople and demand that climate change protection measures are included when rebuilding and repairing. Some of these measures may increase the amount they have to pay out, which will be a challenge for an industry judged on price and cost efficiency, but it will be possible to implement if required by the authorities.

It will be necessary to provide the correct regulatory framework by changing insurance arrangements and potentially also laws. Furthermore, there is a need to prioritise adaptation to climate change within the existing collaboration between the insurance industry and the authorities.

The committee believes there is a need to make the knowledge base for climate change and climate projections more accessible, and to integrate climate change into risk assessments. These needs relate to basic map data and monitoring, but also to research and development. The insurance industry's needs in this regard, will be equivalent to those of the infrastructure sectors discussed in Chapter 9.

10.4.4 The committee's recommendations

To strengthen the insurance industry's adaptive capacity and the role of insurance schemes in adaptation to climate change, the committee recommends:

- Establishing a database for the use of the public sector and researchers with a comprehensive, anonymised record of climate-related damage from the insurance companies and the Norwegian Natural Perils Pool.
- Increasing the quality and standard of work when rebuilding and repairing buildings by imposing more stringent requirements on contractors and by limiting the ability of insurance companies to pay cash compensation for damage.
- The Natural Damage Act and the insurance system for natural damage must be reviewed, with consideration being given to differentiating between assets in terms of the natural damage risk, and to how the system can be made to promote prevention, for instance by earmarking part of insurance premiums for preventive measures such as flood channels and strategies to delay flooding.

10.5 Tourism

The weather has a major impact on people's travel habits. Climate change may therefore change travel patterns. Changes to the regulatory framework will also have a major impact on the products offered by the tourism industry. Winters with little or no snow may have serious consequences for Norwegian winter sports destinations, and more precipitation may reduce the quality of outdoor activities. Meanwhile, warmer and sunnier summers in Southern Norway may lead to an increase in summer tourism. More frequent and less predictable extreme weather incidents may change the risks associated with many of the products offered by the tourist industry. Any parts of the industry that see rising numbers of accidents may become less competitive.

Tourism is one of the fastest growing industries both in Norway and internationally. In 2008, the industry contributed just above 3 per cent of GDP, with total turnover amounting to around NOK 180 billion (Innovation Norway 2009). Outdoor experiences are the main product, and they are the foundation for much of the Norwegian tourist industry. Norway has set a goal of strengthening its position as a destination for outdoor experiences in coming years. Changes in the basis for outdoor experiences may therefore have a major impact on tourism in Norway, and may entail that many companies in the sector will have to adjust what they offer.

The impact of climate change on tourism will largely depend on the ability of enterprises to adapt. The industry has a long history of adapting by tailoring new products to changing markets. Innovation and change are natural parts of the efforts made by tourism companies to offer new

and better products to tourists, and to adapt to a constantly changing reality.

The industry is currently adapted to the existing climate, but it has the capacity to adapt to changes, both through technological innovations and by developing new products. Climate change may also result in an increase in tourism at the expense of other countries more severely affected by climate change. In spite of the fact that tourism is exposed to climate change, the general view of the committee is that the industry is not particularly vulnerable. Above all, tourism needs a good framework for innovation and change. Enterprises need to strengthen and update their expertise in the area of adaptation.

10.5.1 Vulnerability to climate change

10.5.1.1 How is the industry impacted by the present climate?

The Norwegian tourism industry is closely related to the Norwegian countryside, nature and climate. Temperatures, the number of sun hours, precipitation and extreme weather events place important constraints on the industry. It is also affected by the risk of fire, landslides, avalanches, floods and erosion (Aaheim et al. 2009).

The industry is aware that bad weather reduces tourists' enjoyment of outdoor experiences and has developed strategies and measures to make itself less dependent on the weather. In many parts of the country, visitor centres based on the surrounding countryside have been established that offer attractions independent of weather. The North Cape Hall, which is blasted out of the rock, shows films and pictures of the area in good weather, and allows you to enjoy the view through the panoramic windows while staying indoors.

10.5.1.2 How will the industry be impacted by climate change?

Climate change will result in more and larger areas of Norway becoming snow-free towards 2100. In practical terms, a two-month shorter snow season in the interior of Eastern Norway, in the mountains of Southern Norway and on the Finnmarksvidda plateau, and a two to three-month shorter snow season in the lowlands and along the entire coast, will mean that the snow will disappear entirely from many areas. Between now and then, there will be some good snow seasons. For example, for a while the amount of snow in the mountains may increase as a result of greater precipitation, before decreasing again once warming results in a larger proportion of winter precipitation falling as rain.

Winter sports may therefore benefit during the first half of the century, before subsequently experiencing deteriorating conditions. This will particularly affect the lowlands, where ski resorts will gradually start to experience shorter snow seasons with less snow. Ski resorts in the mountains and the interior will also be negatively impacted by climate change towards the end of the century, but to a lesser extent. Ski resorts and other enterprises that currently depend on snow will therefore have to adapt to the new conditions if they are to remain viable. The impact of changing snow conditions on the Norwegian tourism industry also depends on changes in snow conditions outside Norway. One plausible scenario is that demand will increase in spite of conditions deteriorating, because conditions will be worse elsewhere. If snow conditions in Central Europe deteriorate relative to conditions in Norway, it may be that winter tourist numbers will increase. By contrast, demand may fall if deteriorating snow conditions cause a declining interest in ski tourism.

Norwegian summers will probably become longer and warmer. From Møre og Romsdal County and northwards, more precipitation is expected. The warmer climate will accelerate the process of regrowth, which is already happening in many cultivated landscapes, and in many places, previously open landscapes will become overgrown. In the mountains the low-lying glaciers will melt. If the mountains are covered with trees and glaciers melt, the experience tourism that Norway has to offer will probably become less attractive.

As with winter tourism, the impact of climate change on the Norwegian tourism industry in the summer is closely linked to climate change in other countries. In several of the Mediterranean countries, summers may become too hot for tourists. Drought may also become a major problem in many of those countries. According to Hamilton et al. (2005, cited in Vista Analyse 2010) there is a positive correlation between higher temperatures and visitor numbers, but only up to a certain point. If temperatures rise beyond that point, visitor numbers fall. If the climatic conditions on which tourism are based deteriorate as much, or more, in other countries, the result may be that more summer tourists decide to travel to Norway, even if the climate here is worse than it was. However, this is highly uncertain. A number of other factors must also be taken into account, such as potential

changes in Norwegian vacation habits. Even if the Mediterranean becomes less attractive during summer, people will still be able to move their holidays to the spring or autumn.

The tourism industry may also be affected by the consequences of climate change and mitigating measures in other sectors. This applies in particular to the transport sector. As transport is currently responsible for a large proportion of greenhouse gas emissions, the likely introduction of measures to reduce emissions will change mobility patterns. It is also likely that the challenges created by climate change will result in lifestyle changes, with various groups of tourists changing their behaviour patterns, for example by reducing holidays in order to limit emissions. A report by Vestlandsforsking points out that climate change will not only affect tourism, but also government policies. One scenario is that higher fuel prices designed to reduce greenhouse gas emissions will lead to Norwegians vacationing more in Norway. Equally, it will reduce the number of tourists coming from abroad, particularly by aircraft (Vista Analyse 2010). These views are based on the assumption that travel will continue to produce CO_2 emissions in the second half of the century.

Changes in the risks associated with outdoor experiences and activities may have financial consequences if they affect tourist behaviour. The closure of facilities or prohibitions against activities due to increased risk may directly prevent activities. This may affect winter sports and activities such as kayaking and river rafting, either through closed facilities or through recommendations or prohibitions against such activities in certain areas at certain times of the year. Tourist behaviour may also change due to individual perceptions of risk, which may make certain activities that are considered dangerous, less attractive. A single avalanche may have a much larger impact on tourist numbers than gradual changes in snow conditions. By contrast, many of these activities are already associated with risk, and attract people who are willing to accept a reasonable level of risk. It is therefore uncertain whether, or to what extent, changes in risk patterns will affect tourism. What will change is the underlying data used by the industry in its risk assessments. Enterprises in the sector are responsible for risk assessments and safety. Changes to risks may therefore alter the demands on enterprises in terms of understanding risks and taking safety precautions.

Climate change may also be a source of various positive impacts on tourism. An increase in tourism due to comparatively worse climates in other countries has been mentioned. New products based on areas that will become more accessible in a warmer climate are another example. The melting sea ice may provide new opportunities for Arctic cruises. Loeng (2008) points out that Svalbard's growing attraction as a tourist destination is likely to be enhanced further, partly because in recent years there has been far less ice in the fjords on the north and east coasts of Svalbard. Viewed in isolation, this improves accessibility, but the extent of the impact will depend on how tourism is regulated. Cruise tourism is expected to grow, due to higher passenger numbers and more locations where it will be possible to come ashore. This will exacerbate the challenges facing the authorities in terms of reducing impacts on nature and preventing loss of cultural heritage relics. A combination of greater numbers of cruise ships and more frequent and intense extreme weather events may increase both the need for emergency response vessels in the area (Buanes et al. 2009a) and greenhouse gas emissions.

10.5.1.3 Adaptive capacity

Organisation

The tourism industry is mainly comprised of many small enterprises. The Ministry of Trade and Industry has the overall responsibility for the sector. At regional and local levels, county governors, county authorities and municipalities are responsible for the tourism industry through their involvement in regional and local business development. In collaboration with the industry itself, Innovation Norway is responsible for areas such as marketing tourism in Norway internationally. Innovation Norway also offers courses and training to enterprises in the industry.

For commercial activities based on outdoor experiences, there are requirements relating to risk assessments and safety. Any company offering such products is responsible for safety and must have the necessary knowledge to allow it to assess risks. In addition to performing risk assessments, suppliers of these services must have safety equipment, qualified staff and internal control. Participants must also be informed and trained. The Directorate for Civil Protection and Emergency Planning (DSB) is responsible for specifying safety requirements and supervising activities. This supervision does not currently

involve assessing whether climate change considerations have been included in risk and vulnerability analyses (DSB 2010). In certain circumstances, the police can advise against, or introduce a local prohibition on, activities in high-risk locations. This is currently done for the River Sjoa, which is popular for rafting and kayaking.

Resources

The fact that the tourism industry generates annual revenues of almost NOK 180 billion is an indication of its importance to the economy. However, when assessing the resources of the sector, these revenues have to be viewed in the context of the number and geographical spread of the enterprises in the industry. At the same time, the tourism industry is supported by incentives and subsidies from local, regional and central government. The sector is also in a constant state of flux, so that in general terms, it is impossible to say anything definite about how access to resources will affect its adaptive capacity.

In regards to the expertise and capacity of the tourism industry, it does have experience and knowledge that is relevant to adaptation. Tourism companies are used to providing services to tourists regardless of weather. A growing focus on experience tourism will also mean that the industry and individual enterprises will become increasingly proactive in relation to climatic conditions. Experience holidays in particular are constantly adapting to the latest trends and in order to provide new products to the market. Although this expertise is not necessarily specific to adaptation, it will be relevant to the industry's adaptive capacity. As previously mentioned, there are special requirements that apply to suppliers of the kinds of services generally associated with experience tourism. Being familiar with and understanding current safety requirements for skiing and snow-based activities, climbing or rafting, is also relevant to adaptation. At the same time, climate change will expose enterprises to a new situation, which means that knowledge about areas such as natural dangers will have to be adjusted in light of how climate change affects risk patterns. Just as important as the knowledge and expertise of the enterprises themselves is the expertise of the authorities. Adaptation measures such as marketing, restructuring and preserving natural landscapes, as well as clearing vegetation to maintain views, may become more important as means of support for the industry in the future.

Knowledge base

Internationally the World Tourism Organization was quick to highlight climate change as a challenge and opportunity for the global tourism industry. If you do an internet search for "tourism and climate change", you find that there are a significant number of studies and reports on the subject. It is not possible to trace any equivalent activity in Norway – on the part of the industry or the authorities. As far as the committee is aware there has been no comprehensive assessment of the impact of climate change on the sector and adaptive needs.

However, various studies on tourism and climate change have been done by research institutions. The committee does not know if, and potentially how, these are used in the sector, but climate change and tourism has been discussed at several industry conferences.

As demonstrated in Chapter 9, capacity design in the infrastructure sectors is based on observation and mapping of the current climate. Although the tourism industry is unlikely to use, or need, that level of detail, certain observations of climate-related conditions are also important to enterprises in the sector. For instance, this applies to avalanche and flood warnings, which are likely to be used by providers of experience-based holidays to help them assess safety. These warning services may become more important for parts of the tourism industry in the event of a less predictable climate.

Priorities

One of the main areas of focus of the Norwegian tourism industry is developing eco-tourism and experience-based holidays centred on nature and outdoor activities, and sustainable tourism is a key goal of the Norwegian government's policy on tourism (*National Strategy for the Tourism Industry*, Ministry of Trade and Industry 2007). The climate is a key parameter for the development of these kinds of products, and climate change will, as previously mentioned, affect tourism products based on nature. As far as the committee can tell, climate change and adaptation are not treated as subjects in their own right in the documents and strategies that provide guidelines for the industry. It also appears that Innovation Norway is aware of the issues arising from climate change, but that this is not reflected to any degree in the informa-

tion that Innovation Norway provides to the industry (for example through its website).

However, the committee does not believe that this reflects a failure to properly prioritise adaptation to climate change, but rather a lack of knowledge and expertise on the impacts of climate change on the products offered by the Norwegian tourism industry. The committee's belief that adaptation to climate change will become a priority is based on the way in which the industry currently matches its products to the climate. Another reason for believing that adaptation will be given priority is that in the future profitability and competitiveness will be dependent on the industry adapting to the climate.

10.5.2 Socio-economic costs

The socio-economic impacts of climate change on tourism are related to changes in demand and the cost of adapting. During the time scale in question, there is so much potential for adaptation, and the cost of specific mitigating measures, such as snow cannons, is so low, that changes in demand are the most important parameter in terms of socio-economic impacts. Transport costs are nevertheless a major uncertainty factor in terms of how the sector will develop. In line with our assessments in the chapter on transport, we believe that travel will continue to increase. On that assumption, in the second half of the century the Norwegian tourism industry is likely to experience somewhere between NOK 60 billion less and NOK 30 billion more in demand than would have been the case without climate change (Vista Analyse 2010).

Travel and tourism is one of the sectors that have grown significantly in recent years, and this growth appears to continue. If income and leisure time continue to increase in line with many economic projections, tourism will represent a greater share of the economy by the end of the century than it does today. The effect of climate change on tourism may therefore have a major impact on the economy.

The calculations on which the committee has based its assessments estimate that demand for tourism services in Norway will most likely decline, but they do not discount the possibility of it rising (Vista Analyse 2010). An interval of between minus 20 and plus 10 per cent has been mentioned. Lower demand reflects the fact that winter tourism in Norway will probably decline. The decline will be due to snow-based winter tourism contracting, and in some areas disappearing completely. Summer tourism is likely to grow due to warmer and sunnier weather in the south of the country, combined with the fact that summers in Southern Europe will probably become too hot. New opportunities in the Arctic may also attract additional tourists.

10.5.3 Adaptive needs

The needs of the tourism industry are above all related to knowledge and expertise. The authorities, public enterprises with responsibility for tourism and the industry itself all have a need to map vulnerability to climate change and the opportunities and challenges presented by a new climate. There is also a need to innovate and utilise new technology. There are also already examples of various available solutions that can compensate for the loss of snow. For several winter sports destinations, it may be possible to invest in moving their facilities or installing equipment to make snow or keep snow cool.

Up to a certain point, these solutions are not necessarily very costly (Vista Analyse 2010). However, there may be other considerations that speak against these kinds of solutions, such as their impact on nature, emissions and other related costs. How sustainable they are is also a factor (Aaheim et al. 2009). If energy production continues to result in the emission of CO_2 in the future, the cost to society of this kind of adaptation will be greater than the benefit to the relevant enterprises – and thus represent maladaptation from the point of view of society as a whole. Both the direct costs and the costs to society will probably increase the warmer it gets. Finally we will reach a point where it is no longer profitable or responsible to pursue adaptation.

Climate change may make it necessary to revise safety requirements, and with more frequent and less predictable natural events, it may be necessary to strengthen warning systems and procedures.

10.5.4 The committee's recommendations

To create a framework that allows the tourism industry to adapt, the committee recommends:

- Investing in research into the relationship between climate change and tourism.
- Developing additional guidelines for tourism activities in Arctic areas.
- Require that risk and vulnerability assessments and safety measures take climate change into account.

Chapter 11
Society

If you regard society purely as a series of different sectors, there is a risk of overlooking the overall picture and connections. In this chapter, the committee will discuss the impact of climate vulnerability and adaptive needs within the context of local communities, Sámi culture and livelihoods, the international community, and the welfare and living conditions for individuals.

Climate change is a global problem that will impact local communities and individuals. Regardless of whether changes are viewed in a national or global context, there will be large variations in the consequences for, and vulnerability of, the people affected. The variation in vulnerability towards climate change is also closely linked to the capacity of groups and individuals to respond to the challenges. One of the authorities' responsibilities will be to help create a society that is in the best possible position to handle climate change. However, this is not a task that the authorities can fulfil alone. Businesses, professional bodies and trade associations, political parties and voluntary organisations must all contribute to adapt society. One aspect of adaptation is informing and educating people about the fact that the climate is changing and using resources to raise awareness regarding what the changes will entail and how to address them.

The local perspective will be important for understanding how climate change will affect our society, and how various players will have to respond to the changes. The knowledge that local communities have about their own vulnerability, challenges and opportunities will provide an important foundation for choosing the correct adaptation strategies and measures.

This chapter shows that Sámi interests are cross-sectoral. It also shows that the skills of indigenous peoples in responding to changes in nature and their traditional knowledge will play a key role in adaptation. Practical knowledge built up over generations and experience from handling challenging and varying natural conditions will provide an insight into how to handle future changes.

For many people in Norway, quality of life is closely linked to their ability to enjoy sports and other snow and winter activities. Increasing risk of floods, landslides and other natural disasters caused by more intense periods of precipitation may contribute to growing insecurity. Nevertheless, the challenges faced by Norway are not of the same magnitude as those being faced in the rest of the world. Climate change may exacerbate inequality in the world. Many of the poorest countries will experience the greatest problems with droughts, floods and the impact of rising sea levels. Norway has become one of the richest countries in the world due to its exploitation of fossil fuels. That gives us both a responsibility and an opportunity to help mitigate the problems caused by climate change.

11.1 Local communities

Weather and the natural environment have always been key parameters for the living conditions in local communities in Norway. Residents, enterprises and the local authorities must take these factors into account, both in their lifestyle and daily activities, as well as in their long-term planning.

The extent to which local communities are exposed- and sensitive to the weather and climate change varies greatly. This variation means that a potential effective adaptation strategy must be highly tailored to local conditions, within the framework of national guidelines. When considering adaptation it is therefore necessary to understand local perspectives and needs.

Norwegian local communities vary from small, rural settlements and fishing villages to large towns and cities. Throughout most of the world there is a strong trend towards urbanisation, and in Norway the proportion of the population living in cities is also rising. While the Norwegian population rose by 5.9 per cent between 2002 and 2009, the population in metropolitan areas rose by 9.4 per cent over the same period. The

population in the metropolitan areas represents over 55 per cent of the total population (Report no. 25 (2008–2009) to the Storting).

Geographical and topographical variations mean that local communities face different levels of exposure to weather conditions, natural events and changes to ecosystems related to the weather. There are also differences in social, economic, demographic and political circumstances. The vulnerability of any given local community will vary depending on the composition of these factors and how they interact.

Local communities must adapt to climate change by using a number of measures and tools, and local authorities, primarily municipalities, will play a key role in their implementation. However, individual residents, businesses, organisations, etc. will also have important tasks and responsibilities, and together with the municipalities, they constitute a broad range of local stakeholders. The municipalities are discussed in greater detail in chapter 13.

11.1.1 Local communities and climate change

Local communities, local sectors and individuals have always lived with natural disasters such as landslides and floods. A widely-held attitude is that the general public, industries and municipalities are used to significant variations in weather and climate, and find practical solutions for handling these variations in the best possible way.

This does not mean that climate variability has not created major difficulties for local communities. Climate variability over relatively long periods, such as the "Little Ice Age" (15th to 17th century), had a dramatic impact on local communities. Farms and agricultural land were destroyed by expanding glaciers and were subsequently abandoned.

Local communities continue to be vulnerable to climate variability and natural incidents that they do not have the capacity to handle themselves. Climate change and natural disasters are costly – for individuals and the local community. During the period from 1980 to 2009, NOK 8.1 billion was disbursed in compensation for natural damage. The 1992 New Year's storm in north-western Norway alone caused 33 000 reported loss claims and resulted in compensation payments totalling NOK 1.3 billion (*http://www.naturskade.no/no/hoved/statistikk/*).

Section II shows that there is significant geographical variation in how the different areas will be impacted by climate change. While geographical variation has only been briefly addressed in discussions on climate change vulnerability in the various sectors of society, local geography and topography will, along with social, political and economic conditions, be important parameters for assessing how vulnerable local communities are.

Climate change will, for example, increase the risk of drought during parts of the year in some regions, and of floods and landslides in others. In addition to the geography and topography creating local variations in climatic conditions, topography is also one of the key factors that determine the risk of landslides and avalanches.

The reviews of the various sectors have shown that more frequent and more intense precipitation may cause major damage to infrastructure and the built environment. For local communities this may result in higher operating and maintenance costs, in addition to which they will have to take into consideration changing risk patterns (such as floods in different areas and at different times of year than in the past).

Local communities may be particularly vulnerable to climate change if local businesses are negatively impacted. This is particularly relevant to communities that are based around a single company or industry. For example, tourism companies and local communities based around winter sports tourism will be vulnerable to climate change reducing the number of days with snow cover. Correspondingly, local communities and businesses can develop strategies and measures to respond to the challenges. Voss is a good example. In Voss, the winter sports facilities have been moved to areas with more reliable snow cover, while new ideas have been developed for the summer, such as the "Extreme Sports Week". A report on the consequences of changes in the snow season near the Voss town centre, concludes that *"Overall, the tourism industry in Voss has not experienced any downturn, although the snow season has been negatively impacted near the Voss town centre; on the contrary, Voss has experienced growth in recent years"* (Aaheim et al. 2009).

Climate change and the need for adaptation will have both material and non-material impact on the quality of life of individuals. See the discussion of welfare and living conditions in Chapter 11.4.

The geographical variation in the extent and impact of climate change may also have distributional effects. This is discussed in greater detail in Chapter 12.2.

11.1.2 Adaptive capacity and vulnerability

A number of studies have studied the vulnerability of Norwegian local communities. West and Hovelsrud (2008) compared employment rates in various sectors based on natural resources with generation of wealth in these sectors in local communities in Northern Norway (see also West and Hovelsrud 2010). They found that vulnerability and adaptive capacity depend on scale: although Norway as a whole is not vulnerable to climate change measured in terms of the impact on income in any given industry, certain local communities may be highly vulnerable using the same indicators. Hovelsrud et al. (2010b) also found that changes in other social, economic and cultural factors will need to be studied, and concluded that vulnerability must be viewed in a wider context of how climate change impacts and interacts with other factors.

One characteristic of all local communities is that their development is planned and decided through a combination of formal and informal structures and processes. Locally, the municipalities are the most important formal structure, while businesses, voluntary associations, organisations and individuals comprise the informal power structures and influences.

The informal structures may play an important part in efforts to analyse local vulnerability to climate change and the potential to adapt local communities to the changes. Together with the public sector, businesses and organisations will provide a knowledge base and shared local desire for adaptation. This is particularly relevant in terms of local development activities aiming to exploit any opportunities that climate change offers.

The NORACIA report "Tilpassing og avbøtande tiltak, klimaendringar i norsk Arktis" (Buanes et al. 2009b "Adaptation and mitigating measures, climate change in the Norwegian Arctic"), discusses institutional vulnerability to climate change. The authors stress that this must not be interpreted "... as being limited to public-sector management institutions with responsibility for climate-related questions". They claim that "both the market and civil society (local communities) are social institutions with the resources and capacity to influence society's vulnerability to climate change. We must build up and develop our knowledge regarding adaptation through cooperation between experts and the people involved in implementation, users and residents in the affected areas. This is particularly to ensure that we gain an understanding of specific local and sector issues, even if they are not intrinsically linked to climate change".

Various research projects are currently examining how local knowledge may be used in efforts to map vulnerability and adaptation (e.g. NORADAPT, PLAN, EALÁT, CAVIAR, DAMOCLES). Through its investigations, the committee has also come across some instances of organisations that are looking into the question of general local vulnerability to climate change and adaptation. Among the trade associations, the Norwegian Farmers' Union has had a high profile in the media in relation to questions regarding food production and arable land protection in the context of climate change. The Norwegian Red Cross has, at both a national level and through its local branches, pointed out some of the challenges that climate change may create locally. The organisation wishes to cooperate with the local authorities both on preventive measures and responses to undesirable incidents. The Association for the Promotion of Skiing and the Norwegian Ski Federation have established the project "White winter", which is a four-year collaborative project to promote awareness of environmental issues and climate change in the Norwegian skiing community.

The committee believes it is important and necessary to involve a broad range of organisations and individuals in efforts to adapt local communities to climate change. Organisations in particular may have an important role to play in spreading knowledge and making people understand the challenges created by climate change. Many municipalities are aiming for broad involvement of residents and businesses in efforts to create climate change and energy plans. The committee believes that it is similarly necessary to provide framework for involvement in efforts to map vulnerability and adaptation to climate change.

11.2 Sámi culture and society

In Norway there are currently traditional Sámi settlements from Engerdal in Hedmark County in the south to the coast of Finnmark County in the north. The Sámi people are recognised as the second constituent people of Norway.

Norway has an obligation to ensure that the Sámi people are able to exercise their traditional cultural and commercial activities. The ability to continue exercising traditional, culturally significant commercial activities is an important and recognised right of indigenous peoples.

The magnitude of the expected climate change will, along with various economic and social factors, create new challenges for the traditional ways in which the Sámi people have used nature, and will therefore also have an impact on Sámi culture and society. This will create a need for new knowledge and a review of the regulatory framework for Sámi culture and livelihoods with respect to changing conditions.

At the same time, a long history of harvesting natural resources under highly variable climatic and weather conditions means that the Sámi people have built up significant experience and knowledge, with the versatile and extensive harvesting of both land-based and marine natural resources being an important strategy of adaptation to a variable resource-base. This is why one of the key characteristics of the commercial structure in Sámi areas are diversified and flexible.. Traditionally the livelihoods of the Sámi people have been based on and reliant on great flexibility.

By diversifying and harvesting a wide range of resources, the Sámi people have had the flexibility to withstand fluctuations in the resources, in their income and in their ability to save when there is a surplus. This adaptation was essential in order to make a living and as a strategy for spreading risk, and "not putting all the eggs in one basket" (report by the Samediggi - the Sami Parliament (the Sámi Parliament) 'on agriculture 2007).

11.2.1 Vulnerability to climate change

11.2.1.1 How are Sámi culture and society impacted by the current climatic conditions?

Flexibility in the use of the available resources in the north has historically enabled the indigenous peoples of the Arctic to adapt well to climate variability (ACIA 2005). Over the course of history, variability in the weather and climate have affected the abundance and accessibility of marine and land animals, birds and fish that could be used for food, clothing and everyday objects. As many Arctic species are only available in certain areas at specific times of the year, the indigenous peoples have developed the knowledge and skills to allow them to exploit different animals and plants during various seasons.

Historically, indigenous peoples in the High North, such as the Sámi have been dependent on surviving in, and adapting to, a challenging and variable natural environment (Buanes et al. 2009a). The knowledge accumulated through generations of practical experience has been necessary for survival, and represents a rich source of experiential knowledge about both the Arctic natural environment and the interaction between nature and society. For this reason, the traditional knowledge possessed by indigenous peoples continues to be important in the context of the current and projected changes.

The Sámi parliament, the Samediggi, (2007) emphasises that flexible use of resources, which has laid the foundation for developing the knowledge and experience needed for survival in the Sámi areas, has also helped shape people's current relationship with nature. The ability to exploit the various natural resources is an important element of the "good life" in Sámi areas and also includes cultural, social and subsistence activities.

The close relationship with the primary industries also exists in the exploitation of marine resources. The vast majority of Sámi people in Norway have traditionally exploited or had a close relationship with marine resources. This is an important aspect to bear in mind with respect to any adaptation measures that affect fisheries in the Sámi areas. This is particularly true as policies already have, over a longer period of time, created obstacles for traditional small-scale fishing in Sámi areas, thereby undermining an important aspect of the material foundation for Sea Sámi culture. The use of fishing gear in the fjords over prolonged periods of time is part of this pattern (The Sámi parliament, the Samediggi 2004).

For example, the introduction of the vessel quota scheme for cod fisheries in 1989 which resulted in a large proportion of the smaller vessels in the north being excluded from the scheme, and the resulting privatisation and introduction of transferable fish quotas, severely damaged the sustainability and adaptive capacity of local communities. Strict limits on salmon fishing at sea in recent decades have tended to have the same effect (Sameting 2004).

