NORWEGIAN MINISTRY OF
CLIMATE AND ENVIRONMENT

Meld. St. 33 (2012–2013) Report to the Storting (white paper)

Climate change adaptation in Norway

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Translation from Norwegian. For information only.

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Recommendation of 7. May 2013 from the Ministry of the Environment, approved in the Council of State the same day.
(White paper from the Stoltenberg II Government)

Summary

Norway's long coastline and wide mountain ranges extending right up to the Arctic mean that the country is extremely exposed to wind and weather. The climate and weather conditions affect practically every sector of society and are an important element of most people's daily lives. Norwegians are used to taking weather conditions into account and have adapted to climate variability over the centuries.

Over the past 100 years, the Norwegian climate has become warmer and precipitation has increased by about 20 %. These trends are expected to continue. It is estimated that the annual mean temperature in Norway will rise by between 2.3 and 4.6 °C by the end of this century relative to the period 1961–90. Similarly, it is estimated that precipitation may rise by between 5 and 30 %, and projections also indicate an increase in intense precipitation events, which will in turn increase the risk of certain types of flooding and landslides and avalanches.

The severity of the impacts of climate change on the environment and society will depend both on how much the climate changes and on society's adaptive capacity and willingness to factor climate change into planning and take active steps to adapt to change. The present white paper focuses on the challenges associated with climate change and how Norway can become more resilient in the face of climate change.

Everyone is responsible for climate change adaptation – individuals, business and industry and the authorities. This is not a new responsibility, although its substance is described more specifically in the present white paper. The white paper gives an account of what the authorities are doing to enable everyone to take their share of the responsibility for climate change adaptation as effectively as possible, and sets out a common framework for climate change adaptation across sectors and administrative levels.

A preliminary framework for the authorities' work in this field was first set out in the 2009 budget proposal, which focused particularly on reviewing Norway's vulnerability to climate change, developing the knowledge base, coordinating adaptation initiatives and awareness raising. In response to this, a national assessment of the impacts of climate change on Norway has been produced and published as an Official Norwegian Report, Adapting to a changing climate (NOU 2010: 10). Research efforts have been intensified, and a range of capacity- and competence-building measures have been implemented, especially at municipal level. Many authorities in different sectors and a large number of municipalities have already made a good start on adaptation efforts.

Climate projections are an important basis for society's adaptation to climate change. As a precautionary approach, the Government wishes

assessments of the impacts of climate change to be based on figures from the high end of the range of national climate projections. However, when decisions are made in individual cases, climate change considerations and underlying assumptions about the degree of climate change must be weighed against other considerations of the public interest, the lifetime of the development in question and its importance to society.

Knowledge is essential for effective climate change adaptation – both knowledge about climate change and its impacts, and knowledge about how Norwegian society is adapting to climate change. Adaptation work must always be based on the best available knowledge about climate change and how the changes can be addressed. The Government therefore intends to ensure that the knowledge base for climate change adaptation is strengthened through closer monitoring of climate change, continued expansion of climate change research and the development of a national centre for climate services.

Adaptation policies and measures should build on the best available knowledge. The Government therefore plans for regular updates of knowledge about the impacts of climate change and vulnerability and of assessments of adaptation needs in Norway. Updates will be considered when substantial new knowledge is available, particularly related to the assessment reports of the Intergovernmental Panel on Climate Change (IPCC).

Climate projections indicate a trend towards more, and more intense, precipitation in Norway, which will result in more stormwater runoff in urban areas, which may result in urban flooding. Figures for insurance claims show that stormwater is already causing a great deal of damage, and this is increasing, particularly in towns where population density is high. Higher precipitation in the future is expected to exacerbate these problems. The municipalities are responsible for stormwater management, and will have to deal with increasing volumes of stormwater as a result of climate change. The Government will therefore appoint a committee to evaluate the current legislation and as appropriate make proposals for amendments to provide a better framework for the municipalities.

Sea level rise associated with climate change may lead to new challenges in some areas. Individuals, private companies, public bodies and local and central government authorities all have a responsibility for taking steps to safeguard their own property. Under the Planning and Building Act, the municipalities are responsible for ensuring that natural hazards are assessed and taken properly into account in spatial planning and processing of building applications. This includes the responsibility for taking sea level rise and the resulting storm surges into account.

In certain geographical areas, climate change may result in a higher risk of damage caused by natural disasters. Norway has good public and private insurance schemes for insurance against such disasters. The Norwegian model provides major benefits for society, since it gives effective protection against the financial risk associated with extreme weather events.

The local character of the impacts of climate change puts the municipalities in the front line in dealing with climate change. Higher precipitation levels and more intense precipitation will require efficient systems for stormwater management in towns, where there are large areas of impermeable surfaces such as roads and pavements. Challenges will also arise in connection with the development of port facilities and densification of urban areas. To enable the municipalities to ensure that Norwegian communities are resilient and sustainable in the future, adaptation to climate change must be made an integral part of municipal responsibilities. The Government therefore intends to draw up central government planning guidelines describing how the municipalities and counties should integrate climate change adaptation into their land-use and general planning processes. The new guidelines on adaptation will be incorporated into the existing guidelines for climate change mitigation and energy planning.

Information resources, networks for sharing experience, and cooperation with regional authorities will play an important part in climate change adaptation work at municipal level.

1 Introduction

Climate change is already happening: environmental change is being observed on all continents and in all the major oceans. The climatic changes that have been observed over the past 150 years cannot be explained unless anthropogenic greenhouse gas emissions are taken into account. The combustion of coal, oil and gas has generated large volumes of carbon dioxide (CO_2). These releases, combined with greenhouse gas emissions from deforestation and forest degradation and other sources, have resulted in an increase in atmospheric greenhouse gas concentrations. According to the Intergovernmental Panel on Climate Change (IPCC), the rise in greenhouse gas concentrations is the main cause of global warming, which in turn results in climate change. Climate change has impacts on the natural environment and major consequences for most sectors of society.

The severity of the impacts of climate change on the environment and society will depend on how much the climate changes, and also on society's adaptive capacity and willingness to factor climate change into planning and take active steps to adapt to change. Most studies of the possible impacts of climate change are based on the assumption that society will adapt to a rise of 2–3 °C in global mean temperature towards the end of this century. Relatively little is known about adaptive capacity in the event of a larger rise in temperature, for example 4–6 °C. The IPCC stresses that there is a high risk that both natural and human systems will sustain substantial losses and damage if the two-degree target is not met.

The policy set out in the present white paper is based on the premise that the climate is already changing. Despite ambitious national and international policies to cut greenhouse gas emissions, the temperature will continue to rise until 2100. It is therefore necessary to prepare society for the expected effects of unavoidable climate change. This white paper focuses on the challenges associated with climate change, and the policy instruments it proposes are designed to make Norway more resilient in the face of climate change.

Climate change will have a variety of impacts on natural and human systems. Nature is constantly changing as a result of the natural variability of the climate system, but the pace of climate change is now so rapid that it will be difficult for many species and ecosystems to adapt. Moreover, many species and ecosystems are already under pressure for other reasons, such as habitat loss and fragmentation, pollution, overharvesting and the introduction of alien species. A large number of animal and plant species are included on the Norwegian Red List because their survival in Norway is threatened. Species that live in Arctic and mountain areas are adapted to a cold, harsh climate, and are already established as high up or as far north as possible. There is no alternative habitat for them to move to. This means that the very survival of species such as the polar bear and ringed seal is threatened. There is little that can be done to counteract this once global warming has happened. The most important means of ensuring the survival of Arctic and alpine species is therefore to cut greenhouse gas emissions. We need to recognise the likelihood that Norway will lose some species as a result of climate change, and that new species will become established. The report Adapting to a changing climate (NOU 2010: 10) indicates that climate change will make it an even more challenging task to protect Norway's species and habitats.

Box 1.1 The two-degree target

Norwegian climate policy is based on the target of limiting the average rise in global temperature to two degrees Celsius, which practically every country in the world has adopted. In order to achieve this global target, the international community will have to take a more proactive approach than is the case today, and make a more rapid transition to a society with far lower greenhouse gas emissions around the middle of this century. Even if the two-degree target is achieved, the IPCC expects climate change to have major impacts on nature and society.

More frequent and more severe extreme weather events, such as heat waves, storms and flooding, can be a severe test for society, as Norway has experienced several times in recent years. Figures for insurance claims show that stormwater is already causing a great deal of damage, and this is increasing, particularly in towns where population density is high. Higher precipitation in the future is expected to exacerbate these problems. Norway seeks to maintain high safety standards and ensure that people can feel safe in their homes and elsewhere. Climate change will entail a higher risk of landslides and flooding caused by intense rainfall and problems resulting from stormwater in built-up areas, so that people will face a constellation of risks different from that they are used to dealing with. Areas that have previously been viewed as safe may become more vulnerable.

Climate change and social change are taking place simultaneously, and social change will influence our vulnerability to climate change, particularly in towns. A growing proportion of the Norwegian population lives in urban areas, and the growth of Norwegian towns is expected to continue. All Norway's largest towns are either on the coast or near lakes and rivers. Higher and more intense precipitation will require more efficient systems for stormwater management in towns. Because of sea level rise, challenges will also arise in connection with the development of port facilities. Moreover, there is a great deal of infrastructure in urban areas – buildings, roads, railways, sewerage systems and other structures. Infrastructure will be vulnerable in areas where climate change brings more intense precipitation and a higher probability of local flooding caused by heavy rainfall. The electricity grid and ICT infrastructure are more heavily used in densely populated areas, and therefore more vulnerable to unforeseen incidents. Disruption of the electricity supply or ICT services can have greater consequences for more people in a town. Infrastructure is also essential for the business sector and thus for value creation and workplaces.

Because the business sector is so varied, there will also be wide variation in how climate change affects earning power and profitability. Business also has a vital role to play in Norway's transition to a low-emission economy and in taking into use equipment and production methods that are adapted to a changed climate. In addition, the business sector provides products and services that will play a large part in determining the resilience of Norwegian society to a changed climate.

Climate change will have direct impacts on the primary industries and other sectors that are closely linked to the natural resource base. For example, new plant and animal diseases may reduce agricultural productivity. Higher precipitation is also expected to give more difficult growing and harvesting conditions for agriculture. On the other hand, a milder climate with more rainfall and a longer growing season may make it possible to increase crop production and cultivate new species that are generally grown further south today.

Rising sea temperatures may make it difficult for species that are adapted to cold water to survive, or cause them to shift their distribution northwards. Norway is surrounded by clean, cold fjords and coastal waters, which puts the Norwegian aquaculture industry in a uniquely favourable position in Europe. Rising sea temperatures could therefore have major impacts, both negative and positive, on current production patterns. However, the fisheries and aquaculture industries are used to adapting to wide natural variations in sea temperature and in the size of fish stocks.

When CO_2 comes into contact with water, carbonic acid is formed. This process is causing ocean acidification, which may have major impacts on marine life. The basic link between greenhouse gas emissions and ocean acidification is understood, but it is still very uncertain what acidification will mean for algae, other plants and animals and thus for marine ecosystems as a whole. Little is known about how the fisheries and aquaculture industries will be affected.

Changes in precipitation patterns will put pressure on the electricity infrastructure. Hydropower dams and transmission and distribution grids must be sufficiently robust to withstand new weather patterns. On the other hand, higher precipitation may make it possible to increase electricity production, resulting in higher earnings in the future.

In our part of the world, climate change is most marked in the Arctic, where the temperature is rising about twice as fast as the global mean temperature. If the trend that has been observed in the Arctic in recent years continues, it will have major consequences for the population and communities in the region, and particularly for indigenous peoples, whose culture and livelihoods are closely linked to the natural environment.

World food production is vulnerable to climate change. The IPCC's Fourth Assessment Report from 2007 highlights the risk of crop damage and reduced crop productivity. Food production by the fisheries and aquaculture industries may also be

affected. At the same time, the Food and Agriculture Organization of the United Nations (FAO) has warned that by 2050, food production must be almost doubled to feed the growing population. There is already a lack of clean drinking water in many parts of the world. Climate change is expected to make water shortages more severe in dry areas. In other areas, flooding may cause drinking water quality to deteriorate. Rising sea levels are threatening low-lying areas and small island states. These trends will exacerbate many of the problems poor countries and people are already facing. The IPCC has pointed out that a great deal can be done to reduce risk through adaptation and preventive measures.

The UN Secretary-General has repeatedly spoken about climate change as a threat to continued growth and development in developing countries. The white paper Towards greener development (Meld. St. 14 (2010–2011) states that Norway will continue to facilitate adaptation by developing countries to unavoidable climate change. Adapting to a changing climate (NOU 2010: 10) concludes that climate change in other parts of the world will largely have an indirect impact on Norway, linked to Norway's responsibility to support the poorest and most vulnerable countries in their efforts to adapt to a changing climate. Although the impacts of climate change outside Norway are not dealt with here, the possible implications for poor countries and people nevertheless form a backdrop to the present white paper.

Climate change adaptation involves recognising that the climate is changing, understanding the impacts, and taking steps either to prevent damage or to make use of opportunities that may arise. According to Adapting to a changing climate (NOU 2010: 10), Norway is in a good position to deal with climate change and its impacts, but if we are to maintain a safe and secure society in the future, we must incorporate climate change adaptation into planning processes today.

The present white paper is intended to provide a brief general account of the implications of climate change for Norwegian society and to set out a framework that will facilitate the development of adaptation strategies and identification of effective adaptation measures by all those who are affected by climate change.

The white paper starts with a brief account of the impacts of climate change in Norway and of current adaptation policies in the sectors that are most directly affected. It then provides the general policy framework for adaptation in Norway across sectors.

Box 1.2 Norwegian climate policy

The Government's aim is for Norway to become a low-emission economy by mid-century. The most important cross-sectoral climate policy instruments are taxes, emissions trading and the Pollution Control Act. In addition, a series of regulatory measures and schemes for individual sectors are intended to encourage the transition process and cut greenhouse gas emissions.

Norway has been pursuing an ambitious climate policy for a number of years. In April 2012, the Government presented a new white paper on Norwegian climate policy (Meld. St. 21 (2011–2012)). This focused on how Norway can contribute to cuts in greenhouse gas emissions, both in Norway and internationally. The Government also announced that it would strengthen policy instruments for the petroleum sector and establish a new climate and energy fund. The transport sector is to be made more climate-friendly by giving priority to public transport, cycling and walking. The measures set out in the climate policy white paper will also intensify efforts in several other areas to reduce Norway's greenhouse gas emissions. In addition, it includes measures to enhance the carbon stock in forests. Most of the political parties concluded a new agreement on climate policy in June 2012, thus ensuring that Norwegian climate policy continues to be predictable and have a long-term perspective.

The United Nations Framework Convention on Climate Change (UNFCCC) provides the framework for international efforts in this field. Its ultimate objective is to stabilise greenhouse gas concentrations at a level that will prevent dangerous anthropogenic interference with the climate system. The 2012 white paper on climate policy states that the Government will work towards an ambitious, broad-based climate agreement that includes specific emission reduction commitments both for developed countries and for major developing countries, and that is in line with the two-degree target.

The report Adapting to a changing climate, which describes the impacts of climate change in Norway and the need for adaptation, has been an important basis for this white paper. Almost one hundred responses were received during the consultation process after the report was published, and they also provided important input for the white paper.

2 The climate and climate change in Norway

2.1 The present climate and historical climate variability

Norway's long coastline and extensive mountain ranges make the country vulnerable to the forces of nature. There has always been considerable climate variability in Norway, and the climate has important consequences for society. The climate is milder in Norway than in other areas at the same latitude, mainly because the Gulf Stream transports warm water northwards along the Norwegian coast. Prevailing south-westerly winds carry warm, moist air towards the coast, particularly in winter, when low pressure systems are normally a common phenomenon. However, Norway can also experience cold, dry winters, as it did for example in 1995–96 and 2009–10.