11.2.1.2 How will Sámi culture and society be impacted by future climate change?

Climate change is one of the many challenges facing the indigenous peoples of the Arctic, including the Sámi. The previous and current social and economic changes taking place, may lead to significantly greater problems for indigenous peoples than climate change, at least in the immediate future. Various social and economic issues are more pressing than climate change, and some indigenous groups are concerned that a focus on

climate change will divert attention away from other potentially harmful current and future problems (Buanes et al. 2009a).

Buanes et al. (2009a) suggest that the Sámi population is especially vulnerable to climate change because traditional Sámi livelihoods are already under pressure. The report describes how reindeer husbandry and other Sámi livelihoods are currently under pressure and can expect increasing challenges due to climate change.

New species of moth larvae are damaging the forests in many northern areas. The ground vegetation is also being affected, including various types of berries. Large parts of the birch forests of Finnmark County, the county which is home to the largest Sámi population, are, and will continue to be, exposed to autumnal moth larvae. Currently we have only limited knowledge about the direct cause of vegetation being destroyed by the autumn moth larvae. Warmer winter temperatures are a contributing factor to moth larvae attacks (Hagen et al. 2007). The death of the birch forests affects wildlife directly, and indirectly hunting and other nature-based activities (Rybråten and Hovelsrud 2010).

There is no literature which specifically analyses how Coastal Sámi communities and activities are affected by climate change, but the "Community Adaptation and Vulnerability in the Arctic Region" (CAVIAR) project found that Coastal Sámi fishermen are observing new fish species in the region (Rybråten and Hovelsrud 2010). The *Fávllis* project, which is being run by the Centre for Sámi Studies at the University of Tromsø, may also contribute new knowledge in this area.

There is much evidence to suggest that if the sea warms up, new species will migrate to the north, and that existing species will move even further north and east, as discussed in greater detail in Chapter 7 "The natural environment" and Chapter 10.2 "Fisheries and aquaculture". This will affect fisheries in Sámi areas – including many of the fjords in northern Norway.

The mackerel fishery can serve as an illustration. If temperatures rise, it is likely that mackerel will gradually become common in the sea and fjords in the north (Øseth 2010). Few fishermen in Finnmark currently have mackerel quotas. In other words, if there were to be plenty of mackerel in the north, local fishermen would not be able to utilise the opportunity. Meanwhile, the species that coastal fishermen have traditionally caught are expected to decline.

11.2.1.3 Adaptive capacity

Organisation

The Samediggi - the Sami Parliament (the Sámi parliament) is a fairly new constitutional body which in principle has consultative status in all areas and executive power in selected areas. The Samediggi - the Sami Parliament is the government's most important source of information and partner on Sámi policy. The Samediggi - the Sami Parliament has also taken over the management responsibility and authority for certain areas.

The Ministry of Government Administration, Reform and Church Affairs is responsible for the coherent implementation of the government's Sámi policy. This involves coordination with other ministries – informing them about Sámi policy and ensuring that it is included when sector policy is prepared, monitoring and evaluating the consequences of sector policy in relation to Sámi policy, keeping track of funding for Sámi policy measures, liaising between the sector ministries and the Samediggi - the Sami Parliament and ensuring compliance with procedures for consultation and participation.

Requirements and regulations

Under various international agreements, Norway has an obligation to maintain and safeguard the culture and livelihood of indigenous peoples, as well as their property rights to natural resources and land. The key international agreements that define the obligations of the government to the Sámi people are the UN Covenant Civil and Political Rights (article 27), ILO Convention No. 169 on indigenous and tribal peoples and the Convention on Biodiversity (particularly articles 8 and 10). The UN Declaration on the Rights of Indigenous Peoples, adopted by the UN's General Assembly in 2007, is also important in this context.

Article 110a of the Norwegian Constitution states that: *"It is the responsibility of the authorities of the State to create conditions enabling the Sami people to preserve and develop its language, culture and way of life."* This stipulation limits legislation in areas of particular importance to the Sámi people, and the authorities must take this into account when handling matters relating to Sámi culture and society. Pursuant to the Constitution, the Sámi Act and other legislation, the municipal, regional and national government authorities have an obligation to take into account Sámi culture, commercial activity and society, and to give them spe-

cial treatment and consideration in general social planning and land-use planning in particular.

In Norway, there are several legislative measures designed to safeguard Sámi culture and traditions. The Finnmark Act shall *"facilitate the management of land and natural resources in the county of Finnmark in a balanced and ecologically sustainable manner for the benefit of the residents of the county and particularly as a basis for Sámi culture, reindeer husbandry, use of uncultivated areas, commercial activity and social life."*

The Sámi Act shall enable the Sámi people of Norway to safeguard and develop their language, culture and way of life, cf. Section 1–1.

The Marine Resources Act is also important for Sámi commercial activity. It shall ensure sustainable and economically profitable management of wild marine resources, and promote employment and settlement in coastal communities.

The Nature Diversity Act shall ensure the sustainable utilisation of natural resources in such a way that the environment provides a basis for human activity, culture, health and well-being, now and in the future, including a basis for Sámi culture; cf. Section 1.

Resources

Storting White Paper No. 28 (2007–2008) mentions that the economic structure in the Sámi areas means that settlement and employment are typically dependent on agriculture, fishing, reindeer husbandry, hunting and gathering and duodji (Sámi handicrafts), as well as combinations of these. The report underlines that combining various activities makes it possible to exploit resources more efficiently, as well as achieve a higher and more stable income, and that these various industries provide the material foundations for Sámi culture and identity.

Being able to use local, nature-based resources is very important for a large proportion of the Sámi population, financially, for leisure activities and for their sense of identity and sense of belonging. Various combinations of agriculture, fishing, reindeer husbandry and other ways of harvesting various natural resources (*meahcci*) are normal in many Sámi areas. These combinations have changed over time, and today, paid work and tourism are often the dominant activities (Andersen 2009, Rybråten and Hovelsrud 2010). Nevertheless, this does not mean that nature's resources have lost their value.

Activities are either combined through individuals having several different sources of income, or by different members of the family working in different sectors. Examples of combinations which people and families derive their income from, include fishing and nature-based activities such as hunting and gathering, agriculture and nature-based activities, agriculture and fishing, reindeer husbandry and fishing for sea salmon or other species, agriculture and work in the public or service sector, or fishing and work in the public or service sector. In addition, some people combine income from more than two different commercial activities (Andersen 2009, Riseth et al. 2010, Rybråten and Hovelsrud 2010).

These combinations of activities are not detected by the official statistics (Andersen 2009). This can lead to a lack of national recognition, hamper regulatory responsiveness and thereby discourage flexible and adaptable combinations of activities. Management regimes that are based on knowledge and rules that do not leave room for taking into account a traditional way of life may overlook the importance of traditional knowledge for adaptation. The consequence may be that management practices work against the goal of maintaining and developing traditional combinations of professions and sources of income when the climate changes.

Knowledge base

The report by the Samediggi - the Sami Parliament's executive council on the environment and land use, *Leve i landet på landets vis* (2009 – "Living off the land on its terms") highlights the importance of making use of the knowledge that indigenous peoples have acquired over generations, but also of combining this with scientific knowledge-The report concludes that the traditional indigenous knowledge has proved useful in relation to documenting climate change and developing positive adaptation strategies. It also states that integrating traditional and scientific knowledge helps to make the consequences of various mitigating measures more predictable.

One of the subsidiary focus areas of the International Polar Year project CAVIAR, headed by CICERO, were the issues faced by the Coastal Sámi, and there was also an emphasis on traditional knowledge. Another project being run by the Sámi University College, Árbediehtu – "Inherited knowledge", focuses explicitly on traditional knowledge in a Sámi context.

The research project EALÁT has focused on climate change and reindeer-herding communities in Yamal, Russia, and Finnmark County. The project, which is also part of the International Polar Year, was managed by the Sámi University College in collaboration with a number of Norwegian and international partners. The goal has been to reduce the vulnerability of reindeer husbandry to the impacts of a warmer climate. As a follow-up to this project, the Institute for Circumpolar Reindeer Husbandry is being established within the University of the Arctic, based at the Sámi University College.

Priorities

There is political awareness regarding the potential consequences of climate change on Sámi culture and society, cf. Report No. 28 (2007–2008) to the Storting, *Sámi policy*, where the government states that it is an important national priority to safeguard the valuable natural resources in the core Sámi areas for the future – not least in order to enable continued Sámi settlement, commercial activity and culture. In the same report, the government also concludes that *"Climate change poses a major challenge to the cultures, commercial activities and ways of life of indigenous peoples. Sámi culture remains closely linked to the primary industries and proximity to nature."*

This is a clear indication that there is political awareness and willingness to prioritise the adaptation needed to ensure that Sámi culture and society can endure in the face of climate change.

11.2.2 Adaptive needs

The committee believes the Samediggi - the Sami Parliament's viewpoints on measures to adapt to climate change are an important consideration. This view is expressed, among other places, in the report by the Samediggi - the Sami Parliament's executive council on the environment and land use – *Living off the land on its terms*. The report also focuses on climate change and the key preconditions for the Sámi people to be able to cope with it. Chapter 6.5 of the report – *Global environmental challenges* – provides a summary of the situation. It also highlights the causal relationships and how various types of adaptation measures may impact indigenous communities: *"The principle should be that all national measures in response to climate change cause minimal damage, and that the rights of indigenous peoples are respected."*

Traditional Sámi commercial activity and knowledge are important pillars of Sámi culture, and must be taken into account in the assessment of various types of adaptation measures. , Traditional knowledge is an integral part of the Sámi languages. It is therefore important to preserve and reinforce these languages.

Management regimes must also consider traditional Sámi commercial activities. Increased ocean temperatures may make it necessary to introduce new fisheries regulations, because of both Sámi and regional considerations. This is clearly a question of adaptation to climate change, and the committee recommends that the necessary adjustments are made, due to the expected movement of fish stocks.

Fishing for salmon in the sea and rivers is an important aspect of the Sámi livelihood, particularly in the northernmost region. Climate change represents a major threat to the large salmon populations in the north, particularly from the aquaculture industry. Warming ocean temperatures may result in the aquaculture industry in the south increasingly moving to fjords in the north, where temperatures are lower. This may pose a threat to the wild salmon populations there, partly because of problems with sea lice. If the aquaculture industry grows rapidly in these areas, it will also tie up large areas in the fjords currently used for traditional fishing by locals and the Coastal Sámi people. The committee would like to stress that any adaptation measures that encourage rapid growth in the aquaculture industry in the fjords of Finnmark and other Coastal Sámi areas in the north, may conflict with the aim of ensuring the viability of traditional Sámi commercial activities; also discussed in Chapter 10.2 "Fisheries and aquaculture".

In relation to developing knowledge in conjunction with climate change, the committee emphasises the importance of making use of and classifying traditional Sámi knowledge. One important reason is the need to recognise both Sámi and other traditional knowledge as part of the basis for making decisions about adaptation measures.

The government's strategy for the High North, *New building blocks in the north* (2009), emphasises the importance of ensuring that traditional knowledge is integrated into knowledge development processes and is used by the authorities, businesses and future generations. The government therefore wants to start documenting traditional Sámi knowledge within the context of

the High North, as part of a cross-border knowledge development programme based on the model and experiences offered by the national programme at the Sámi University College. The objective is to ensure that traditional knowledge is incorporated in knowledge development programmes and is integrated in the planning and management of nature, resources and the environment and in the monitoring of the High North.

The committee believes that there is a particular need to improve the authorities' and politicians' understanding of the Sámi people and their culture – including their traditional knowledge. This will provide a solid foundation for constructive cooperation between Sámi society and Norwegian society as a whole, including on the question of climate change.

Acquiring expertise and capacity in Sámi society is fundamental in order to meet the challenges that lie ahead. This also applies to developing sustainable methods of collecting and using traditional knowledge and the capacity to develop courses that relate to climate change and adaptation. This will place people in a better position to exploit any opportunities that may arise within traditional Sámi activities – simultaneously with the needs that climate change may create. Flexibility is a key concept here. It appears likely that one important adaptation strategy will be, to an even greater extent than today, the ability to combine traditional commercial activities with completely new activities.

The knowledge and expertise of indigenous peoples regarding climate change that has been compiled through ongoing research projects must be preserved, passed on and communicated. Further research into various traditional Sámi commercial activities is also a key focus area. Another equally important area is developing courses and training programmes to build expertise regarding climate change and its impact on traditional Sámi activities at various levels of society. There is, of course, the Sámi community itself, but equivalent training should also be offered to relevant authorities, decision-makers and other stakeholders.

Knowledge-building programmes should emphasise both the findings of modern scientific methods and traditional knowledge about relationships in nature, at the core of which is the inherited knowledge contained in the Sámi languages.

In addition to the above-mentioned R&D projects and bodies, a number of other institutions are to a greater or lesser extent working on the issue of climate change and adaptation in relation to traditional Sámi livelihoods and culture. It is important to encourage the people working on these questions to work closely together, so that the combined knowledge which exists in this area is made available in the best possible manner. Given the emphasis placed on using the Sámi languages as a starting point for including and addressing traditional knowledge, the committee considers it natural that the Sámi University College should play a key role in this work.

Viewed from the perspective of the Sámi people and other indigenous groups, the overall challenge is how indigenous communities in the High North may react to, handle and adapt to future climate change, while safeguarding the existing cultural values and knowledge.

The committee therefore considers essential that adaptation measures are implemented in such a way that they do not undermine the viability of traditional Sámi livelihoods and thereby Sámi culture.

The committee views it as important that the Samediggi - the Sami Parliament is given a key role in protecting the rights and interests of the Sámi with respect to future adaptation, and to give it influence over policy through consultations and participation in decisions that affect these interests. This also involves increasing the capacity and expertise of the Samediggi - the Sami Parliament so that it is in a position to be an equal partner to other government agencies during discussions and decisions on adaptation measures.

11.2.3 The committee's recommendations

In order to improve the adaptive capacity of Sámi culture and society, the committee recommends:

Research and development

- Increased funding of research on traditional Sámi knowledge, using the Sámi languages as a key source.
- Development of courses and educational programmes on adaptation using traditional Sámi knowledge as an important starting point.
- More research on biological threats in the High North area: such as autumnal moths and other pests.
- Land-use research that helps explain the ways in which climate change may affect land cover, vegetation, forests and agricultural conditions in the Sámi areas.

- Knowledge about altered competitive conditions among land-based primary industries as a result of climate change.

The management regime

- Review of the parameters for the Sámi industries, taking into consideration the need for adaptation.
- Implement ecosystem-based management of both land-based and harvestable marine resources.
- The Samediggi - the Sami Parliament's expertise and opportunity to become an important party in adaptation efforts should be improved through additional resources.
- The Samediggi - the Sami Parliament should be given an active role in key processes and bodies that have tasks in national planning related to adaptation.

11.3 International dimensions of climate change

Drought, floods and hurricanes are becoming increasingly common features of the international news. The flood in Pakistan in August and the forest fires that ravaged Russia in the summer of 2010, illustrate the enormous human suffering and economic losses that natural disasters can cause. Although these individual incidents cannot be linked to climate change, the Intergovernmental Panel on Climate Change stresses that climate change is already affecting the intensity, frequency and pattern of what is often referred to as extreme weather (IPCC 2007). Many vulnerable societies in coastal areas, in slums by river deltas and on low-lying islands will probably have to relocate.

Norway will be affected by climate change beyond its borders. The media often talks about higher food prices and so-called "climate refugees" when discussing how climate change in other countries will affect Norway directly through more expensive food and increasing numbers of refugees coming to Norway, but there is currently little scientific evidence to support this. Increased international food prices will impact the poor the hardest, and the people who are forced to flee are likely to become internal refugees. The impact of this on Norway will primarily be connected to its humanitarian obligations and responsibility to assist developing nations in their efforts to develop and adapt, and to prevent and handle natural events.

Globally, climate change will have a wide-ranging impact, presented in numerous studies. In looking at how climate change will affect the global community and what kind of consequences this will have for Norway, the committee has selected four focus areas: food security and international food prices; migration; international obligations; and regional issues, with an emphasis on the Arctic.

11.3.1 Food security

The world's food supplies depend on the production of biomass on land, in freshwater and in the sea. Globally, the most important climate change impacts on agriculture are higher temperatures, changes in precipitation levels and reduced access to meltwater. Total global food production will probably decline if temperatures rise by more than three degrees, but large regional variations are expected, which means that even with moderate temperature increases, food production will decline in parts of Asia, Africa and South America (Easterling et al. 2007). Ocean acidification and higher water temperatures in the sea and freshwater bodies may also reduce the world's food security. Little is known about what the combined effects of these changes will be on the global production of fish and other seafood. Although the impact on the productivity of the sea is highly uncertain, this uncertainty must be taken into account in the assessment of the overall impact of climate change on the global food supply; see Chapter 10.2.

According to the Food and Agriculture Organization of the United Nations (FAO), global food production must increase by 50 per cent by 2030, and 70 per cent by 2050, in order to meet the needs of a population expected to reach 9 billion. Increasing urbanisation, the destruction of land and restrictions on farming in new areas are factors that limit the area available for future food production. After access to arable land, access to water is the second most important limiting factor for agricultural production. Agriculture accounts for 70 per cent of global freshwater consumption. The consequences of climate change may therefore significantly exacerbate both various serious existing challenges and annual variability in global food production.

Rising food prices have the most serious impact in poor countries, where food represents 60 to 80 per cent of household expenditures, whe-

reas the proportion in the industrialised world is 10 to 20 per cent. Furthermore, the poorest countries are most dependent on food imports. During the food crisis of 2006–2008, and the subsequent credit crisis in 2008 and 2009, the number of people affected by famine rose by more than 100 million (FAO 2009). Several of the countries where a high proportion of the population does not have enough food to eat on a regular basis, lie in regions where the impacts of climate change are expected to be most significant, thus reducing or resulting in less reliable food production.

International food prices are determined by a number of factors beyond supply and demand. Disease and insect pests, oil prices and preferences for meat and dairy products have been highlighted as decisive factors for increased food prices (Stancich 2008). The events of 2007 and 2008 demonstrate that food prices are sensitive to changes in the balance between supply and demand. In countries where national food prices follow the world market, people are rapidly impacted by rising prices due to shortfalls in supply in the world food markets.

Norwegian consumers are to a great extent protected against fluctuations in world market prices through import restrictions and national price controls stipulated through the agriculture agreements. If climate change, potentially in combination with other factors, leads to greater fluctuations in global food markets, this is likely to result in changes to the agreements that govern international trade of food products. This may cause Norwegian consumers to become more directly exposed to changes in global food prices. However, the committee believes that due to the low proportion of household income currently spent on food products and expectations of continued economic growth over the remainder of the century, higher food prices will have a limited impact on Norwegian consumers.

Nevertheless, Norway has a particular responsibility if climate change further reduces global food security, leading to higher world market prices and more unstable food markets. While climate change is expected to have a negative impact on food production in many regions of the world, it will most likely allow the Norwegian agricultural sector to increase food production, and will most likely alter and result in an overall increase of the productivity of Norwegian waters; cf. Chapters 10.1 and 10.2 for further details. In light of the risk of declining global food security, and the impact of this on the poorest and most vulnerable people, the committee believes that Norway has a responsibility to maximise domestic food production when the climate changes. The committee also believes that Norway has a special responsibility for helping ensure balanced food markets and stable prices both through high domestic production and by supporting the development of sustainable production methods in poorer and more exposed countries.

11.3.2 Migration

Drought, floods and other natural disasters force people to flee their homes. Although there is no agreed definition of the term, and they are not granted any special protection under international law, these people are often referred to as "climate refugees". The Intergovernmental Panel on Climate Change has suggested that the number of refugees may rise as a result of climate change, and that migration may become permanent if floods and drought become more frequent and intense. At the same time, it has been pointed out that migration is rarely caused solely by climate variability or change (Wilbanks et al. 2007).

Conflict, degradation of the natural environment and population pressure are factors that, in combination, force people to leave their homes (Storting White Paper No. 13 (2008–2009), Ministry of Foreign Affairs). The UN High Commissioner for Refugees (UNHCR) stresses that climate change will combine with these factors and contribute to migration in the most exposed and vulnerable parts of the world (UNHCR 2009). People in the most exposed countries in Africa, the Asian megadeltas, small, low-lying island states and the Polar Regions are considered particularly vulnerable (IPCC 2007). Rising sea levels and persistent drought may make low-lying island states and drought-affected areas permanently uninhabitable. Studies of climate change and migration provide a sufficient basis for concluding that climate change will affect migration, and may lead to increased migration, primarily due to people , temporarily or permanently, becoming refugees within their own countries, or so-called internally displaced people (Kolmannskog 2008, UNHCR 2009). The Intergovernmental Panel on Climate Change stresses that if an area becomes uninhabitable due to rising sea levels or persistent drought, this is likely to lead to permanent migration (Wilbanks et al. 2007). However, there is no evidence to suggest that climate change alone will result in migration. Climate change's direct impact on Norway as regards migration is therefore expected to be limited (Rottem et al. 2010).

The fact that the most vulnerable people in the world will come under growing pressure as a result of climate change is therefore primarily a humanitarian and ethical issue for Norway.

11.3.3 Climate change and development

Every year, eight million children under the age of five die (You et al. 2010). The vast majority of these children live in developing countries and die of treatable diseases such as pneumonia, diarrhoea and malaria. Without going into detail on the reasons behind this, it is safe to say that there is extreme inequality across the globe. The UN's millennium development goals will be unachievable and global inequality will increase, unless drastic cuts in CO_2 emissions and adaptation measures reduce both the scope and consequences of climate change.

When natural incidents become disasters, or when people are forced to move from an area, this is largely due to the way in which infrastructure and buildings are designed, and the destruction of the natural environments and ecosystems that would normally provide protection against the elements. Climate change is therefore often described as an "amplifier" of existing challenges. This means that people who already live at the fringes of what nature can provide will face the largest climate change consequences. The vast majority of these people currently live in developing countries with limited capacity to implement measures to prevent and manage the consequences. Developing countries and vulnerable people and communities will therefore be severely impacted by climate change. Regions with shared resources, such as the countries that share major river systems like the Nile, Ganges and Mekong, will face challenges from changing flooding patterns and potentially decreased influx. Parts of Africa that are already suffering from drought will become even drier. Meanwhile, the world will need to feed a constantly growing population. In 2050, the world's population will be nine billion, and the FAO has estimated that global food production will need to increase by 70 per cent by then. This requires close international and regional cooperation.

Development and climate change are intrinsically interlinked. Good health, an education that allows you to choose work in sectors outside agriculture, and democratic structures that safeguard the needs and rights of the poor are all essential in order to increase the resilience of a society – including towards climate change. It could be said that the circumstances that make people vulnerable today, also make them vulnerable to climate change, and that climate change "adds just another extra layer of risk" (Commission on Climate Change and Development 2009).

However, this does not mean that traditional development measures are identical to increased adaptive capacity. On the contrary, development measures that fail to take into account climate change may increase vulnerability (Ulsrud et al. 2008). For example, agricultural measures that focus on high-yielding varieties (HYV) requiring heavy irrigation may result in failed harvests in areas that become more exposed to drought, and a road built in a low-lying coastal area without taking into account rising sea levels will be a waste of money at best. Therefore, as in Norway, an important aspect of adaptation to climate change in developing countries will be taking climate change into account in social planning. This involves adapting general development programmes to the changing situation, as well as implementing programmes solely in response to climate change. One example of the latter is the programme to protect low-lying islands against rising sea levels (UNFCCC 2007).

If Norway's development aid is to provide an effective contribution to sustainable development, climate change must be taken into account in Norway's development cooperation activities. What this means in practice will vary from country to country, and must be based on studies and analyses of local communities and of countries' vulnerability to climate change and adaptive needs.

Who should pay the financial costs of adaptation in developing countries is a heated debate in international forums. The most recent available estimate puts the cost at USD 100 billion annually between now and 2030 (World Bank 2009). This is based on a temperature increase of just two degrees. Other calculations estimate the cost as being even higher. These calculations are not precise and are based on a number of assumptions, but they do tell us that there will be significant financial costs associated with climate change.

The developing countries have a clear demand: the industrialised world must pay. Although the committee has not reached any conclusion as regards Norway's exact share of responsibility, this matter is discussed in Chapter 17. There is no doubt that Norway has a clear responsibility within this context. Norway must be prepared for the fact that climate adaptation efforts will require increased efforts and increased Norwe-

gian commitments vis-à-vis developing countries over an extended period of time. Given the close link between the development of a country and its vulnerability to climate change, there is little sense in reallocating funds from traditional poverty-alleviating measures to specific adaptation programmes, as failure to deal with poverty will make the society more vulnerable to climate change.

Norway has just started incorporating adaptation into the development cooperation. Both Storting White Paper No. 9 (2007–2008), *Norwegian policy on the prevention of humanitarian crises*, and Storting White Paper No. 13 (2008–2009), *Climate, conflict and capital*, state that efforts to promote adaptation can be improved. The Storting's discussion of these reports also shows a growing interest in, and willingness to start using a wider range of policy measures than traditional development aid in order to assist these countries with adaptation. Among other things, a proposal has been made for a fund for so-called shared global assets. Various NGOs involved in development, such as the youth organisation *Spire*, have suggested allocating a certain proportion of the Government Pension Fund of Norway to adaptation in developing countries. Given the nature of its mandate, the committee has not assessed these solutions, but would, however, like to stress that creative solutions will probably be needed at both national and international levels (e.g. so-called innovative financing schemes) if the estimated costs of adaptation turn into actual financing requirements.

There may be a risk that focusing exclusively on the financial value of aid will prevent measures from being based on vulnerability and needs analyses that uncover the needs of the most vulnerable groups. What experience tells us as regards aid is that quick "technological fixes" in many cases make vulnerable people even more vulnerable. Programmes and funding aimed at adaptation in developing countries must learn from our dearly bought experiences with aid, which indicate that it takes time to build up a local sense of ownership of development programmes, but that doing so must nevertheless be a priority.

11.3.4 Resources and interests in the Arctic

The northernmost and southernmost latitudes will experience the greatest temperature changes (IPCC 2007). In these regions, climate change will significantly alter the ecosystems and harm the natural environments (ACIA 2005). Meanwhile, changes in fishery resources and a reduction in ice cover both at sea and on land will allow for greater activity and new business opportunities; cf. Chapter 10.2 for further details. The committee has previously highlighted the ensuing dilemmas and conflicts of interest between the natural environment and greater commercial activity. New business opportunities may also create potential conflicts of interest between countries with rights in the Arctic. Climate change that affects fish stocks, for example, may alter the basis for distributing and exploiting resources. Uncertainty in relation to the management regimes for these resources may create intergovernmental tension (Rottem et al. 2010). Increasing activity may also lead to emergency situations that will require greater cooperation between the five countries that border the Arctic Ocean (Norway, Russia, Canada, the US and Denmark); see the more detailed discussion in Chapter 9.1 "Transport".

Questions regarding climate change have received particular attention within the context of the Arctic Council. Although the council is not able to make binding resolutions, it has played an important role as a scientific forum for assessing challenges and opportunities in the Arctic in a cooperative fashion (Rottem et al. 2010).

The committee has not reviewed the extensive rules that apply to cooperation between the "Arctic" nations and utilisation of resources. However, our impression is that the legally binding agreements between the states do little to integrate climate change considerations. The committee underlines the importance of following up the 2008 Ilulissat declaration by Norway, Russia, Canada, the US and Denmark, which aims to ensure predictable regulation of increased activity in the area, with legally binding agreements on the management of a highly vulnerable natural environment. It is also important that the knowledge foundation that has been built up through the Arctic Council's ACIA report, follow-up project and working groups such as AMAP are used as a basis for the political cooperation.

The Norwegian management plan for the Barents Sea and Lofoten from 2006 establishes the principle of ecosystem-based management in all Norwegian territorial waters. Without directly referring to ecosystem-based management, international cooperation in the Arctic does emphasise the importance of protecting the natural environment. Storting White Paper No. 15 (2008–2009), *Interests, Responsibilities and Opportunities: The main features of Norwegian foreign policy*, states that: *"People have no moral right to destroy the*

natural environment, and Norway is not entitled to accept that species become extinct or to use up the natural resource base for future generations or less fortunately situated countries". It also points out that *"The climate problems, the threats to biodiversity, the spread of environmentally hazardous substances / chemicals, the dangers associated with nuclear facilities close to the Norwegian border, the risk of oil spills and pollution along our coast, and our responsibility for ensuring sustainable management of the Arctic all involve important foreign policy tasks for Norway."*

11.3.5 The committee's recommendations

In order to improve the adaptation to impacts of the global consequences of climate change and help facilitate international adaptation, the committee recommends:

- Norway must ensure that the national adaptation efforts do not directly or indirectly increase the challenges for adapting in more vulnerable countries, but must support and improve the conditions that facilitate adaptation for these countries. For example, this may be done by ensuring high domestic production of food at the same time as we assist in establishing sustainable production systems in more vulnerable and less wealthy countries.
- Norway has a responsibility to help ensure that vulnerable countries and countries with fewer resources become more resilient in their encounters with a changing climate. This will require increased funding and existing efforts will have to be adapted so as to ensure sustainable development. Norway must help ensure new international financing schemes are set up through which long-term, predictable funds can be generated to support adaptation measures and to cope with an increased frequency of natural disasters.
- Through management of the Norwegian Arctic and through international forums, Norway must contribute to management and legally binding agreements that ensure preservation of the vulnerable natural environment in the High North.