Measurements of temperature, precipitation and wind show wide variation between years and between decades. This is mainly due to natural variability in the climate system. To see how the climate changes over time, it is necessary to define reference periods. These are internationally defined 30-year periods for calculating climate «normals». The current climate normal period is 1961–90. Discussions of how much the climate has changed are often based on temperature, precipitation and wind data for this period.

Box 2.1 The North Atlantic Oscillation (NAO) has a strong influence on Norway's weather

The weather in Norway varies considerably from year to year. Whether the winters are mild and stormy or relatively cold and dry is linked to natural variability in the atmospheric circulation over the North Atlantic. This pattern of variability is known as the North Atlantic Oscillation (NAO), and is an important factor behind the wide natural fluctuations from year to year in wind, temperature and precipitation throughout mainland Norway.

Precise observations of temperature and precipitation from all parts of Norway are available from the late 1800s onwards. On the basis of these observations, we can conclude that mainland Norway has warmed by about 0.8 °C in the past 100 years, which is in line with the rise in global mean temperature in the same period. The greatest rise in temperature has taken place in the most recent decades. Since the normal period 1961–90, the growing season has become one to two weeks longer in most parts of Norway. The areas that experience hot days, defined as days when the daily mean temperature is above 20 °C, have expanded considerably.

Box 2.2 Natural climate variability since the last Ice Age

After the end of the last Ice Age a little more than 11 000 years ago, there was a warm period in Norway when summer temperatures were probably 1.5–2 °C higher than the normal for 1961–90. This allowed pine trees to grow on parts of the Hardangervidda mountain plateau that are now above the treeline. There were also periods during the Middle Ages when Scandinavia had a generally mild climate, which allowed people to settle in Greenland. During the Little Ice Age in the mid-1700s, most Norwegian glaciers advanced to their greatest extent for several thousand years. The warm period during the Stone Age was caused by variations in the position of the Earth relative to the Sun. The warm period during the Middle Ages and the cold period a little less than 300 years ago were probably related to variability in solar activity and the frequency of major volcanic eruptions. Much of the natural climate variability is apparent at the regional rather than the global scale. For example, the warm medieval period was most marked at northern latitudes, while the tropics were probably not much warmer than they are today.

Norway's climate is also wetter than it used to be. Annual precipitation has risen by about 20 % since 1900, with the steepest rise after 1980. Over the most recent 20 years, there have only been four years when annual precipitation was lower than the normal value for 1961–90, whereas in the first 20 years of the period (1900–20) there was not a single year when annual precipitation was higher than the current normal level. Precipitation has risen most in winter, by about 17 % relative to 1961–90. In the wettest parts of Western Norway, winter precipitation has risen by 25 % in the same period.

2.2 The climate of the future – climate projections for 2050–2100

Climate models are used as a basis for computing projections of how temperature, precipitation and wind may change towards the end of this century. The model simulations include a number of different values for model variables and a range of other assumptions. The results of the simulations are analysed and used as a basis for projections. The projections that are presented below are based on a compilation of a large number of different projections and a combination of different scenarios for global greenhouse gas emissions.[1]

Temperature

All climate projections indicate that the climate will become warmer in all parts of Norway and in all seasons during this century. It is estimated that the annual mean temperature in Norway will rise by 2.3–4.6 °C towards the end of the century relative to the value for the normal period 1961–90. The temperature rise will be largest in inland areas, North Norway and Svalbard. There is considerable uncertainty associated with such projections, and the temperature changes may be either larger or smaller than the interval quoted here.

Growing season, snow cover, glaciers

The growing season in Norway, defined as the number of days when the mean temperature is above 5 °C, is expected to become considerably longer during this century. Projections show an increase of one to two months in much of the country and two to three months in some upland areas.

The duration of snow cover will decrease throughout Norway up to 2100. Figure 2.2 shows that the greatest changes are expected in low-lying areas, where some projections indicate that the length of the snow season will decline by two to three months. This means that there will be many years with hardly any snow in the lowlands, but still certain years with considerable amounts of snow. In the mountains and inland parts of Finnmark county, the average maximum snow depth may increase until mid-century as a result of higher winter precipitation, and thereafter decline.

Glaciers fluctuate in size because of variability in summer temperatures and winter precipitation. Inland glaciers in Norway, for example in the Jotunheimen mountains, will probably continue to retreat as summer temperatures rise. Trends for coastal glaciers are driven more by changes in winter precipitation, and they will continue to advance as long as snowfall in winter exceeds ice melt in summer. By 2100, more than 90 % of all Norwegian mainland glaciers may have disappeared, and the total area of glaciers may have declined by 30–40 %. These figures are based on mean values for temperature projections.

Precipitation

Annual precipitation for the country as a whole is expected to rise. Projections indicate a rise of 5–30 % in annual mean precipitation by 2100 relative to the period 1961–90. The mean projections for Norway as a whole indicate a rise of about 20 % in autumn, winter and spring, and about 10 % in summer. Mean projections for different regions indicate that autumn precipitation will rise by more than 25 % in all coastal areas from the southernmost tip of Norway to western Finnmark. They also indicate a 25 % increase in winter precipitation in Eastern Norway and inland areas of Nord-Trøndelag and Sør-Trøndelag counties. Summer rainfall in Eastern and Southern Norway may decrease somewhat, while it may increase by about 20 % in Nordland county.

[1] I. Hanssen-Bauer, H. Drange, E.J. Førland, L.A. Roald, K.Y. Børsheim, H. Hisdal, D. Lawrence, A. Nesje, S. Sandven, A. Sorteberg, S. Sundby, K. Vasskog and B. Ådlandsvik (2009) Klima i Norge 2100. Bakgrunnsmateriale til NOU Klimatilpassing, Norsk klimasenter, September 2009, Oslo. (The Climate in Norway in 2100. Background material for Official Norwegian Report on climate change adaptation. In Norwegian only.)

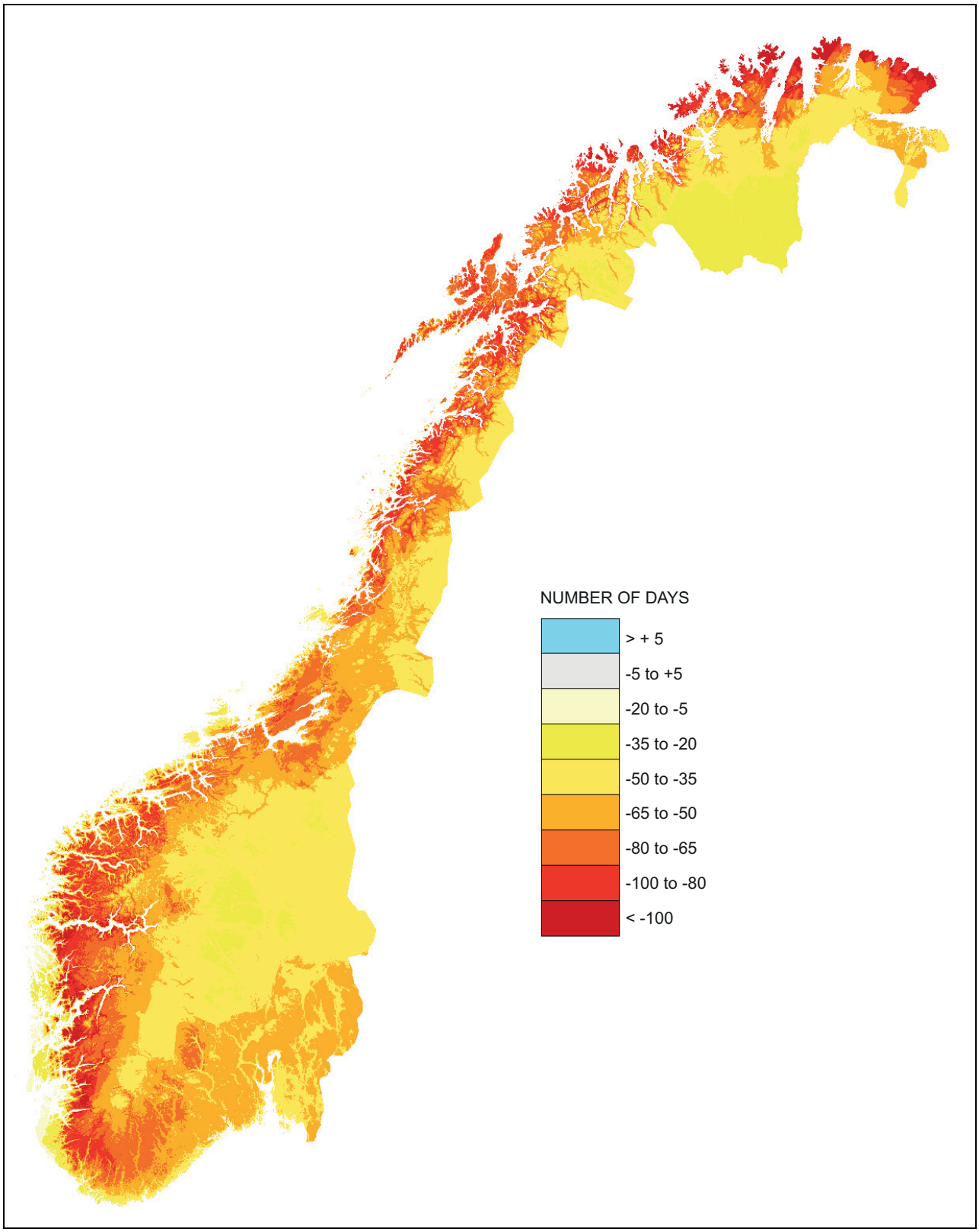

Figure 2.1 Map showing projected changes in the number of days of snow cover in Norway, 2071–2100[1]

[1] Example of a projection based on emissions scenario B2 (IPCC, SRES B2, medium global growth in emissions) and the global climate model ECHAM/MPI (relative to the normal period 1961–90).

Source: Norwegian Water Resources and Energy Directorate and Norwegian Meteorological Institute, 2013

There are large differences between the upper and lower limits of the range of precipitation projections throughout the country. The mean projection indicates a trend close to that observed during the 20th century, while the high projection is closer to the trend we have observed over the past 20–30 years. In many areas, the high projection indicates a rise of more than 50 % in autumn, winter or spring precipitation.

The projections show that the number of days of heavy precipitation will rise during this century, and that the amount of precipitation that falls on such days may also rise. This applies to all seasons and all regions. The models do not provide enough detail for calculations relating to heavy showers, but the results nevertheless indicate that the frequency of heavy rain showers may rise in the future. This may increase the risk of thunderstorms and lightning strikes.

Drought

Higher temperatures, increased evaporation and the possibility of lower rainfall in summer may result in longer periods of low flow in rivers, and soil moisture and groundwater deficit. This may in the longer term lead to problems with drinking water supplies and agriculture in certain parts of Norway. Summer droughts may increase the need for irrigation and the risk of forest fires.

Flooding

Changes in precipitation and temperature patterns will also result in changes in flooding patterns in Norway. With higher temperatures, spring floods will occur earlier, while lower snowfall will result in smaller snowmelt floods in the larger rivers. When more precipitation falls in the form of rain instead of snow, flooding in late autumn and winter may become more frequent. In those parts of the country where the largest floods are caused by rain, floods will become more severe. More frequent intense rainfall may cause particular problems in small, fast-flowing rivers and streams and in urban areas.

Landslides and avalanches

There are many different types of landslides and avalanches, and the causal relationships between these events and climate change are more com-

Figure 2.2 Concrete avalanche defence, Hardanger municipality

Photo: Stig Tronvold/Samfoto/NTBscanpix

plex than those between flooding and landslides and avalanches. However, there is a clear link between precipitation, temperature and wind conditions, and different types of avalanches. Higher temperatures will reduce the risk of dry snow avalanches at altitudes below 500–1000 metres, but may increase the risk of wet snow avalanches and slush flows. A higher frequency of intense precipitation events may also increase the risk of landslides and flood-related debris flows. Quick clay slides can also be triggered by prolonged intense rainfall and river erosion, although in most cases they are triggered by human activity. Changes in precipitation patterns may also increase the risk of landslides and avalanches in areas that have not suffered from them previously.

Wind

Climate models show little or no change in average wind conditions in Norway up to 2100. However, there are indications that high wind speeds may become more frequent.

Waves

A few studies have been conducted of future wave conditions based on selected climate projections. These show relatively small changes along the Norwegian coast, with the exception of the North Sea and Skagerrak. Here, it is estimated that the significant wave height of the most extreme waves will increase by 6–8 %. Because of systematic weaknesses in the models, it is not yet possible to draw any conclusions about how wave conditions may change in the Barents Sea.

Sea temperature

There have only been a limited number of studies involving modelling of changes in sea temperature in Norwegian waters. It has been estimated that the annual mean temperature of the North Sea may rise by 1.5–2 °C.

Ocean acidification

Since the beginning of the industrial era, the oceans have absorbed about 40 % of the CO_2 emissions from fossil fuel consumption and cement production. This is making the world's seas more acidic. The rate of acidification varies from one part of the world to another, and is more rapid at high latitudes, because CO_2 dissolves more readily in cold water. The current global climate models show that acidification is most rapid where seawater temperatures are lowest, i.e. in the polar regions.

Acidification is a direct result of the higher atmospheric concentration of CO_2, and is taking place independently of the greenhouse effect and global warming. Changes in circulation patterns in the oceans and atmosphere, and stratification in the oceans, influence uptake of CO_2 in seawater and the degree of acidification in different areas.

The pace of ocean acidification is closely related to trends in CO_2 emissions to the atmosphere. Studies show that in Norwegian waters, pH can be expected to drop by more than 0.5 units by the end of this century. The chemical processes that result in acidification are clearly understood, but less is known about what impacts acidification will have on marine ecosystems.

Sea-level rise

Global sea level has risen by about 17 cm in the past 100 years. In a longer perspective, global sea level has risen by 120 metres since the last glacial maximum about 20 000 years ago, but has been more or less stable for the past 4 000 to 5 000 years. Despite this, most of the Norwegian coast has experienced a net drop in sea level since the last Ice Age. This is because the land surface has been rising considerably after the Fennoscandian ice sheet melted around 11 500 years ago, so that the crust was no longer depressed by the weight of the ice and could slowly rebound.

Global mean sea level is now rising by about 3 mm per year. In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) presented 18–56 cm as a possible range of global average sea rise up to 2100. However, these figures do not capture the full effect of melting of the major ice sheets on land. This is a weakness of the underlying data, particularly since more recent studies show that the Greenland ice sheet seems to be melting more rapidly than previously assumed. The estimates of sea-level rise up to 2100 are very uncertain, primarily because it is uncertain how rapidly glaciers and the large ice sheets in Greenland and Western Antarctica are likely to melt.

3 Impacts of climate change on nature and society

Climate change will affect everyone, but the severity of its impacts will vary from one part of the world to another. There will be wide geographical variations within Norway as well. In addition, the impacts of climate change will vary between sectors. Much of Norway's infrastructure is vulnerable to wind and weather. All biomass-based products (food, fodder, fuel, chemicals and so on) are derived from the natural environment, which also provides many other essential ecosystem services.

Many infrastructure assets, such as roads, railways, ports and breakwaters, the electricity grid and buildings, have long operational lifetimes. The average lifetime of buildings in Norway is 78 years. Many of the buildings being constructed now will therefore still be standing towards the end of this century, and will need to be resilient to changes such as an increase in the intensity of precipitation. The adaptive capacity of human societies depends strongly on how they are organised, the resources, tools and data at their disposal, and the available knowledge on climate change. The adaptive capacity of society is also important for understanding the impacts of climate change, and for identifying strategies and specific solutions that can be used to increase climate resilience.

In recent years there has been a great deal of research on the effects and impacts of global warming. We have learnt more about the possible impacts of climate change on different elements of the natural environment and sectors of society. Most analyses are based on the assumption that global mean temperature will rise by 2–3 °C. We know less about what is likely to happen if the global mean temperature rises by as much as 4–6 °C. There are several reasons for this. First and foremost, there is considerable uncertainty about the effects and impacts of such a dramatic degree of warming. The more we allow atmospheric greenhouse gas concentrations to rise, the more serious the impacts will be. The UN Intergovernmental Panel on Climate Change (IPCC) has warned that if the two-degree target is not met, there is a risk of mass species extinctions and a loss of ecosystems throughout the world, flooding in densely populated coastal areas, prolonged drought in larger and larger areas, and a decline in global food production.

As the temperature rises, climate change will become more and more marked during the present century. We can expect more frequent extreme weather events such as intense rainfall, flooding, and landslides and avalanches. At the same time, the impacts of climate change on society depend on many different factors that are constantly changing. Climate change adaptation is at an early stage, and our experience is limited. Our knowledge and understanding of climate change and its impacts on nature and society are steadily improving.

3.1 The natural environment

Climate change has major impacts on species and ecosystems. In addition, it acts together with many other pressures such as habitat loss and fragmentation, pollution, harvesting, invasive alien species, traffic and other disturbance by humans. The overall result can be to put great pressure on the natural environment. If there are several significant environmental pressures acting in the same area at the same time, this increases the risk of negative impacts such as loss of biodiversity. Land use change is considered to be the greatest threat to biodiversity today, but climate change is expected to become a more and more important factor. In the marine environment, the pace of ocean acidification is expected to be particularly high in cold Arctic waters, which will alter living conditions for marine organisms.

The goods and services supplied by the natural environment are known as ecosystem services, and they can be divided into four categories:

- Provisioning services: for example food, energy, fresh water, medicinal resources and raw materials for building;
- Regulating services: for example water purification, air quality regulation, flood control and erosion prevention;

Figure 3.1 The violet copper (Lycaena helle) is red-listed in Norway, and is dependent on open semi-natural vegetation types found in traditional farmland.

Photo: Ove Bergersen/Samfoto/NTBscanpix

- Cultural services: for example recreation and mental and physical health;
- Supporting services: for example soil formation, nutrient cycling and primary production.

Healthy ecosystems can provide a first line of defence against the impacts of climate change: for example, floodplain wetlands can absorb water and thus moderate flooding.[1] Ecosystem services are thus crucial for life on Earth and as a basis for health, welfare and value creation in any society. In addition, nature has an intrinsic value that we have an obligation to safeguard.

Impacts of climate change on the natural environment

The climate in an area determines the type of natural environment that is found there, and species and ecosystems are adapted to specific climatic conditions such as temperature and rainfall patterns. Moreover, species and ecosystems are continually adapting to natural fluctuations in such variables. This is a slow process, and climate change is a problem because the changes are now happening so rapidly that many species do not have time to adapt to them. A milder climate in Norway may lead to changes such as earlier sexual maturity in animals, earlier flowering in plants, a longer growing season, the earlier arrival of migratory birds and shifts of spawning grounds in fish. This can disturb the balance of nature and ecological interactions. For example, migratory birds may arrive on their breeding grounds before there are sufficient numbers of the insects they depend on, or plants may flower before pollinating insects have become active. Climate change may also result in an upward and northward shift in vegetation zones, and other species associated with the different vegetation zones will also have to move to survive. Changes in land use may create barriers that prevent species from moving to new areas.

The UN Millennium Ecosystem Assessment concluded that throughout the world, species are being lost at much higher rates than natural background rates.[2] However, there is considerable uncertainty associated with the figures in the assessment. Climate change may reinforce these developments. According to the IPCC, between 20 and 30 % of the species that have been evaluated are at risk of disappearing if the global temperature rises by more than 2 °C during the present century. The loss of biodiversity is one of the main reasons for intensifying efforts to combat climate change. The estimates of biodiversity loss illustrate the importance of adaptation to such major processes of change, and in addition, of being able to make use of any benefits they bring.

Climate change is already happening, and will continue, driven by the greenhouse gases that have already accumulated in the atmosphere. The extent of climate change will be determined by further greenhouse gas emissions, but climate change will continue, together with ocean acidification and the melting of glaciers, even if we are able to limit the global temperature rise to no more than two degrees Celsius. Knowledge of these processes of change makes it possible to consider them in the context of other environmental pressures such as land-use change and habitat fragmentation, harvesting, the spread of alien species and pollution. By developing an integrated

[1] Rusch, G. M. (2012): Climate and ecosystem services. The potential of Norwegian ecosystems for climate mitigation and adaptation. – NINA Report 791.

[2] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC

Figure 3.2 Lupins – an alien species in Norway

Photo: Marianne Gjørv/Ministry of the Environment

management regime, it is possible to minimise the losses and damage caused by climate change.

The introduction of invasive alien species is a major cause of biodiversity losses today. Some new species spread to Norway through natural processes, while others are introduced by human activity. These can displace naturally occurring species and cause irreversible changes in ecosystems.

A longer growing season and shorter and milder winters may provide more suitable conditions for alien species that are not yet present in Norway, and allow species that are already present to become established and spread further. For example, rising sea temperatures have already resulted in changes in marine biodiversity. The Pacific oyster, which is classified as a very high risk on Norway's Black List of alien species, has already become established at a number of sites along the southern half of the Norwegian coastline. A rising volume of shipping in Arctic waters will also increase the risk of introducing alien species from the Pacific Ocean; one route of introduction is ballast water containing alien species. The report Alien species in Norway – with the Norwegian Black List 2012 includes ecological risk assessments of species that do not occur naturally in Norway. They include 134 species that are not yet established in Norway, but that are known to pose an ecological risk in nearby countries, and that may become established here if climate change makes conditions more suitable for them.

Climate change in different ecosystems

Rising temperatures, higher precipitation and more frequent and more severe extreme weather affect all ecosystems, from the highest mountains to deep-sea areas off the Norwegian coast. Marine and coastal ecosystems are also under pressure from ocean acidification and sea level rise.

Alpine ecosystems are particularly vulnerable to higher temperatures because the species found there have nowhere else to move to, and many of them are adapted to climatic extremes and low temperatures. In response to the changing climate, the treeline and vegetation zones are shifting upwards and the area of suitable habitat for alpine species is shrinking. This affects species such as the Arctic fox, wild reindeer and various alpine plants, which like species in Arctic ecosystems do not have alternative suitable habitats.

Box 3.1 Wild reindeer need stable cold weather

Throughout the cold winter months, wild reindeer dig down through the snow to find lichens and evergreen plants. A rise in mean temperature increases the risk of repeated melting and freezing of the surface snow. This results in the formation of a hard crust of ice that makes it more difficult for the reindeer to reach food under the snow. If adult reindeer have poorer access to their food supplies through a long, cold winter, the calves born in spring will be smaller and lighter and therefore less likely to survive. This is only one of the climate-related threats to wild reindeer – others include changes in disease status and in the species composition of the vegetation on their grazing grounds.

Figure 3.3 A wild reindeer on winter grazing grounds in the Dovre mountain range

Photo: Tore Wuttudal/Samfoto/NTBscanpix

Competition from new species will also be a threat – for example, the Arctic fox can be displaced and outcompeted by the red fox. These changes are taking place at the same time as infrastructure development and other human activities are putting increasing pressure on mountain. The wild reindeer, a species for which Norway has a special international responsibility, is dependent on large continuous areas of natural habitat in the mountains, and is particularly vulnerable to such changes.

Small rodents are key species in alpine ecosystems, and disruption of their population cycles as a result of changes in snow cover and the formation of ice crust may also affect threatened species such as the Arctic fox and snowy owl. Willow grouse and ptarmigan populations may also be affected because they are more important prey for predator species when numbers of small rodents are low.

Climate change in the Arctic is discussed further in Chapter 9.

Higher temperatures and changes in precipitation patterns are also causing glacier melt in Norway. Estimates indicate that the volume of the glaciers may drop by 30–40 % by 2100, and that only

the largest glaciers will still exist by then. In addition to the loss of an important landscape element, this process will change flow patterns and temperature in glacial meltwater rivers, and thus alter living conditions for many freshwater species.

For forest ecosystems, the growing season is expected to become longer, which will result in faster growth, a rise in the proportion of trees that prefer a warmer climate and perhaps changes in the species composition of forests. Rising temperatures may also result in the northward and upward spread of forest. According to the IPCC, northerly forests will be particularly vulnerable to climate change in the long term, but also in the short term if climate change results in more damage by factors such as storms, pest outbreaks, drought and forest fires. Such factors can be serious threats to forest health, vitality and productivity. Research shows that forests where biodiversity is higher are better able to provide both provisioning and regulating services, including water purification and the maintenance of biodiversity.[3, 4]

According to the 2010 Norwegian Red List, about half of all threatened or near-threatened species in Norway are associated with forests. However, there is nothing to suggest that the situation of Norway's threatened and near-threatened species has deteriorated between 2006 (when the previous Red List was published) and 2010. For example, none of the woodpecker species in Norway are any longer on the Red List: in other words they are all considered to have viable populations in Norway. The goshawk has been downgraded from vulnerable in 2006 to near-threatened in 2010. Knowledge about the impacts of climate change on red-listed species is very limited. In general, a warmer climate will make conditions in Norway more suitable for species with a southerly or south-westerly distribution, but more difficult for species associated with the most northerly forests.

Cervid populations may also be affected by climate change. For example, higher temperatures and an earlier spring may mean that moose calves are no longer born at the right time to be able to feed on the most nutritious plant shoots. This will reduce calf body weight, which in turn will reduce the probability of their surviving the first winter and result in poorer recruitment to the adult population.

Many marginal areas of cultural landscape, particularly in North Norway, along the coast and in the mountains, are becoming overgrown by trees and scrub because they are no longer used and actively managed. This is resulting in the loss of species-rich habitats such as hay meadows and pastures. Climate change may speed up this process and thus make active management even more important.

Wetlands perform a number of important functions, including water filtration and purification and the storage of large quantities of carbon, nitrous oxide and methane. Floodplain wetlands also provide protection against the erosion of river banks and reduce the effects of moderate levels of flooding. In addition they are important habitats for a wide range of species, such as migratory birds that use them as staging areas. Many wetlands in Norway, and particularly peatlands, have been damaged and lost through drainage and conversion into farmland, the removal of peat for fuel, and other types of development. Because water flow is already high in river systems, higher precipitation may increase the transport of soil and sediment, exacerbating erosion. Canalisation of rivers tends to result in faster water flow, and higher and more intense precipitation can increase the risk of flooding.

Climate change may influence biomass production, life cycles and species composition in freshwater ecosystems. Together with an increase in extreme precipitation events and flooding, this will result in more runoff, transport of particulate matter and leaching of nutrients and other pollutants. Higher erosion rates along river banks and runoff of particulate matter and nutrients from farmland may become a greater problem, and such tendencies have already been registered in smaller rivers in Eastern Norway. Particulate matter and pollutants are transported downstream to coastal waters, adding to the overall environmental pressure on marine ecosystems.

Temperatures in excess of 20 °C can be critical for sensitive and important fish species such as salmon, trout and Arctic char. In parts of Norway, prolonged periods of summer drought and low water flow are expected, which will also make high water temperatures more likely. Rivers that are regulated for hydropower production, where a minimum water flow has been fixed, may be particularly vulnerable.

In marine waters, climate change will result in higher temperatures, and a higher CO_2 content in

[3] Gamfeldt, L. *et al.* Higher levels of multiple ecosystem services are found in forests with more tree species. Nature Communications (2012)

[4] Aerts, R. and Honnay, O. Forest restoration, biodiversity and ecosystem functioning. BMC Ecol. 2011: 11:29.

sea water will lead to ocean acidification, which may have serious impacts on marine ecosystems. A large proportion of CO_2 of anthropogenic origin is absorbed by the oceans, where it reacts with water to form carbonic acid, making the seawater more acidic (lowering the pH). The changes will first become apparent in northern waters, because cold water can dissolve more CO_2 than warmer water. This can have a range of impacts, particularly on organisms that build calcium carbonate shells and skeletons. They include coralline algae, zooplankton, crustaceans, molluscs and corals. There are many cold-water coral reefs in Norwegian waters, including the world's largest known cold-water coral reef complex. Coral reefs are among the most species-rich ecosystems, and are a vital habitat for many types of fish. Ocean acidification has negative impacts on these ecosystems, and by the end of this century, up to 70 % of all Norway's coral communities are expected to show signs of reef erosion. Phytoplankton form the basis of marine ecosystems, and the zooplankton that graze on them are essential food for many fish species. Some plankton species have calcareous skeletons, and may not survive in more acidic seawater. Such changes at low levels in food chains can have major impacts at higher trophic levels.

Higher sea temperatures also enable new species to spread into Norwegian waters from further south, while other species extend their range further northwards. Newly-hatched fish larvae are dependent on specific types of plankton. In the North Sea, quantities of the common copepod Calanus finmarchicus have dropped considerably as the sea temperature has risen; at the same time, the quantities of a plankton species that prefers higher temperatures but is less nutritious have increased. Spawning of C. finmarchicus and the commercially most important fish species is normally synchronised. A decline in C. finmarchicus and an increase in plankton species that spawn later in the season may result in a mismatch between spring-spawning fish and their prey, and also between seabirds and marine mammals and the herring. Some fish species will expand their distribution in response to climate change, while species belonging to Arctic ecosystems, such as Arctic char and polar cod, may disappear from parts of the Barents Sea because of changes in food supplies in the form of zooplankton species associated with the marginal ice zone. However, overall, it is very uncertain how changes in the distribution of fish stocks will affect species composition and total production in marine ecosystems.

Norway's coastal waters will be influenced by what happens in the open sea as the climate changes, and also by land-based processes. There has been a decline in several coastal cod stocks in recent years. Several factors are probably involved in this, one of which may be climate change. A plan for rebuilding coastal cod stocks has been adopted. It has been suggested that a combination of higher water temperature, eutrophication and sediment deposition explains the loss of sugar kelp forests (important as a nursery area for coastal cod and other species) from many areas along the southern half of the Norwegian coastline. Climate change will have a number of impacts on wild stocks of anadromous salmonids at different stages of their life cycle. A higher water temperature may for example result in changes in the numbers and distribution of important food species for anadromous salmonids in coastal waters and the open sea, and of disease organisms and parasites such as salmon lice. On the other hand, higher precipitation will increase water flow in rivers and the freshwater content in the coastal zone. This may improve conditions for juvenile salmonids in rivers and reduce the impacts of salmon lice. It is important to maintain the genetic diversity of wild salmon stocks, among other things by reducing genetic interaction between farmed and wild salmon, since this will ensure that the species as a whole and the different stocks are more resilient to changes in conditions resulting from climate change. Higher precipitation will also result in more runoff from land, which may lead to sediment deposition and pollution and subsequently to more frequent algal blooms, sometimes of toxic algae.

Seabirds along the coast are subject to a range of different pressures, many of which are caused by human activity – pollution, fisheries, predators, disturbance by people, habitat degradation and the introduction of alien species. Many seabird populations have shown a dramatic decline in recent years. Moreover, a number of seabirds are specialised feeders, which makes them particularly sensitive to climate change and changes in the availability of prey species such as sandeels, herring and capelin.