11.4 Welfare and living conditions in Norway

The preceding chapters in Section III have dealt mainly with the physical and material impact of climate change on nature and society. Climate change also has significant non-material consequences. These are harder to measure and assess, but should nevertheless not be underestimated.

Many aspects of our day-to-day lives and the factors that contribute to our quality of life will be affected by climate change. Climate change will alter the basis for leisure activities involving nature and outdoor experiences. Among other things, increased precipitation combined with milder winters will reduce opportunities for practising winter sports, which is considered an important expression of Norwegian culture and pivotal to the quality of life for many Norwegians. However, changes will be gradual, which will help us to adapt. The risk of landslides and floods will increase in many places, which may affect the sense of safety. Furthermore, people will face increasing threats to their health from tick-borne diseases, pollen allergies and respiratory complaints. To some extent, people will likely grow accustomed to changing threat patterns, but it is reasonable to believe that the Norwegian population will become more fearful of natural disasters as a result of climate change.

There will likely be great variation in how individuals and groups experience the consequences of climate change. Whether they experience the consequences of climate change as being positive or negative is related to the preferences and values that are most important to the individual or group (O'Brien). While less snow and shorter periods of snow cover will be negative for the avid skier, for others it will be positive. It is also true that we grow accustomed to the climatic conditions we live in. Furthermore, new generations have different values from the preceding ones and various trends have an influence on how we value outdoor activities, for instance (O'Brien and Wolf 2010).

Nevertheless the committee considers that, overall, climate change will have a negative impact on the perceived quality of life and safety of people in Norway.

11.4.1 Outdoor activities

Analyses of Statistics Norway's 2007 Living Conditions Survey show that 9 out of 10 Norwegians participate in some sort of outdoor activity. In addition to outdoor activities, outdoor sports are also important to many Norwegians. The authorities' goal for outdoor activities is described in Storting White Paper No. 26 (2006–2007): *"Everyone shall have the opportunity to take part in outdoor recreation as a healthy and environmentally sound*

leisure activity that provides a sense of well-being both near their homes and in the countryside."

Climate change will increasingly limit traditional outdoor winter activities. In the mountains, 90 per cent of the glaciers may melt, and towards the end of the century the areas with stable winter snow conditions may be located at altitudes 250–450 metres higher than today. The snow season is expected to become shorter throughout the country, with the largest reduction in the lowlands, which will make it harder for most people to practise winter sports near their homes. People who do want to practise winter sports will have to travel to areas with reliable snow in the alpine areas or on the Finnmarksvidda plateau, or compensate by using artificial snow. All of these responses are expensive and increase emissions. Businesses that depend on snow-based outdoor activities will also be affected by shorter snow seasons, as discussed in greater detail in Chapter 10.5.

A warmer climate will accelerate the forest regrowth that is already taking place in many cultivated landscapes. Regrowth may make these landscapes both less accessible and less attractive for outdoor activities. Ticks, for instance, may also become more common in these areas.

Climate change will lead to changes in the composition of species in the Norwegian countryside, and the species that can be hunted and fished will probably be different. Furthermore, the breeding season of species may also be extended with climate change.

11.4.2 Cultural heritage

Inadequate maintenance and the loss of cultural heritage assets is a problem in the current climate as well, and this applies particularly to farm buildings that are listed or of high cultural heritage value. Climate change will expose buildings, in particular, to more humidity, thus increasing the risk of rot. Adaptation measures such as carrying out more maintenance and other preservation activities may help protect the fabric of the buildings, but there is a limit to what can be done without reducing their cultural historical value. If there is serious damage, it is difficult to reconstruct the cultural historical value. Cultural heritage monuments such as buildings and other infrastructure of historical value may therefore be lost as a result of climate change; cf. Chapter 9.6. For example, rising sea levels may threaten Bryggen, the old wharf in Bergen, and various kinds of damming will only help up to a certain point.

11.4.3 Perception of safety and security

For human beings, a sense of safety and security is vital for welfare and quality of life. A 2007 survey (DSB 2007) concluded that there is a high degree of awareness in the population that climate change affects society. Two-thirds of the respondents were concerned about what climate change would mean for them and their families. The survey was not able to document any link between the level of fear and geographical exposure to climate change.

There is not much available documentation on how the population will react to the effects of climate change, but a number of studies have been carried out mapping the psychosocial impact of natural events. A survey following the landslide at Hatlestad terrace in Bergen in 2005, revealed that a majority of the inhabitants were already coping well 1.5 to 2 months after the incident (Dyregrov and Gjestad 2009). The results showed that two-thirds of the people who were unable to return to their homes experienced significant psychological discomfort, but relatively few people suffered post-traumatic stress. The response rate to the survey was low, which means that the results must be used with caution. By contrast, the many protests from people living along landslide-prone roads show that protection against landslides is an important requirement for well-being and welfare.

11.4.4 Adaptive needs and opportunities

It may sometimes be possible to replace current arrangements with alternatives for outdoor activities, but in most cases this will be a relatively short-term solution, and may also increase emissions. Correspondingly, roller skis and ski tunnels are unlikely to be able to replace the experience of using freshly prepared trails in wintery forests. Any complete or partial loss of the ability to pursue traditional winter sports activities in parts of the country will therefore represent a genuine loss of something people consider to be a valuable part of their quality of life (O'Brien 2009), with the only possible adaptation involving gradually taking up other activities. To help achieve the goal of everyone being able to take part in outdoor activities near their homes and in the countryside in

general, it will nevertheless be necessary to facilitate various activities throughout the year.

Safety measures such as landslide prevention and building tunnels will help increase people's sense of safety to some extent. Good warning and evacuation systems, and appropriate capacity design criteria when developing and maintaining infrastructure, as discussed in Chapter 9, may also help contribute to greater safety.

To help prevent unwanted regrowth affecting landscapes and trails, it will be necessary to promote agricultural activity throughout the country in addition to introducing preservation measures. Within management of the natural environment it will be necessary to consider changes to what species can be hunted, and during what periods the various species can be hunted and fished. Measures to combat nuisances such as new insects, snails and health complaints will also affect people's quality of life.

Chapter 12
General assessment of vulnerability and adaptive needs

The committee is of the opinion that, generally, Norway is in a good position to adapt to climate change. In order to be successful, climate change considerations must be incorporated into planning and decision-making processes in all areas and all levels of society. The committee considers that the degree to which this is achieved varies between different areas of society.

Climate affects all areas of society, but in different ways and to different extents. In our assessment of the various areas of society in Section III, vulnerability has been considered on the basis of how exposed the area is and its adaptive capacity. How areas will be impacted by climate change has been assessed on the basis of the climate projections presented in Section II, other research results and contributions from people involved in the sectors. Adaptive capacity has been evaluated in light of the sector's organisational structure, resources, knowledge base and priorities. The interaction between these factors is also an important part of the assessment. Our review shows that vulnerability is not just dependent on the impact of climate change; it is also very closely linked to the adaptive capacities of the various areas.

The committee believes that the natural environment, infrastructure and buildings are particularly vulnerable to climate change in Norway.

The impact of the climate varies between regions and types of terrain. The nature of the exposure varies between the coast and the interior, between Northern Norway and Southern Norway, and between steep, mountainous areas and low-lying, flat areas.

The committee considers the north, particularly from Finnmark County and northwards, and alpine areas to be particularly vulnerable to climate change. Part of the Sámi population in the north derives its livelihood from natural resources, and Sámi culture is therefore vulnerable to the impact of climate change on nature.

Certain local communities that are not currently at risk for landslides, avalanches and floods, will face these risks in the future, but in general, climate change will mainly increase existing challenges.

The review of the various sectors and areas of society in Section III identifies a number of shared challenges. To some extent, these recurring themes take on different guises in different sectors, but they challenge adaptive capacity across sector boundaries.

12.1 Vulnerable areas of society

The consequences of climate change will alter many natural environments. The rate of the changes will make it difficult for many species and ecosystems to adapt. The combined impacts of climate change, land-use changes, pollution and increased human presence will make the natural environment more vulnerable.

In the case of certain natural environments, there are limits to what society can do to prevent the loss of biodiversity through adaptation. This is particularly true of marine ecosystems and in Arctic and alpine regions. Furthermore, adaptive capacity will be weakened by current insufficient prioritisation of environmental considerations, meaning that environmental goals will not be met. These are the main reasons why the committee considers the natural environment to be particularly vulnerable to climate change. The characteristics of marginal habitats, such as mountain areas, will change as a result of climate change. Species that are adapted to these areas will lose their habitats, and in some cases completely disappear. Adaptive capacity can be improved by maximising the area available to threatened species and by providing habitat corridors for them, but the committee believes that we must expect climate change to affect the diversity and composition of species in Norway. Land use, the harvesting of natural resources and pollution affect nature and make natural environments less resilient.

Ocean acidification is one area where Norwegian waters will be affected before many other parts of the world, giving us the opportunity and responsibility to obtain early observation data and to carry out research that will benefit the international community. There are currently no adaptation strategies for ocean acidification, in Norway or internationally. Mitigation in the shape of emissions reductions to stabilise global warming is the only known measure that will limit ocean acidification.

All infrastructure is affected by climate and weather. Nevertheless, vulnerability to climate change varies between types of infrastructure. The committee believes that the energy and electronic communications sectors have a relatively high adaptive capacity, helping to counteract the fact that these sectors are highly exposed to climate change. Overall vulnerability is therefore low. The committee considers the adaptive capacity of the water and sewage sector to be low, making it highly vulnerable. The assessments of the transport sector and building stock yield a more complex picture of adaptive capacity and vulnerability.

However, within the context of an assessment of the vulnerability of society as a whole, infrastructure and buildings stand out as particularly vulnerable areas. Critical infrastructure is vital to maintaining essential services such as food, water, heating, security, safety, etc. (NOU 2006:6). Inadequate adaptation to climate change may affect the country's ability to provide a number of essential services. Various kinds of vital infrastructure are mutually dependent, making them more vulnerable to climate change. In addition, much of the infrastructure has a long service life, which means that what we construct today must have the capacity to deal with future demands. The committee therefore sees a clear need to give these sectors specific policy signals to encourage them to integrate climate change considerations into their strategies, planning and implementation of measures.

Overdue maintenance work is a major challenge for much of our infrastructure and building stock. Climate change will increase the need for maintenance, thereby exacerbating the challenges associated with the maintenance backlog. This is particularly an issue in the transport, buildings and water and sewage sectors. Due to ageing infrastructure, the energy sector is also in great need of investments and upgrades. The maintenance backlog means that the infrastructure is not adequately adapted to current climatic conditions. The combination of overdue maintenance and climate change significantly impairs adaptive capacity and may entail significant costs for society.

Overall, the committee considers business and industry's vulnerability to climate change to be low. In this report, we distinguish between industries that are directly exposed to climate change, through being affected by the access to raw materials, and industries that will be affected indirectly through consequences in other sectors. Most of the business sector falls into the latter category, being primarily affected through impact on demand, infrastructure and buildings. The impact of climate change nevertheless depends largely on the level being considered. Although individual enterprises will be severely affected by climate change, for instance due to a reduction in snow cover or coastal cod stocks, the committee believes that climate change will not have a major permanent impact on the profitability and competitiveness of the private sector as a whole. This also applies to affected industries that rely on natural resources. Businesses are good at responding to change, and they are constantly adapting to current weather conditions. Nevertheless, to enable them to do so is important to facilitate innovation and restructuring.

The primary industries are directly exposed to both weather and climate, and will therefore be affected by climate change. However, their adaptive capacity is strengthened by clear regulatory structures, and by the fact that the industries have had to adapt to climate variability for generations. As these industries are exposed to large fluctuations they have developed adaptation strategies such as breeding and developing new varieties, in order to adapt the various domesticated plants, domestic animals and trees for optimal production. The committee therefore believes that the primary industries, in spite of being highly exposed, are not particularly vulnerable to climate change. New opportunities for business development arising from a warmer climate will, however, require the industries to adapt and restructure.

Outdoor experiences are the main product offered by many Norwegian tourism companies, and any change in their ability to provide these experiences may have a serious impact on the tourism industry. Whereas travellers are very good at adapting, individual tourism companies are largely tied to a specific location, which means they will face major challenges. This is particularly true of winter destinations that depend on snow, but also summer activities such as cruises and

experience tourism involving hunting and fishing. Similarly, climate change can be expected to affect most outdoor activities, particularly during winter, but participants are likely to be very good at adapting here as well.

For businesses, adaptation is also about exploiting the new opportunities offered by climate change. In the primary industries, the power sector, petroleum sector, tourism industry and shipping industry, new opportunities for value creation as a result of climate change have been identified. However, this creates a dilemma, as exploiting them may come into conflict with other political goals and adaptive needs in other areas of society. For example, utilising the new possibilities for economic activity may come into conflict with the goal of emission reductions and the desire to preserve natural diversity.

Climate change will affect human health. An extended pollen season and the arrival of alien species may create additional problems for a relatively large proportion of the Norwegian population. This may reduce the individual's quality of life and increase costs for society. Nevertheless, the committee considers that the general health of the Norwegian population is good, the health service sector works well and the general level of preparedness is high. The committee therefore believes that overall vulnerability to climate change is limited in this area.

Climate change will create increasing challenges for civil protection and emergency preparedness efforts. Any increase in the risk of floods, landslides, avalanches and other natural incidents exposes individuals and society to greater risk and more stress. This will test the nation's capacity to prevent and respond to natural disasters. This will increase the challenges associated with civil protection and emergency preparedness efforts for authorities in many areas of society, such as the power supply sector, the transport sector and municipalities. As a result, civil protection and emergency preparedness efforts will need to be adapted.

12.2 Vulnerable geographical areas

Currently, the impact of climatic conditions varies between different parts of the country, regions and local communities. Coastal municipalities in Finnmark County face different challenges from municipalities in the interior of eastern Norway. The challenges faced by urban areas will differ from those faced by less developed areas. The impact of any given climate change depends on the topography, vegetation, population density, etc.

The climate projections in Section II suggest large variations in how climate change will impact different parts of the country. Climate change will increase the risk of floods, landslides, avalanches, driving rain and rot damage. In general, the areas that are most exposed today will remain so in the future. However, there will also be areas currently not at risk that will be exposed to, for instance, floods and landslides in the future.

Geographically, the committee considers the High North and the alpine regions to be the areas that are likely to be more exposed to climate change than others. In the High North, the extent and rate of climate change will be so high that regardless of knowledge, priorities and resources, the consequences will be significant. The temperature increase will result in the Arctic sea ice melting rapidly, the permafrost on Svalbard thawing, fauna and flora habitats shrinking and pressure on the foundations for Sámi culture and the Sámi way of life.

Climate change in the High North will create opportunities for new value creation, while also threatening vulnerable environments and natural assets. Petroleum production and shipping may lead to conflicts between the desire for economic development and conditions needed to allow species and ecosystems to adapt. The committee therefore believes that adaptation considerations relating to the protection of the natural environment should primarily set the ground rules for the development of commercial activities.

12.3 Distribution effects

The committee's mandate requests an explanation of the distributional effects of climate change and a discussion regarding appropriate measures to limit them. Distribution covers a variety of parameters, with the distribution of income and wealth between individuals and social groups being the ones most frequently discussed. The committee has chosen to cover the topic in two sections: distribution between the Norwegian regions, which

is discussed in 12.3.1; and intergenerational and global distribution, which are discussed in 12.3.2.

12.3.1 Distribution effects between Norwegian regions

Below we have outlined some thoughts on the regional distribution of the impact of climate change. The committee would like to emphasise that the basis for these views is limited. However, we hope to be able to point out the kind of factors it will be useful to consider when discussing distributional effects. The starting point for this discussion is that climate change affects regions through impact on: the value creation ability of industries; infrastructure and buildings; and non-material wellbeing. When assessing distributional effects it is important to remember that society will adapt to climate change as best as it can, thus helping to mitigate the consequences. Furthermore, for the foreseeable future, the profitability of businesses, for instance, will primarily depend on developments other than climate change.

In Norway, the climate varies a great deal from region to region. The impact of climate change will vary between the north and south, east and west, coastal and interior areas, and high and low altitudes, consequently altering regional distribution.

The committee considers the High North and alpine areas to be most vulnerable to climate change. This reflects the fact that climate change will have a greater impact on existing fauna and flora, traditional ways of life and industries in those areas than elsewhere. At the same time, this does not necessarily mean that the same conclusion applies to distributional effects. The losses suffered by northern and alpine regions will primarily relate to the natural environment.

Climate change will also have an impact on businesses in the north, and in particular on Sámi activities. Vulnerability affects specific types of industry, whereas distribution is more closely linked to the overall level of activity. Sámi economic activity is also highly flexible and adaptable, cf. Chapter 11.2. Warmer weather and improved conditions for new business opportunities may counteract the negative impacts and increase the overall potential for value creation in the north. The decline in Arctic sea ice will improve conditions for fishing, shipping and the petroleum industry in the Arctic regions, although environmental considerations may prevent some of those developments. Based on current knowledge, it is most likely that the waters off the coast of northern Norway will become more productive, and the warming of the sea will improve conditions for aquaculture. The long-term impacts of ocean acidification present an unknown threat to this prospect. Agriculture in central and northern Norway will benefit from a longer growing season and milder climate.

Certain consequences of climate change will vary greatly from region to region, and may create varying distributional effects. Some parts of the country are more landslide-prone, and risks will increase more in some areas than others. If precipitation becomes heavier during autumn and winter, the landslide risk will increase most for steep terrain in western and northern Norway that receives a lot of precipitation. Landslides may also occur in areas that were previously not particularly exposed to them. Areas where the permafrost is expected to thaw are also landslide-prone. Any increase in landslide risk may impose higher costs on western and northern areas than on the rest of the country, but there is insufficient evidence to draw conclusions about the distributional effects of this.

Floods can result in fatalities, and cause extensive physical damage to infrastructure, buildings and other equipment. Most damage will be caused where there are high-value assets located on river floodplains. In urban areas, where population density is high and the capacity of water and sewage systems is limited, floods have the potential to cause significant material damage.

There will be major variations in increases in precipitation. According to estimates by Orskaug and Haug (2009), by the end of the century, higher levels of precipitation may increase damage costs by 50 per cent in certain counties; see the more detailed discussion in Chapter 10.4. There are significant geographical variations, but increases in costs are not necessarily directly correlated to increases in precipitation. For example, smaller increases in precipitation may have a larger impact in eastern Norway, and conversely, western Norway may experience less additional damage in spite of a larger increase in precipitation.

For businesses, a warmer and wetter climate may benefit the primary industries such as agriculture, and in certain places, aquaculture. For the fishing and aquaculture industries, the fact that fishery resources will migrate northwards along the west coast will change the distribution of jobs and value creation. More precipitation may increase power generation, but both the power

sector and other infrastructure sectors are also vulnerable to floods and landslides.

Overall, the committee does not expect climate change in Norway to have dramatic distributional effects. However, this assumes that the adaptive capacities of the various sectors and of the authorities will be utilised through appropriate prioritisation, and that climate change considerations will be incorporated into social planning.

12.3.2 Intergenerational and global distributional effects

When looking at climate change, distribution over time and between generations is perhaps the most important parameter. Fundamentally, climate change is an issue that has been caused by our generation, and generations before us improving standards of living by emitting greenhouse gases. Exposure and vulnerability to climate change are the costs that future generations will have to pay for this. This results in a distributional effect that can hardly be considered fair from a generational point of view. The challenge for our generation is therefore to implement proactive adaptation measures to reduce the negative impacts on future generations.

There will also be significant global distributional effects. In all probability, developing countries and poor people will find that climate change enhances problems associated with health, food security, access to clean water and so forth. For many local communities, more frequent and intense cyclones and hurricanes, a rising sea level, floods, drought and changing precipitation patterns will make it impossible to survive. The first islands in the Pacific Ocean have already been abandoned as a result of erosion and salt water penetrating freshwater supplies.

The need for industrialised countries to support adaptation measures in developing countries is high up on the international agenda. During international climate change negotiations, Norway has already faced demands for more financial support. The committee believes that Norway should be prepared for the fact that support for adaptation in developing countries will become an increasingly important part of Norway's international obligations for the foreseeable future.

12.4 Economic costs and benefits

Estimates of the economic costs and benefits for individual sectors are referred to in Chapters 8, 9 and 10. The estimates reflect the inherent uncertainties in assessing vulnerability, but there is also an additional layer of uncertainty associated with assessing economic impact at the various levels of vulnerability.

The background material used by the committee is primarily based on available projections of average changes in precipitation, sea levels and temperatures, and the consequences of this such as storm surges, floods and landslides. However, the biggest costs of climate change will probably be due to other phenomena such as wind, extreme weather and natural disasters such as floods and landslides triggered by extreme weather events. Extreme weather events can potentially cause very serious and expensive damage, but we do not currently have the knowledge that allows us to predict their impact. It is therefore also impossible to calculate the economic costs of extreme weather events. The cost of rising sea levels, the impact of ocean acidification and the loss of terrestrial and aquatic ecosystems are other issues that are probably not fully included in all of the vulnerability assessments and economic analyses; see the research requirements identified in Section V.

The analysis of economic costs and benefits is therefore fundamentally incomplete: it is like a map where some sections have been drawn, while other parts have been left blank and incomplete. This gives a strong indication that the economic costs will rise over time.

Economic costs and benefits relate both to impact on material standards of living and non-material impact that affects people's quality of life. As discussed by the committee in Section III, many of us are deeply affected by non-material impact such as any loss of quality of life due to increased health problems, less security, damage to the natural environment and poorer conditions for traditional Norwegian outdoor activities. Some of the non-material impact can be mitigated, for example through medicine, landslide protection measures, snowmaking equipment and indoor sports facilities, while others, such as the traditional Sunday cross-country ski outing, are hard to replace.

The economic cost of non-material impact is hard to estimate for a variety of reasons. People have different values, desires and opportunities. Besides, climate change is slow enough for people to grow accustomed to new activities and values.

The committee still believes that the non-material cost of climate change may be significant. This is related to the fact that many people are expec-

Table 12.1 Economic consequences of climate change. Annual cost, Norway 2070–2100 (Vista Analyse 2010)

Impact category	Economic cost in NOK billions *
Cost for infrastructure (transport, energy, ECom, water and sewage, etc.) and buildings	(-0.5)–7
Impact on travel and tourism	(-30)-60
Impact on fishing and aquaculture	(-8)-80
Increased productivity in agriculture and forestry	(-10)–(-7)
Increased power generation	(-16)–(-5)
Health impact	(-15)–15
General	(-50)–70
Also: Non-material costs	Unknown, but significant

* Economic cost: positive numbers. Economic profit: negative number in brackets.

ted to have more leisure time in the future. This will increase the importance of leisure activities for people and increase their will to pay. If economic growth continues, it is also likely that rising income levels will mean that people are willing to pay the high price for a good climate for leisure activities and for protection against landslides.

The material consequences towards the end of the century are also uncertain, but the committee has made an attempt to quantify the ranges of economic costs. The size of the ranges illustrates the uncertainty surrounding calculations relating to climate change. This uncertainty, and how to handle it in planning, are discussed in greater detail in Chapter 16.

Based on the available analyses, the overall impact of climate change on material standards of living is moderate this century. The fact that the material losses are moderate also supports the general impression given by the review of the various areas of society in Section III, which is that Norway is a resilient society.

For the period from 2070 to 2100, the annual impact of climate change on infrastructure is estimated to be in the range between a net profit of NOK 0.5 billion and a net cost of NOK 7 billion (table 12.1).

The potential profit is due to the possibility of reduced household heating costs. See Chapter 9 for a more detailed discussion, assumptions and provisos. The cost of climate change for Norwegian businesses depends on the industry. The largest impact has been identified in the tourism and fishing and aquaculture industries. In the tourism industry, the overall economic impact may be positive or negative, depending on which factors are most prevalent. The range has been estimated as being between NOK 30 billion in additional profit and NOK 60 billion in additional costs. These figures must be viewed in the context of the expectation that the tourism industry will be significantly larger at the end of the century than now. For the fishing and aquaculture industries, the range is between NOK 8 billion in additional benefits and NOK 80 billion in additional costs. The latter figure is a discretionary estimate of the cost of any loss of fishing due to ocean acidification. This risk is low, but based on current knowledge, not so low that it can be discounted entirely. The economic impact in relation to health falls within the range between NOK 15 billion in profit and NOK 15 billion in costs. The main reasons for this range are different scenarios with lower mortality rates (during winter) and higher mortality rates (during summer). Currently, just above 20 per cent of the population suffers from pollen allergies, which incurs major costs for society. Even a slight increase in the length or intensity of the pollen season may result in a significant increase in these costs, although it is impossible to calculate the scope of this. It is also impossible to calculate the impact of any increase in tick-borne diseases and other infectious diseases, but according to Vista Analyse, they are less significant from a socio-economic point of view.

Section IV
The administration's work on adapting to climate change

Chapter 13
Local level adaptation to climate change

Box 13.1 Section IV The administration's work on adaptation to climate change

Climate change will reinforce current weather challenges and also pose new challenges. Work on adapting to these new framework conditions for social development is still at an early stage, both in research institutions and in the administration. We live in a country with "plenty of weather", and various tools have already been employed in social planning to handle climate-related issues. Section III shows that such tools and our experience in handling the current climate are useful as a basis for the adaptation.

In this section, the committee uses the instruments, or "toolbox", currently available for social planning as a basis. In the review of existing administrative functions, land-use planning and management, work on civil protection and building issues emerge as vital to adaptation to climate change. In order to achieve sustainable land-use management, good civil security and robust buildings in the future it is crucial to include climate change considerations in these processes.

Integration of climate change considerations largely concerns the knowledge base, expertise, capacity and resources. This is a shared challenge across sectors and administrative levels. Adaptation work also requires good cooperation between relevant parties, administrative levels and sectors. This requirement applies both internally within sectors, at the individual administrative level and between different sector administrations.

In this section, the committee discusses various aspects of the administration's work on adaptation to climate change. The committee's recommendations on these subjects are summarised in Section V.

The 430 municipalities in Norway comprise the local government level. The municipalities have a comprehensive responsibility as local authorities for social development, planning and provision of services within their respective geographical areas. They provide public welfare services, exercise authority pursuant to legislation, work to develop their local communities and play an important democratic role. If the tasks are to be carried out in a manner that ensures resilient local communities in the future, it is necessary to integrate climate change considerations in municipal areas of responsibility.

Climate change will affect most of the sectors and services the municipalities are responsible for. The operation and administration of the municipalities face numerous challenges in a changed climate. Exposure to the climate, the need for adaptation and adaptive capacity will vary between individual sectors and services. This has been addressed in the discussion on the various social areas in Section III. In this chapter, the committee reviews the municipalities' collective adaptive capacity on the basis of their role as local authorities.

Studies indicate that adaptation work is under way in several Norwegian municipalities. According to the Directorate for Civil Protection and Emergency Planning's (DSB's) survey of municipalities in 2010, nine out of ten municipalities state that they take adaptation to climate change into consideration in various planning or governing documents (DSB 2010). However, these considerations vary greatly between municipalities (DSB 2007). Amundsen et al. (2010) describe adaptation to climate change in Norwegian municipalities as reactive, in that adaptation measures are mainly implemented as a response to incidents such as floods, landslides and avalanches. Climate change increases the need to adapt before the effects of the change occur in order to limit the negative consequences of climate change. This is called proactive adaptation (IPCC 2007).

The municipalities are the planning and building authorities and are responsible for civil protection at the local level. These roles place the municipalities at the forefront of proactive adaptation to the consequences of climate change.

13.1 The toolbox for adaptation to climate change

Section III describes how the consequences of climate change, such as rising sea levels, increased risks of slides and floods, greater negative impacts on the natural environment and more problems with stormwater in developed areas, will pose challenges to society as a whole. In social and land-use planning in the municipalities, different sectors are viewed in conjunction. Climate change affects almost all areas of society, and this makes land-use planning the most suitable arena to integrate adaptation to climate change in social planning.

Land-use planning is the most important tool the municipalities possess to ensure long-term, robust and sustainable development and management of land and the natural environment in the municipality. Through land-use planning the municipalities can direct new development and infrastructure towards areas that are less vulnerable to climate change. Aall et al. (2010) point out that climate-adapted land-use planning can prevent infrastructural vulnerability. While land-use planning will identify risks in the event of new or changed use of land, the municipality's work on civil protection will also identify risks in existing land-use. Through its role as the building authority, the municipality can directly influence individual building projects through its ability to impose requirements on the location, design and size of buildings.

The combination of land-use planning, civil protection and the authority to decide on building permit matters provides municipalities with a good foundation for meeting their responsibility for local adaptation.

In the management of land-use, civil protection and building applications, various tools are used for planning, such as various topographical and thematic maps. In the future, there will be a need to integrate climate change considerations into these tools. The need to develop the mapping tools is discussed in more detail in Chapter 16.3.