Climate change will also have consequences for outdoor recreation. Shorter duration of snow cover will reduce opportunities for winter sports in some southern and low-lying parts of Norway, and may encourage more people to travel to the mountains to find good snow conditions. The boat-

Box 3.2 Tipping points in ecosystems

The UN report Global Biodiversity Outlook 3 warns that changes in ecosystems may be irreversible if they are pushed past «tipping points», beyond which the ecosystem shifts to a new state and changes character. It is difficult to predict how close we are to particular tipping points, but if they are reached the resulting changes may cause many species to become extinct, which would also have impacts on human food supplies and on biomass production.

ing and bathing season in summer will be longer, which may result in more activity along the coastline. The changes will open up opportunities for outdoor recreation and the travel and tourism industry in these areas, but more activity may also increase the pressure on the natural environment in the mountains, in vulnerable Arctic areas and along the coastline. In a warmer and wetter climate, scrub and woodland will encroach more quickly on open cultural landscape, and this will also have impacts on opportunities for outdoor recreation, for example if paths become overgrown and blocked. Higher precipitation and more intense precipitation episodes can cause more damage to paths and other facilities for public access. Climate change may also affect outdoor recreation through factors such as more frequent drought, a greater risk of forest fires and the spread of tick-borne diseases.

3.2 Food production

World food production has increased a great deal in recent decades, in step with the rising global population. According to the Food and Agriculture Organization of the United Nations (FAO), the proportion of people who are undernourished has been reduced in the past 40 years, from about 33 % of the world population in about 1970 to 12.5 % today.[5] It now appears that the decline in undernourishment has stopped for various reasons, including food price spikes, more unstable food markets and repercussions of the global financial crisis. The reasons for unstable and at times high food prices are complex and include high oil prices, the use of agricultural land for purposes other than food production, and a growing demand for food in emerging economies. Major food-producing countries have also introduced export restrictions. In the last few years, extreme weather conditions in important food-producing countries have also resulted in lower crop yields. There is still a great deal of potential for developing more effective and sustainable global fisheries, aquaculture and agriculture, but it will be a challenging task for the world community to ensure the necessary increase in food production in the time ahead.

Climate change and higher average temperatures may result in a greater risk of extreme weather events such as flooding and drought. In addition to reductions in crop yields, climate change may increase the prevalence of animal and plant diseases. Drought and water shortages are already causing problems for agriculture in many large food-producing countries. Areas where food security is already poor and where the population is least equipped to adapt to such changes are probably also most vulnerable to climate change. All in all, climate change entails a risk of changes in the basis for world food production, which may cause instability in food production and food markets. Norway is largely self-sufficient in seafood, meat, eggs and milk, and about half of the population's nutritional needs are met by food produced in Norway. Norway is a major seafood exporter, and exported seafood to a value of more than NOK 50 billion in both 2011 and 2012. However, over the past 10 years, the value of annual imports of agricultural goods into the country has doubled, and reached about NOK 43 billion in 2012. Climate change that has impacts on food production in other countries will therefore also affect Norway. If seafood is included, Norway is currently a significant net exporter of food. Climate change, involving for example higher air and sea temperatures, ocean acidification, unstable weather and changes in precipitation, will have impacts on food production in Norway as well. A moderate rise in temperature combined with adequate water supplies may allow an increase in our food production, particularly in northern parts of the country and upland areas, but higher temperatures and more precipitation may also result in more damage by plant pests such as insects, viruses and fungi, including species that are

[5] FAO, WFP and IFAD. 2012. The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. Rome, FAO. Figure corrected from 15?% to 12.5?% in the translation

already present and new species. Higher temperatures, more moisture and a longer growing season may also result in a more varied weed flora that will benefit from the longer growing season, making it necessary to use larger quantities of chemical pesticides. Climate change may also result in changes in the degradation of chemical pesticides and their environmental impacts. Furthermore, higher precipitation and unstable weather may make it more difficult to carry out plant protection measures at the appropriate time of year.

Norway has a short growing season and a cold climate, and agricultural areas are fragmented. There is little arable land in relation to the size of the population, but large areas of grassland and pasture. Norway is a high-cost country, and there is intense competition for skilled labour. These factors, together with economic developments and global trade agreements, influence the development of the Norwegian agricultural sector.

A warmer climate is likely to affect animal health and welfare, and this applies both to livestock and to wild species. Temperature has a considerable effect, and in particular, winter temperatures above a certain threshold may allow a number of organisms that until now have not been found naturally in Norway to become established. Higher moisture levels will have a similar effect for certain plant and animal species. Climate change and globalisation may result in outbreaks of new animal diseases, including diseases that can also be transmitted to people, or allow known diseases to become established in new areas. Wild animals may also be infected, spreading diseases over larger areas and making them more difficult to control. Climate change may particularly affect the prevalence and spread of vector-borne diseases that are transmitted by blood-sucking organisms such as ticks and mosquitoes.

Reindeer husbandry is a particularly vulnerable sector, and may be severely affected by climate change. Ice crust may form on grazing areas in winter, entailing a risk of heavy stock losses. Climate change may also bring a greater risk of stress caused by insects. On the other hand, a higher average temperature may mean that summer grazing grounds can be used for longer periods of the year. Higher precipitation may also result in better food supplies for reindeer because lichens will grow faster, but this is based on the assumption that the lichens are not outcompeted by other species.

Climate change will have impacts on the marine environment, fisheries, aquaculture and coastal infrastructure. The sea will become warmer and also more acidic, as a result of the uptake of large quantities of CO_2 from the atmosphere. There are signs that fish stocks are shifting further northwards and that more southerly species are moving into Norwegian waters, among other things in response to higher seawater temperatures. Ocean acidification may have major impacts on calcifying organisms, and thus on food chains and the availability of food for species at higher trophic levels. Extensive research is being done in this field, but there is still little detailed and reliable knowledge about the impacts these changes will have on marine ecosystems. Climate change may also affect seafood safety. Inputs of contaminants and their spread will be changed by higher precipitation and runoff from land, rising atmospheric deposition and releases from sediments and sea ice, and more human activity in the Arctic. Furthermore, rising temperatures and ocean acidification may influence the transformation and degradation of contaminants, and therefore their toxicity.

There is great uncertainty associated with the economic consequences of climate change for the fisheries industry, and it is therefore difficult to make any quantitative estimates for this sector.

More frequent extreme weather events and sea level rise will have impacts on fisheries and aquaculture infrastructure and on coastal roads. Boats, equipment, safety installations and other infrastructure may have to withstand more severe weather conditions, and must be designed and dimensioned appropriately. If climate change results in more frequent polar lows and an increase in wave heights, this may cause problems, especially for smaller vessels.

For the aquaculture industry, temperature is a key factor, among other things for growth rates, utilisation of feed, algal blooms and disease. Conditions will become less optimal for farmed species that are adapted to cold water as the sea temperature rises. In the long term, rising sea temperature may result in changes in which species are farmed, which are the best areas for aquaculture production and where facilities are located.

The nature and level of the risks associated with communicable diseases in aquaculture species may also change with a rise in seawater temperature. Higher precipitation will result in a greater proportion of fresh water in the fjords: this may influence current patterns in these areas and thus alter the patterns of spread of pathogens. It may also be necessary to change the composition

Box 3.3 Norwegian seafood contributes to global food security

The UN Conference on Sustainable Development (Rio+20) in June 2012 stressed the crucial role of fisheries and aquaculture in global food security. Norway is a net exporter of food products, mainly because of its large-scale production of seafood, 95 % of which is exported. We are the second largest exporter of seafood in the world, and in 2012 exported about 2.3 million tonnes of seafood to a value of NOK 51.6 billion to more than 150 countries. It is estimated that the Norwegian fishing and aquaculture industry provides 33 million meals of seafood every day. Sustainable resource management and aquaculture management, and Norwegian fisheries and aquaculture technology, also contribute indirectly to global food security, and Norwegian management expertise is in great demand internationally. FAO estimates that fishing and aquaculture currently meet about 8 % of global food needs.

Figure 3.4 Norwegian salmon

Photo: Richard Hauglin/NTBscanpix

of fish feed in response to higher seawater temperatures.

Aquaculture facilities may need to meet high technical standards to withstand extreme weather events. For example, it is important to avoid damage that may allow fish to escape from these facilities.

3.3 Human life and health

Public health is generally good in Norway. This gives us a good starting point for coping with changes in health risks. Climate-related factors always affect people's health, and climate is already a general risk factor in Norway.

A warmer climate may affect public health in a number of ways, but the main effect will be to intensify the health risks posed by today's climate. The quality of drinking water may become poorer, increasing the risk of waterborne infections. The prevalence of communicable diseases may rise as conditions become more suitable for infective agents such as ticks and mosquitoes. A longer and more intense pollen season may aggravate the symptoms of people who suffer from allergic diseases. Climate change may also have indirect impacts on health if for example medical transport services are blocked by damage to transport or other critical infrastructure caused by extreme weather events. However, climate change is not expected to cause any large changes in mortality in Norway.

Climate change may result in a negative trend in drinking water quality. In general terms, the impacts can be split into two categories, impacts on the raw water and water treatment plants, and impacts on the distribution infrastructure. About 90 % of the Norwegian population is supplied with drinking water from surface water sources. Climate change will probably result in higher average water temperature, more intense precipitation and more frequent flooding in such water sources. These changes will in turn increase the likelihood of larger numbers of microorganisms and larger amounts of organic material, nutrients and pollutants in water sources. Norway's 48 largest water works (which supply more than 20 000 people each, and 2.6 million people in total) can maintain drinking water quality even if the raw water quality deteriorates, but this is probably not the case for most of the smaller water works.

During periods of intense precipitation, a rise in the groundwater level and water levels in drainage channels may result in polluted water seeping into water pipelines and other parts of the water supply infrastructure. There is no satisfactory information on which parts of the water distribution system are most vulnerable. The situation may deteriorate if the drinking water and sewerage pipelines become overloaded.

In future, raw water from drinking water sources is likely to be of poorer quality, and problems in the water pipelines are likely to arise more frequently. The National Institute of Public Health and the Norwegian Directorate of Health have assessed the vulnerability of parts of the drinking water pipeline system to be high. The vulnerability of raw water sources and water treatment plants is also relatively high, but lower than is the case for water pipelines.[6]

Food- and water-borne infections are among the commonest infections both in Norway and in other parts of the world. They are considered to be particularly sensitive to climate change, and show seasonal variation)*.

Climate change may also entail a higher risk of vector-borne diseases carried by organisms such as mosquitoes, ticks and snails. These diseases spread because the distribution of vector species expands with higher temperatures, their populations grow, and they are active for longer periods of the year. Internationally, there is concern that diseases such as malaria, schistosomiasis, dengue and various types of encephalitis transmitted by mosquitoes or ticks may spread to new areas. As regards malaria and dengue, the higher risk is largely associated with travel abroad. It is less likely that these two diseases will become established in Norway.

An important disease vector in Norway is the sheep tick (Ixodes ricinus), which can carry a variety of diseases, including borreliosis (or Lyme disease), anaplasmosis, tick-borne encephalitis (TBE), babesiosis and tularaemia. At present, sheep ticks are common near the coast from partway up the Oslofjord to Brønnøysund in Nordland, but there are also scattered records from further inland. In recent years, there has been an increase in tick numbers, probably associated with higher temperatures, a longer growing season, an increase in moose, roe deer and red deer populations, and overgrowing of open landscapes, which is favourable for ticks.

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[6] Source: Helsekonsekvenser av klimaendringer i Norge, Bakgrunnsmateriale til NOU 2010: 10 Norwegian Institute of Public Health and Norwegian Directorate of Health (Health effects of climate change in Norway. Background material for Official Norwegian Report on climate change adaptation. In Norwegian only)

Box 3.4 Climate change will influence the risk of food- and water-borne diseases

There are factors along the entire production chain from fjord or farm to fork that will be influenced by climate change.

- Certain types of food- and water-borne infections that are not currently common in Norway may become more widespread as farmers have to operate in warmer and wetter conditions.
- Heat waves or extreme precipitation may be stressful for livestock and increase the risk of diseases. Heat stress may also cause injury and higher mortality, for example during transport for slaughter.
- Climate change may create new ecological niches, with changes in the bird and mammal fauna and corresponding changes in the microbial ecology, which may entail a higher risk of disease among livestock as well. This in turn may result in a higher risk of pathogens in food.
- Changes in the conditions for algal and plankton growth in the sea and in freshwater may increase the risk of diseases associated with fish and seafood.
- Drinking water quality may deteriorate if higher precipitation results in overloading of sewerage systems.
- It will become more difficult to maintain food hygiene standards in restaurants, institutions, workplaces and private households under warmer and wetter conditions
- Most infectious intestinal disease occurs during the summer months, and a longer summer will result in a higher risk of such infections.
- A higher prevalence of infections in livestock may result in higher consumption of antibiotics, increasing the risk that resistance will develop. More widespread resistance to antibiotics will make it more difficult to treat infections both in livestock and in humans.

Source: Helsekonsekvenser av klimaendringer i Norge, Bakgrunnsmateriale til NOU Klimatilpasning, 2010, Norwegian Institute of Public Health and Directorate of Health. (Health effects of climate change in Norway. Background material for Official Norwegian Report on climate change adaptation. In Norwegian only.)

The duration of the growing season and snow cover are probably the key climatic factors in determining tick distribution. According to projections of the length of the growing season in the period up to 2100, all lowland areas of Norway except in the far north will probably provide suitable conditions for ticks. It is therefore assumed that the prevalence of tick-borne diseases may increase with the expansion of suitable tick habitat.

Higher temperatures and a greater risk of heat waves may entail greater health risks in future, although this will probably not have major implications for public health in Norway in the near future. The increase in mortality associated with heat waves indicates that people with chronic diseases and the elderly are most vulnerable. A rise in the risk of prolonged heat waves in Norway is to be expected, but there have been no studies of the possible effects on public health. On the other hand, a reduction in cold-related mortality is expected, since the risk of prolonged extreme cold will be reduced as a result of global warming.

Air quality may also be affected by climate change. A longer pollen season and the introduction of new aeroallergens as species spread northwards with the rising temperatures will result in a higher risk of symptoms in the allergic population and a higher prevalence of pollen allergies in Norway. It is considered likely that the quantity and/or potency of important pollen types will increase, and that the distribution of existing and perhaps new types of pollen-producing plants will expand. Air pollution may worsen; for example, there may be higher levels of ground-level ozone and changes in the composition of airborne particulate matter.

Climate change may entail a greater risk of flooding and landslides or avalanches later in the present century. This may result in such events in locations where they have not previously occurred, which will entail a greater risk to human life and health. However, precisely how and to what extent climate change will influence this risk is uncertain.