13.1.1 Land-use planning

The Planning and Building Act instructs the municipalities to draw up a planning strategy every four years. The purpose of the strategy is to identify and prioritise the planning tasks that the municipality should initiate or continue in the municipal council term. The planning strategy provides the political framework for planning and general guidelines for the municipal master plan, for example when and to which degree it must be revised. The planning strategy must adopt guidelines for future land-use and illustrate the connection between this use and future social development.

The municipal master plan consists of a social aspect and a land-use aspect and is the most important governing document for development and land-use management in the municipalities. The social aspect must incorporate long-term social development, and the land-use aspect must ensure sustainable management of land and the natural environment. In the opinion of the committee, a long-term perspective is possible according to the Planning and Building Act and the municipal comprehensive plan as a governing document for local planning. The normal perspective of municipal comprehensive plans is 10 to 12 years. Climate change reinforces the need to increase the time perspective in municipal planning, which is discussed in more detail in Chapter 16.2.

The need for a long-term perspective will be a basic assumption for climate-adapted land-use planning. Many of the measures whose design and location are determined by land-use planning will have a long lifespan. When planning, there is a need to take into consideration that the environment around buildings and infrastructure may change as a result of climate change. In the recommendation to the Storting relating to the Planning and Building Act, Odelsting Proposition No. 32 (2007–2008) the need for a long-term perspective was emphasised as a basic assumption for the act.

The Planning and Building Act requires the municipalities to take into consideration a general goal of sustainable development in land-use planning. Land-use planning must also safeguard outdoor recreation as well as landscape values and biodiversity. By establishing buffer zones, the land-use aspect of the municipal master plan may restrict the use of areas. These zones may be areas that are prone to floods, landslides and avalanches or other natural hazards, or areas where different considerations must be taken into acco-

unt, for example outdoor recreation activities, agricultural areas, landscape or the need to protect the natural or cultural environment. The Planning and Building Act also stipulates risk and vulnerability analyses to be carried out when planning new development areas.

The land-use plan is legally binding for land-use. A zoning plan is a detailed and specific plan for the use of a limited area. Municipal plans and zoning plans both influence the actions of a number of parties and thereby provide an opportunity to stimulate adaptation to climate change and reduce vulnerability to climate change. The involvement of businesses and residents in the planning processes helps ensure that the plans are based on local requirements and local knowledge. This is important for adaptation to climate change because vulnerability to climate change varies geographically. See the more detailed discussion in Section III, Chapter 11, "Society" and Chapter 12, "Summary".

The national government and the county authorities are obliged to provide input and the necessary assistance to the municipalities in planning work. This gives them the opportunity to provide guidelines, knowledge and information to the municipalities. Adaptation to climate change is a new discipline in both research and administration. In relation to adaptation, the exchange of knowledge and experience on climate change and adaptation will be decisive. The land-use planning process is an arena for the communication of requirements and governmental guidelines, and also an arena for the communication and exchange of advice, guidance and knowledge between the administrative levels.

13.1.2 Civil protection

There are several statutes that stipulate requirements for the municipalities' work on civil protection, such as the Civil Protection Act and the Act on Health and Social Preparedness. In statutory and regulatory requirements in the area of civil protection, there is a general requirement for the municipalities to use risk and vulnerability analyses. These assessments are intended to identify risks, assess the probability of incidents occurring and the possible consequences of these, and thereby form the basis for preventive measures and planning of emergency measures. Climate change will alter the risk scenario and must therefore constitute a basic element in risk and vulnerability analyses.

The risk and vulnerability analyses that are currently carried out in land-use planning primarily focus on risks and unfortunate consequences in connection with new building projects. In methodological terms, risk and vulnerability analyses have been based on knowledge of historical events and have therefore not taken into consideration that the natural conditions may change. Climate changes will therefore contribute to strengthening the need to assess risk and vulnerability in existing developed areas.

In accordance with the new Civil Protection Act, which will come into force on 1 January 2011, the municipalities must perform a cross-sector risk and vulnerability analysis. The analysis must make relations between the various sector assessments apparent and help ensure a more comprehensive perspective in civil protection. The analysis will therefore be a tool to identify risk and vulnerability in an existing settlement. The requirement also provides the opportunity to strengthen coordination at the local level.

Based on the risk and vulnerability analysis, the municipality must prepare targets and strategies for work on civil protection and prepare proposals for measures that can reduce risk and vulnerability. Pursuant to the Planning and Building Act, the intention of the social aspect of the municipal master plan is to consider long-term challenges, targets and strategies for the municipality as a whole and as an organisation. It also provides the basis for general priorities in the land-use aspect.

The requirement for comprehensive risk and vulnerability analyses in the Civil Protection Act, points out that these analyses must be used in municipal planning work pursuant to the Planning and Building Act (Section 14.2 of the Civil Protection Act). It is the opinion of the committee that this represents a possible venue for adaptations. In order to achieve such integration, there is a need for close cooperation between municipal bodies.

Even when climate change considerations are included in planning work, more frequent emergency situations must be expected in the future. The municipalities play a key role in handling such challenges. For example, a power supply and telecommunications services failure could cause great problems for healthcare services. Retirement and nursing homes with electricity-based heating could become cold in the event of extended power failures, and safety alarms would stop

functioning in the event of telecommunications failures. An important part of the municipalities' adaptation work will therefore be related to ensuring they are able to respond to any incidents that occur.

13.1.3 Building application authorities

As the planning, approval and supervisory authority for applications pursuant to the Planning and Building Act, the municipalities have considerable responsibility in contributing to ensure that the buildings in the municipality have a high standard and protect users from harm and inconvenience.

The building aspect of the Planning and Building Act entered into force on 1 July 2010. Among other things, it entailed a strengthening of the requirements regarding the municipalities' supervisory duties in building matters. The municipality is obligated to check that measures are implemented in compliance with permits and applicable statutes and regulations. Through their inspection activities, the municipalities have the opportunity to discover and pursue breaches of regulations that may subsequently lead to damage. The municipality may choose to audit all applications, and, in compliance with the building application regulations, prepare a strategy for the control work.

In its review of the effects of the previous Planning and Building Act, the building legislation committee pointed out that municipal application advisers no longer reviewed the technical aspects of the applications, and that the former construction site inspection also had been discontinued in some municipalities (NOU 2005:12, Harvold et al. 2010). This changed as the new Act entered into force in 2010. Too little time has passed since the changes in the processing of building applications came into force to allow a qualified opinion on the effects of these. The committee nevertheless believes that the new Act and associated regulations provide the municipalities with the opportunity to process building applications in accordance with adaptation to climate change. However, here as well there is the question of whether the municipalities have the ability to strengthen their own resources in order to handle these additional tasks. Section 25, third paragraph of the Planning and Building Act emphasises the importance of planning and constructing buildings so that local climatic considerations are maintained. The technical building regulations include comprehensive requirements concerning the design and location of buildings, including requirements concerning protection from natural events such as floods, storm surges and landslides.

13.2 Barriers for adapting to climate change in the municipalities

Land-use planning, civil protection and building application processing in the municipalities constitute a good basis for adapting to climate change. A number of municipalities are already working on adapting to climate change.

Based on Amundsen et al. (2010), Aaheim et al. (2009) and Harvold et al. (2010), the committee wishes to highlight five requirements that should to be in place for a municipality to fulfil its responsibility for adapting to climate change in planning:

1. a solid and accessible knowledge base
2. expertise and capacity for adaptation work
3. national support and clear guidelines
4. priorities and resources
5. cooperation across sectors and administrative levels

In the following, the committee takes a closer look at the terms, opportunities and challenges related to the current state of adapting to climate change in the municipalities.

13.2.1 Knowledge basis for adapting to climate change

Municipal planning is currently based on a comprehensive foundation: maps and other coordinate-determined information, statistics, geological and hydrological surveys, local knowledge, statutes, regulations, guidelines, instructions as well as own risk and vulnerability analyses. It is the committee's opinion that some aspects of this are not adequate as a basis in planning for a changed climate. Large sections of land are not surveyed for flood and landslide risk or rising sea levels. Maps, for example, are not detailed enough for municipal planning in many cases. The maps are based on the current situation because methods to include the effects of climate change have not been made. Consideration towards climate change will pose new and changed requirements towards the precision and thematic content of maps. The need for map data is discussed in more detail in Chapter 16.3.

Climate projections must be made relevant in order for them to be used in municipal planning. There is therefore a need for climate projections

that are downscaled to the local level (Hovelsrud et al. 2010).

The Office of the Auditor General's review of the authorities' work on prevention of floods, landslides and avalanches indicates that the municipalities vary in their use of available tools and resources in this work (Document 3:4 2009–2010). Amundsen et al. (2010) also point to inadequate experience with the use of existing climate data, lack of specific data and expertise as possible barriers for adapting to climate change in the municipalities.

13.2.2 Expertise and capacity

The municipalities have extensive knowledge of local conditions such as population and industry structure, landscape and topography and weather conditions. These conditions affect vulnerability to climate change. However, many municipalities lack the adequate expertise or capacity to handle all of the problems related to climate change (Aaheim et al. 2009, Harvold et al. 2010).

According to a survey of four municipalities and two counties in the Oslo fjord region (Westskog and Vevatne ed. 2007), the lack of knowledge and expertise regarding climate change and the ability or opportunity to link experiences gained from past events to future challenges in terms of adaptation, are the two most important barriers to good adaptation work at the local and regional level. In the survey, the municipalities expressed a need for more knowledge on climate change, possible local effects and relevant adaptation strategies. Several of the municipalities recognise a need for updating the available information, e.g. flood zone maps, or mapping of slide-prone areas in order to take a changed climate into consideration.

Amundsen et al. (2010) identify a significant variation in the municipalities' use of available climate information, for example online landslide and avalanche information, flood zone maps and the online resource seNorge.no. This is in line with the Office of the Auditor General's study of the authorities' efforts to limit flood and slide hazards (Office of the Auditor General 3:4 2009–2010). Other reports also indicate that many municipalities find it technically difficult to assess local vulnerability to climate change, as they do not know where to find information or how to downscale the data (Hovelsrud et al. 2010).

The lack of expertise and capacity related to adaptation to climate change is a general challenge in the municipalities. At the same time there are significant differences among the municipalities (Harvold et al. 2010). While large municipalities have extensive technical departments with broad expertise, small municipalities naturally have a more limited range and are more dependent on external expertise. Size also affects capacity.

Several municipalities participate in various collaborative programmes such as *Cities of the future*, *Sustainable municipalities* and *Green energy municipalities*. These are loosely organised cooperation venues between municipalities that do not alter the municipalities' responsibility for their own development. Reports show that the municipalities benefit in terms of knowledge by participating in regional, national and international networks (Saglie 2009). In *Cities of the future*, some of the municipalities have most of their experience from climate work as advisers, so-called "climate coaches". Experience from the UK, has shown that such schemes can be effective in promoting adaptation work in municipalities.

On their own, many municipalities will lack the capacity and expertise to handle new and challenging tasks related to adaptation to climate change. It is the opinion of the committee that inter-municipal cooperation will therefore be a solution in order for the municipalities to take on technically challenging adaptation tasks they are required to carry out. An objection towards inter-municipal schemes is that they result in a more indirect form of government and may thus contribute to weaken local governments.

13.2.3 National governance

Amundsen et al. (2010) point to a lack of national policy as a barrier for local adaptation and call for a framework for management between the administration levels. They conclude that the main barrier for adaptation to climate change in the municipalities is the relation between local and national government and make reference to a report by Hovik and Reitan (2004), which points out that the adaptation area lacks institutional support and clear objectives from the government.

Inadequate access to expertise, basis for decisions and governance signals stand out as barriers for adaptation to climate change. Explicit governmental responsibility is positive for the development of the planning basis and guidelines. As demonstrated in Section III, the fact that the responsibility for handling stormwater runoff and sea levels rise is not placed with a national autho-

Box 13.2 Cities of the future

Cities of the future is a collaborative effort between the government and Norway's 13 largest cities to reduce greenhouse gas emissions and make the cities better places to live. The programme is coordinated by the Ministry of the Environment and has four focus areas: 1) land-use and transport, 2) stationary energy consumption in buildings, 3) consumption patterns and waste, and 4) adaptation to climate change. The participating cities have prepared action plans for how they will reduce greenhouse gas emissions, create good urban environments and develop strategies to face future climate change. Within the adaptation to climate change focus area, both physical measures such as slide protection, water and sewage network measures and more general measures, such as updating risk and vulnerability analyses and the integration of adaptation to climate change in social and land-use planning are mentioned. In order to ensure optimum adaptation, the cities report a need for more knowledge on how climate change will affect their municipalities. The cities call for good tools to get started, while at the same time there is a need for specific examples of adaptation. Some cities have done a lot of work and examples of best practice have already been presented at *www.klimatilpasning.no*.

rity is a barrier for adaptation. The establishment of the role of a governmental slide/avalanche body with the Norwegian Water Resources and Energy Directorate (NVE) has correspondingly contributed to removing a barrier within an important area of adaptation (Harvold et al. 2010).

In the report on sustainable land-use planning and land-use in Norway, the Office of the Auditor General (3:11 2006–2007) identifies a number of deficiencies in the management of national interests in land-use policy. It is apparent from the report that land development in several areas is not in accordance with the target of sustainable development, and that land-use planning is not sufficiently used as an instrument to achieve these targets. According to the report, land-use management is currently contributing to a reduction of areas that should be protected: the coastal zone, farmed and cultivatable land, the watercourse belt, mountain areas and large contiguous natural environments. This has consequences for important assets such as outdoor activities, cultural heritage and the cultural environment, productive land resources and biodiversity. The analyses also indicate that some parts of the land development do not sufficiently contribute to environmentally-friendly land use in cities and developed areas. It is the opinion of the committee that such conditions will also contribute to reduce adaptive capacity.

The Office of the Auditor General relates these conditions to inadequate and unclear guidelines, follow-up and instruction from national authorities. In its report, the Office of the Auditor General stresses that a strong governmental effort is necessary to ensure that municipal and regional planning contributes to long-term, sustainable land-use planning and land-use.

It is the opinion of the committee that there is a clear division of responsibility within land-use planning in the Norwegian administration, with distinct boundaries between different levels of administration. The Planning and Building Act clearly places responsibility with the municipality as the authority for land-use planning. The main question is how this responsibility is handled (Harvold et al. 2010). Land-use planning is an arena with potential for conflict between different interests. The diversity and complexity of considerations to be taken into account in planning may lead to an unclear overall picture; however this is a reflection of the complexity of society and not due to unclear divisions of responsibility.

Norway's municipalities face a number of legal requirements that must be prioritised during planning and operation. A consequence of this is that tasks that are not mandatory are given lower priority. It is the opinion of the committee that the current legislation is not strong enough to secure the required long-term focus on adaptation to climate change in the municipalities. This is discussed in more detail in Section V.

13.2.4 Priorities and resources

Adaptation to climate change is a cross-sector and long-term consideration that must be integrated into the municipalities' existing tasks. At the same time, adaptation to climate change is added to a set of competing considerations in the municipalities' work. Adaptation work requires resources, funds and personnel, and the committee believes it can be challenging to achieve adequate focus on

adaptation work in competition with other worthy purposes.

The Norwegian Association of Local and Regional Authorities (KS) has claimed that weakened municipal economies currently represent one of the barriers to local adaptation to climate change. In a letter to the committee, KS writes that the government "… is responsible for providing the necessary basis for decision-making and the means for the municipalities' implementation of adaptation to climate change measures". According to a survey conducted by the Norwegian Institute for Urban and Regional Research (NIBR) and the Centre for International Climate and Environmental Research-Oslo (CICERO) in the spring of 2007, 98 per cent of mayors in the country believe that the national government should have the main financial responsibility for adaptation to climate change (Berglund and Nergaard 2008).

Other studies identify other issues as more important than municipal finances. According to Westskog and Vevatne (2007), lack of capacity, knowledge and expertise regarding climate change pose a greater obstacle than lack of funds and other resources in adaptation work. At the same time, the report emphasises that there are limited resources in the municipalities, both to acquire the necessary climate expertise and for planning and implementing adaptation measures. Studies of municipalities in Sweden and Canada show that financial and human capacity is a greater barrier for adaptation than knowledge and expertise (Keskitalo 2010; Matthews and Sydneysmith 2010).

It is the opinion of the committee that the development of capacity and expertise for adaptation depends on economic resources. The provision of resources for this work depends to a large degree on priorities, regardless of the size of the budget. In Norway, a general block grant is provided for allocation by the municipalities. It is up to the local politicians to allocate the municipality's total income. Local politicians are familiar with the local conditions and local requirements and must make priorities that provide the best possible local welfare. This strengthens local democracy and also promotes efficient use of resources.

Block grants to municipalities may pose challenges in terms of securing resources for building capacity and expertise in adaptation work. Adaptation to climate change is a long-term consideration that cross-cut conventional sectors. In municipal budgets, areas with short-term, local and more urgent user requirements, such as care for the elderly and schools, tend to be prioritised. Many of these are also legal requirements. This is also reflected in the municipalities' processing of planning and building applications. There are clear statutory deadlines for the processing of planning and building applications, and the inhabitants also want quick processing of applications. Resources and expertise for long-term tasks and tasks without specific recipients or users may thus lose out and disintegrate over time.

The opportunity to change this situation lies with national government grant schemes that ensure adaptation work does not have to compete with urgent needs for municipal services. Earmarked grants are one such form of financing. There are mixed experiences with the use of earmarked funds. Previous initiatives for local environmental work are examples of this. As a stage in the reform *Environmental protection in the municipalities* (MIK) in the early 1990s (see box 7.3), earmarked grants were provided to all municipalities that employed their own environmental consultant; see the more detailed discussion in Chapter 7, "The natural environment". When the earmarked grant scheme was discontinued, the number of environmental positions in the municipalities dropped fairly rapidly. Harvold et al. (2010) describe earmarked financial support for specific tasks as a double-edged sword: in the short term, it may lead to a flourish of activity in a specific area, but the work stops when the scheme is discontinued. Earmarked schemes may also be skewed, such as ENOVA's support to municipalities that prepare climate and energy plans, which in practice has only benefited the municipalities with the largest populations (Harvold et al. 2010).

The committee is nevertheless of the opinion that earmarked funds may be relevant as a method of financing some parts of the municipalities' work on adaptation to climate change. This applies to measures that are directed at strengthening planning capacity and expertise, so that adaptation to climate change is incorporated in land-use planning and land-use management. One example of such a measure could be support for mapping vulnerability and adaptive needs.

With respect to specific adaptation measures related to sectors where the municipality is the owner and has the operative responsibility, such as water and sewage, buildings and roads, the committee is of the opinion that earmarking is less suitable. The specific measures that are implemented to develop or maintain this infrastructure must take the climate into consideration both now and in the future. In decision processes related to such measures, a number of considera-

tions will have to be included in the decision basis. Separating adaptation to climate change as a separate cost in such matters would be difficult. Here, costs for adaptation must be an integrated part of the overall costs in the sector for operation, development and maintenance.

For water and sewage, earmarked revenue for the municipalities, in the form of fees for services that are financed at cost, are suitable for financing. Within water and sewage and waste disposal, the municipalities have a statutory right, and in part obligation, to charge for services the municipality provides. The revenue may not be used for other purposes than for financing the services. The costs of adapting to climate change for the water and sewage area may only partially be included in the charge basis under the current regulations.

Earmarked funds and general block grants may beneficially be combined with various statutory requirements with accompanying reporting and audits. This is discussed in more detail in Section V. Block grants may also be combined with statutory requirements concerning the percentage of a position devoted to work on adaptation to climate change in the municipalities. The committee is of the opinion that this is not a suitable solution for financing adaptation to climate change. Establishing requirements for position percentages is an efficient, but inflexible form of regulation. This is currently employed for fire preparedness, where the municipalities must employ a minimum position percentage according to the population of the municipality. The Directorate for Civil Protection and Emergency Planning is the supervisory authority for this statutory requirement.

There are other solutions for funding costs for adaptation to climate change, such as an incentive-based system where municipalities are awarded allocations depending on results. The UK has used an indicator-based reporting system for the local authorities for some time. In total, it comprises 198 different indicators, so-called "National Indicators" (NI). In April 2008, a planning and adaptation for climate change indicator was introduced (NI 188). Two other climate indicators are linked to emission reductions. The local authorities can earn points, and thereby allocations, depending on what they have done in the various areas covered by the indicator. Such result-based financing schemes are not common for public financing in Norway, but may nevertheless provide an example of new financing schemes that could be considered in the future.

A different system for organising government support may be to establish a fund for financing adaptation to climate change. A certain sum may be awarded each year based on applications from stakeholders with adaptation responsibility. This kind of model may supplement one or more of the solutions mentioned above and would be particularly well-suited for the implementation of specific measures, such as flood or slide protection.

13.2.5 Cooperation between sectors and administrational levels

According to the report *Adaptations to climate change in the Oslo region* (Westskog and Vevatne, ed., 2007), there is inadequate cooperation between the national and local government within adaptation work. In this report, the municipalities called for clear management principles on the part of the national government, and several wanted greater governmental commitment, better coordination and improved guidelines. It was also emphasised that there is a need for better cooperation with central governmental institutions.

The work on preventing flood and landslide risk is one example of the need for cooperation between administrative levels. The Planning and Building Act gives the municipality the responsibility to protect and secure the population from flood and landslide risk (Office of the Auditor General 3:4 2009–2010). At the same time, they need governmental guidance and assistance in this work, and national government authorities have produced flood and landslide risk maps in several municipalities. Through the Norwegian Water Resources and Energy Directorate (NVE) and the county governors' work, the government checks that the flood and landslide risks have been evaluated in the municipalities' land-use planning. The report cannot determine whether municipalities change building activities in those areas which the mapping identifies as prone to landslides.

The Office of the Auditor General therefore considers that there is a "… *need for more governmental follow-up and assistance in raising expertise to the required level, particularly for smaller municipalities. The Office of the Auditor General questions whether the dissemination of information has been good enough*". Even though the responsibility of protecting the population lies with the municipality, cooperation with the national government is required in order for the municipalities to carry out the work in a satisfactory manner.

In the National vulnerability and preparedness report for 2008, the Directorate for Civil Protection and Emergency Planning concludes that "*…there is a need for coordination and more binding cooperation between the various stakeholders who have roles in civil protection and preparedness. This applies both between stakeholders at the same level, between different sector authorities at the national and regional levels, and between municipalities. Smaller municipalities rarely have the capacity for the required expertise or the necessary emergency capacity within their own organisation. Such challenges may be resolved through inter-municipal collaboration schemes, among other things. There is also a need for more coordination between various administrative levels, such as regional and local levels*". It is the opinion of the committee that DSB's description also applies to work on adaptation to climate change.

Adaptation to climate change demonstrates the municipalities' need for cooperation within the municipality, with other parties and with national and regional authorities.

Chapter 14
Adapting to climate change at the regional level

At the regional level, the county governor and county authority have a number of tasks and roles that are relevant for adaptation to climate change. The county governor is responsible for communicating and following up national guidelines for land-use planning and for coordinating work on civil protection and preparedness regionally and vis-à-vis the municipalities. The county governor also has specific tasks in the area of adaptation to climate change related to oversight, guidance and supervision of municipal adaptation work (Directorate for Civil Protection and Emergency Planning 2008). The county authority is the regional planning authority. The county governor and county authority both have wide-ranging roles which partially overlap. It is the opinion of the committee that cooperation between the county governor and county authority is important for good adaptation to climate change in both local and regional terms.

14.1 The county authority

The county authority has a general responsibility for regional planning. Planning must contribute to achieving political objectives for economic, social and cultural development in the county and to ensuring that the municipalities receive guidance and assistance in their planning tasks. The county council must approve a regional planning strategy at least every four years, which, among other things, must report important regional development trends and challenges. The strategy must be followed up by municipal and national government planning authorities. In accordance with new provisions in the Planning and Building Act, the county authority can also prepare regional plans and legally binding planning regulations for special topics and geographical areas. This replaces the system of county plans and regional county plans. There is currently little experience regarding the effects of the changes.

The county authoritys may initiate and develop inter-municipal planning cooperation. In the planned guidelines to the municipalities, the county authorities must provide input on regional interests in the planning area and provide guidance on processes and requirements regarding planning documents. The county authority have been given the responsibility of organising a planning forum. In the planning forum, national, regional and local interests must be clarified and coordinated in connection with the work on regional and municipal planning matters. National and regional bodies and relevant municipalities must participate. Other stakeholder representatives that could be affected may be invited to participate in the planning forum. The forum discusses municipal master plans and zoning plans. It is the committee's view that planning forums may be suitable as a venue for the integration of considerations concerning adapting to climate change and as guidance and motivation for the municipalities.

The county authorities have, in accordance with the Planning and Building Act, the authority to block municipal plans, but use this authority to a lesser degree than the county governor and other regional government bodies.

In addition to the role as a regional planning authority, the county authorities received certain tasks in the environmental area from the county governor in 2010, including regional water authority and the management of harvestable, non-endangered game species and freshwater fish. The county authorities is also responsible for the management of regional cultural heritage matters, has decision-making authority in several matters that concern cultural heritage and monitors listed cultural heritage assets. The county authority serves as a consultant for the municipalities in the area of cultural heritage. Cultural buildings are particularly vulnerable to climate change, as mentioned in Chapter 9.6, which means that the county authorities must integrate climate change

considerations in their cultural heritage work, and act as a link in this area between the Directorate for Cultural Heritage and the municipalities. The county authorities also play an important role through their responsibility for upper secondary education, including vocational and technical education. The committee has previously pointed out that adaptation to climate change should be included in the curriculum in vocational and technical education (see the more detailed discussion in Chapter 9.6). Responsibility for ensuring that the curriculum also includes adaptation to climate change will be a task for the central government authorities, but the county authorities have an important role in pursuing this as a part of their responsibility for upper secondary education.

The committee is of the opinion that local and regional awareness of the opportunities that climate change may provide is crucial. The county authority responsibility for regional development enables it to play an active role in adaptation and increased economic growth. The county authority should therefore be responsible for promoting positive exploitation of the consequences of climate change for industrial development and strengthening the competitive advantages of the regions.

14.2 The county governor

The county governor shall ensure that national policies are implemented locally and is responsible for coordinating national government policy signals vis-à-vis the municipalities. The county governor is also responsible for providing advice and guidance for the municipalities' work on following up the government guidelines. The county governor has the authority and tasks on behalf of twelve ministries and a number of directorates, as well as being the appeal and supervisory authority. Furthermore, the county governor must coordinate work on civil protection in the county and stimulate work on municipal civil protection and preparedness.

The ministries and directorates communicate their assignments to the county governor in the form of official assignments. In recent years, adaptation to climate change has been included in these. The official assignments state that climate change is one of the considerations that should form the basis of the county governor's work on county-based risk and vulnerability analyses. It is presumed that other stakeholders will be involved in this work in order to arrive at a common risk scenario. The committee is of the opinion that such an analysis will be an important and necessary source of information on what impacts climate change will have on important social areas in each county. Collectively, these analyses could also be used to prepare a national risk scenario where climate change is a part of the overall evaluation of risks faced by Norway.

The county governor must also ensure that climate change is included in the municipal risk and vulnerability analyses and is followed up in municipal plans. The official assignment instructs the county governor to provide guidance to the municipalities and asks the county governor to address climate challenges in the dialogue with the municipalities. As adaptation to climate change has only recently been included in the official assignment, the committee has no knowledge of the parties' experience with this. The committee would nevertheless like to point out that this is a step towards including adaptation in the governance loop from the national to the local level.

Pursuant to the Planning and Building Act, the county governor must ensure that the municipalities comply with statutory requirements for planning, and that issues of national or significant regional importance are safeguarded. This applies to issues related to arable land protection, biodiversity and civil protection. The county governor must participate in planning processes from an early stage. The office must provide guidance, be a consultative and appeals body, issue rejections and act as arbitrator. In the autumn of 2010, the Directorate for Civil Protection and Emergency Planning (DSB) prepared revised guidelines for the county governor's use of rejections to ensure civil protection in land-use planning. These guidelines emphasise that the county governor must reject land-use plans in cases that will significantly reduce civil protection. Examples of this include the prevention of risk for fatalities, damage to health, critical infrastructure and socially important functions that are inadequately protected. It has also been pointed out that rejections can be issued if the risk and vulnerability analysis for the relevant area does not include a sufficient assessment of the consequences of climate change.

In the discussion of municipal adaptation work, the committee has pointed out the significance of clear guidelines for integrating climate change considerations in local planning processes. It is the opinion of the committee that the authority to reject plans provides a formal opportunity to introduce important adaptation considerations. Participation by the county governor early

on in the planning processes so that the municipalities receive support in the form of advice and guidance is equally important.

In addition to direct dialogue in individual cases, the county governor provides advice and guidance to the municipalities through professional networks, gatherings, meetings and seminars. The Agency for Public Management and eGovernment's (Difi's) report on the municipalities' experience with the county governor shows that the decidedly most frequent contact between the county governor and the municipalities is in planning matters pursuant to the Planning and Building Act. According to the municipalities, the second most frequent area of contact with the county governor is civil protection. The planning area also stands out as the area where the municipalities believe that they will face the greatest challenges in the future, and where the need for guidance by the county governor is the greatest (Difi 2010).

This is why dialogue in the planning forum is so important, as discussed above. The forum will help promote good, constructive dialogue between the national government, the county authorities and the primary municipality.

14.3 Expertise and capacity in the counties

The committee notes that several county governors and county authorities have already started working on adaptation.

Among the county authorities, Sør-Trøndelag for instance, has prioritised investigating the impacts of climate change in its regional planning strategy for the 2009–2012 period. Another example is the vulnerability analysis carried out by the Eastern Norwegian County Network, where the county authorities of Akershus and Buskerud counties participated. The examples demonstrate that adaptation to climate change is on the agenda in the county authorities. However, the committee lacks good documentation on how systematically the county authorities are working on adaptation to climate change. The Directorate for Civil Protection and Emergency Planning's (DSB's) study of adaptation to climate change in counties and municipalities from 2007 shows that adaptation work is generally only just starting in the county authorities (DSB 2007). The committee would nevertheless like to stress that work may have been carried out since 2007 that would change this impression.

In the annual official assignment for 2010 the county governor is asked to make adaptation a priority. Reports from the county governors' follow-up of the 2009 assignment show that adaptation has been followed up, but in different ways and to varying degrees. It is largely in the county governor's follow-up of municipal risk and vulnerability analyses in land-use planning that adaptation to climate change has been invoked. The reports also show that several county governors feel that they lack information regarding the municipalities' vulnerability to climate change, and that there is a need for more detailed charting and follow-up in this area. Adaptation efforts have also been followed up through participation in projects or investigations at the county level. For example, the County Governor of Buskerud, together with the county authority, participated in the climate vulnerability evaluation that was carried out by the Eastern Norwegian County Network. The committee also notes that certain county governors, such as the County Governor in Troms County, have chosen to find internal organisational solutions to support the interdisciplinary aspect of adaptation work. Skjeggedal and Harvold (2008) note that the county authorities have sound formal expertise in physical planning and social planning. At the same time, Harvold et al. (2010) note that there are significant challenges in terms of capacity in the county authorities. It is furthermore noted that increasing the capacity in the county authorities will help reinforce the work done as regards the municipalities' planning work, not least in municipalities with small populations. Here the authors are talking about a general strengthening, but the study points out that this should also include adaptation to climate change.

The offices of the county governor have good, broad experience in social planning and in land-use planning in particular. Harvold et al. (2010) point out that the county governor is an important partner and source of expertise for the municipalities in a number of areas. The investigation carried out by Difi relating to the county governor's cooperation with the municipalities indicates the same (Difi 2010). The county governor also has responsibilities and a portfolio related to health, agriculture and forestry, biodiversity, land-use planning and civil protection. This facilitates an interdisciplinary approach. Harvold et al. (2010) further emphasise that it is important that knowledge on climate change is integrated into these tasks. They also point out that there is a need to strengthen expertise to enable the county

governor to act as a consultant in the area of adaptation. A lack of knowledge and expertise regarding climate change has also been identified as a significant barrier to adaptation work at the county level in the investigation on climate vulnerability and adaptation referred to in Section 13.2.2 (Westskog and Vevatne, ed., 2007). The committee agrees with the assessments on expertise requirements, and the committee believes greater expertise is a precondition for the county governor to provide good guidance and coordination to the municipalities in the future.

The Directorate for Civil Protection and Emergency Planning's (DSB's) report *Adaptation to climate change in municipalities, county authorities and among county governors* (DSB 2007) confirms that county authorities and county governors themselves are of the opinion that a strengthening of expertise is required. In the report, all county governors and county authorities stated that they to varying degrees require greater knowledge within the area.

Harvold et al. (2010) also discuss the capacity and resources among regional authorities to provide guidance and supervise municipal planning. According to the report, a number of county governors state that the responsibility for adaptation to climate change is demanding, and that they do not have access to adequate financial resources or the expertise to carry out these types of assignments. Husabø's study (2010) of the county governor's work on climate and natural hazards discusses the county governors' administrative capacity. The report claims there has been a reduction in the number of positions in the civil protection area, while there has been an increase in new and demanding tasks.

Husabø's study indicates a connection between priorities and resource availability. Although the study focuses on the office of the county governor, the committee believes that much of the same applies to the county authorities. The committee also finds a similar connection in the municipalities' approach to adaptation to climate change.

The committee concludes that both the county authority and county governor have important roles to play in the work with adaptation to climate change and that there is a need to strengthen capacity in both the county authority and with the county governor.

14.4 The division of roles and responsibilities at the county level

Skjeggedal and Harvold's report (2008) on expertise within planning and local development in municipalities and counties identifies a need to clarify the division of work and cooperation at the county level in terms of planning pursuant to the Planning and Building Act. They claim that the activities of the county authorities and county governors are so interconnected that it is unclear as to who actually has the responsibility for what. The committee is of the opinion that, based on the municipalities' need for clear governmental requirements as regards adaptation, there is a need to clarify the division of roles and responsibilities, also in the area of adaptation.

The committee believes that in the work vis-à-vis the municipalities, the county governor should be specially tasked with following up the municipalities through advice, guidance, control and objections. This is related to the need for clear policy signals from the national government to the municipality on adaptation work, which is discussed in more detail in Chapter 13 relating to municipalities. The county governor's role is entrenched in the governance loop between the national government, counties and municipalities, and is, by virtue of its role as an approval/ rejection authority, in a position to contribute clear guidelines for adaptation work at the municipal level. The county governor currently has such a role through the official assignment, but the committee sees a need to strengthen this. Furthermore, the county governor needs more resources to be able to take on such a role. The committee would nevertheless like to emphasise that climate change does not affect the relationship between local autonomy and state control of land-use management, but that clear signals from the national government, distinctly defining national interests in land-use policy, will promote efficiency in the public sector.

Even though the county governor should be given a more distinct role within adaptation work, good interaction between the county governor and county authority will be important in order to carry out good adaptation work. The committee believes that the planning forum mentioned above, will be an important arena for finding common solutions and for adapting to climate change.

14.5 Cooperation and coordination across counties

Both county governors and county authorities participate in cooperation and coordination efforts across county borders through informal and formal networks, committees and meetings. The county governors have regular meetings with the specialist ministries and directorates where experience and knowledge are discussed and exchanged. In addition, there are different forms of contact between the offices at the management and technical levels where there is cooperation on training, exchange of experience and discussion of practice. The county governors meet regularly, as do the county executives. These meetings are utilised to exchange knowledge, experiences, opinions, etc. There are also various specialised networks and cooperation schemes between the counties.

The county authorities have established regional cooperation venues, such as the Regional Council for Western Norway and the Eastern Norwegian County Network. The purpose is to cooperate on tasks such as regional development, training and skill development, and international cooperation. Adaptation to climate change is an area of cooperation in the Eastern Norwegian County Network, and has, among other things, resulted in a case study on climate vulnerability and adaptation in four municipalities and two counties in the Eastern Norwegian County Network. This study is discussed above.

The committee believes that regional cooperative forums and networks are good venues for developing expertise and sharing experiences across county borders and that they should be integrated into the current regional cooperation.

Chapter 15
Adaptation to climate change at the national level

In order for climate change considerations to be prioritised, they must be rooted in policy. Adaptation considerations must be integrated into relevant governance instruments that are largely developed at the national level, such as legislation, regulations and guidelines.

The Ministry of the Environment has the general responsibility for the national climate policy, including adaptation to climate change. The Ministry also has the role as directorate for municipal and regional planning and the general responsibility for the environmental governance dialogue with the county governors.

Within the various sectors, the sector authorities draw up policy and actions for adaptation to climate change within their respective areas of responsibility. As discussed in Section III, there are great differences in how far the various sectors have progressed in identifying challenges and planning strategies to meet their own adaptation to climate change needs. In Storting Proposition No. 1 (2009–2010), all ministries are requested to provide an account of the consequences of climate change and adaptive needs within their areas of responsibility. The committee has noted that the sectors have responded to this. The Ministry of Agriculture and Food, for instance, presented a Storting White Paper on climate policy for the sector in 2009, which discussed adaptation.

15.1 Cooperation across sectors and social fields

Cooperation across policy areas is a precondition for adaptation to climate change. Mutual dependencies between the sectors may obstruct one sector in its adaptation efforts due to issues that another sector is responsible for.

The coordination work for adaptation to climate change was initiated in 2007 through the establishment of an inter-ministerial coordination group for adaptation with representatives from 13 ministries. The ministerial group is a forum for the exchange of information among ministries. The committee believes that the establishment of the group was a necessary step and that this function should be continued.

In the spring of 2008, the government presented the document, *The government's work on adaptation to climate change*, outlining the first steps in the national adaptation work. The document focuses on joint challenges and establishes the main lines for adaptation work in the period 2009–2012. The document paves the way for work on information, enhancing expertise and strengthening the knowledge base. The sectors' responsibility for initiating adaptation work in their own sectors is emphasised in this document. The committee notes that all three target areas have been followed up, for instance through the establishment of the online portal Klimatilpasning.no, courses in climate change adaptation for planners and the appointment of the committee for this report. The sectors' work on adaptation to climate change has also been followed up in Storting Proposition No. 1 and implemented in several areas, as mentioned in the introduction.

As a part of the follow-up of the Planning and Building Act, the government will, by 1 July 2011, present a document containing national requirements for municipal and regional planning. The committee believes that adaptation to climate change must be integrated in the work on the expectations document, yielding a potential to further strengthen cross-sector coordination.

15.2 The practical coordination work

In connection with the ministerial group, a secretariat was established to handle the practical coordination. The secretariat's tasks involve coordination, information and development of expertise as well as providing an overview of climate vulnerability and the work on adaptation to climate change in society. The secretariat must also promote the integration of climate considerations in social

planning. In September 2008, the coordinator for the sub-project on adaptation to climate change in the *Cities of the future* project joined the secretariat. As part of the information work, the adaptation portal Klimatilpasning.no has been established which gathers information on climate change and adaptation from a number of bodies and research institutions. The secretariat has also initiated and been involved in reports on adaptation to climate change in Norwegian counties and municipalities, and has established courses arranged by the National Emergency Planning College (NUSB).

The secretariat is headquartered in the offices of the Directorate for Civil Protection and Emergency Planning (DSB), which is organised under the Ministry of Justice, but its mandate and parts of its funding come from the Ministry of the Environment. The secretariat reports to both the Ministry of the Environment and the ministerial group.

The secretariat describes its role as primarily related to coordination and the development of information and expertise at municipal and regional levels. The secretariat's main target group is municipal and county level planners, and it emphasises that contact with these parties has had a positive effect on the progress of the work.

In a conversation with the secretariat, information and awareness raising were highlighted as the most key elements of the current adaptation work. This is in line with findings from other countries, particularly at an early stage. Although the scope of efforts and foundation differs, the focus on the local level and composition of tasks and roles has many similarities with adaptation work in the UK and other countries. In meetings the committee held with various administrative levels in the UK in January 2010, it emerged that information and awareness raising have been crucial for the process of integrating climate change considerations in social planning. This is also supported by research (Hovelsrud and Smith 2010).

The secretariat has also handled work directed at national stakeholders; for example, reporting to the ministerial group, cooperation on rising sea levels, where an informal working group has been established, and cooperation with the Norwegian Water Resources and Energy Administration (NVE) and others for providing material for the adaptation portal Klimatilpasning.no. The committee believes the secretariat nevertheless lacks the resources to fully handle the role of coordinator. The secretariat comprises 4.5 full time positions and must make difficult priorities. In the current resource situation, lower priority has been given to dialogue with the directorates that have governance dialogue with the county governors and surveys of the municipalities' adaptation efforts. Information work is prioritised through the work on Klimatilpasning.no. It is the opinion of the committee that inadequate resources are used for this. Adaptation to climate change is a new task, and the requirement for information is great at all levels of the administration and in society at large.

The Norwegian Climate Adaptation Programme secretariat is currently organised as a project. In the initial phase of adaptation work, this form of organisation has had several advantages. A project allows for quick decision-making and for defining roles and tasks as experience grows. The project organisation has also been a good approach in a new area that is not a sector, but rather a consideration that requires integration. However, the committee believes that such an organisation will have its limitations in the long term. In a project organisation, personnel resources can easily be redirected to more urgent areas, resulting in adaptation work being given lower priority. Adaptation to climate change is long-term work and requires solutions that are not limited by a mandate or funding. The committee believes a more permanent arrangement will highlight the long-term perspective of adaptation work. It will also provide a more distinct organisational line, which will make it easier to include adaptation considerations in the ordinary decision-making structure.

Planning expertise is a key skill in adaptation work. Although knowledge regarding the climate system and climate change is important, the coordinating secretariat role primarily requires knowledge about society and social and land-use planning. The secretariat is currently close to the planning communities in the Directorate for Civil Protection and Emergency Planning (DSB) and the Ministry of the Environment, and the committee considers this positive. There are also valuable links between the work on civil protection preparedness and adaptation to climate change, including risk and vulnerability analyses, as discussed in more detail in Chapter 13.

Establishing an expert environment is time-consuming and requires considerable resources. The current expertise in the climate adaptation secretariat is a valuable foundation for establishing a broader professional community.

15.3 Shared administrative tools for adaptation to the climate

Shared administrative tools, such as the Planning and Building Act and associated regulations and governmental guidelines for cost analyses, are vital in integrating adaptation considerations. If climate change is to be included as one of the considerations that are assessed for analysis and planning work in the administration, these tools must include guidelines for how this consideration is to be safeguarded. For instance, the committee has noted that in the government's report on adaptation in 2008, there is a provision for analysing climate change in connection with major public investments of more than NOK 500 million. However, the instruments for these analyses, such as the Norwegian Government Agency for Financial Management's guidelines for cost analyses related to major public investments, do not mention the impact of climate change.

The Directorate for Civil Protection and Emergency Planning (DSB) has prepared several guidelines for the municipalities' risk and vulnerability analysis work, including on civil protection in land-use planning (DSB 2010). Adaptation to climate change is integrated in the 2010 guidelines. The guidelines for cross-sector, general risk and vulnerability analyses dates from 1994 and discuss certain incidents that are relevant in a climate change perspective, for example landslides, avalanches, floods and forest fires, but climate change is not specifically mentioned. Harvold et al. (2010) claim that these guidelines are outdated and do not represent a useful instrument for the current challenges where climate change and possible adaptation measures must be included in the analysis.

The above examples show that adaptation is not integrated well enough in the guidelines developed by specialist bodies at the national level. Such integration requires specialist expertise on adaptation to climate change. This is also necessary in order for the sectors to provide guidance to players in the private sector (for example the construction industry) and to the administration in counties and municipalities. Such a focus will entail that resources must be channelled to the relevant bodies in order for them to be in a position to perform their tasks related to guidance and developing knowledge.

Section V
A policy for adapting to climate change

Chapter 16
Recommendations for a policy for adapting to climate change

Box 16.1 About Section V: A policy for adapting to climate change

Climate change will primarily intensify current climate challenges. With a few exceptions, the current challenges are handled by the authorities. The parties currently responsible for an area are generally best equipped to handle the consequences of the climate changing and to integrate adaptation considerations in the management of this area. The committee therefore believes that the responsibility for adaptation should be integrated in the current administrative structures. An integrated approach is at the core of the committee's recommendations.

The committee has noted an increasing awareness regarding climate change in all areas of society. A number of sector authorities have already started work on adaptation to climate change, but this is not sufficient.

Individuals and private and public enterprises will gradually and autonomously adapt to changes in the climatic conditions, but only up to a certain point, and not necessarily in a coordinated manner or at the same rate. Independent and parallel adaptation will in all likelihood not be sufficient due to limited information, uncertainty and a lack of coordination or incentives. Uncoordinated measures that reduce vulnerability for one activity or in one geographical area may increase vulnerability for other activities or areas and thereby society as a whole. For example, measures to protect infrastructure from floods in one area may lead to increased floods in another area or destruction of ecosystems. In addition, adaptation considerations will have to compete with other considerations, both cross-sector and sector-specific. As for many other areas of significance to society as a whole, a public policy which facilitates adaptation to climate change is therefore needed. The purpose of this public policy will be to support the individual sectors' work on adaptation, to reveal challenges that traverse sectors and to ensure the responsible parties have the necessary prerequisites to implement adaptation measures.

Successful adaptation may resolve a number of challenges and reduce society's vulnerability to climate change. Climate change will nevertheless also cause irreparable damage involving permanent loss of assets. This primarily applies to natural assets, but also cultural and other values in society will be lost as a result of climate change. These are areas with limited adaptation options and where reducing emissions emerges as the sole solution to impede developments.

Section V discusses how society can best handle the consequences of climate change. Based on the challenges highlighted in Section III and the current responsibilities and instruments for adaptation described in Section IV, the committee discusses the need for further development of the field, presents its recommendations for how adaptation efforts may be strengthened, and proposes the main elements of a policy for adapting to climate change in Norway.

Both the climate and society are in a constant state of flux. For this reason, society can never adapt fully, but must continuously adapt to new changes. At the same time, we have the opportunity to make choices that increase our resilience in the longer term.

Adaptation requires good planning. The planning system currently includes consideration of weather and natural events, but lacks satisfactory integration of climate change considerations. A better planning system that includes adaptation to climate change thus emerges as the most important measure society can implement in order to adapt to a changed climate.

Clear division of responsibility is a requirement for good planning. The committee finds that

mechanisms are already in place in the established administrative structures to cope with many climate-related challenges, for example slides (landslides, avalanches, etc.) and infrastructure failures. At the same time, certain areas of society lack satisfactory integration of climate change considerations. In addition, there are areas that no authorities are currently responsible for. This primarily applies to rising sea levels, which is a completely new area, and the handling of stormwater runoff. Responsibility for these areas needs to be assigned in the public administration.

Good planning requires good tools, sound knowledge and expertise, and the capacity to plan for a changed climate. In the case of climate change, historical weather data is no longer a sufficient basis for planning. Uncertainty is a recurring theme for all planning, but climate change magnifies this uncertainty. All planning work must take the increased uncertainty into account.

The current knowledge basis for planning for climate change is inadequate. The need for more, better and more easily accessible knowledge applies to nearly all sectors and areas of society that are discussed in Section III and levels of government discussed in Section IV. Knowledge must be strengthened through increased mapping, monitoring and research in order to support decision-making and planning.

Knowledge not only has to be established; it must also be put into use. Even though knowledge already exists in many cases, adaptation work depends on relevant expertise and adequate capacity at all administrational levels. Expertise and capacity for adaptation to climate change must be strengthened in government.

Some areas of society have an adaptation deficit. The deficit is primarily related to the maintenance backlog in infrastructure, which is already a major challenge. It also applies to follow-up of national environmental targets, which are often overshadowed by other considerations in government. This deficit should be covered in order to reduce climate vulnerability in Norway.

Climate change will affect society in nearly all areas. Coordinated national planning is therefore required to ensure that the various strategies all pull in the same direction and contribute towards reducing society's vulnerability to climate change. The committee therefore believes that the current coordination of the adaptation efforts should be strengthened.

Based on these challenges, the committee will in the following propose certain central components of a national strategy for adaptation to climate change.

16.1 The planning system must be strengthened

Social planning involves all sectors at a local and regional level, and the planning processes are a particularly suited venue for coordination of adaptation efforts. A strengthened planning system that takes adaptation to climate change into consideration is therefore the single most important measure society can implement in order to adapt to a changed climate.

The climate-related challenges in a number of areas – such as the natural environment, primary industries, infrastructure and buildings – vary according to the local conditions and involve the use of land. Climate change will place greater demands on sound land use and long-term land-use planning.

Climate change poses several challenges for land use, and land use is pivotal to the adaptive capacity of society. Increased occurrences of floods, landslides, avalanches and erosion along the coast and waterways will have consequences for settlement and infrastructure in the affected areas. This makes it even more important to emphasise considerations towards these risks in land-use planning and to clarify guidelines and responsibility.

Land-use planning is, in the opinion of the committee, an important instrument for adaptation to climate change. This is discussed in more detail in Section IV. The view of the committee is in line with Storting White Paper No. 26 (2006–2007) *The Government's environmental policy and the state of the country's environment*, which points out that land-use planning must help reduce the threat of climate change against life, health and material assets, important functions of society and infrastructure.

Current land use also includes the capacity for adaptation in a number of areas. For example, fragmentation of natural environments may increase vulnerability in these areas, while adapted land use may make them more resilient by preserving viable ecosystems. At the same time, communities may be made less vulnerable by ensuring that areas exposed to rising sea levels, landslides, avalanches and floods are not put into use.

The committee therefore sees a need for increased incorporation of climate change considera-

tions and adaptive needs in several areas in the planning system, primarily in land use and management of the natural resources, but also in civil protection.

Good and accessible planning tools are a prerequisite for good planning. A general strengthening of the planning system must be viewed in conjunction with the use of climate projections in developing map data, guidelines and requirements, as discussed in Chapters 16.3 and 16.4.

The committee believes the majority of the challenges climate change will pose to society, such as increased risk of landslides, avalanches, etc. and risk of critical infrastructure failure, will best be handled by the established administrative structures. In some areas the committee sees the need to assign responsibility more clearly than is currently the case. This particularly applies to rising sea levels and handling of stormwater runoff. An increased risk of stormwater runoff is a new challenge, and rising sea levels is a completely new phenomenon faced by society. At the local level, the municipalities must handle both these challenges, but the committee believes there is also a need for clear delegation of authority at the national level. This is discussed in more detail in Chapters 16.1.2 and 16.1.3.

16.1.1 Land use

As we have seen in Section III, adaptation considerations affect land use and planning in a variety of different ways.

Floods will become a greater challenge for cities and developed areas and will require measures that directly impact land use. Rising sea levels will require changes in planning and development along the coast. A heightened risk of landslides and avalanches requires even better analyses of where it is safe to locate infrastructure and buildings, and may reinforce the need for protective measures in existing areas. A change in optimum growth areas for aquaculture organisms along the coast will require new plans for land use and investigation of the environmental consequences, as discussed in more detail in Chapter 10.2, "Fisheries and aquaculture". Provisions in the Nature Diversity Act on preserving biodiversity and objectives related to arable land protection will simultaneously increase the pressure on land use and the opportunity to locate new structures in a climate-adapted manner. This is discussed in more detail in Chapter 7, "The natural environment" and Chapter 9, "Infrastructure and buildings".

As discussed in Chapter 7, "The natural environment," land-use changes constitute the greatest threat to biodiversity in Norway. Climate change will increase the pressure on habitats and ecosystems, particularly in alpine and Arctic areas. This makes it even more important to prevent fragmentation of habitats and to secure large contiguous habitats in order to improve the possibility of adaptation for threatened species and ecosystems. Land use must also be viewed in connection with the various chapters of the Nature Diversity Act on the management of species and areas and principles for sustainable use. These provisions facilitate a future-oriented and coherent management of species on land, in lakes, rivers, and at sea, and will be important for adaptation to climate change. As part of an adaptation strategy, it is therefore important to view land use and nature management together.

It is important to include the time perspective when assessing how the climate affects land use. Investment costs for buildings and infrastructure are high, and the opportunity to make structural or land-use changes later on will often be limited and costly. Early assessments of climatic conditions must therefore be integrated in planning and decision-making processes. This is discussed in more detail in Chapter 9, "Infrastructure and buildings".

The Planning and Building Act

The Planning and Building Act includes a broad range of instruments, making it an important "toolbox" for the municipalities' adaptation efforts. Including this work in municipal land-use planning enables adaptation to be planned on the basis of local knowledge of risk and a local interpretation of uncertainty. It also entails that the national authorities' ambitions in terms of adaptation measures are dependent on municipal implementation. This is discussed in more detail in Section IV.

The exercise of authority pursuant to the Planning and Building Act is based on interpretation. This is both a strength and a potential weakness of the Act. On one hand, it provides the required flexibility to take various considerations and to make locally-based comprehensive decisions. On the other hand, freedom of interpretation makes adaptation considerations dependent on the planning authorities' ability and willingness to follow this up. The municipalities are responsible for ensuring safe development, but how seriously they take this responsibility varies (Harvold et al.

2010). This may have a number of causes, such as lack of time and the practical management of conflicting objectives. There may also be actual conflicts with national guidelines. Finally, there may be varying political interests related to including climate change considerations. A number of municipalities also lack sufficient expertise and capacity to engage in the various problems related to climate change. This is discussed in more detail in Chapter 13 on the municipalities' work on adaptation to climate change.

According to the Office of the Auditor General (3:11 2006–2007), land-use planning is not sufficiently used as an instrument to achieve objectives regarding sustainable development. Land-use management often contributes to a reduction of values that are to be protected: outdoor activities, cultural heritage and cultural environments, productive land and biodiversity. The Office of the Auditor General relates this to inadequate and unclear guidelines, follow-up and guidance from national authorities, and concludes that a stronger effort on the part of the national government is required to ensure that municipal and regional planning contributes towards long-term sustainability.

As these challenges become clear also in terms of adaptation, the committee identifies a need for greater coordination of general considerations in land-use planning and increased governmental guidance to the municipalities. As discussed in Section IV, the committee believes that the planning forum must be actively used as a venue for coordination at the regional level.

The municipalities face a number of demands that must be prioritised, cf. Chapter 13.2, "Barriers for adapting to climate change in the municipalities." Non-statutory tasks therefore risk not being prioritised. Furthermore, adaptation considerations may conflict with other considerations, for instance the establishment of businesses that can create new jobs or other local developments. Similar conflicts can also arise in the county administrations' regional planning.

It is important that there are strong initiatives in place for social planning that ensure sustainable and climate-adapted land use. The Planning and Building Act includes several provisions that provide direction for the municipalities' planning. Among other things, it states that sustainable development is a general consideration in planning that the planning authorities are obliged to safeguard. The Act also states that planning must promote civil protection by minimising risk. There are also specific requirements instructing municipalities to include climate change considerations when processing planning and building applications through other provisions, including the technical regulations to the Act.

The committee nevertheless believes that a regulation under the Planning and Building Act is required which clearly establishes adaptation to climate change as a general planning consideration. It is important that any regulations are followed-up through both support and supervision.

The committee believes there should be a regional authority with general responsibility for ensuring that national requirements towards climate change are taken into consideration in municipal land-use planning and work on civil protection. This task should be assigned to the office of the county governor. This is discussed in more detail in Chapter 14.

16.1.2 Managing stormwater

In a changed climate, more precipitation and an increased frequency of large amounts of precipitation will increase challenges related to managing stormwater. Stormwater runoff is a challenge for all facilities with drainage, and floods can cause damage to buildings and infrastructure and pose a threat to life and health. Climate change will therefore reinforce the need for proper management of stormwater.

The European Floods Directive (COM (2006) 15 final) is a premise for stormwater management in Norway as well. The purpose of the Floods Directive is to reduce and manage the risk that floods pose to people, the environment, infrastructure and property. Implementation in Norway is being prepared by the Ministry of Petroleum and Energy and the Norwegian Water Resources and Energy Directorate (NVE). NVE has been tasked with mapping the area's most prone to river floods, performing a draft analysis, and looking at long-term development trends. Once this has been implemented, more detailed mapping will be carried out. The Ministry of Petroleum and Energy is working on clarifying responsibility for the mapping of stormwater flooding and coastal flooding and is assessing the need for regulations. The European Floods Directive also includes requirements for coordination and distinct divisions of responsibility. The municipalities are responsible for local management of stormwater, while the Norwegian Water Resources and Energy Directorate (NVE) provides specialist assistance related to river floods. The flood inundation mapping does not solve the issues rela-

ted to stormwater flooding and management. Currently, the national government management responsibility related to managing floods from rivers and streams lies with the Ministry of Petroleum and Energy, with the Norwegian Water Resources and Energy Directorate (NVE) as the executive agency. This applies to mapping, land-use planning, flood warnings, emergency and crisis management. Allocation of responsibilities for the national work on flooding related to stormwater and sea level rise has not been decided, but will be clarified by the Ministry of Fisheries and Coastal Affairs, the Ministry of the Environment and the Ministry of Local Government and Regional Development.

It is the opinion of the committee that the current stormwater management is too fragmented, shared among different sectors and private and public players. Placing the responsibility for stormwater management with a national authority will improve the possibility of resolving challenges related to increased stormwater runoff and will also reduce climate vulnerability in society. Among other things, a national authority would be able to prepare governmental, advisory guidelines for the capacity design of stormwater runoff systems where climate change considerations are included, and could contribute towards clarifying stormwater management. The committee believes that it will be natural to view this in connection with the implementation of the European Floods Directive in Norway. In particular, it should be considered whether the Norwegian Water Resources and Energy Directorate should be given responsibility for this.

16.1.3 Sea level rise

Norway has significant settlements in coastal areas. Rising sea levels will have consequences for settlements, infrastructure and land, and could have serious consequences in combination with storm surges. At the same time, there is increasing interest in developing seafront areas (SOU 2007:60, Harvold et al. 2010). Norway has a ban on building in the 100 metre zone along the sea, and in places where the terrain is relatively steep, rising sea levels will not have any consequences where the building ban is complied with. Zoned areas are exempt from the ban, and many cities, including Oslo, Trondheim, Tromsø, Bergen and Stavanger, are intending to concentrate development along the waterfront. One of the motivations behind this is the desire to densify urban areas in order to limit transport requirements and thereby reduce emissions. Conflicting objectives may arise in these cases.

Changes in the sea level will occur gradually over a long period of time. This allows for early action and preventive planning, mapping of risk areas and the development of protective measures, emergency planning and crisis management.