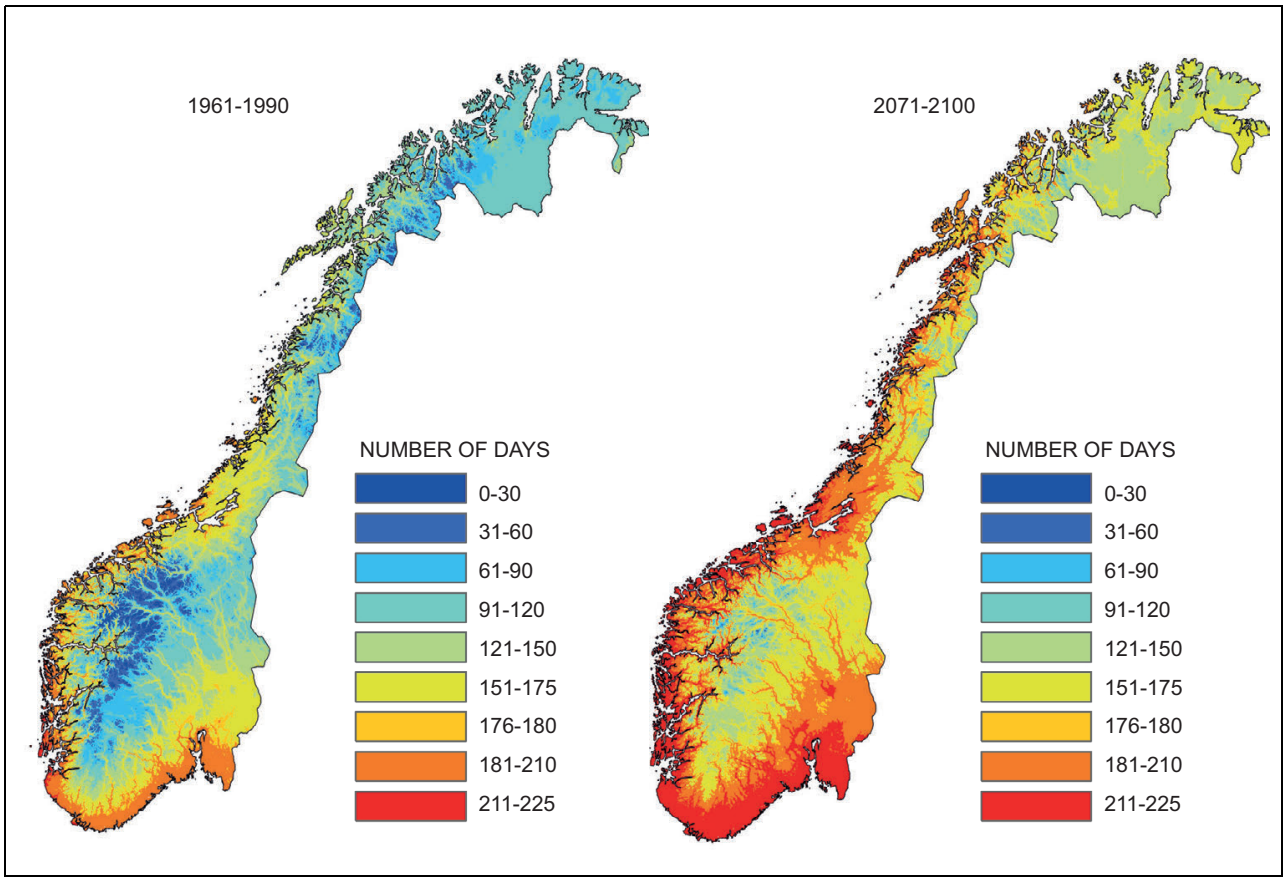

Figure 3.5 Tick distribution is related to the length of the growing season

The left-hand map shows the length of the growing season in Norway in the period 1961–90. The distribution of sheep ticks today coincides with the area where the growing season lasts for 176–180 days or more (coloured orange to red on the map). The right-hand map shows projections for the length of the growing season in the period 2071–2100, according to the model Hadley A2 2071–2100. This indicates that the growing season will last for 176–180 days or more in almost all lowland areas of Norway except in the far north.

Source: Norwegian Meteorological Institute 2013

3.4 Infrastructure

Both society and individuals are dependent on access to electricity, transport and communications, water, waste management services and shelter. Much of the infrastructure that provides these services is designated as critical infrastructure, and society makes substantial resources available for ensuring that it is resilient to various types of stress. Almost all infrastructure is sensitive to climate variability and therefore vulnerable to climate change. The vulnerability of infrastructure, including buildings, has major implications for the ways in which society is affected by climate change.

Infrastructure comprises roads, airports, railways, ports, the electricity grid, ICT infrastructure, water supply and sewerage systems, waste management services and buildings. All these infrastructure elements are interdependent. The power supply is essential for the maintenance of vital societal functions, and a functioning ICT infrastructure is necessary for a stable power supply. If the power supply is disrupted, it is crucial that the transport system functions so that repairs can be carried out. However, at present the maintenance backlog for the building stock and other infrastructure is a considerable challenge. Climate change will increase the need for maintenance and thus the problems posed by the maintenance backlog. The interdependence of these factors will intensify the overall vulnerability of infrastructure to climate change.

However, in the report Adapting to a changing climate (NOU 2010: 10), the committee pointed out that the degree of vulnerability to climate change varies with the type of infrastructure, among other things with the various operational lifetimes. Roads and railways that are being constructed today have a long lifetime and must be designed to cope with different types of stress over the very long term, whereas cables in the

ICT infrastructure have a short lifetime and this infrastructure has a high adaptive capacity. Priorities, divisions of responsibility and the resources available for adaptation also influence the degree of vulnerability, and these factors make for example the water and sewerage sector especially vulnerable.

Society is dependent on a well-functioning transport system. It is essential to avoid disruption to road, rail, sea and air traffic for individuals, emergency services, businesses and other key services and actors.

The problems caused by the current maintenance backlog in the land transport sector, both roads and railways, will be intensified by climate change. In recent years flooding, landslides and avalanches have in some cases had serious consequences for the transport network and shown that roads and railways are already vulnerable and will be even more vulnerable to future climate change. Higher precipitation levels will put more pressure on drainage systems. The higher risk of flooding, landslides and avalanches is a threat to traffic safety, and may increase the frequency of disruption and cause considerably more damage to both roads and railways. Sea level rise and storm surges may cause wave erosion and inundation, which may disrupt traffic and lead to erosion damage. This could also increase the risk of water flowing into undersea tunnels, and increase stresses and erosion of road embankments and bridge foundations.

Maritime traffic along the coast is important for Norway, and is dependent on infrastructure in the form of fairways, lighthouses, buoys, breakwaters, and ports and their associated infrastructure. The wind, wave and current conditions along the Norwegian coast already pose problems for maritime transport, and climate change may aggravate these conditions and increase the loads and wear on lighthouses, buoys, breakwaters and quays. Sea level rise, storm surges, ocean acidification and harsher weather conditions will make infrastructure operation and maintenance a more challenging task. Navigation infrastructure, breakwaters, port facilities and so on must be designed to withstand more rapid corrosion as a result of ocean acidification.

Norwegian airports will be affected by climate change in different ways and to different degrees. Many airports in coastal areas are situated on flat land close to the shore or open water, which makes them vulnerable to the effects of higher water levels and high waves. The infrastructure of these airports is vulnerable, and safety zones and lighting facilities may suffer from erosion. Wet runways reduce braking action and higher precipitation levels will make drainage for stormwater runoff more important but also more difficult. At some airports more frequent temperature fluctuations around freezing point and more precipitation in the form of snow will pose problems for winter maintenance and snow clearance. Changes in wind strength and direction, turbulence and perhaps more frequent extreme low pressure events may affect air traffic.

Norway's power supply is primarily based on hydropower, and the country has about 1 700 hydropower dams. These run-of-river or storage hydropower systems deliver electricity through the nationwide electricity grid. Higher precipitation resulting from climate change will probably make it possible to increase electricity production, while higher temperatures may reduce the demand for electricity. The electricity supply system is designed to withstand extreme weather events. This is a critical infrastructure, since society depends on a secure and stable power supply in order to function. Major disruption of the power supply would have significant economic consequences and pose a threat to life and health.

Today the power supply system is vulnerable to climate conditions, and about half of all power cuts and disruption of the electricity grid are weather-related. While lightning is the most common cause of power cuts, these can also be caused by other factors such as overgrown vegetation, fallen trees, snow and ice. However, the NOU committee considers that the electricity sector infrastructure is well adapted to today's climate.

Some of the factors that constitute risks to the electricity supply today may become more pronounced in future. Higher humidity, higher precipitation, a longer growing season and more rapid shifts between frost and thaws and wet and dry periods may increase the need for maintenance. A higher frequency of extreme weather events involving lightning strikes, icing on power lines in areas that previously had stable cold conditions, extreme heat, flooding, landslides and avalanches, rising sea levels and less stable seasonally frozen ground may result in more frequent damage. The higher risk of landslides and avalanches could affect the safety of dams, since a slide into a reservoir can cause damage to dams and other infrastructure.

Climate change will also result in a need for new power lines, for example to take account of increased hydropower production.

Buildings account for a large proportion of society's investment in infrastructure. In 2008 there were 3.8 million buildings in Norway, 40 % of which were residential. About 80 % of today's buildings will still be standing in 2050. Buildings are vulnerable to a number of different types of natural hazards, including those caused by extreme weather events. In 2011 insurance companies registered 37 113 cases of damage resulting from water entering buildings, and according to Finance Norway, the compensation payments amounted to a total of NOK 2.2 billion. Many of the risks to buildings posed by climate factors may be intensified by climate change. The most important variables will be higher precipitation, exposure to humidity, and changes in wind patterns. Sea level rise and higher precipitation will mean that humidity becomes more of a problem, and the risk of exposure to decay is expected to increase in large parts of the country. A higher frequency of extreme weather events such as storm surges, landslides and avalanches, and flooding will pose risks to buildings in exposed locations, and the large maintenance backlog, especially in the municipal building stock, will increase the risks.

Higher precipitation will result in a warmer, more humid climate and an increase in the decay of wooden materials. Today 615 000 buildings in Norway are in the high decay hazard category. According to SINTEF Building and Infrastructure, this figure will increase substantially. By 2100, a total of 2.4 million of today's buildings will be in the high decay hazard category, and this will include to virtually all the buildings in Oslo, which are currently in the moderate decay hazard category (just over 125 000 buildings). In Hordaland about 190 000 buildings, or well over half the total stock, are currently in areas where the decay hazard is high, and this will increase to about 220 000 of the existing buildings. In addition, a large proportion of the building stock in Buskerud, Oppland and Hedmark will be affected by a rise in annual precipitation of more than 25 %.[7]

In Norway almost 90 % of the population are connected to the water supply and sewerage systems, which are municipally owned. Well-functioning water supply and sewerage systems are essen-

7 Source: Lisø, K.R. and Kvande, T.: Klimatilpasning av bygninger (Climate proofing buildings, in Norwegian), SINTEF Building and Infrastructure, Oslo 2007.

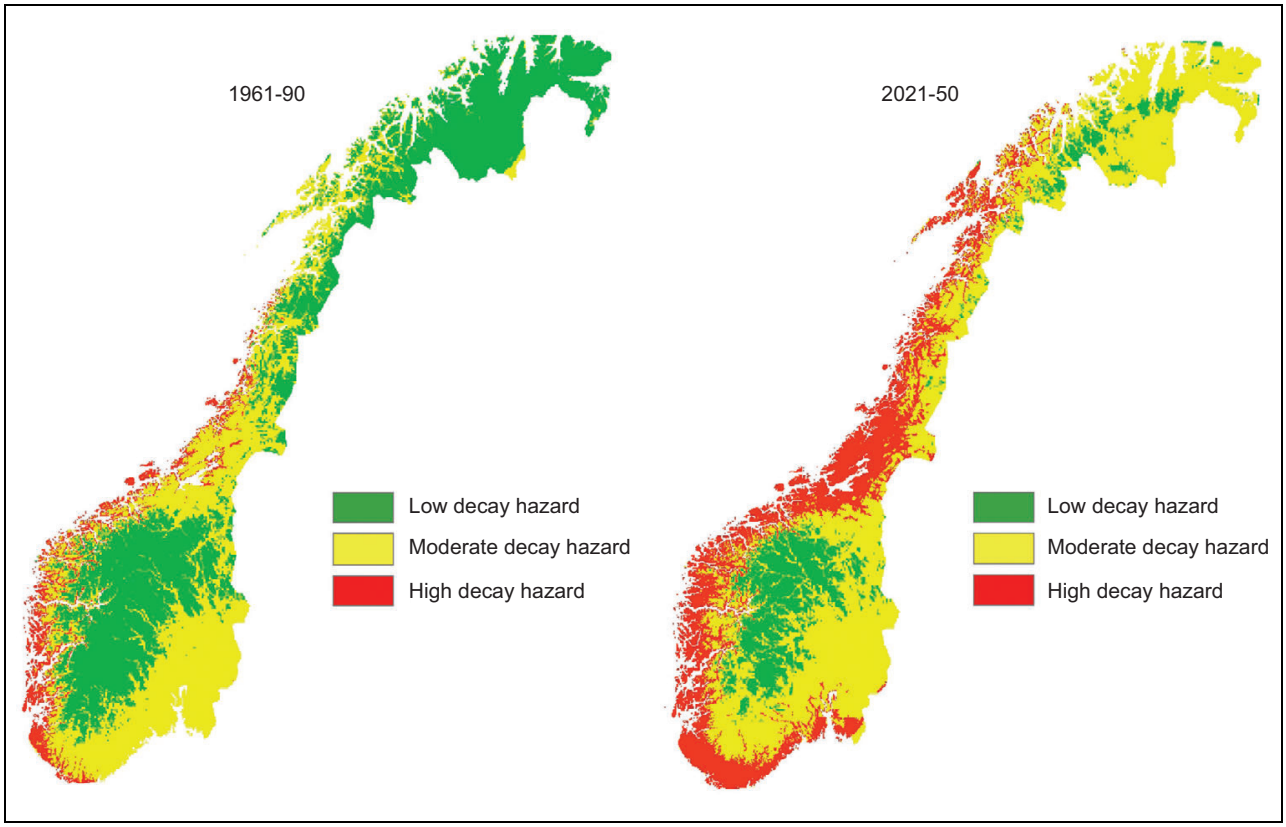

Figure 3.6 Buildings – estimated changes in decay hazard

Source: Lisø, K.R. and Kvande, T.: Klimatilpasning av bygninger (Climate-proofing Buildings, in Norwegian) SINTEF Building and Infrastructure, Oslo 2007.

tial to health and for maintaining the natural environment and societal functions in general. Even today, many municipalities suffer from flood and water damage and sewage backup resulting from intense precipitation events. This may be due to under-dimensioning of the sewerage system and increased densification of urban areas, which in turn results in overloading of the system. Studies indicate that there is a maintenance backlog in these sectors, and the problem of poorer quality raw water in drinking water sources is growing, due to higher temperatures and precipitation and greater volumes of runoff. Climate change will increase the risk of disruption of water supply and sewerage services. More stormwater runoff is also likely to lead to overloading of sewerage pipes and waste water treatment plants. If large volumes of stormwater enter the sewerage network, unnecessarily large volumes of water have to be processed through the sewerage treatment system, resulting in lower treatment efficiency. Intense precipitation events and flooding may increase the pollution risk due to polluted water from submerged pipes and cisterns seeping into the distribution network for drinking water.

Climate change may also put pressure on ICT infrastructure, in the form of flooding, landslides, avalanches and icing of power lines. However, this sector is less vulnerable than many other infrastructure areas since new technology is continually being developed and installations upgraded. The sector is fairly well adapted today, but in the long run measures to adapt to climate change and ensure delivery will have to be considered. Norway's widespread use of new and existing ICT technology gives the country a high degree of resilience. ICT systems play an important role in ensuring efficient electricity distribution, and ICT tools also play an important role in early warning and emergency response systems.

3.5 The Norwegian business sector

The Norwegian business sector consists of more than 350 000 enterprises in many different sectors located in all parts of the country. The effects of climate change on the various sectors will depend on the nature and location of the sector and its connection to the necessary infrastructure. The diversity of the business sector makes it difficult to gain an overview of the all the problems related to climate change faced by the sector as a whole. In some sectors, such as forestry, climate change will alter the framework for production and profitability. Others, such as many of the service industries, will primarily be affected if climate change leads to disruption of services on which they depend. At the same time the business sector is a key actor in efforts to make society more resilient to climate change, since it is businesses that are responsible for developing and constructing buildings and other infrastructure, and thus supply goods and services that will be substantially affected by climate change.