Although rising sea levels is a challenge that Norwegian authorities have no experience in handling, much has already been done that will be relevant for managing changes in the sea level. For instance, the Norwegian Meteorological Institute has a system for storm surge warnings through the county governors to the municipalities.

Several national government specialist agencies are responsible for coastal zone conditions. The most central are the National Office of Building Technology and Administration, which determines the safety level to prevent damage to buildings, the Norwegian Water Resources and Energy Directorate (NVE), which is responsible for flood protection along waterways, and the Norwegian Coastal Administration, which is responsible for accessibility and safety along the coast and supervision of public harbours. In addition, the Directorate for Civil Protection and Emergency Planning (DSB) is responsible for coordinating the overview of risk and vulnerability in society, and the Norwegian Public Roads Administration is responsible for safety and accessibility on roads in addition to being the specialist authority and initiator of new road projects. The Norwegian Directorate for Nature Management is responsible for management related to the natural environment. Through collection and distribution of basic data and through monitoring post-glacial rising, the Norwegian Mapping Authority and the Norwegian Meteorological Institute contribute to the knowledge basis that other agencies and government levels use in their planning.

The responsible agencies are currently also responsible for planning and measures related to rising sea levels. However, the committee believes considerations towards rising sea levels are not adequately safeguarded. There is a need to raise awareness of what a rising sea level will entail for local land-use planning, business and industry, as well as settlements. As a foundation to carry this out, the administration requires knowledge regarding the development of the rising sea level and the consequences for society. There is already a sizeable knowledge basis, for instance, in the report *Rising sea level in Norwegian coastal municipalities* (the secretariat for the Norwegian Cli-

mate Adaptation Programme 2009), but responsibility for communicating this knowledge is currently not satisfactorily established. The committee believes there is a need for a clear delegation of authority and use of instruments in the area.

As discussed in Section II, there is great uncertainty related to future rising sea levels. This poses challenges in terms of communication and the form of communication on this subject. Currently, municipalities are not explicitly obliged to include projections for rising sea levels in planning and governance. The committee believes that it must be easier for various stakeholders to include rising sea levels in planning. In order to do this, more efforts should be directed at detailed mapping of exposed areas and support for protective measures. There is also a need for detailed elevation mapping in order to determine the scope of areas that may be affected by rising sea levels. Recommendations related to map data are discussed in more detail in Chapter 16.3.

Preparation and communication of guidelines for rising sea levels should be handled by a national authority. The same authority should be responsible for providing guidance for local authorities in planning work. The committee believes that it will be natural to view this in connection with Norway's implementation of the European Floods Directive. It should be considered whether the Norwegian Water Resources and Energy Directorate (NVE) should be given responsibility for this as well.

16.1.4 The committee's recommendations

In order to strengthen the planning system and incorporate climate change considerations in social planning, the committee recommends:

- making adaptation to climate change mandatory in land-use planning by incorporating adaptation considerations in a new regulation pursuant to the Planning and Building Act
- protecting exposed types of nature from fragmentation and ensuring habitats for threatened species by extending protected areas and through closer follow-up of developments
- applying an ecosystem-based approach in plans that concern management of nature or natural resources

In order to strengthen stormwater management in planning work, the committee recommends:

- appointing a national stormwater authority for management and viewing this in connection with implementation of the Floods Directive in Norway

The national authority for stormwater management should have tasks including the following:

- provide assistance for detailed mapping of areas that are exposed to stormwater flooding where the consequences are expected to be severe
- contribute towards preventing damage as a result of stormwater flooding by developing guidelines to design stormwater runoff systems in which climate change considerations are included
- strengthen considerations towards managing stormwater runoff in land-use planning and provide the municipalities with advice, guidance and comments regarding individual plans
- have the authority to reject municipal land-use plans

In order to reduce vulnerability to rising sea levels, the committee recommends:

- appointing a national authority for rising sea levels and viewing this in connection with implementation of the Floods Directive in Norway

The national authority for rising sea levels should have tasks including the following:

- provide assistance for detailed mapping of areas that are exposed to rising sea levels where the consequences are expected to be severe
- contribute to prevent damage as a result of rising sea levels by preparing guidelines and guides for managing rising sea levels in land-use planning, provide the municipalities with advice, guidance and comments regarding individual plans
- have the authority to reject municipal land-use plans

16.2 Dealing with increased uncertainty

Climate change is uncertain in several aspects, constituting one of several uncertainties related to the future. As described in Sections II and III, there is uncertainty regarding a variety of factors: the scope of the climate change, the type and severity of its impact, when it will occur, and which communities it will impact. In addition, there are uncertainties related to aspects of the actual adaptation work. There are uncertainties concerning investments and time related to various measures, uncertainty concerning the effects of measures and uncertainty related to how diffe-

rent measures will work together. The complexity of the climate system and society ensures that there will always be uncertainty related to both natural and man-made processes and the interaction between them.

Managing uncertainty is not new in planning. All long-term social planning must take into account that society is evolving. The only thing that is certain is that society will be different in the future. Financial forecasts, demographic projections and other planning factors are all uncertain. In planning, uncertainty therefore concerns more than just climate and is a natural component in the day-to-day work of social planners and decision-makers.

With the current climate, we are within the framework of natural climate variability that are generally known, and historical data therefore provides a good basis for planning. However, climate change will transcend the current natural climate fluctuations and thus undermine the relevance of historical data. In this way, climate change exacerbates the uncertainty.

Decisions must be made despite scientific uncertainty and a lack of experience with climate change as a challenge. In many cases, postponement will increase vulnerability. Planning without taking climate change into consideration will leave society more exposed to the climate. As discussed in Chapter 16.1, strengthening the planning system, it is necessary to include climate change considerations in social planning and to manage the associated uncertainty. This is of course difficult to implement in practice, for instance when making decisions regarding land use, capacity design of wastewater pipes, submerged installations or harbour front height .

Uncertainty should not be a barrier to adaptation, but should be integrated and managed in adaptation efforts. In the following section, we will discuss how it may be managed. The committee presumes that the basic principles for handling uncertainty described in Section I form the basis for all planning of measures for adaptation to climate change, see Chapter 3.4 on uncertainty.

16.2.1 Planning under more uncertain conditions

Planning under conditions of great uncertainty is demanding. It is more complicated to plan for a range of possible outcomes than for one, and it is difficult for authorities to take into account that the sea level, or amount of precipitation, will, with a probability of 80 per cent, be between certain volumes. Many politicians, voters and other parties would rather have specific figures to relate to than possible outcomes within a range.

There are a number of different methods and tools for identifying and analysing uncertainty, but it is beyond the scope of this report to discuss them all. What is important is that the user is familiar with the basis of the selected method, and that the tool in question is appropriate. In the following section, we will focus on some instruments and criteria that may be useful in decision-making and prioritisation of measures when there is uncertainty.

Cost–benefit analysis

In order to assign priorities in adaptation work, there is a need to find the balance between the expected benefit of early intervention and the probable damage. According to the cost–benefit principle, a given measure should be implemented if the expected benefit of the measure, adjusted for the probability of the effect occurring, is equal to, or higher than, the cost of the measure.

Cost–benefit analysis is a method for clarifying and visualising the consequences of public measures. In a cost–benefit analysis, all the effects of the public measure are assigned a value as far as possible. Both the benefit and the cost may be purely financial, or may be related to other indicators, such as biodiversity, welfare, quality of life, etc. In financial terms, there is a need to consider the costs of an adaptation measure against the expected benefit of the measure.

In some cases, the premise may be that the benefit is greater than the cost without including the benefit of adaptation to climate change. These are often termed win–win measures, as implementing them provides a benefit no matter what, and we also gain the benefit of adaptation. When considered as measures for adaptation to climate change, such measures have a negative net cost.

Even when using the cost–benefit principle as a general rule, it is not always necessary to carry out a formal cost–benefit analysis. The point is to consider the beneficial effects and the cost of the measure. Adhering to the cost–benefit principle forces us to question a given measure: what is the actual cost and what is the actual benefit? The cost–benefit principle is flexible in the sense that probability is based on subjective assessments. However, applying the cost–benefit principle can also provide us with an excuse to not prioritise measures that have low expected benefits instead of other measures with a higher expected effect

as long as the presumptions follow the same methodology.

As discussed in Section III, there is a maintenance backlog in large sections of infrastructure and buildings. Increased maintenance of infrastructure and buildings are thus measures that should be implemented. We do not need to analyse probability and effects under various climate projections to claim this. The first priority in adaptation work should therefore be to implement win–win measures without including climate change in the analysis.

Risk and vulnerability analysis

Risk and vulnerability analyses can be used to assess the risks climate change may entail. Risk and vulnerability analyses "identify possible hazards and undesired incidents that the subject of analysis may be exposed to" (DSB 2009).

Requirements for performing risk and vulnerability analyses are stipulated in the planning part of the Planning and Building Act (Section 4-3) that instructs the planning authorities to ensure that a risk and vulnerability analysis is performed for the planning area or to perform such an analysis themselves.

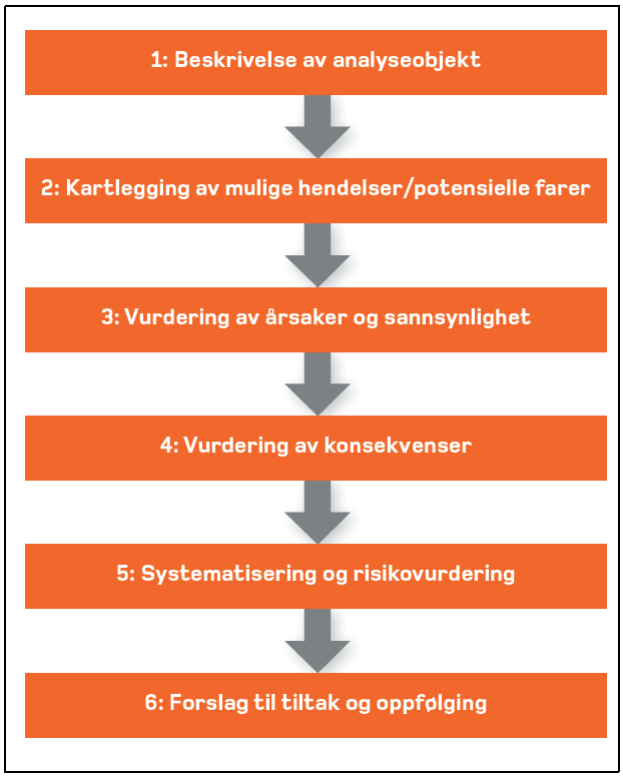


Figure 16.1 The phases of risk and vulnerability analysis (DSB 2008)

A number of different methods and tools for risk and vulnerability analysis have been developed. The objective of risk and vulnerability analysis is to answer the following questions:

- What type of events may climate change lead to (both abrupt natural disasters and gradual changes)?
- What are the possible consequences of the events?
- What can be done to prevent the consequences or reduce the potential for damage?

16.2.2 Uncertainty and time

As we have seen in Section II, climate projections operate with a time horizon of 30–100 years before anthropogenic climate change will become distinguishable from natural climate variability. The further ahead in time we look, the greater the impact of climate change will be. As a result, adaptation to climate change should be considered based on expected service life. If a structure has a short service life, adaptation is unnecessary. If the lifespan is long, relevant measures must be considered based on use far ahead in time and risks related to acting prematurely as opposed to too late. In other words: how does one consider the value of acting now against waiting to see what happens?

Whether it makes sense to wait and see depends on development trends in terms of both cost and benefit. The benefit perspective indicates that we should wait. As we approach the second half of the century, it will become clearer how climate change will affect Norwegian society at that time. The risk of implementing erroneous measures – i.e. unnecessary or inadequate measures – will thus be reduced significantly.

The costs and benefits of a measure rarely arise simultaneously. It is therefore necessary to use a method that allows us to compare and summarise the effects that arise in different years. When calculating the current value of a measure, future effects are discounted with a positive discount rate. A consequence of this is that effects count for less the further ahead in time they move. Some measures become less costly over time, and it is therefore better to postpone these due to cost. The interest effect also indicates that it is better to wait. Simply put, the interest effect entails that every krone in postponed spending may be invested in interest-bearing securities in the interim.

It is better to implement certain other measures without delay. If drainage pipes must be repla-

ced, it will be costly to excavate the same pipes later on in order to lay new ones with increased capacity. The cost of increasing the size of the drainage pipe is therefore lower if carried out in connection with the initial replacement. In land-use planning it makes sense to take into account the fact that it is more expensive to repair or move houses after the fact than to zone areas in advance so that people do not build in areas that will be exposed to rising sea levels, floods or landslides/ avalanches. Another example is diseases that are inexpensive to eradicate now, may involve dramatically higher costs if climate change accelerates their proliferation . The general rule is thus that it makes sense to implement measures that become more expensive over time now. By contrast, if the cost of a measure does not increase over time, it may be more pertinent to wait.

16.2.3 Probability assessments

According to the cost–benefit principle, social planners and decision-makers must assess the probability of a specific climate change effect occurring and also whether the measure will work as intended. This probability – or these probabilities – depends, as we have seen, on numerous different factors, with climate change as one of the variables. A more detailed discussion of the probability of climate change is therefore worthwhile.

Norwegian and international authorities are working towards the "two-degree target". This target entails radical emissions reductions as the century progresses. The question is whether we should therefore also use the two-degree target as a reality for a strategy for adaptation to climate change.

It is the committee's view that this is not a good idea. We should distinguish between what is desirable and what is probable. It is desirable to achieve the two-degree target, but it is unlikely that it will be achieved. Adaptation based on the cost–benefit principle must be used as a starting point for the most realistic scenario, not what we hope will happen.

16.2.4 The committee's recommendations

In order to manage increased uncertainty in social planning, the committee recommends that:

- The climate projections that entail the greatest challenges should be used as a starting point for assessing possible consequences and measures, see Chapter 5 on the climate in the future. Ordinarily, high projections will entail the greatest challenges because they indicate the greatest changes compared with the current climate, but this must be considered in each individual case. For example, the risk of droughts and forest fires should be considered with low precipitation projections in mind, while for flood risk it is recommended to consider consequences and measures in the light of high precipitation projections.
- The first step in planning measures should be an assessment of whether it is beneficial to implement measures and instruments regardless of the climate. If the relevant measure is a win–win measure, it should be implemented.
- Considerations regarding expected lifetimes should be integrated in planning to a greater degree. A Norwegian municipal main plan usually has a time horizon of 10–12 years. A horizon of 30 or 100 years will, of course, not be suited for all aspects of a municipal main plan, but should be used in those areas that are affected by climate change, for example when zoning new development areas and establishing new infrastructure. Measures should be considered based on whether they must be built to withstand climate change that is expected during the course of the measure's lifetime, or whether they are to be built on the basis of the current climate, but prepared for reinforcement or alteration.
- The responsible national authorities should carry out a review of different methods to analyse uncertainty and incorporate considerations of uncertainty in adaptation efforts.

16.3 The knowledge basis must be strengthened

Knowledge regarding climate change is a precondition for efficient adaptation in society. There is a clear need for knowledge in almost all the areas mentioned in Sections II and III. In the following section, we will discuss various aspects of the knowledge requirements by looking at some of the areas where the lack of knowledge and expertise has been emphasised.

The production and distribution of knowledge is mainly a public responsibility. In financial terms, knowledge is not a typical commodity – it cannot be owned and exchanged as other commodities, and its value increases when it is shared and used. The production of knowledge can therefore not be left to market forces. Individuals and enterprises have a limited benefit from investing

in knowledge that society as a whole needs. There is therefore a significant market deficit for the production and dissemination of knowledge. This information gap must be filled by public authorities.

The committee supports Klima21's conclusion that the organisation and financing of climate research needs to be more predictable and long-term, and that education, recruitment, fundamental research and infrastructure must be strengthened. Only public authorities can assume a comprehensive responsibility to secure this basic foundation for climate research.

The volume of knowledge regarding climate change and its effects is growing, internationally, nationally, locally and within different disciplines. It is challenging for decision-makers and planning authorities to maintain a general overview of this knowledge and to keep up to date on the status of knowledge in a broad range of fields.

There is a need to increase knowledge through systematic analysis, mapping, monitoring and research in a number of fields. Furthermore, there is a need for communication and dissemination of knowledge. This chapter covers these fields as follows: Chapter 16.3.1 discusses the needs for monitoring and mapping that the committee has identified through its work; Chapter 16.3.2 discusses the needs for research that the committee has identified; and Chapter 16.3.3 discusses the need for adaptation of data and model results for users.

16.3.1 The need for monitoring and mapping

Monitoring and mapping are examples of systematic data acquisition that helps us in many different ways in our efforts to ensure adaptation to climate change. Solid monitoring programmes will both help indicate whether the climate really is changing and reveal the impact of climate change. Monitoring data may be used to improve the climate models we depend on to predict future changes. Relevant and quality-assured data series from monitoring programmes are also useful for calculating and furthering research on the consequences of climate change.

Mapping provides geographical information on a wide range of variables that are relevant for adaptation to a changed climate. For instance, geodata (map data and other information based on coordinates) is required in land-use planning, which the committee views as a key venue for climate change adaptation.

Monitoring requirements

Many areas already have good monitoring systems. Examples include:

- climate monitoring (the Norwegian Meteorological Institute and the Institute of Marine Research's monitoring stations)
- hydrology and cryosphere monitoring (NVE's monitoring stations)
- monitoring of the natural environment and natural resources (the Norwegian Directorate for Nature Management, the Institute of Marine Research, etc.)
- monitoring of harmful organisms, as regards human, animal and plant health
- monitoring in the form of systematic sampling and analysis in connection with the import of high-risk goods

The committee believes there is a need to assess whether these systems are sufficient to reveal climate change and improve climate models. In addition, there are many areas relevant to the climate that are not monitored or that are insufficiently monitored. The committee would like to highlight areas such as ocean acidification, wind and short-term precipitation in particular.

Ocean acidification

As emerges from Chapter 7 "Natural environment" and Chapter 10.2 "Fisheries and aquaculture," ocean acidification represents a particular challenge for Norway. Norwegian waters will be among the first areas of the world's oceans that will be affected by ocean acidification, as our waters are a core area for the transmission of CO_2 from the atmosphere to the deep ocean, and because the physical characteristics of the seawater in the Nordic oceans will intensify the effects of acidification. This gives Norway an international responsibility to monitor the effects of ocean acidification on marine ecosystems. Monitoring supports research efforts in this area (see Chapter 16.3.3). It is particularly important to initiate studies on the impacts on key organisms such as deep-water fish, deep-water corals, zooplankton and phytoplankton. The monitoring must comprise the entire water column. The deepest areas of the Norwegian Sea and the Greenland Sea should be the main focus of Norwegian studies, but the deepest fjords must also be included in the monitoring programme. The international nature of the problem indicates that this monitoring and research should be coordinated internationally.

Wind

Changes in wind speed and direction may constitute significant challenges in the future climate. Monitoring of wind is complicated and resource-intensive, and there is a lack of long-term monitoring series with good and relevant wind measurements. As a consequence, it is difficult to say whether wind conditions in different parts of Norway have changed. There is also a need for good wind data for the testing and calibration of climate models. In the long term, improved data will reduce uncertainty in projections for changes in wind direction and speed. Better wind measurements will also contribute to better forecasts of avalanches, and is a precondition for planning and operation of infrastructure.

Short-term precipitation

The monitoring of short-term precipitation (precipitation monitoring with an interval of one hour or less) is important for a climate where we can expect more intense, short-term precipitation events with subsequent flash floods and flooding. Such data is particularly relevant for the capacity design of drains. In urban areas, precipitation data should have a resolution of ten minutes. Short-term precipitation is also important for assessing the risk of several slide types, such as flood-related landslides.

The need for geodata and mapping

Norway has a well-functioning system for detailed topographical mapping with Geovekst. Correspondingly, agreement-based cooperation has been established regarding the management and sharing of topographical and thematic geodata through Norway Digital. Most municipalities, regional and national agencies participate in this cooperation. The committee considers it natural that these models of cooperation are applied when new geodata needs arise, and that advanced, online geographical services are also developed within the framework of this cooperation to ensure the users good access to data, adapted services and products.

However, the committee would like to stress that much of the mapping of other issues that will be important for adaptation also takes place in small and decentralised projects and is therefore governed by the parties' short-term needs, financial willingness and ability. The result is a patchwork with coverage only in selected areas. Comprehensive national programmes for some topics will be appropriate to provide more complete data coverage. This may also provide data that is more homogeneous and that has better quality assurance by way of better national standards. Such coordination will in many cases also save time and money compared with continuing the current, somewhat fragmented model.

The committee has pointed out that land-use planning is particularly vital for climate change adaptation. Based on contributions from the Norwegian Mapping Authority, among others, the committee has reviewed the need for geodata related to adaptation.

A detailed elevation basis is very important for various public tasks in the municipalities and is also very important as a starting point for better estimates of flood zones, landslide-prone areas and the consequences of rising sea levels. Norway does not have a precise, nationwide three-dimensional terrain model based on detailed elevation mapping (laser scanning). The current elevation data is not accurate enough to carry out adequate impact studies pursuant to the Planning and Building Act. A national terrain model based on laser scanning will provide data suitable for calculating terrain gradients, terrain profiles, mass calculation and mapping of slide-prone and flood-prone areas, for indicating impact areas for rising sea levels, location of wind power stations, registration of cultural monuments and forestry resources and numerous other activities. Laser scanning has been or is currently being carried out in certain areas of Norway. A total area of approx. 75 000 km^2 (approx. 23 per cent of the Norwegian land mass) has been scanned, primarily funded by the Geovekst cooperation. However, this work is decentralised and is being carried out as small and thus costly projects. The committee recommends the establishment of a national programme to ensure acquisition of elevation data based on laser scanning for the entire country following Sweden's lead, which has decided to carry out laser scanning over four years.

Land-use plans pursuant to the Planning and Building Act govern land use and contain information on current and planned land use. As regards adaptation, a good overview of the current planning situation for larger areas becomes more important. The planning basis should therefore be made available digitally to ensure that this knowledge is familiar to all parties in local and regional planning processes. The committee therefore proposes that complete planning records are developed that cover all of the country's municipalities.

The planning records must be incorporated in the national infrastructure for geographical information and include online access solutions.

The Norwegian Water Resources and Energy Directorate (NVE) coordinates landslide, avalanche and flood mapping. Mapping is carried out in three levels: vulnerability maps, hazard zone maps and risk maps. Vulnerability maps are rough and only serve as a basis for determining the areas where more detailed mapping of hazard zones should be carried out. Hazard zone maps may be used directly to process building applications and in land-use planning, but are only produced for selected areas. Risk maps are even more detailed and are important for assigning priority to protection measures. Such maps are only produced for a few areas. Hazard zone maps for flooding are currently available for selected stretches of waterways with a high potential for damage. The mapping of areas prone to quick clay slides primarily comprises those areas of the country that have large deposits of quick clay. There is national vulnerability mapping for rock slides and avalanches. There is still much that remains in terms of preparing hazard zone maps and risk maps for the various types of slide events. As a result, municipalities lack maps that may form the basis for the municipalities' processing of building applications and land-use planning. Methods to include the impact of climate change in hazard zone maps are currently being designed, and, particularly with respect to landslides and avalanches, we are dependent on results from R&D activities. The effect of climate change has thus not yet been implemented in maps. The committee therefore proposes that a national comprehensive programme is initiated for detailed mapping of areas that are exposed to natural hazards. This should include themes such as landslides, avalanches, floods and storm floods.

Lillethun (2010) emphasises that there is inadequate mapping of the pipeline and cable networks both above and below ground, and that information is often dispersed across several systems. The information on underground pipelines and cables, such as electrical cabling, water and drainage pipelines and telecommunications cables, is particularly sparse. These systems may be vulnerable to climate change. It would therefore be an advantage for adaptation work to map the current pipelines and cables and to have this information readily available, for example in the form of databases for pipeline and cable maps.

Good mapping of natural diversity is necessary to enable identification of the impact of climate change on nature. This type of basic data is also necessary for land-use planning. Although most municipalities have mapped biodiversity, the degree of coverage within the municipalities is relatively low. There is therefore a need to extend the current mapping and ensure coverage of those species and nature types that are considered to be particularly threatened by climate change. It is natural that this takes place through extension of and increased priority of the work currently included in the *National programme for mapping and monitoring*.

At present there are no overviews of vulnerable objects, or they are difficult to access. Links between various registries and improved adaptation through online services could significantly improve the overview. This could provide municipalities and other agencies with tools to estimate financial and population-related consequences. Access to such data will be important in land-use planning, risk and vulnerability analyses, impact assessments, etc.

In Chapter 13.5, the committee has concluded that it is necessary to improve adaptation of buildings in Norway to climate change. In connection with this, the committee points out that regional climate indices or mapped climate zones based on these may be useful tools in clarifying building requirements in different regions.

16.3.2 Research requirements

The committee has reviewed relevant research programmes and discussed which areas in particular require more knowledge regarding the climate system, consequences of climate change and relevant adaptation measures. Through its work, the committee has also identified research subjects that may help encourage society to prioritise the most effective adaptation measures.

Current climate research

The parliamentary climate agreement that was adopted by the Storting in 2008 provides the general premises for climate research in Norway (Storting White Paper No. 34 (2006–2007), the Norwegian Labour Party et al. 2008). The climate agreement states that research on adaptation to climate change should be strengthened in the following areas:

- research on regional and global climate change. Research and monitoring of climate processes and the impact of climate change in

the High North are highlighted as particular priorities
- the consequences of, and adaptation to, climate change for society, trade and industry
- social research that provides increased insight into decision-making processes and framework conditions in climate policy

In addition, the climate agreement provides a framework for research on lower emissions of greenhouse gases.

A working group, called Klima21, was established after the climate agreement, which was tasked with being "a strategic forum for climate research to enable climate policy, management and action to build upon research-based knowledge" (Klima21, 2009). One of the first tasks for the working group was to prepare a research strategy, which the group called "Knowledge for climate". The main recommendations of particular relevance to the committee are:
- to establish a long-term research programme to reduce uncertainty in climate projections
- to establish an administration-oriented long-term research programme to better understand the consequences for nature and society and to ensure that the administration and industries are better equipped to adapt to climate change
- to establish long-term and industry-oriented research centres, also to better understand consequences for nature and society and enable better adaptation

In addition, Klima21 recommends establishing critical infrastructure for research and monitoring with respect to climate projections, consequences and adaptation.

Currently, NORKLIMA is the central research programme in Norway in the field of climate change. NORKLIMA will be discontinued in 2013. NORKLIMA's primary objective is to "provide the necessary new knowledge on the climate system, climate trends in the past, present and future, and the direct and indirect impacts of climate change on nature and society that provide the basis for social adaptation" (NORKLIMA 2008). In addition, NORKLIMA has the following five secondary objectives:
1. increase understanding of the climate system and its variability, and quantify uncertainty
2. increase knowledge of climate change and its effect on buildings, infrastructure and other physical facilities, both terrestrial and marine
3. increase knowledge of climate change and the impact for natural and cultivated ecological systems and nature-based industry
4. increase knowledge of how climate change affects social conditions and what strengthens the adaptive capacity
5. increase knowledge of the connections between emission developments and social developments, and of international cooperation to limit climate change

In its 2009 annual report, NORKLIMA states that while secondary objective 1 will be achieved during the programme period, secondary objective 2 will only be achieved in selected areas. Secondary objective 3 will have the best achievement of objectives for the marine ecosystems and marine natural resource-based industries. As regards secondary objective 4 relating to social conditions and ability to adapt, NORKLIMA states that achievement of the objective will be good "given that this is a new subject and expectations must be lower than e.g. research on the climate system".

NORKLIMA's budget for 2009 was NOK 65 million. In addition to NORKLIMA, research is being carried out on the climate system, consequences and adaptation at centres for research excellence, the Oslo Centre for Research on Environmentally friendly Energy (CREE), at centres such as the Bjerknes Centre and CICERO, and at universities, university colleges and institutions. The research projects are often international and are largely funded by the European Union's research programmes. In financial terms, this research is at least of the same scope as NORKLIMA's research.

The Research Council of Norway's total portfolio of climate-related research constitutes approximately NOK 300 million, according to estimates obtained by the committee. In addition, there is self-funding by research communities and user-funding, which is a requirement for most research projects. The Research Council of Norway has in stated in various contexts that the amount is inadequate and that it should be doubled or tripled in the course of a few years. Klima21 has proposed a grant of NOK 1 billion more for climate research by 2015.

Need for research

The committee believes there is a need to prioritise research on the climate system, the impact of climate change and adaptation across the board.

The need for regularly updated knowledge produced under stable terms indicates that it is not adequate for this work to be funded with grants through research programmes and projects with a short horizon. The committee therefore supports Klima21's proposals regarding increased predictability and a long-term focus of major long-term research programmes on the climate system, the consequences of climate change and adaptation. The committee particularly wishes to highlight the need for a long-term focus related to maintenance and development of the data base in the form of long time series. The committee also wants to highlight the need for resources for the development and operation of a national modelling system for analysis, global and regional studies and research into the impact and social costs of climate change and adaptation.

The committee has identified research subjects that should be prioritised in order to strengthen the knowledge basis for accurate and cost-effective adaptation. These are described in random order below. Research on the climate system is discussed first, followed by the impact of climate change, and finally social significance and adaptation.

Climate research

Existing climate models do not provide good, clear and quantitative indications of change for all climate variables. This applies to, for instance, wind and ice conditions, short-term precipitation and lightning strikes. The committee would like to emphasise that wind and extreme precipitation have the potential to cause great damage to infrastructure and buildings, particularly if increased wind forces occur simultaneously with extreme precipitation events and storm floods. Forests can also be severely affected by such conditions. Changes in extreme precipitation will also affect flood and slide conditions and have great significance for the mapping of buffer zones in land-use planning. It is therefore particularly important to gain an overview of this.

The UK has estimated the kind of damage and financial costs that can be expected in London if the wind changes direction and becomes stronger. In Norway, there are corresponding estimates of what sort of damage and financial costs may be expected in eastern Norway if the region were to be exposed to so-called "Bergen weather" in the future, i.e. wetter and windier conditions. Calculations show that storm paths and polar depressions may be displaced in the event of increased warming. This may cause local changes in both wind speeds and wind directions, but weaknesses in the current climate models make it impossible to draw any conclusions at present.

It is also impossible to estimate future changes in aspects such as the frequency of lightning and risk of icing on the direct basis of existing climate models. It is therefore important to develop both the climate models and the methodology to produce local and detailed information from the models.

In a time frame of 10–20 years, it is expected that natural climate variability will be in the same range as climate change caused by an increased greenhouse effect (see Section II). In the light of slower ocean circulation and the ocean's systematic effect on the atmosphere, research has recently been initiated to study the possibility of developing climate projections for the coming 10–20 years. Such forecasts can be of great value to national and local adaptation measures and for a number of sectors and industries. They will also help us distinguish anthropogenic climate change from natural climate variation within the normal planning horizon for industry and authorities. It may also be possible to forecast variations in intensity and the position of the Westerlies during the winter (the North Atlantic oscillation (NAO)), which governs much of the natural climate variability in Norway's nearby environment. The current oceanic climate models still have weaknesses with respect to the distribution of ice in the Arctic.

Research on the consequences of climate change

Most studies on vulnerability in Norway are based on projections with global warming of approximately two degrees. The committee would like to stress that even though it is a political goal to limit global warming to two degrees, it is looking increasingly likely that global warming will be at least three degrees this century, and perhaps even higher in the following century. This makes it essential to intensify research efforts on the consequences of warming beyond two degrees.

Ocean acidification is a potentially extremely serious problem for marine ecosystems, but research into the effects on marine organisms has only just started. Knowledge about the consequences for certain organisms with calcium carbonate shells is becoming known, but the significance of this for the rest of the marine ecosystem and the direct impact of further acidification in other parts of the ecosystem are not known. It is evident that if ocean acidification causes the exter-

mination of key organisms in the marine ecosystems, this will have irreparable consequences. The committee would therefore like to emphasise that it is important to advance research on the effects of ocean acidification. Firstly, it will be important to investigate whether key organisms such as copepod, which has its winter habitat at depths from 400 to 2 200 metres, can tolerate the predicted ocean acidification. These are the areas that will be affected first by changes in the conditions for calcification as a result of increased absorption of CO_2 in the ocean.

As the consequences of changes to the frequency and extent of natural hazards may be particularly significant, it is important to increase knowledge about the effect of climate change on such events and reduce uncertainty of the results. The effect of climate change on hydrology, including floods and drought, and the cryosphere, must be studied. The need for knowledge is also significant in order to assess the combined impact of changes to the climate, hydrology and the cryosphere on society and the natural environment, particularly in relation to landslides and avalanches.

It is important to study the consequences of significant warming for the vulnerability of the natural environment. There is reason to believe that the consequences for the natural environment will be more extensive than previous studies have suggested. In addition to focusing on moderate temperature increases, most studies so far have been directed at individual species or simple systems. What impact climate change will have on *entire* ecosystems, and how the effects will be influenced by other social changes that may occur at the same time, is also largely unknown. One hypothesis is that the natural environment's vulnerability is moderate up to a certain "tipping point," but that vulnerability increases dramatically once the tipping point is reached. It is also important to investigate the significance of the rate of climate change, as this may play a role in its own right. It is therefore important to prioritise research that highlights and tests hypotheses related to the vulnerability tipping point. Areas other than the natural environment may also be exposed to tipping points, so it could be generally useful to research the consequences of significant and rapid climate change.

In some sectors, disruptions and loss of regularity represent a major risk related to climate change. For example, precipitation, stormwater runoff, floods and landslides/avalanches can lead to the closure of roads and road systems; wind and extreme weather can shut down airports; storms and extreme weather can cause power outages, etc. The scope of this risk has received little attention. In turn, this entails that it is easy to underestimate the socioeconomic cost of climate change on infrastructure. The committee considers it important to identify the risk and socioeconomic costs inherent in disruptions and loss of regularity, to provide a better basis for investments in water and sewage, transport, power supply, etc.

Good knowledge has been developed of the adaptation of building processes and climate-adapted solutions for new buildings in the current climate. It is now important to develop and apply knowledge of climate change adaptation in the building sector. At the national level there is a need to strengthen knowledge of the possible impacts of climate change on the construction industry. One precondition to prevent unnecessary costs and other negative effects of climate change on buildings is to develop the knowledge basis in time with the manifestation of the effects of climate change. The need for a research programme should be assessed against alternative solutions for long-term knowledge requirements that will ensure continuity in knowledge development. The assessment should also consider whether there is a need for a new, consolidated resource centre for climate change adaptation for buildings, and if so, the target group, role and form of affiliation for such a centre.

Climate change alters the natural environment and the premises for agriculture, forestry, reindeer husbandry and other nature-based sectors. There is a great need for better understanding of how a changed climate will affect the natural environment and the biological systems of production. A changed climate will alter the competitive balance between existing species, and it is important to understand such effects better in order to modify the management regime and sector use of resources. Climate change will also lead to new species being able to establish themselves in Norway, either as a result of natural or assisted migration. There is therefore a need to strengthen research on these issues in order to implement preventive measures, and also to allow exploitation of new opportunities that arise without conflict with the natural environment. The fact that the interaction between climate, soil, water and plants will change with climate change should also be prioritised in research. For the primary industries there is also a need for research-based development of technological solutions and methods that are adapted to a changed climate.

Measured economic costs related to climate change have a tendency to amount to a small percentage of the total economic growth in society. The committee is of the opinion that this is due to the fact that many possible consequences of climate change have not been sufficiently investigated. Wind and extreme weather, for example, have the potential to incur major costs, but so far we know too little about the effect of climate change on wind and extreme weather to include it in socioeconomic estimates. We also know too little about the consequences of climate change greater than that associated with a warming of two degrees. These are just two examples. These subjects need further elucidation, not just from a natural science and technical point of view, cf. the above, but also from a social science and economic point of view.

In order to understand the full significance of climate change for Norwegian society, it is necessary to look beyond the material costs and also include cultural and welfare values. The destruction of the stave churches, Bryggen wharf in Bergen and other historically significant buildings by rain or storms would entail a loss of cultural assets. In addition to providing good skiing conditions, snow also brightens the dark winters, meaning that when large parts of Norway are no longer covered by snow for most of the winter, individuals will experience this as a loss in their general quality of life. An increased risk of natural events may lead to greater perceived insecurity for the populations in exposed locations. Research on the effects of climate change on cultural and welfare issues (non-material issues) is currently at an early stage, but it shows that such values are an important element in adaptation to climate change and assessing vulnerability.

The committee has also noted that some impact assessments of climate change are based on the assumption that society in the future will not undergo other changes than climate change. This is mainly due to the fact that we have not yet developed good methods to project various social changes at different levels. This particularly applies with respect to a downscaling of social projections to the local level and in relation to linking them to climate projections. The committee stresses that there is a lack of knowledge in this area. Social and other changes take place at the same time and in many cases independently of climate change, and it is important to shed light on this in order to understand how being exposed and vulnerable to climate change changes with time, and which types of requirements will be imposed on future adaptive capacity. In that they illustrate the importance of social and climate change for vulnerability, this type of interdisciplinary analysis will also be useful in efforts to find ways of reducing society's vulnerability.

It is the opinion of the committee that there is therefore a particular need to strengthen interdisciplinary research and expertise on adaptation to climate change. Because the consequences of climate change affect both society and the natural environment, adaptation and vulnerability must be studied in a comprehensive perspective. This means that we must be able to merge knowledge from different scientific disciplines both within the social sciences and between these and the natural science communities. The committee recommends establishment of a separate national interdisciplinary research programme, including PhD studies, for adaptation to climate change in order to strengthen research expertise. This kind of interdisciplinary programme must be based in the social sciences in order to ensure that issues surrounding adaptation and vulnerability have sound relevance for the various stakeholders and levels of society.

16.3.3 Need for generation and adaptation of data and research results

Data from monitoring, mapping and climate models do not necessarily provide the information that the data users need. The monitoring data needs to be adapted and made available in the form of intuitive tools such as tables, graphs and online research tools. There is also a great need for downscaled and adapted climate projections. Such end-products are a necessary basis for work on adaptation to climate change in a number of sectors that lack meteorological and hydrological expertise.

Establishing good map data with online solutions, as the committee has proposed in Chapter 16.3.1, will also ensure better adaptation of the data. The committee would also like to emphasise the need for model calculations, damage impact research and adaptation of precipitation and flood data.

The use and development of a national model calculation instrument for regional climate studies is a precondition to provide the best possible climate projections for use in adaptation work. In addition to the actual model system, there is a great need to adapt climate information, results and products related to climate change projections in line with specific sector requirements, for use by authorities, impact research and the general public. Currently these activities take place

through short-term (3–4 years) competitive research projects. The current structure is highly vulnerable to changes in the acceptance of such research projects, with potentially major negative consequences for national work on adaptation to climate change. It will therefore be especially important to ensure a more predictable and long-term financial foundation for these activities.

There is currently insufficient knowledge about climate-related damage to buildings and infrastructure, and no coordinated, general overview in this area. As a step on the way to a better overview, the committee proposes establishment of a database for public use and as a basis for research. Such a database should include coordinated, anonymised data regarding climate-related damage from the insurance companies and the Norwegian Natural Perils Pool. Research where climate variables from monitoring programmes are compared with data from such a register is expected to provide new, useful knowledge.

Two important tools for determining the required capacity of infrastructure are intensity-duration-frequency curves (IDF curves) based on precipitation series, and flood frequencies based on watercourse time series. IDF curves are an established tool for the calculating the required capacity of the sewage system and drainage. The existing curves need to be updated to reduce uncertainty and to include recent changes in precipitation patterns, particularly for short-term precipitation. This requires quality control, the reworking of data and additional calculations. There is also a need for an assessment of the uncertainty in the calculations and to define the practical limitations of their application. The Norwegian Meteorological Institute has done a great deal of work in recent years, but demand has outstripped capacity.

The current IDF curves only contain data from the registration of rainfall during the summer months. For a future climate, where increased rainfall is expected during the winter, often in combination with melting snow, it is necessary to find ways of producing IDF curves that also include the winter months and the effect of melting snow.

As a result of the expected increase in both the frequency and the intensity of extreme precipitation, an increase of floods in small rivers and streams is also expected. In order to improve the basis for calculation of the necessary capacity for managing floods in small catchment areas, we need flood frequency analyses with updated water flow data with high time resolution in the form of momentary maximum flood values. The Norwegian Water Resources and Energy Directorate (NVE) states that there is a substantial amount of water flow data with a higher monitoring frequency than 24 hours, but that much of the data is not quality-assured and/or digitised. This is a task which will be useful to perform, regardless of climate change.

16.3.4 The committee's recommendations

In order to improve the foundation for knowledge production in areas relevant to the climate through monitoring, the committee recommends:

- strengthening monitoring of ocean acidification through studies of impact on key organisms and measurements in the entire water column
- focus on wind measurements
- focus on measuring short-term precipitation

In order to improve the map and data basis for adaptation to climate change, the committee recommends that the following be prioritised:

- a national programme to establish a digital terrain model (laser scanning)
- a national programme for the development of a complete digital land-use planning registries
- improved mapping of natural hazard data such as landslides, avalanches and floods
- a national mapping programme for pipelines and cables
- improved monitoring of bio diversity
- improved coordination of mapping of vulnerable assets with the goal of developing national summaries of population, industry and vulnerable buildings and cultural heritage assets
- development of regional climate indices for use in the construction industry and by the municipal building application authorities

For the climate system the committee recommends strengthening research within:

- mapping
- modelling
- analysis of climate developments in general, and of future wind and extreme weather in particular

For the consequences of climate change the committee recommends strengthening research within:

- the impact of ocean acidification on marine organisms
- future changes in hydrology and the cryosphere
- the role of climate and hydrology on triggering of landslides/avalanches

- the possibility of a tipping point in the climate system
- tipping points in natural environments
- loss of regularity in infrastructure due to extreme events
- how changes in hydrology and the cryosphere have consequences for social planning
- positive and negative impacts of a changed climate on primary industries
- economic consequences for different levels of society
- the possibility of estimating the economic costs of non-material consequences of a changing climate
- changes in cultural and welfare conditions as a consequence of climate change

For projections the committee recommends strengthening research within:

- climate projections, including quantifying, reduction of uncertainty and downscaling
- how to best develop downscaled social projections, including strengthening research regarding how social projections may be used simultaneously with, and be linked to, climate projections

In order to facilitate the data for use in management and by other stakeholders, the committee recommends the following measures:

- funding a Norwegian climate service centre for adaptation to climate change to ensure continuous updates of the model basis and adaptation of climate and hydrological data for impact research and administration
- establishing a database for climate-related damage to buildings and infrastructure
- strengthening the capacity to update IDF curves and flood frequency analyses

16.4 Expertise must be strengthened

Sections III and IV highlight the critical need for more information and expertise regarding adaptation to climate change. This applies to all levels of government and among many of the stakeholders in the sectors.

Work to strengthen expertise in the area of adaptation to climate change at the regional and local levels has started in recent years. The establishment of the national climate adaptation website Klimatilpasning.no, and the courses and information activities that were initiated by the Norwegian Climate Adaptation Programme secretariat with the Directorate for Civil Protection and Emergency Planning (DSB), are measures that have been initiated as part of the national coordination work. Adaptation activities in networks and projects such as the Eastern Norwegian County Network and Cities of the Future also help strengthen expertise. Research projects such as NORADAPT, in which eight municipalities participated, is one of several examples where researchers cooperate with municipalities to survey climate vulnerability and develop adaptation activities. Such projects also help improve expertise.

The committee recognises a significant need to build expertise in adaptation within various areas of society and at various administrative levels. Knowledge regarding climate change and the possible consequences are crucial in order to enable different parties to assess their own vulnerability and adaptive needs, and in order for expected changes in precipitation, temperature and sea levels to be taken into account when planning. An important component of this is the need for climate projections and knowledge of how these may be utilised in practical management. There is also a need for greater exchange of experience in and between sectors and administrational levels. The committee believes it is important that much of the expertise building takes place within the various sectors and is incorporated in the sectors' regular systems for information exchange and expertise building.

The responsibility for developing and communicating updated knowledge regarding climate change and climate effects should, according to the committee, be assigned at the national level. This type of knowledge is a common good that cannot be developed locally. Otherwise, this development would be inefficient and fragmented. Coordinated, national development of expertise will consist of compiling updated knowledge on climate change, obtaining knowledge and experience and distributing information.

There are several tools that may be used to distribute knowledge and information. The committee proposes strengthening online information solutions such as Klimatilpasning.no and online map solutions. In Chapter 16.3, the committee recommends establishing a climate service centre, which will be particularly important to adapt for user-oriented climate projections. Courses and training activities should also be developed.

As highlighted in Chapter 9 "Infrastructure and buildings", inadequate expertise among parties in the construction industry increases society's climate vulnerability and is a barrier for adap-

tation of buildings. The expertise challenge is particularly pressing among small stakeholders, which constitute a significant proportion of the industry. The construction industry will have specific training requirements that are best handled by the industry itself and the sector authorities.

In order to uphold expertise development for adaptation to climate change at the national level, the committee believes that there also is a need for a broader focus on expertise building at the agency level. The integration of adaptation considerations in the various sectors creates a need for specialist knowledge of adaptation as a basis for coordination at the national level and guidance and supervisory roles vis-à-vis the local administrative levels. Such focus will involve channelling resources to the relevant bodies in order for them to be in a position to safeguard their tasks related to guidance and developing knowledge.

The committee also finds that knowledge venues are necessary as a meeting place for the authorities and other stakeholders from various sectors. Currently, municipalities and counties are provided with training from the National Emergency Planning College (NSUB). The committee believes this service should be extended and provided regionally. It is important that as many stakeholders as possible participate, and with a regional approach, it will be possible to tailor training to regional issues to a greater degree. Such a regional platform could also be a venue for the exchange of experience and cooperation between stakeholders facing similar climate challenges. While there will of course be significant variations within regions too, the committee believes that providing courses and training at four centres would be a cost-effective solution that would provide good geographical proximity to the parties. The committee proposes establishing training for southern Norway, western Norway, central Norway and northern Norway, as well as for Arctic issues with a particular focus on Sámi culture and society.

Access to good online services for data from relevant national databases, other aids and tools will also be useful for administrative purposes, see Chapters 16.3.1 and 2. This type of information may be used in cross-sector, general integration of adaptation considerations in planning and analyses, but there will also be a need for tools that are tailored for individual sectors and parts of planning processes.

In the UK, UKCIP has developed *The Adaptation Wizard*[2]. This aims to be a practical tool for local authorities and others to create a strategy for adaptation within their areas of responsibility. It is the opinion of the committee that this type of tool would also be suitable for Norwegian conditions as a common tool for all sectors and areas of administration. Among other things, such a tool should facilitate the development of analyses of vulnerability to climate change, cost–benefit analyses, assessments of adaptation opportunities and guidelines for local adaptation to climate change.

It is the opinion of the committee that the county governors should have the main responsibility for maintaining the government's obligations in terms of guidance and developing expertise vis-à-vis the municipalities. In order to maintain this task, the committee believes it is necessary to strengthen the county governors' expertise and capacity. This could be done in connection with the establishment of regional training services.

Climate change also entails a need to develop expertise outside the administration. In Chapter 9.6 "Buildings", the need for systematic communication of knowledge and transfer of experience is discussed. Chapter 10.1 "Agriculture, forestry, reindeer husbandry and wilderness-based sectors" discusses the need to integrate new knowledge of adaptation to climate change in both vocational and higher education.

16.4.1 The committee's recommendations

In order to ensure good coordination and the coordinated distribution of knowledge to decision-makers and planners, the committee recommends:

- continuation, extension and strengthening of the national secretariat role for adaptation, discussed in more detail in Chapter 15 "Adaptation to climate change at the national level"
- improvement of Klimatilpasning.no as a portal for knowledge, information and support to all parties that will be affected by climate change
- increasing resources for relevant agencies so that they may reinforce their specialist knowledge regarding the effects of climate change and opportunities for adaptation within their specialist and social areas
- strengthening training services for municipalities and other government levels through development of regional training services. The committee recommends establishment of regio-

[2] http://www.ukcip.org.uk/index.php?option=com_content&task=view&id=147&Itemid=273

nal training centres. These should be linked to educational institutions that already work with issues relevant to adaptation to climate change
- increasing resources for the development of guidelines for adaptation to climate change in the municipalities, both from the government agencies and the national coordination body

In order to enhance expertise regarding the effects of climate change and possible adaptation strategies, the committee recommends:
- including vulnerability and adaptation to climate change in relevant study programmes, for example in land-use planning, building trades and other relevant vocational educations
- measures to ensure communication of knowledge regarding climate change and adaptation to all the relevant stakeholders in the various sectors and industries

16.5 The adaptation gap must be bridged

In some areas we have not adapted properly to the current climate. Areas that are currently poorly adapted to the climate will be especially vulnerable to climate change, primarily as a result of maintenance backlog for infrastructure and buildings and inadequate protection of natural environments. The maintenance backlog and inadequate environmental sustainability constitute an adaptation deficit that must be compensated in order to achieve a society adapted to climate change.

Inadequate maintenance is not a good starting point for facing climate change and increases society's overall vulnerability to climate change. Climate change will make maintenance particularly important in the infrastructure sectors, as more precipitation and extreme weather will cause severe damage to poorly maintained buildings, roads and power supply facilities. Maintenance can act as a preventive measure to reduce vulnerability to climate change. It can help avert serious incidents, for instance in relation to pollution of drinking water, disruptions in traffic, and power supply or electronic service failures as a result of extreme weather incidents.

The adaptation deficit in natural environments is related to inadequate protection. Currently, ecosystems are being destroyed and species are becoming extinct despite politically adopted protection objectives. The natural environment thus operates with a net deficit of biodiversity in the current climate too. Climate change will increase the pressure on the natural environment, and more species and ecosystems will have problems adapting. The preservation of functional ecosystems can help reduce vulnerability and maintain the natural adaptive capacity. There is therefore a need for larger habitats and continued development of ecosystem-based management of the natural environment.

16.5.1 Maintenance of infrastructure and buildings

The maintenance backlog in infrastructure and buildings poses a major challenge for society in general, which depends on infrastructure and buildings being operational. Inadequate maintenance increases vulnerability in these sectors and thus has a major impact on society's overall vulnerability to climate change. This is discussed in more detail in Chapter 9 "Infrastructure and buildings".

There are several areas where maintenance has not been given adequate priority. The maintenance backlog is currently a problem in the transport infrastructure, water and sewage and buildings. Drainage systems in agriculture, which are of great significance for surface runoff and for retaining water in connection with extreme rainfall, are also generally poorly maintained. The committee believes the maintenance backlog is primarily related to the fact that maintaining infrastructure does not have satisfactory short-term profitability.

Compensating the maintenance backlog will be very costly for society. Multiconsult and PricewaterhouseCoopers have estimated that the maintenance backlog in the municipal sector amounts to between NOK 94 and 142 billion (Multiconsult and PwC 2008). Estimates made in 2003, suggest a backlog of NOK 340 billion for commercial buildings and NOK 210 billion for private homes (Bjørberg 2003, RIF 2010). For the road sector, the backlog has been estimated at NOK 41–53 billion (National Transport Plan 2009, Multiconsult 2009).

Continued low priority of maintenance will also have a great cost for society, and could, in extreme cases, cause loss of life. Climate change is expected to lead to greater wear and tear on structures and equipment and to lead to greater depreciation of value in that increased exposure increases the write-down rate and as a result, reduces value. Infrastructure breakdowns will also affect individuals, key functions of society (such as emergency and preparedness services) and economic growth in trade and industry. For example, closure of a major airport for a single day has great socioeconomic implications, cf.

Chapter 9.1.4. The committee therefore recommends that an increased focus on maintenance is incorporated in the national climate change adaptation efforts in order to counter this effect and maintain society's assets.

Maintenance may be costly in the short term, but saves considerable costs for society in the future. This justifies the use of financial tools, such as earmarked funds for maintenance in particularly exposed sectors such as transport infrastructure, and the protection of natural environments.

16.5.2 The adaptation deficit in the natural environment

The natural environment as a whole currently has a significant adaptation deficit. Interventions in the natural environment reduce biodiversity, habitats and the basis for natural resource-based industries. These losses are currently much higher than growth. Increased temperatures, more precipitation and ocean acidification will intensify this development. This is discussed in more detail in Chapter 7 "The natural environment".

Unlike infrastructure and buildings, we cannot repair losses in the natural environment: the loss of ecosystems and species is irreversible. The impairment or loss of natural resources and ecosystem services may have high costs for society. Nature also has an intrinsic value that society is morally and legally obliged to protect.

There are limits to the adaptation measures society can implement to assist adaptation in the natural environment. Adaptation to climate change in nature will primarily entail limiting negative impact on the existing natural environment and efforts to ensure that existing species and ecosystems can adapt to a changed climate as best as possible. What society can do mainly concerns managing land and natural resources in a way that minimises the total impact on the natural environment and ecosystems. The committee believes that this is best achieved through ecosystem-based management.

Species and ecosystems require intact and resilient habitats in order to adapt to climate change. The preservation of functional ecosystems can help reduce vulnerability and maintain, or increase, natural adaptive capacity. This can be achieved through the reduction of emissions, protection of land and restoration of nature. When new areas are to be protected or existing areas are to be extended, climate change considerations should be included in the assessment basis. There is also a need to improve protection of the most intact natural areas to secure both biodiversity and carbon storage through resilient and well-functioning ecosystems.

16.5.3 The committee's recommendations

In order to compensate for the adaptation deficit in infrastructure and buildings, the committee recommends:

- increasing political awareness and prioritising maintenance, including in national plans
- developing financial incentives that promote prioritisation of maintenance
- systematic reviews of the condition of buildings, structures and other infrastructure to gather information on vulnerability as a basis for assigning priority to maintenance as an adaptation measure
- strengthening the work on landslide/avalanche and flood protection

In order to compensate for the adaptation deficit in the natural environment, the committee recommends:

- using ecosystem-based management as the basis in all relevant sectors
- prioritising and designing protected areas that can provide species with the possibility to migrate and counteract genetic depletion
- elevating the priority of work to secure intact and resilient habitats to increase the species' and ecosystems' opportunities to adapt to climate change

16.6 Coordination must be strengthened

In an integrated approach, climate change considerations will be an integral part of policy and instrument development within all relevant sectors. At the same time, the sectors' responsibility to facilitate and implement adaptation within their areas of responsibility should be supported by coordinated efforts at the national level. There is a need for strengthened interaction and coordination both between areas of society and sectors and between various administrative levels. The committee has also identified the need for a unified and updated knowledge basis for adaptation work and stresses the importance of this knowledge being communicated to various stakeholders in a coordinated, efficient manner, as discussed in more detail in Chapters 16.3 and 16.4. Furthermore, there is a need to give both business stakeholders and government

agencies at various levels distinct policy signals on adaptation to climate change. This is discussed in more detail in Section III and in Section IV, Chapter 13. As a response to these needs, the committee has recommended measures in Chapters 16.1 to 16.5. These are cross-sector in scope and are intended to boost the sectors' and various administrative levels' capacity for adaptation. This applies, for example, to the implementation of adaptation to climate change in regulations under the Planning and Building Act, discussed in Chapter 16.1, and the development of guidelines and other tools to manage uncertainty, discussed in Chapters 16.2 and 16.4.

The committee recommends that many of these tasks be supported by national coordination work. The committee further recommends clarification of the county governor's role as an advisor, advocate and coordinator for local and regional adaptation.

16.6.1 National coordination work

The committee is of the opinion that tasks currently handled by the secretariat comprise all the main tasks for national coordination. However, the committee believes that in its current form, the secretariat lacks the resources to handle all the tasks it has been assigned. In addition, its current organisation as a project does not provide clear and predictable framework for the national coordination work. This is discussed in more detail in Chapter 15. The committee is of the opinion that the national coordination work should be established with a fixed resource framework and become a permanent agency.

The committee is of the opinion that two criteria should be met for the organisation of a national coordination function for adaptation work:

1. *Relevant expertise*. The challenge of adapting society to climate change has a very wide scope, and for this reason, the coordinating administrational body must have wide-ranging expertise. Expertise must be sufficiently broad to allow a general overview of the status, challenges and requirements in the sectors. Adaptation work is largely about planning, and planners primarily work with adaptation. The secretariat should therefore have good insight into social development, social and land-use planning, and management of the natural environment. The current secretariat has a close dialogue with the planning communities in the Directorate for Civil Protection and Emergency Planning (DSB) and the Ministry of the Environment, and this should be continued and reinforced. A national coordination body should also possess expertise regarding climate and the impacts of climate change and be able to interpret and understand the significance of research results. An important task will be analysing vulnerability to climate change in society and nature. Expertise related to mapping vulnerability and identification of possible adaptation measures will therefore be necessary.
2. *Line vis-à-vis regional and local authorities*. A large proportion of the operative adaptation work will take place in the municipal sector. A coordination body should therefore have an advisory role vis-à-vis the municipalities, and requirements should primarily be communicated to the municipalities via the county governor. It will also be necessary to communicate expectations for the county governor's work in this area.

A strengthening of the national coordination role should be followed by a strengthening of the agencies that facilitate the knowledge basis. Resources must therefore be provided to agencies with a particular responsibility to advise counties and municipalities on adaptation to climate change, primarily the Norwegian Meteorological Institute (met.no), the Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Directorate for Nature Management (DN), the Climate and Pollution Agency (KLIF), the Directorate for Civil Protection and Emergency Planning (DSB) and the Norwegian Agricultural Authority (SLF).

Sámi culture and society will be severely impacted by climate change and the committee identifies the High North, especially the areas from Finnmark County and northward, as particularly vulnerable. As a policy area, Sámi issues cross a number of sectors and administrational levels. The committee believes it is important to give Sámi interests a distinct role in adaptation work at the national level. The committee recommends that the Samediggi - the Sami Parliament (the Sámi parliament) and Sámi interests are included in the work carried out at the national level.