All businesses will be indirectly affected by climate change through the vulnerability of services on which they depend. This applies among other things to infrastructure, such as communications (roads, railways, air and maritime transport), water supply and sewerage, power supplies, the electricity grid, ICT infrastructure, and buildings and equipment, all of which are largely outside the control of the individual business. Resilient infrastructure, communications and energy supplies are essential for the maintenance of the welfare society, for future value creation and for the competitiveness of the business sector. Thus the impacts of climate change on society's infrastructure in the broadest sense will also have consequences for the business sector.

The pace of restructuring in the business sector influences the degree to which the various businesses are affected by climate change and how rapidly they can adapt to new climatic conditions. This applies particularly to service industries such as the tourist industry. However, in the next few decades the industrial structure will have changed dramatically; for example, two of three new Norwegian businesses have a lifetime of less than five years, and in 50 years' time most of them will probably no longer exist and have been replaced by new ones and new markets. In the course of this century the technology and products used by businesses today will have been replaced several times. This flexibility and adaptive capacity is likely to make businesses more resilient to climate change.

The need and capacity to restructure in response to climate change vary from sector to sector. The primary and related industries such as fish processing will be directly affected by climate change and will have to undergo major adaptations in order to maintain their earning power and profitability under new climatic conditions. For example, certain businesses might need to adapt by moving northwards from the coast of Western Norway to follow shifts in the distribution of resources such as fish stocks. This also applies to service industries that are directly related to the

primary industries and outdoor industries. For example, a shorter winter season will in some areas have a significant impact on the operation of ski resorts and the hotel industry in winter sports areas. Thus climate change could have serious impacts on small local communities reliant on a single industry. Such situations will require high adaptive capacity and measures to facilitate knowledge-based business development.

However, climate change may also provide opportunities for new business activities and value creation; for example, it could increase profitability in the electricity sector. An analysis conducted in connection with the report Adapting to a changing climate (NOU 2010: 10) estimated that production will increase by 7–22 % in the second half of this century. On the basis of certain assumptions about future prices, this means that revenues from hydropower production could increase by NOK 5–16 billion annually. Another example is the melting of the Arctic sea ice, which could open up new opportunities for maritime transport. Ice-free routes across the Arctic Ocean and through the Northwest Passage and the Northeast Passage provide new opportunities for maritime transport in polar waters. For example, for ships sailing from Asia to Europe, the Northeast Passage would be about 40 % shorter than the route through the Suez Canal, and bunker oil consumption about 20 % lower. However, the volume of international commercial maritime traffic in the future is uncertain. Proximity to the Arctic will probably give Norwegian companies a competitive edge and increase the use of ports in North Norway. However, a greater volume of maritime traffic in the Arctic will pose a risk to the vulnerable environment. Extreme weather conditions, the period of darkness in winter, incomplete mapping, inadequate communication systems and ice-covered waters are constant challenges. The remoteness of these areas also makes search and rescue operations, and preparedness and response to acute pollution, difficult and costly. As for transport in other waters, ensuring safe maritime transport in polar waters requires rules for ship standards and crew qualifications, and the necessary maritime infrastructure.

The insurance sector is in a unique position because insurance products are directly affected by climate change. By assuming the risk of unforeseen damage, including that related to natural hazards, on behalf of other actors, insurance companies play a potentially important role in reducing vulnerability and promoting progress towards a climate-resilient society. The sector also has the potential to create incentives for climate change adaptation by imposing requirements on policy-holders, including businesses, to take preventive measures to reduce damage resulting from climate change. The role of the insurance sector is described in more detail in Chapter 6.5.

3.6 Cultural heritage

Tangible cultural heritage is a non-renewable resource that allows us to understand and appreci-

Box 3.5 Cultural monuments, sites and environments

The Cultural Heritage Act defines cultural monuments, sites and environments as «all traces of human activity in our physical environment, including places associated with historical events, beliefs and traditions.» The individual cultural monument or site is usually part of a larger context that is also meaningful: a cultural environment. In addition, a cultural environment may consist of elements that are not in themselves important but that taken together form a visual or functional whole of great cultural and historical value.

More than 250 000 archaeological monuments and sites have been registered in Norway, but there are far more that are unknown. Some, like burial mounds, rock carvings and animal trapping systems, are easily visible. Others are hidden below the ground, like stone-age sites and medieval streets and alleys, or under water, like sacrificial offerings and submerged sites. Monuments and sites dating back to before 1537 are automatically protected under the Cultural Heritage Act. The same applies to Sami monuments and sites that are more than 100 years old, and pre-1946 structures and sites in Svalbard.

In Norway there are around 6 000 buildings that are protected under the Cultural Heritage Act and about another 5 500 in museums. Around 1 000 churches are protected or registered and managed in the same way as protected buildings. In some cases the surroundings are also protected, for example historic gardens or valuable cultural landscapes. In addition a large number of buildings are regulated for protection under the Planning and Building Act. Around 375 000 buildings were built before 1900. Most of them have no statutory protection, but many of them are historically important.

ate the past and people's lives and activities in previous times. It also serves as a source of enjoyment and enhances the quality of life and of the environment. The loss of any part of the cultural heritage can be a loss for individuals, local communities and society as a whole.

As part of the efforts to prepare the cultural heritage authorities to deal with the consequences of climate change for cultural heritage management, the Directorate for Cultural Heritage has headed a Nordic cooperation project on the effects of climate change on cultural heritage. The resulting report, «Climate change and cultural heritage in the Nordic countries» (TemaNord 2010:599), concluded that the acute effects of extreme weather events such as storms, flooding, landslides and intense precipitation, and the more long-term effects of sea level rise, warmer temperatures, higher humidity and higher precipitation, can be expected to result in more damage to cul-

Box 3.6 Nordic cooperation

The project «Effects of climate change on cultural heritage sites and cultural environments» was established as a collaboration between the cultural heritage administrations of seven Nordic countries: Iceland, Greenland, the Faeroe Islands, Denmark, Sweden, Finland and Norway. It was primarily financed by the Nordic Council of Ministers, and the aim was to assist cultural heritage administrations to prepare for the expected consequences of climate change and to strengthen Nordic collaboration and network building between the Nordic cultural heritage administrations. The published report, «Climate change and cultural heritage in the Nordic countries» (TemaNord 2010:599) contains the main results and conclusions.

Box 3.7 Karmøy

Karmøy is located in the coastal area where the sea level will rise most. Historical buildings connected with trade, fisheries and shipping are usually situated right on the sea front. During the storm Inga in 2005, storm surges, waves and wind damaged a number of historic buildings in Karmøy municipality.

During its restoration, the foundations of the old seahouse that now houses the Åkrehamn Coast Museum were raised by 60 cm to create a buffer against a rise in sea level. Raising the foundations of buildings is one of several measures that need to be considered when important buildings have to be protected from rising sea levels.

Figure 3.7 Nordneshuset in Skudeneshavn. A tourist attraction in Karmøy.

Photo: Robert Harding Images/Masterfile/NTBscanpix

tural heritage sites, increased loss of such sites, changes in conservation conditions and new finds of archaeological artefacts and sites.

A higher frequency of extreme weather events such as flooding, landslides and avalanches, storms and intense precipitation will increase the risk of damage to buildings and archaeological material. Global mean sea level is now rising by about 3 mm per year, and in the coming century will probably rise by considerably more than this. Rising sea levels and larger storm surges will threaten built-up areas close to the coast and other elements of the cultural heritage in exposed areas. Extreme rainfall events are likely to lead to flooding and will threaten urban landscapes with inadequate storm drain systems.

More gradual processes of climate change will put more pressure on the cultural heritage. A more humid climate will increase the risk of biological, physical and chemical decomposition of cultural monuments, and wooden buildings and elements will be at higher risk of decay and dam-

Box 3.8 Climate change and Svalbard's cultural heritage

The supports for the aerial cableway that are so characteristic of Longyearbyen are beginning to rot where the poles are in contact with the damp soil. The active layer of the permafrost is becoming deeper, causing settling and damage to buildings; for example cracks are appearing in the brick walls of Pyramiden, the former Soviet and now Russian settlement. The ice in the fjords and along the coast, which weakens wave action, is melting, and erosion is a growing problem throughout the Arctic. The hunting station Fredheim on the Sassenfjorden in Svalbard is a high-priority cultural environment that is threatened by erosion. In 2001 the oldest cabin, dating back to 1911, was moved 6 m away from the sea shore. The main cabin, dating back to 1924, which was 17.7 m from the shore in 1987, is now only 8 m away. Together with a project group from the University Centre in Svalbard (UNIS), the authorities are considering moving the whole complex further inland.

Figure 3.8 Supports for an aerial cableway from a coal mine in Svalbard, part of its protected cultural heritage.

Photo: Ministry of the Environment

Box 3.9 Klimapark2469

Mímisbrunnr Klimapark2469 is the result of a cross-disciplinary collaboration in the fields of archaeology, glaciology, meteorology and botany, and is situated in the alpine zone close to the Juvfonna glacier at the foot of Galdhøpiggen, Norway's highest mountain, in Lom municipality. The intention is to provide a unique arena for research, value creation and information about climate change, cultural heritage and the mountain landscape from a long-term perspective. Climate change research is a rapidly developing field, and Klimapark2469 aims to teach children and young people, and the public in general, more about the historical climate. Klimapark2469 provides an opportunity to physically experience current climate processes and interactions between nature and humans. The main attraction is the Mímisbrunnr ice tunnel dug into the glacier, which was opened to the public this year. It replaces the first tunnel, which had to be closed after two years of rapid ice melt.

Figure 3.9 Reindeer scare-stick emerging from the Juvfonna glacier, Jotunheimen.

Photo: Bård Løken/Samfoto/NTBscanpix

age from pests. About four of five protected buildings in Norway are constructed of wood, and in virtually all of the remaining buildings wood is used in roof structures or beams.

Higher temperatures lead to thawing of the permafrost, which is already a threat to the conservation of archaeological remains in Svalbard. Coastal erosion in Svalbard is also increasing due to the declining extent of the sea ice. Because so much of the cultural heritage in the archipelago is located on the coast, coastal erosion is a serious threat. Svalbard's cultural heritage used to be referred to as being frozen in time, or preserved through natural freeze-drying processes in the cold climate. Archaeological excavations of whalers' graves undertaken in the 1980s revealed 17th- and 18th-century corpses that still had skin and hair and almost intact woollen clothing. However, due to the warmer and more humid climate, many of the archaeological remains in the Arctic have now reached a critical point as regards conservation.

A milder climate will prolong the growing season, speeding up vegetation growth so that areas around heritage buildings and sites and cultural landscapes will become more rapidly overgrown. A large number of archaeological sites and protected buildings in Norway are situated in existing or previous farmland that is at high risk of becoming overgrown. Once woodland has encroached on heritage sites, there is a risk of damage from tree roots or from windthrow, which puts buildings at risk of physical decomposition and decay. Another effect of overgrowing can be to alter the historical landscape context of cultural monuments, obscuring their original function in the landscape. This reduces people's enjoyment and consequently the utility value of the site, which in turn reduces opportunities for value creation and learning opportunities for the public.

There is hard evidence of the climate change now taking place in the form of the hundreds of archaeological artefacts that are being exposed by the melting snowpack in the mountains of Norway. They date from different historical periods, and the oldest, which have been discovered in the Jotunheimen mountains, date back more than 3 000 years. In earlier historical periods people were drawn to the mountain snowpack and glaciers by the opportunities for reindeer hunting, and most of the finds are linked with this activity. They are mainly made of organic materials that

have been well preserved by the cold ice, but when exposed to air begin decomposing rapidly.

3.7 The Sami culture and way of life

Today there are traditional Sami settlements in Norway in the region extending from Engerdal in northern Hedmark and all the way to the border with Russia. The Sami are recognised as an indigenous population with special rights in this country, and Norway has undertaken to ensure that they have the opportunity to practise their traditional culture and economic activities.

Sami culture and economic activities are so closely linked with natural resources that climate change is likely to have substantial effects on both. However, other economic and social factors are also expected to alter the framework for traditional Sami culture, and climate change is thus one of several factors that will affect this people's culture and way of life.

The Sami culture and way of life rely heavily on the natural resource base in their traditional settlement areas and other areas they utilise. Sami activities such as sea fishing, reindeer husbandry, agriculture, salmon fishing, commercial activities based on uncultivated land, and combinations of these, are important bearers of Sami culture, and these activities are likely to be affected by climate change. An example is Sami reindeer husbandry, which is practised in an area extending from Hedmark in the south to Finnmark in the north. Reindeer husbandry is nomadic, and the reindeer are moved between different seasonal grazing grounds. Because this requires extensive areas and because the animals graze outside all year round, reindeer husbandry is particularly vulnerable to climate change. Climate change will be additional to a variety of other disturbances and will affect the use and quality of the grazing grounds. Climate change adaptation measures for reindeer husbandry are described in Chapter 8.2.

Other Sami industries on land are also under pressure and the problems are expected to increase as a result of climate change. For example, new species of geometrid moths may damage birch forest in many parts of North Norway, and also have impacts on the field-layer vegetation. Large areas of birch forest in Finnmark, the county with the largest Sami population in Norway, are vulnerable to outbreaks of geometrid larvae, and this may have impacts on the fauna and thus for hunting and other uses of these areas.

Figure 3.10 From a Sami settlement in Kaperdalen Museum, Troms, from the beginning of the 1900s. Window in a gamme (turf house) from the early 1900s, used by forest Sami until the 1960s.

Photo: Øystein Søbye/Samfoto/NTBscanpix

Climate change may also have impacts on marine industries, since higher sea temperatures may result in a northward shift in the distribution of wild stocks and in where aquaculture organisms are farmed. We do not know exactly how climate change will affect the livelihoods and way of life of the sea Sami. Changes in the species composition of marine ecosystems may cause problems, but may also create new opportunities for fjord and coastal fisheries in Sami areas. Whether or not such changes have economic and social benefits will depend on the fish species involved, seasonal changes in their distribution and the extent to which the fishers are able to take advantage of new fisheries opportunities and at the same time address new problems resulting from climate change and its impacts in Arctic areas. Climate change adaptation measures for fisheries and aquaculture are described in Chapter 8.2.

The close links between livelihoods and Sami culture make this people vulnerable to climate

change. However, their history of harvesting natural resources despite climate and weather variability has given them a sound foundation of experience and knowledge. The Sami have always shown considerable flexibility in adapting and diversifying their traditional economic activities. Extensive, diversified harvesting of both terrestrial and marine natural resources has allowed them to adapt to fluctuations in the resource base, and is the reason why so many Sami combine different income-generating activities such as agriculture, fisheries, reindeer husbandry and harvesting other resources from uncultivated areas. Combinations that include paid employment and tourism are becoming increasingly common. This flexibility in their use of traditional resources by combining different forms of harvesting and harvesting from different areas has made the Sami highly adaptable.

It is important in the context of climate change adaptation to consider how various measures will affect indigenous communities. For example, it is important to ensure that the goal of maintaining the foundation for traditional Sami industries can be met and to recognise the value of traditional knowledge in addressing climate change. Competence- and capacity-building within the Sami community will also be essential to meet these challenges. Sound methods of gathering and using traditional knowledge and capacity should be developed to equip the Sami to take advantage of any new opportunities that may arise in traditional occupations, while adapting to the new needs that may result from climate change.

The overriding question from the perspective of the Sami and other indigenous peoples in the Arctic is how to equip these communities to address and adapt to the inevitable climate change while at the same time safeguarding the role and value of their traditional knowledge. Care must therefore be taken to ensure that climate change adaptation measures do not weaken the foundation for traditional Sami industries and thereby undermine Sami culture.

4 Common framework for adaptation to climate change

The Government:

- As a precautionary approach, wishes assessments of the impacts of climate change to be based on figures from the high end of the range of national climate projections. However, when decisions are made in individual cases, climate change considerations and underlying assumptions about the degree of climate change must be weighed against other considerations of the public interest, the lifetime of the development in question and its importance to society.
- Plans for regular updates of knowledge about the impacts of climate change and vulnerability, and of assessments of adaptation needs in Norway. Updates will be considered when substantial new knowledge is available, particularly related to the assessment reports of the Intergovernmental Panel on Climate Change (IPCC).

4.1 Everyone shares the responsibility for climate change adaptation

Weather conditions and the climate affect practically every sector of society and are an important element of most people's daily lives. Both individuals and society invest substantial resources in adapting their activities to weather conditions and the climate. The business sector constantly has to adapt to the current climatic conditions, and this is particularly true of industries such as agriculture, forestry and fisheries that are directly dependent on the environment. Many of Norway's voluntary organisations are also engaged in activities related to weather or climatic conditions. The Norwegian Red Cross and Norwegian People's Aid have developed special expertise and preparedness for natural hazards such as avalanches. Sports associations devote considerable time and resources to providing facilities for seasonal activities. Winter activities such as skiing and skating are also being adapted to some extent to weather and climate variability, for example through the artificial production of snow and ice when necessary.

The authorities are responsible for providing a framework that enables individuals, the business sector and the voluntary sector to carry out their tasks and meet their responsibilities under varying weather and climatic conditions. In certain areas, this is formalised through legislation or other forms of regulation. For example, there are standards regulating building in flood zones, and regional and local authorities are responsible for ensuring compliance with these. Areas that are particularly vulnerable to certain types of natural hazards, like flooding, landslides and avalanches, have therefore been mapped and safety measures have been introduced.

The report *Adapting to a changing climate* (NOU 2010: 10) concludes that Norway is in a good position to adapt to climate change, but that it will be necessary to implement appropriate adaptation measures for human and natural systems. The Government agrees with this conclusion, and considers it vital for society to adapt to climate change. This white paper is intended to provide a basis for effective adaptation of Norwegian society to climate change.

Climate change will first and foremost alter the framework for planning and decision-making rather than the tasks to be carried out. It will affect the various parts of the country and the various sectors in different ways, to different degrees and at different times. Moreover, climate change will be only one of a number of factors that influence the framework for planning and decision-making. This means that adaptation work has to be closely linked to the area and task in question. A fundamental principle of climate change adaptation in Norway is therefore that the actor responsible for the work is the actor responsible for the task or function affected by climate change. In consequence, everyone has a responsibility for climate change adaptation: individuals, households, private businesses and the public sector. Interest groups and the voluntary sector also have an important role to play in climate change adaptation.

In order to adapt, it is essential to understand how activities will be affected by climate change

and to integrate climate change considerations into planning and decision-making processes. The authorities have management tools to facilitate the incorporation of a range of different considerations into planning and decision-making. Wherever relevant, climate change considerations should be integrated into management tools used as a basis for general planning processes.

Climate change adaptation must be made an integral part of the work of actors in various fields, and at the same time it is important to ensure that everyone can use the same common knowledge base. The authorities also need to provide consistent guidelines on how different sectors, and particularly the municipalities, should address climate change.

4.2 Key considerations in climate change adaptation

In *Adapting to a changing climate*, the committee points out that if climate change considerations are not incorporated into long-term planning and decision-making, this may increase the risk of damage resulting from climate change and entail substantial costs. The committee therefore emphasised the importance of starting adaptation work now. Adaptation must be based on the knowledge available at any given time. There is considerable *uncertainty* about climate change and the impacts it will have on nature and society, and our knowledge of these issues will change during the present century. The level of uncertainty in climate projections can be reduced through research, but there will always be an element of uncertainty in connection with the future climate. The climate system is complex, and emission trends are uncertain. Moreover, it is not only the climate that will change in the period up to 2100; society will also change in ways that influence the impacts of climate change in different sectors. *Adapting to a changing climate* also points out that although the level of uncertainty associated with planning processes is increasing as a result of climate change, the uncertainty associated with future climate change is not does not justify delaying adaptation.

The time horizon is an important factor in climate change adaptation. Incorporating climate change considerations into planning processes is primarily necessary in long-term planning . The climate has changed substantially in Norway over the past 100 years – for example, precipitation has risen by about 20 %. In the course of this century, climate change will gradually become more marked and will influence the nature and level of the risks in many areas of Norwegian society. Risk assessments and planning today are largely based on historical data on the climate and natural hazards such as flooding, landslides and avalanches. Many of the decisions we make today will have implications far into the future. For example, buildings have an average lifetime of 78 years, and will therefore have to withstand the climatic conditions that are expected by the end of the present century. The same applies to areas that are to be zoned as residential areas today. It is therefore important to ensure that climate projections are part of the basis for assessments made in connection with investments and planning processes with a long time horizon. In this context «a long time horizon» is related to the time frame of the available climate projections. In general, climate projections for Norway are made for 2050 and 2100. To ensure that adaption measures are based on projections, it is sensible to take climate change into account in investments and planning processes with a time frame extending up to or beyond 2050, in other words with a lifetime of 30 years or more. For investments and planning processes with a shorter time frame, it will be sufficient to use the climate today as a basis.

Adapting to a changing climate takes into account that it may not be possible to limit the rise in global mean temperature to two degrees Celsius, which is the international target. There is a risk that global greenhouse gas emissions may continue to rise and that the world will not achieve the two-degree target, even though Norway and practically every other country in the world have adopted it. As a precautionary approach, the Government wishes assessments of the impacts of climate change to be based on figures from the high end of the range of national climate projections. However, when decisions are made in individual cases, climate change considerations and underlying assumptions about the degree of climate change must be weighed against other considerations of the public interest, the lifetime of the development in question and its importance to society.

Even if figures from the high end of the range of national climate projections are used to assess the impacts of climate change on an investment or a planning process, climate change considerations will in the individual case need to be weighed against other important considerations such as the implications for life and health or material assets, and what level of risk is considered to be

Box 4.1 Vulnerability to climate change

A number of factors influence vulnerability to climate change. Vulnerability is often understood as a function of the degree of exposure of an area to the impacts of climate change and of adaptive capacity, in other words the degree to which it is possible to deal with the challenges posed by climate change. In the report *Adapting to a changing climate* (NOU 2010: 10), adaptive capacity is linked to institutional factors and the resources available, and to the political will to give priority to climate and climate change in planning and decision-making processes. Analyses of how and to what extent climate change will affect a sector must be used as a basis for assessing adaptation needs. There are elements of uncertainty in all long-term planning. Climate change adds a new element of uncertainty in addition to those associated with other changes and trends that affect society.

acceptable. Cost-benefit analyses are an important tool in this work. Thus, assessments of climate change should be incorporated into the basis for making planning and investment decisions. This has already been done for many areas within the transport, energy and public safety sectors. The economic consequences of climate change and the potential damage to life and health will vary from one sector to another.

In some contexts, climate change will result in a higher risk of damage, or in the worst case loss of life, in Norway as well as in other countries. We are already at risk from natural hazards today, and will in future have to weigh up these risks against a number of other factors. This issue was discussed more thoroughly in a white paper on living with the risks of flooding, landslides and avalanches (Meld. St. 15 (2011–2012)), which states that both individuals and society as a whole must be aware of natural hazards such as flooding, landslides and avalanches, and take the risks into account in order to limit damage. The main focus should be on a proactive approach and preventive measures to keep damage at an acceptable level. Although the dangers must be taken into account when new buildings and other infrastructure are being planned, the terrain and ground conditions in Norway are such that it is not realistic to avoid all building in areas that are at risk of flooding, landslides or avalanches. It has been suggested that the safety requirements relating to these risk factors for new developments are too strict. The white paper concludes that a balance must be found between safety requirements and the continued need for further development in parts of the country where the topography or ground conditions are difficult.

Climate change will alter Norway's natural environment and entail a growing risk of losing characteristic species and habitats. At the same time, the natural environment can function as a buffer against many negative impacts of climate change. For example, vegetation plays an important role in preventing the erosion and damage that could otherwise be caused by higher precipitation and more intense precipitation events. Climate change adaptation must be designed to support the capacity of species and ecosystems to adapt to rising temperatures, and to avoid any increase in the vulnerability of the environment. The general provisions on sustainable use in Chapter II of the Nature Diversity Act must be used as a basis, including the requirements for decisions that affect the environment to be based on scientific knowledge of the impacts of environmental pressures and on assessments of the cumulative environmental effects on ecosystems.

4.3 Coordination needs

The Government first set out a framework and key objectives for climate change adaptation in May 2008, and these were incorporated into the 2009 budget proposal. They state that the goals of Norway's adaptation work are to reduce the vulnerability of Norwegian society to climate change and to strengthen Norway's adaptive capacity. These goals are to be achieved by:

1. reviewing Norway's vulnerability to climate change and incorporating climate change considerations into planning processes;
2. developing the knowledge base on climate change and climate change adaptation;
3. coordinating adaptation initiatives, awareness raising and competence building.

In the period 2008–12, Norway has made important progress in its national adaptation work. *Adapting to a changing climate* (NOU 2010: 10), the first national assessment of the impacts of climate change on Norway, has been published. A range of capacity- and competence-building meas-

ures have been implemented. For example, all municipalities and counties are now offered courses in climate change adaptation, and Norway's 13 largest cities and urban areas, which are involved in the cooperation programme «Cities of the Future», have established climate change adaptation plans. Various sectoral authorities have carried out surveys and made changes to requirements and guidelines in order to take future climate change into account.

Climate change adaptation involves many different central government authorities. The Directorate for Civil Protection and Emergency Planning is responsible for assessing the risks associated with different types of natural hazards, and draws up guidelines for making risk assessments in connection with land-use planning. The Norwegian Water Resources and Energy Directorate is the government agency responsible for mapping the risk of landslides and avalanches and flood-prone areas, for dam safety and for calculations of flooding levels for use in designing infrastructure near river systems. The Directorate for Nature Management[1] monitors and assesses the impacts of climate change on the natural environment, the Norwegian Mapping Authority has important functions relating to sea level rise, and the Climate and Pollution Agency evaluates current knowledge about climate change, facilitates municipal planning for climate change and administers the legislation relating to water supplies and sewerage. The Norwegian Building Authority and the Norwegian Public Roads Administration are responsible for assessing the implications of climate change for infrastructure such as buildings and roads. A number of other central government authorities are also involved in climate change adaptation. In addition to ensuring the necessary efforts within their own organisation, they are required to provide information to municipalities, counties and the general public.

It is both practical and effective for municipal, county and central government authorities to base climate change adaptation on a common knowledge base and to coordinate their efforts closely. To promote coordination at the central government level, a working group including representatives of all the relevant ministries was established, headed by the Ministry of the Environment. This ministry is responsible for Norway's overall climate policy, including climate change adaptation, and is also the central government planning authority. Knowledge about climate change is the common starting point for both mitigation and adaptation to climate change.

In 2007, the Directorate for Civil Protection and Emergency Planning was given time-limited responsibility for coordinating the work of central government authorities on climate change adaptation. The secretariat for this five-year project, which was under the directorate, has focused especially on facilitating the efforts of municipal authorities and others to address the long-term challenges that climate change will bring. The secretariat's efforts have included information work, courses and the development of a national portal that can be accessed from the Government's website. The portal provides relevant information on climate change adaptation for public authorities, companies and other interested parties, examples of practical adaptation work and links to key actors that can provide advice and guidance within specific fields. The secretariat has also been responsible for coordination of work on climate change adaptation in the «Cities of the Future» cooperation, which includes Norway's 13 largest cities. In addition, the secretariat has established cooperation on climate change adaptation with Portugal, Latvia, Hungary and Slovakia under the EEA and Norway Grants scheme.

The organisation of central government agencies' adaptation work was evaluated in *Adapting to a changing climate*, which points out that a flexible, project-based organisational model has a number of advantages in this new and unfamiliar area. However, the model also has limitations in the longer term, particularly as regards predictability and a long-term approach. The experience gained from the five-year project during which the Directorate for Civil Protection and Emergency Planning provided the secretariat will be evaluated, and after this it will be decided where the responsibility for coordination of climate change adaptation at directorate level is to be placed. The evaluation will include responsibility for work relating to storm water management and sea level rise. The Government will give a fuller account of how climate change adaptation at directorate level is to be coordinated in connection with the 2014 budget.

[1] Since the white paper was published, the Directorate for Nature Management and the Climate and Pollution Agency have been merged to form the new Norwegian Environment Agency.

4.4 International developments

The IPCC's special report *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* states that there is evidence of an increase in certain types of extreme weather events, and that it is likely that this is a result of anthropogenic climate change. Insurance payouts are rising, and the world community is spending more and more on humanitarian aid related to natural hazards. The IPCC report points out that although the economic losses from climate-related events are rising, the number of human lives lost as a result of such events has dropped considerably. In other words, our ability to deal with extreme weather events has improved as measured in human lives, but in economic terms the costs have risen. The IPCC points out that the costs can be considerably reduced through adaptation and disaster risk reduction. The UN International Strategy for Disaster Reduction points out that in some cases, risk reduction measures can reduce the costs of natural disasters by as much as 80 %. The conclusion is clear – adaptation and risk reduction highly cost-effective.

Although the economic costs of natural hazard events are highest in developed countries, the economic burden for the poorest countries is considerably higher.

Support for adaptation in developing countries has become an increasingly important issue under the UN Convention on Climate Change. A framework known as the Cancun Adaptation Framework has been built up under the Convention in order to enhance action on adaptation in both developed and developing countries. Among the main elements are strengthening the knowledge base for all countries, capacity-building for adaptation, and providing support for developing countries through capacity-building, transfer of technology and financing. Norway has followed up its commitments by increasing support for climate change adaptation in developing countries. This support is being channelled among other things to building up climate services, which are an essential basis for climate change adaptation and disaster risk reduction, planning adaptation at national level, and adaptation in important sectors such as agriculture and health. Norway has played a key role in the establishment of the Global Framework for Climate Services under the World Meteorological Organization. Climate change adaptation is also one of the two main pillars of the recently established Green Climate Fund.

In its national adaptation efforts Norway can learn a great deal from the work being done within the framework of the Climate Change Convention and the International Strategy for Disaster Reduction, and from reports published by the IPPC. These serve as arenas for bringing together experience and case studies of sound ways of organising adaptation work. A great deal of work is also being done internationally, particularly within the OECD, on the development of methods and tools for economic analyses of climate change and adaptation and cost-benefit analyses of adaptation measures. Norway can benefit from this in its work at national level.

4.5 Knowledge and learning in climate change adaptation

Although our techniques for dealing with the challenges posed by today's climate have produced a considerable body of knowledge to draw on, climate change adaptation is a relatively new field. Knowledge about climate change and its impacts, and about how Norwegian society is adapting to climate change, is advancing rapidly. Adaptation work must always be based on the best available information about climate change and how the changes can be addressed.

In addition, regular updates of the knowledge base are needed, including climate projections for Norway and analyses of the impacts of climate change on nature and society.

5 A shared knowledge platform

The Government:

- intends to ensure that the knowledge base for climate change adaptation is strengthened through closer monitoring of climate change, continued expansion of climate change research and the development of a national centre for climate services.