16.6.2 Regional coordination work

Land-use planning is one of the areas where the interaction between the authorities on the municipal, regional and level national is clearly visible. This is discussed in more detail and assessed in Section IV and in Chapter 16.1. The Planning and

Building Act emphasises the national governments' and the county authorities' duty to assist and support the municipalities' planning work. The committee has pointed out the necessity for clarity in requirements and advisory work, see Chapters 13 and 14. The committee believes there is also a need for better coordination at the regional level. The committee would nevertheless like to stress the importance of ensuring clear distribution of responsibilities and tasks between the county governor and county administration. This is discussed in more detail in Chapter 14.

In order to strengthen the regional and local adaptation work, the committee recommends that the county governor's responsibilities regarding supervision and follow-up of the municipalities' adaptation work are increased and defined more clearly. This will complement the county administrations' work on regional planning, ensure that national considerations are included in the work, and integrate considerations regarding civil protection and preparedness in regional and local adaptation work. The responsibilities should be related to the tasks the county governor already has in planning, agriculture and management of the natural environment. Work should include both guidance and supervision. The office of the county governor will have to be strengthened in order to be able to carry this out. Simultaneously, cooperation on adaptation to climate change at the county level should be strengthened by the planning forum integrating adaptation into its work.

16.6.3 The committee's recommendations

In order to strengthen coordination in adaptation work, the committee primarily recommends pursuing and strengthening the existing coordination work.

- The secretariat role for the practical coordination of adaptation policy must be strengthened. The role should be made permanent and be assigned an administrative position that provides a good foundation for this role and that is also relevant for its other activities.
- The county governor must be assigned particular responsibility for following up municipal adaptation work.

Table 16.1 Roles and responsibilities: ongoing work relevant to adaptation and the committee's recommendations

	Ongoing work relevant to adaptation	The committee's recommendations
The national level	– Ministry of the Environment, the responsible ministry – project-based secretariat: a cooperation between DSB (Ministry of Justice) and Ministry of the Environment	– Ministry of the Environment as responsible ministry – permanent secretariat role
Norwegian Climate Adaptation Programme secretariat	– knowledge of ongoing adaptation work – initiate studies on status of work on adaptation at different levels in cooperation with DSB – contact point for R&D work in and beyond government – driving force for the development of tools and methodology in vulnerability analyses – driving force and collaborator for the development of advisory material in the sectors – cooperation on adaptation with the Nordic countries, the EU and UN/UNFCCC	– expert resource that provides government bodies with advice and information – continuously update overview of work on adaptation in different sectors, counties, municipalities, etc. – devise regular national analyses of vulnerability to climate change and national status reports for adaptation – contact agency for R&D work in and beyond government – driving force and initiator for the development of tools and methodology – coordinate policy signals and reports to/from county governor – cooperate on adaptation with other countries and international bodies

Table 16.1 Roles and responsibilities: ongoing work relevant to adaptation and the committee's recommendations

	Ongoing work relevant to adaptation	The committee's recommendations
The sectors	– work on assessing climate challenges for the sector – assessment of own vulnerability in the face of climate change – the opportunity to implement measures that reduce vulnerability – evaluate new opportunities that arise as a result of climate change	– strengthen the agencies' role as adaptation adviser and knowledge provider in the area of adaptation – take the initiative for and participate in cooperation on adaptation across sectors
County governor	– follow-up of national policy in the counties – regional health, agriculture, environment and civil protection authority – coordinator of national policy signals to the municipalities – advisory and supervisory role in municipal land-use planning and approval/rejection authority with respect to municipal plans – analysis of regional challenges in terms of risk and vulnerability – guidance and supervision with municipal risk and vulnerability work	– strengthen the county governor's role as advisor, driving force, supervisory authority and coordinator for municipal adaptation work – adopt an interdisciplinary approach to work on adaptation – emphasise the coordination role regionally in relation to other government bodies – supervisory role for the municipalities' follow-up of the committee's recommendation of introducing regulations for the consideration of adaptation in the Planning and Building Act
County administrations	– regional development player – regional transport authority – regional cultural heritage authority – main responsibility for ensuring municipalities receive guidance and assistance in planning matters – approval/rejection authority as regards municipal plans – R&D work	– exploit the opportunities climate change presents for economic growth – consider climate change in regional plans – develop planning forums for an important specialist venue; strengthen the role as regional cultural heritage authority to protect cultural heritages that are vulnerable to climate change
The municipalities	– authority responsible for land-use planning and land-use management in the municipality – building application authority – responsible for civil protection and preparedness at the local level – risk and vulnerability analyses related to preparedness and preparation of plans, etc. – evaluation of climate challenges and vulnerability – network for work on adaptation	– strengthen planning capacity and expertise so adaptation is incorporated in land-use planning – integrate climate change considerations in all risk and vulnerability analyses – implement regulatory adaptation obligations in land-use planning – responsibility to survey natural hazards in own municipality – strengthen building application supervision – strengthen risk and vulnerability analyses related to existing settlements

Section VI
Financial and administrative consequences

Chapter 17
Financial and administrative consequences

The financial and administrative consequences of the committee's recommendations will depend on the details and scope of the actual measures implemented. The magnitude of public expenditure for adaptation to climate change will also depend on political priorities and ambitions in subsequent adaptation work.

The committee would like to emphasise that the actual costs of adaptation will be far higher than the costs related to the committee's recommendations. The committee's recommendations are primarily concerned with facilitating adaptation, while the costs for the actual adaptation measures will come in addition. Measures such as flood and landslide/avalanche protection, increasing the capacity of water and sewage pipes and drainage solutions will be very costly. These costs will have to be covered by both public and private stakeholders: homeowners and builders, owners and users of infrastructure, insurance customers and consumers of other services. There are particularly large costs associated with reducing the maintenance backlog. These costs also include investments for other purposes than adaptation to climate change, but at the same time, clearing this backlog is a crucial precondition to reduce society's vulnerability to climate change.

The committee would also like to stress that the actual costs of adapting society will not be equal to the expenditure through annual budgets. The actual costs must also be viewed in relation to the actual savings achieved by preventing accidents, disruptions and other damage. The committee's point of departure is a positive economic net benefit for many individual recommendations. There is also great risk that the costs will be far higher in the long term if steps are taken immediately to prevent increased vulnerability. For measures to be economically viable, the gross cost must be lower than the gross benefit of the individual measures. The costs discussed in this chapter concern the gross costs of the proposals.

There is some variation as to who carries the costs and who benefits from the committee's proposals. Many of the proposals concern beefing up, coordinating and rationalising national bodies that monitor and handle adaptation to climate change. Rationalisation and coordination are expected to reduce the total administrative costs over time. Strengthening the government administration and planning and prioritisation of knowledge and research will probably primarily be financed using public funds.

The public sector will be responsible for clearing the maintenance backlog in buildings and infrastructure, and for many buildings, the bill will probably be footed by private owners. The benefits will accrue to the users and society as a whole. The same applies to reducing the adaptation deficit in the natural environment.

The committee recommends an integrated approach to adaptation to climate change. In many cases, it is difficult to isolate adaptation from other tasks in the area. This also makes it difficult to quantify the exact costs of adaptation.

However, the cost estimates displayed below, in principle, cover the costs of integrating climate change considerations in public planning. Some of the measures to adapt society to global warming would have been implemented no matter what, either because of damage caused by natural incidents, or because there are other benefits related to implementing them; such as upgrading roads, which will provide more comfortable driving conditions and may reduce the number of accidents. This may also apply to measures to combat climate change that are already included in other plans, for example research programmes that already have been established. In practice, in many cases it is not possible to distinguish measures that would have been carried out anyway. The costs presented in Chapter 17.1 may therefore constitute more than the costs of the committee's proposals.

There is great uncertainty associated with calculating the costs of adaptation. Both the climate system and society are complex, and the relationships between impacts on the natural environment

and society are numerous and uncertain. In addition, the climate and society are continuously changing. Another problem is that we lack satisfactory, adequately detailed analyses to enable us to pinpoint and calculate exactly what it will cost to adapt, or to identify and assess all of the challenges climate change will entail for society. All analyses must therefore include presumptions based on best judgements.

17.1 Financial consequences of the individual recommendations

The committee presents ten main recommendations that are intended to help strengthen Norway's adaptation to climate change.

A comprehensive approach to adaptation

The committee proposes a comprehensive approach where the consequences for greenhouse gas emissions, pollution and the natural environment shall always be assessed when adaptive measures are planned. In particular, the increase in temperature will open up new opportunities for exploiting resources in the north, which may lead to new negative impacts on the natural environment. If we fail to achieve financial gain through a comprehensive approach, the costs will constitute lost (private and public) revenue through lower exploitation of more accessible petroleum resources, loss of revenue through reduced Norwegian transport, expenses for purification of local harmful emissions to air or expenses in the event of measures that reduce the risk of breakdowns, failure and uncontrolled emissions in areas under Norwegian jurisdiction.

The costs of reducing the environmental impact of increased tourism will be related to adaptation to regulate access and human activity, and financial loss due to a reduction in the number of visitors. The travel-related turnover on Svalbard was close to NOK 320 million in 2007 (Bjørnsen and Johansen 2008), with approximately 30 000 cruise ship tourists in 2008 (Statistics Norway 2009). The costs related to not realising financial gain to the benefit of the natural environment must be weighed against the benefit of protecting ecosystem services. The possible scope of new accessible petroleum resources, the impact on Norwegian shipping and tourism, and the financial value of various ecosystems are all very uncertain.

Management of the natural environment must have an ecosystem-based approach

This proposal entails balancing environmental values and values of ecosystem services with traditional economic values in adaptation to climate change. The costs in the short term will depend on unrealised financial revenue in the balance. Some examples are provided in connection with the previous recommendation. In the longer term, ecosystem-based management will have positive benefits in the form of prolonged and increased economic growth based on natural resources and ecosystem services, compared with a scenario where the ecosystems are not taken into consideration in management.

Adaptation to climate change must be integrated into regular social planning

This recommendation entails more efficient division of responsibilities among various public bodies and is based on several of the other recommendations. Where new areas of responsibility are established, the measure will probably involve higher gross costs. Where integration is limited to moving responsibility between institutions, the measure may entail transaction costs related to moving, while the long-term costs most likely will be reduced, based on the presumption that the proposal entails more efficient social planning.

Climate change considerations must be given higher priority in the planning system

The committee recommends increasing the priority of climate change considerations in the planning system with an earmarked scheme to strengthen planning capacity and planning expertise in the municipalities, and estimates the costs at NOK 250–300 million annually to cover the municipalities' requirements in terms of personnel, map resources, mapping and the acquisition of other planning material.

The committee furthermore proposes national responsibility for stormwater runoff and sea level rise. The actual allocation of the responsibility will be limited to increased administrative costs and personnel costs for the responsible body. The Norwegian Water Resources and Energy Directorate (NVE) has estimated the costs of assuming responsibility for stormwater and sea level rise as a result of implementation of the Flood Directive, see table 17.1. The estimate totals NOK 17 million per year.

Table 17.1 Costs in NOK million of assigning the national responsibility for stormwater and sea level rise through implementation of the Floods Directive to NVE.

	Annual additional expenses
Stormwater	11
Sea level rise	6
Total	17

Source: Norwegian Water Resources and Energy Directorate

Increased uncertainty must be addressed

Increased uncertainty as a result of climate change must trigger new risk-reducing measures through financially sound management, even if the expected value of the climate consequences remains unchanged. This assumes risk aversion, which is the usual precondition for society's preferences. In addition to the actual investments, the development of increased expertise and new tools to handle risk will entail increased personnel costs. The development of expertise is related to the strengthening of the knowledge base, discussed in item 6.

The knowledge basis must be improved through studies, monitoring and research

These proposals all recommend an increased focus on research, development and analysis activities related to climate impact, instruments and adaptation.

The committee proposes an evaluation of whether existing measurement data and monitoring programmes satisfy the requirements that follow from climate change and adaptation. The committee has estimated costs for national programmes related to five priority areas within surveying, mapping and monitoring: NOK 200 million over four years for laser scanning, NOK 20 million over four years for the development of digital land-use planning registries, NOK 30 million over four years for a series of pipeline and cable maps, NOK 50 million annually for river floods, landslides and avalanches and other natural hazard data, and NOK 7.5 million over three years for vulnerable objects. The committee also highlights the need for better data in other areas, such as biodiversity and buildings. The cost of the committee's recommendations will also include measures that have benefits for other areas beyond adaptation to climate change.

The costs of the proposals that entail increased investments through the Research Council of Norway will depend on the degree to which they may be covered under the existing plans for growth in research funding. The limits for the type of climate research that is included in the committee's proposals will be difficult to determine.

The 2008 parliamentary climate agreement defines strengthening three primary activities: environmentally-friendly energy, CO_2 processing and climate research. The combined grants through the Research Council of Norway for climate-related research, which cover all three primary activities, were almost doubled from 2008 to almost NOK 1.3 billion in 2010 (Klima21 2010 steering group). The growth from 2008 to 2010 was primarily within environmentally-friendly energy and CO_2 processing, and to a lesser degree climate research. The total portfolio for climate research is approximately NOK 300 million in 2010. Of this, the Research Council of Norway estimates that NOK 30 million is directed at research on adaptation to climate change. The budget of the Norklima programme was NOK 65 million in 2009. The need to finance climate research is under constant assessment, including in the budget process in the Norwegian Research Council. The Klima21 forum has been assigned with assessing the strategy for climate research in Norway. According to Klima21, there is a need for increased support for climate research to the amount of NOK 1 billion by 2015. The Norwegian Research Council's proposal for increased research into the impacts of and adaptation to climate change will entail an annual increase of NOK 100 million.

The Norwegian Meteorological Institute has estimated the annual costs for a Norwegian service centre for adaptation to climate change to be NOK 25 million (Hov 2009). This includes a need for NOK 20 million for maintenance and use of a national climate model system, including expert personnel and technical structure, and NOK 5 million for expert-based consultation and communication to social planners, researchers and user communities. Combined with the responsible institutions' own efforts, the committee estimates that NOK 15 million for a service centre for adaptation to climate change will ensure continuous updates of the model basis and facilitation of climate and hydrological data for research and management.

Expertise in the public administration must be improved.

Costs will be related to training services and advisory expertise. Currently, the National Emergency Planning College (NUSB) helps strengthen expertise within adaptation through courses and external training activities.

The committee estimates the annual costs for the establishment of four regional centres for the training of municipal and regional authorities to be approximately NOK 6 million.

The committee estimates the need for resources related to a strengthening of the county governor's follow-up and advisory services to the municipalities to be NOK 10–15 million annually.

The adaptation deficit must be compensated

The maintenance backlog in the road sector has been estimated at NOK 41–53 billion (National Transport Plan 2009, Multiconsult 2009). With NOK 50 billion as a starting point, the annual cost will be approximately NOK 2.5 billion with a timeframe of 20 years.

In Chapter 9.6, the committee made reference to the need to upgrade municipal buildings at a cost of NOK 94–142 billion depending on the level of ambitions (Multiconsult 2008). Approximately 60 per cent of the backlog is related to buildings, while the remainder is related to the need to upgrade water, sanitation and electricity facilities, which cannot be directly linked to climate. Using a rough estimate of the backlog of around NOK 120 billion, of which 60 per cent is related to buildings and with a timeframe of 20 years, the annual cost of clearing the backlog in municipal buildings will be approximately NOK 3.5 billion.

Upgrading private and public buildings outside the municipal sector comes in addition to this. Estimates from 2003, illustrate a maintenance backlog of around NOK 550 billion for commercial buildings and private homes (Bjørberg 2003). These figures are uncertain.

The Norwegian Water Resources and Energy Directorate (NVE) has estimated the costs of improving flood and landslide/avalanche protection. These indicate an increase in costs of around NOK 100 million annually.

The costs related to compensating the adaptation deficit in the natural environment are difficult to estimate. A stronger emphasis on ensuring intact and resilient ecosystems to strengthen the possibility of adaptation for species and natural environments will entail both negative and positive costs. These are related to measures for protection and loss of revenue from other possible exploitation of the same areas balanced against the beneficial effects of ecosystem services. These values are very difficult to estimate, cf. item 1.

Coordination of the adaptation efforts must be improved

Costs will be related to stronger coordination of the adaptation efforts, including strengthening the secretariat role to support the government in adaptation efforts. This entails costs for additional personnel, operation of the website Klimatilpasning.no, lectures, studies and reports, etc. Currently, the secretariat has an annual budget of approximately NOK 5 million for this work. Costs for strengthening the secretariat and the secretariat's tasks within coordination, distribution of information and knowledge to a sufficient degree are around NOK 10 million. The total costs for national coordination will thus increase to NOK 15 million a year.

Adaptation efforts must include international responsibility

The cost of this proposal will correspond to Norway's financial contributions to the international work on adaptation to climate change. The World Bank (2006) has estimated the annual global adaptation costs in response to climate change to be USD 75–100 billion towards 2030. The 2009 Copenhagen climate summit decided that industrialised countries shall support emission reductions in developing countries with USD 100 billion annually towards 2020 (UNFCCC 2009). Subsequent estimates carried out by the European Union indicate that approximately USD 25 billion should be spent on adaptation. This figure is far below what the World Bank has used as the basis for its calculations of actual costs.

The literature refers to a number of principles for the distribution of climate costs (Kverndokk and Rose 2008, Bruvoll 2008). In general, these are based on revenue and revenue differences. Norway's proportion of the world's GDP was approximately 0.007 per cent in 2009. Based on a rough estimate of annual support to developing countries of USD 50 billion, as a compromise between the World Bank's and the European Union's estimates and taking into account the principle that the burden should be relative to GDP and that Norway therefore contributes 0.007 per cent,

this will correspond to a contribution of close to NOK 2 billion. Assuming that the 20 richest countries are going to carry the entire cost of USD 50 billion, the Norwegian contribution increases to NOK 2.5 billion annually.

17.2 Administrative consequences

Adaptation efforts involve a number of stakeholders, sectors and all levels of government. An efficient policy for adaptation is dependent on the various areas that affect Norway's combined vulnerability being put into context and places great demands on coordination of policies. Efforts in different areas should therefore, to the greatest extent possible, focus on the common goal of reducing the Norwegian society's vulnerability to climate change.

Assigning the responsibility for stormwater and sea level rise, as well as establishing a national service centre for adaptation will have administrative consequences for the responsible institutions. Likewise, a scheme to integrate adaptation to climate change in local land-use planning and land-use management will have administrative consequences in the form of organisation of the scheme, implementation and reporting in the municipalities.

The committee recommends strengthening several existing functions and administrative units. This may have administrative consequences. The committee's recommendations for improved coordination will, for instance, involve strengthening the dialogue between various policy areas and government levels. Strengthening the central coordination role and the establishment of a permanent secretariat for adaptation to climate change has administrative consequences.

Adaptation efforts entail strict demands for constant development and updating of the knowledge basis. The responsible authorities will experience a greater need for information in order to accomplish adaptation tasks. Increased efforts in improving expertise and the dissemination of knowledge will require organisation, preparation and communication of material and procedures for evaluation.

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Annex 1

Definitions

Adaptation to climate change

Adjustments in biophysical or social systems that result from actual or expected climate effects to reduce damage or exploit opportunities. IPCC (2007) describes three types of adaptation to climate change:

Biodiversity

The variation among living organisms, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes diversity within species, at the species level and at the ecosystem level.

Capacity for adaptation to climate change

The ability of a system to adapt to climate change, including natural climate variability and extremes, to limit any damage, exploit any advantages and opportunities that arise, or cope with consequences.

Climate consequences

The consequences of climate change for society and the natural environment.

Climate forcing

Persistent difference between the energy the earth receives and the energy the earth emits at the outer boundary of the atmosphere. Climate forcing can arise due to natural reasons, for example changes in solar radiation or volcano activity, or due to human activity, for example changes to vegetation, deforestation or the emission of greenhouse gases and particles that alter the composition of the atmosphere. Climate forcing causes the climate to change until a new balance between received and emitted energy is achieved. The forcing is reduced as the climate adjusts to the new energy balance.

Climatic normals

See Normal values.

Climate projections

Are also often termed climate scenarios. These are projections of the climate for given framework conditions. The term here is related to anthropogenic climate change, and the framework conditions are thus given in the form of emission scenarios for greenhouse gases and particles. The emission scenarios provide the basis for estimating anthropogenic climate forcing – and thus anthropogenic climate change. There is uncertainty related to climate projections because a) framework conditions are uncertain, b) natural climate change and variability will occur in addition to anthropogenic change and c) the calculation methods in themselves are uncertain.

L – low climate projection

The 10th percentile of a group (ensemble) of climate projections. This entails a climate change that nine in ten projections exceed.

M – medium climate projection

The median value of a group (ensemble) of climate projections. This entails the interval that eight in ten projections are within.

H – high climate projection

The 90th percentile of a group (ensemble) of climate projections. This entails a climate change that one in ten projections exceeds.

Climate variability

Diverges from climate change in that it does not have a systematic direction. Climate variability may either be caused by varying external forces, such as volcano eruptions or variation in solar radiation, or internal variations of the climate sys-

tem. Internal variability may be caused by changes in ocean circulation or interaction between ocean and atmosphere and are often expressed as cycles, for example the North Atlantic Oscillation, NAO, or the Southern Oscillation, El Niño/La Niña. The variability most often has a regional character, but may also occur at a hemispheric, or, in some cases, at a global level.

Climate variables

Measurable and modelling quantities that describe the climate, such as air and sea temperature, precipitation, moisture, wind speed, air pressure, ocean current, sea level and wave height.

Climate vulnerability

Climate vulnerability describes society's and the natural environment's vulnerability to climate change. This includes society's capacity to cope with unfavourable climate effects, including climate variability and extremes. Vulnerability can be viewed as a function of the strength and variation of the changes/events a system is exposed to, the system's sensitivity and its capacity for adaptation to climate change. Resources that make it possible to cope with vulnerability, the distribution of these resources in various systems and the institutions that enable use of resources and coping strategies may be decisive for climate vulnerability.

Ecosystem

A dynamic complex of plants, animals and microorganisms and the non-living environment around them, that by way of interaction constitutes a functional unit. (The interaction between the living organisms and the environment).

Ecosystem-based management

An integrated management of human activities based on knowledge about the ecosystems' dynamics to achieve sustainable use of products and services from the ecosystems, and to maintain the ecosystems' structure, functionality and productivity.

Emission scenario

Projections of man-made emissions of greenhouse gases and particles that affect the climate. They are based on perceptions of demographic, economic and technological development. There are many different emissions scenarios. The most important, used in the third (2001) and fourth (2007) reports from the UN climate panel, have the following primary characteristics:

Scenario B1: Global solutions to economic and social sustainability. Rapid changes in economic structures and the introduction of clean technology. Seven billion people in 2100. CO_2 content of atmosphere is 540 ppm in 2100, as opposed to 390 ppm today (ppm is parts per million).

Scenario A1B: Rapid economic growth. Rich world, but unevenly distributed. 7 billion people in 2100. Technological developments lead to balance between fossil and non-fossil energy technology. CO_2 content of atmosphere is 703 ppm in 2100.

Scenario A2: Divided world with high population growth and less concern for rapid economic development. 15 billion people in 2100. CO_2 content of atmosphere is 836 ppm in 2100.

Equilibrium line

An imaginary elevation line on a glacier where there is a balance between accumulation (growth) and ablation (melting) of snow and ice. If the equilibrium line is elevated due to climate change (for example, due to increased summer temperatures), the lowest parts of the glacier, or the entire glacier, may disappear.

Example projections

Selected climate projections that have been post-processed in that they have been adjusted in accordance with climate observations and terrain.

Exposure

The character, scope and degree of the effect of climate change on the natural environment and society.

External climate forcing

See Climate forcing.

Extreme precipitation

Precipitation values that, during an extended period, can be expect to occur once during a n-year period, for example once during a 100-year period (*100-year value*).

Growing season/growing degree days

There are numerous definitions. The definition used in this report is the number of days per year with an average temperature above 5 °C. For a day in the growing season, *growing degree days* is the average temperature minus 5 °C.

Hydrology

Science that deals with the processes governing the depletion and replenishment of the water resources of Earth's land areas, and treats the various phases of the hydrological cycle.

Natural climate change

See Climate variability.

Normal values

Mean values of meteorological and hydrological variables for specific 30-year periods. In accordance with an international agreement, the standard normal periods are 1901–30, 1931–60, 1961–90, 1991–2020, etc. These have been defined in order to allow comparisons of median values for the same periods all over the world.

Planned adaptation to climate change is adaptation that is a result of conscious political decisions, based on an understanding that the climate has changed or will change, and that action is required to return to, maintain or achieve a desired state.

Polar low pressure

Low pressure that is often created in the transition between sea ice and open sea at high latitudes. Polar low pressure areas are usually small in extent, have a short lifetime, are difficult to forecast and can be very intense and dangerous. Occurs in the northern Norwegian Sea and the Barents Sea, often in the area between Svalbard and continental Norway.

Proactive adaptation to climate change is adaptation that takes place before the consequences of climate change occur (advance adaptation, precautionary adaptation).

Resilience

A characteristic of systems related to flexibility, robustness and capacity to recover key functionality following sudden (non-linear) climate change or threshold leaps.

Return level

See Return values.

Return values

Values that on average are exceeded with a defined frequency. A five year return value for precipitation is the precipitation value that on average is exceeded once during the course of a five-year period. Correspondingly, 100-year return value for a storm surge means that a storm surge of a defined size will occur on average once every 100 years. Note that return values do not represent the worst conceivable scenario for e.g. precipitation or storm surges in the stated period, as it is fully possible for higher levels to occur.

Risk

Risk is understood as a combination of the probability of an undesired incident and the possible consequences of the incident.

Runoff

That part of precipitation that flows towards the stream on the ground surface (surface runoff) or within the soil and rock (subsurface runoff or interflow). Normal units are mm or $ls^{-1}km^{-2}$.

Short-term precipitation

Describes precipitation volumes during periods ranging from minutes to a few hours. The precipitation volumes one must expect in such short periods are important for the scaling of infrastructure, for example water and sewerage networks.

Soil moisture

Expression for the volume of water in the layer of soil between the groundwater table and the surface. The maximum volume of water that can be retained in this layer of soil is called field capacity. The difference between the soil's actual water content and the field capacity is called the soil moisture deficit.

Species – indigenous, non-indigenous and invasive

Those species that naturally exist in Norway are usually termed indigenous. Species that have arrived in the country by way of a human agent are termed alien species. Some of the alien species are strong competitors and displace indigenous species. These are termed invasive species.

Spontaneous adaptation to climate change is adaptation that doesn't constitute a conscious response to climate change, but is triggered by ecological changes in natural environments or by e.g. market forces or welfare changes in the social systems. Is also called autonomous adaptation or reactive adaptation if the adaptation is triggered by a climate-related event (for example a flood, slide or drought).

Spring tide

Strengthened tides at full moon and new moon. Caused by the combined gravitational effect of the sun and the moon on the sea level. Occurs approximately every fortnight. Also see Storm surge.

Storm surge

Tides that are strengthened due to low pressure effects. Both low atmospheric pressure and the forcing of water towards the coast due to strong wind may contribute to storm surges. Also see Spring tide.

Streamflow

The water that flows in a river or stream, defined as the volume of fluid flowing through a cross-section of a stream per unit time. Common units of measurement are m^3s^{-1} or ls^{-1}.

Sustainable development

Sustainable development is development where current human needs are satisfied without destroying the possibility for future generations to satisfy their needs.

The High North

There are many different definitions of the High North. According to NOU 2003:32, *Mot nord!* [Northwards!], the High North comprises the entire circumpolar Arctic region, including the Barents region and the Barents Sea area. The circumpolar Arctic region is the land area north of the Arctic Circle and somewhat further south in marine areas. With respect to Norway, this definition of the High North will comprise Nordland, Troms and Finnmark counties.

The Norwegian Arctic

The Norwegian part of the Arctic is defined as Svalbard, Jan Mayen and the continental land mass north of the Arctic Circle. A smaller area south of the Arctic Circle is also included for practical reasons. This includes Saltfjellet-Svartisen national park and the whole of Rana municipality. For maritime areas, the ice-covered parts of the Barents Sea, the Norwegian Sea and the Greenland Sea around Jan Mayen are defined as the Norwegian Arctic.

According to international definition, the entire area of Nordic oceans (the Iceland Sea, the Greenland Sea and the Norwegian Sea) and the entire Barents Sea up to the Arctic.

The Norwegian Black List

List of alien species in Norway that are assessed in relation to ecological risk and classified in accordance with high, low or unknown risk, published by the Norwegian Biodiversity Information Centre.

The Norwegian Red List

A list of species that are considered to be under threat in Norway, published by the Norwegian Biodiversity Information Centre.

Tipping point

Describes a strong and/or sudden change of one/several climate variables or biological variables where one following the tipping point enters a state that one cannot predict in advance.

Tropical day

A period of 24 hours where the maximum temperature is above 30 °C and the minimum temperature does not fall below 20 °C.

Uncertainty

An expression of how unknown a value is, for example a future climate. Uncertainty may be due to inadequate information or disagreement on what is known or not possible to know. The sour-

ces of uncertainty may be due to quantitative errors in data, vague concepts and terminology, inadequate knowledge or uncertain projections of human behaviour. Uncertainty may therefore be presented as quantitative measures or through qualitative explanations.

Vulnerability

See Climate vulnerability.

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