Global climate change is already resulting in major changes for many local communities in Norway. Towards the end of this century, the consequences of climate change for both nature and society will become more and more marked.

5.1 A shared need for knowledge

Knowledge is an essential basis for effective climate change adaptation. The need for more knowledge is a recurring theme in nearly all areas affected by climate change. Generation and dissemination of basic knowledge about climate change in Norway is largely organised under the auspices of the public authorities. In 2013, the Research Council of Norway will provide funding totalling an estimated NOK 400 million for climate research, about twice as much as in 2005. This research is carried out at universities, university colleges and other institutes that supplement the funding with resources of their own. Norwegian researchers are also taking part in a range of EU-funded research projects. This section following presents basic knowledge needs related to the climate and climate change across sectors. They are based on the report *Adapting to a changing climate* (NOU 2010: 10) and the report presented by Klima21, the Government's strategic forum for climate research.

Social transformation and adaptation in response to climate change

More frequent and more severe extreme weather events will mean an increasing risk of losses and damage, and will entail substantial economic costs. Effective preventive work requires knowledge of how exposure to climate-related risks increases in different sectors and in local communities. More knowledge is needed about the future costs of climate change, and how adaptation needs can be incorporated and taken into account in current policy and planning.

Research should help to identify the instruments and policies that will best enable us to promote a low-emission economy and at the same time address the impacts of climate change. The links between adaptation to and mitigation of climate change are becoming increasingly important. Social science research on climate change has been strengthened in recent years, but we still need much more knowledge on how climate change considerations can be incorporated into practical policies and specific measures.

Climate change will have political, social and cultural implications. To make climate policy more effective, we need a better understanding of changes in value systems, management systems, financial institutions and technological and biological systems. This also involves questions relating to the development of prosperity, general framework conditions and changes in attitudes and behaviour. The way people communicate about climate change is an important research topic in itself.

The climate in the Arctic is changing rapidly, which is opening up new prospects for economic activity and boosting international interest in the region. Commercial activities are expected to expand in the years ahead, and the Arctic environment is vulnerable. New and expanded activity must therefore be based on sound knowledge of the risks and environmental impacts associated with different types of commercial activities.

For the primary industries, it is particularly important to ensure that any new opportunities arising from climate change are included in research and development activities.

Impacts on nature and society

Human society is dependent on ecosystem services such as food supplies, pollination, access to clean drinking water and flood control. More knowledge is needed about how climate change will affect ecosystem services in Norway and neighbouring areas, including the economic impacts. We also need a good overview of the impacts of climate change on species and ecosystems, the resilience of ecosystems, and the tipping points beyond which changes may be irreversible. Moreover, it is important to improve understanding of interactions between climate change and ocean acidification, persistent, bioaccumulative and toxic substances and other pollutants, changes in biodiversity, and other environmental pressures. The environmental authorities need to receive new information about changes in ecosystems on an ongoing basis, so that uncertainty about trends for key populations and species can be reduced. The boundaries of a number of climate zones and ecological systems go through Norwegian waters, and this means that knowledge about changes in ecosystems and species distribution in response to climate change is particularly important for Norway. Studies of key species and further development of ecosystem models can provide important information as a basis for climate change adaptation.

The uptake of CO_2 in seawater is resulting in ocean acidification. According to the Intergovernmental Panel on Climate Change (IPCC), this will particularly affect the Arctic and other cold regions. Climate change combined with ocean acidification will have major impacts on the marine environment, and more knowledge is needed about the impacts of ocean acidification on ecosystems, fisheries and aquaculture. More intensive monitoring and identification of suitable indicator species will be needed in this connection.

Flooding, landslides and avalanches put pressure on important infrastructure such as roads, railways, ICT infrastructure, buildings, and energy, water and waste water installations. Climate change will affect the economic base for agriculture, forestry, fisheries, aquaculture and other food production. Many sectors and industries are vulnerable both to gradual changes and to extreme weather events, and more reliable and more detailed local knowledge is needed about the impacts of climate change in a number of different areas. More knowledge is also needed about the impacts on different sectors and industries, for example through vulnerability and risk assessments, and on which types of investments, operating routines and rules will result in effective transformation and adaptation.

The climate system and climate change

In the 2012 white paper on Norwegian climate policy (Meld. St. 21 (2011–2012)), the Government announced that it would make a substantial contribution to the global efforts to improve the knowledge base for addressing climate change, and to strengthening basic climate research. This was followed up in Norway's 2013 budget, in which the Government proposed an increase of NOK 47 million in allocations to climate research.

Basic knowledge about the climate system is the foundation for research on the impacts of climate change, which in turn provides the basis for research on risk management and adaptation. Climate change adaptation is dependent on projections for variables such as temperature, precipitation, wind, flooding, sea level, ocean currents, wave height and sea ice in different areas and regions. A number of key research goals are therefore related to improving understanding of the climate system. They include targeted work to develop downscaling methodology for climate models and the development of seasonal forecasts and decadal-scale scenarios. More specialised cli-

Box 5.1 Climate models and downscaling climate projections

Climate models are used as a basis for assessing how the climate will change towards the end of this century. They are the starting point for specific estimates – for example of how much the summer temperature will rise in Tromsø by 2050, or how much more rain and snow Bergen must expect in winter by the end of the century. But there is a considerable element of uncertainty in such projections, and the level of uncertainty increases when projections are made for smaller geographical areas. It is easier to make reliable global or regional projections of climate change than to make them for a single municipality. The climate models are therefore being further developed in order to reduce the uncertainty of projections with better spatial resolution, so that they are more suitable for practical use by municipalities.

mate services are also needed for planning purposes, and basic climate research should be used to support the development of such services.

Recent research has helped to improve forecasting of extreme weather in the Arctic. New research also indicates that it should be possible to develop seasonal and decadal forecasts. If this is successful, it will have major implications for society's adaptive capacity. Such forecasts would provide industries such as agriculture, forestry and fisheries, shipping and construction with valuable additional information as a basis for their decisions. Continuing targeted research on the climate system will therefore have major benefits for society. Links between oceans/ice, the atmosphere and land surface, and the exchange of energy and water vapour are a fundamental part of this research. Changes in the climate system near the poles play a key role in global change. Studies of the Arctic and Antarctic climate will provide information that is of great value for understanding global climate change and developing adaptation strategies. Studies of the climate in the polar regions are also of interest in the context of short-lived climate forcers, which are particles and gases including black carbon (soot particles), ozone, methane and some HFCs. They have rapid effects on the climate system, the precise impacts varying from one type of climate forcer to another. They also have other negative environmental impacts and adverse effects on people's health. Much more knowledge is needed to identify the best ways of reducing emissions of these substances and to understand their impacts on climate change and their implications for health and environmental policy.

Changes in carbon stocks on land and in the oceans and marine ecosystems are of great significance for climate change. Knowledge about the natural carbon cycle is therefore needed to predict more precisely how the climate will change during the present century. Measures to enhance carbon uptake by natural sinks and to alter the heat balance of the Earth have attracted growing attention in recent years as possible instruments for addressing climate change. Such measures are controversial because it is difficult to assess their impacts and verify whether they function as intended, and because they will generally only have short-term effects. Nevertheless it is important to obtain more knowledge in this field. A better understanding of the climate system is essential for developing measures of this kind.

New climate programme under the Research Council of Norway

The NORKLIMA programme is the Research Council's main climate research initiative and one of its seven large-scale programmes. It is a 10-year programme due to be completed in 2013, and the Research Council is setting up a new major climate research initiative.

The new research programme that is being established will also be a large-scale programme. Large-scale programmes are the Research Council's flagship programmes for key research areas. They have clear social and scientific objectives and a broad scope, promote the internationalisation of research, have substantial annual budgets, and are financed by several ministries.

Future Norwegian climate research should strengthen the interdisciplinary aspect of research. There must be a closer focus on the links between research questions in different areas, both within climate research and between climate research and related areas. For example, there is a pressing need for closer links between climate and energy research and climate and environmental research. Achieving this will require dialogue, cooperation and the involvement of both researchers and users in planning and carrying out research.

A national climate research programme is a good platform for enhancing Norwegian participation in international research cooperation, such as the EU framework research programmes and the European Joint Programming Initiative JPI Climate.

Climate change is making the development process more difficult, because exposure and vulnerability to environmental and climate change are particularly high in many poor countries. A concerted global effort to enhance knowledge about the climate is needed. Norway has a respon-

Box 5.2 JPI Oceans

JPI Oceans is a joint European research programme established on Norway's initiative. Its purpose is to coordinate and enhance research on the most important issues in European seas and oceans. Climate change adaptation will be a key topic in this programme too.

Box 5.3 The European Climate Adaptation Platform

The web-based European Climate Adaptation Platform CLIMATE-ADAPT was launched in March 2012. It is an initiative of the European Commission and helps users to access and share information on:

- Expected climate change in Europe
- Current and future vulnerability of regions and sectors
- National and transnational adaptation strategies
- Adaptation case studies and potential adaptation options
- Tools that support adaptation planning

sibility here, and an international evaluation concluded that Norwegian climate research is of a very high standard. This puts Norway in a particularly good position to contribute to the development of knowledge about the climate system for the international community.

Climate monitoring

Monitoring is essential to reveal changes in climate variables such as precipitation and wind. Extreme precipitation events have been identified as one of the main climate-related threats in Norway. It is to be expected that wind direction and wind strength will be affected by climate change. Since both precipitation and changes in wind patterns can have major impacts, it is important to monitor the situation closely in order to detect any trends. To ensure that sufficient data is available for modelling short-term precipitation, measurements from a large number of sites in all regions of the country are needed, since extreme weather events are generally local in character. Sound wind and precipitation data are also needed as a basis for improving forecasting of extreme weather events in the future and preventing loss of life and material assets.

Climate monitoring will be important for many sectors to detect changes and gain an overview of the impacts of climate change. Because natural hazards such as storms, flooding, landslides and avalanches can have such serious impacts, more knowledge is needed about how climate change will affect the probability of such events. For example, we need to know more about how the risk of landslides and avalanches will change. Climate monitoring programmes are often linked to research projects or the management tasks of public authorities in various sectors. For instance, the fisheries management authorities need good time series of observations so that they can identify changes that need to be taken into consideration. To provide the authorities with a complete overview of the impacts of climate change on the natural environment and key sectors, monitoring activities must be coordinated. It may also be necessary to collate and coordinate results and analyses as a basis for policy development and the development of specific adaptation measures across sectors.

5.2 Tailored knowledge about the future climate

Climate change is creating a need for a generally available service to provide information on the current and future climate and play a part in translating climate science into practical adaptation work. People who are involved in municipal land-use planning need to know how the probability of flooding will change in flood-prone areas. Farmers need to know what changes to expect in the growing season and rainfall patterns. Those who are responsible for drinking water supplies need information on changes in water temperature and run-off to reservoirs. And people who make economic analyses of public and private investments need information on how climate change will affect the structure and profitability of investments. It is much easier to take climate change into account if we have a sound knowledge of today's climate and know more about what to expect in the future.

Regional climate models are already available, and there are projections that quantify expected changes in temperature and precipitation. The projections are based on climate models and are available in map form and in reports. However, the resolution of the maps is too low for use in practical planning, and will not meet the specific mapping and planning needs of actors in various sectors. Some enterprises and municipalities have obtained data that are better tailored to their needs, for instance through participation in research projects.

The Norwegian Meteorological Institute is the Norwegian institution responsible for monitoring the atmospheric climate and for providing information to the public on how variables such as precipitation and temperature are expected to

change. The Institute of Marine Research has similar responsibilities for the marine climate, from the open sea to coastal waters and the fjords. The Norwegian Water Resources and Energy Directorate has national responsibility for hydrological and cryosphere monitoring. All three institutions provide projections and information on various climate variables to municipalities, agencies and research institutions.

Data tailored for specific purposes, combined with information about today's climate, has proved to be a good basis for assessments by companies and municipalities of how climate change will affect their activities in different areas. The report *Adapting to a changing climate* (NOU 2010: 10) highlights the need to improve dissemination of data on both today's and the future climate. The Government agrees with this conclusion, and will step up the dissemination of relevant climate data as a basis for assessing the impacts of climate change in various fields. The municipalities have a particular need for this kind of information.

The term «climate services» is used to mean the delivery of climate information to different users. This is a high-priority field internationally. It is high on the agenda of the EU's framework research programmes, and research on climate services is one of the main activities of the new joint programming initiative JPI Climate. The World Meteorological Organization (WMO) has for a number of years been focusing on capacity building and international assistance to enable developing countries to build up climate services. Norway has played a key role in this vital international work.

According to the WMO, climate services include a wide range of activities intended to generate and make available information on the historical, current and future climate and its impacts on human and natural systems. Climate services also include information and support that can help users to choose the right product for the decisions they need to make and explain the uncertainty associated with the information provided.

In Norway, cooperation on the development of a national centre for climate services was established in 2001, involving the Norwegian Meteorological Institute, the Norwegian Water Resources and Energy Directorate and the Bjerknes Centre for Climate Research, in Bergen. The Bjerknes Centre has Norway's leading expertise on climate modelling and has provided important input to the IPCC's work. The Meteorological Institute has overall responsibility for the centre for climate services. The Water Resources and Energy Directorate is Norway's national centre of expertise for hydrology, and monitors hydrological changes, including flooding.

One important reason for establishing a centre for climate services is to provide support for work on climate change adaptation by the municipalities and sectoral authorities. The national centre for climate services is also one of the specific measures recommended by the committee in the report *Adapting to a changing climate*. The framework for the new centre must enable it to provide practical support and make it easier for the municipalities to carry out the necessary impact assessments and climate change adaptation measures.

Norway's centre for climate services should be developed in a way that enables those who are responsible for risk assessment and for adapting their activities to climate change to carry out their work as effectively as possible and with clear targets.

The centre will:

- make available and coordinate climate and hydrological data and other information that is currently held by many different central government agencies;
- improve dissemination of climate data and hydrological projections for use by the public administration, especially at municipal level;
- analyse how the consequences of climate change will vary from one part of Norway to another, as a basis for the development of climate indexes and climate zones for use in practical climate change adaptation, see Chapter 8.5 on infrastructure and the 2012 white paper on building policy (*Gode bygg for eit betre samfunn* Meld. St. 28 (2011–2012), in Norwegian only);
- share its expertise on climate change through advice and courses held in cooperation with other authorities.

The centre will be developed in close dialogue with its users. A pilot project in Troms county, also involving the Directorate for Civil Protection and Emergency Planning, is currently developing and evaluating products that municipalities can use to incorporate climate change into their planning activities. Information technology plays an essential role in climate research. Basic climate research, including modelling of the climate system, requires high-performance computing resources. The use and development of ICT tools and products will be a key task for the centre.

Box 5.4 Short-term precipitation monitoring and forecasting

In recent years, there has been a growing demand for short-term precipitation data. To meet this need, the Norwegian Meteorological Institute has intensified monitoring and analysis of precipitation intensity. Activities have included improving forecasting models, more extensive use of weather radar, more real-time measurement of precipitation intensity and stepping up the research effort.

Precipitation was measured at least once an hour at 50 stations in 2005, increasing to 170 stations in 2012. Many weather stations have been established and are operated in cooperation with for example municipalities. Most of these transfer data directly to the Meteorological Institute, which carries out quality control and makes the data available on its websites. The municipalities either receive the data automatically or download measurements and statistics (intensity-duration-frequency (IDF) values) from the websites. In the course of 2013, about 100 of the Meteorological Institute's automatic stations will be upgraded to register precipitation every 10 minutes.

Information on the extent and intensity of areas of precipitation for large parts of Norway can also be obtained from the weather radar network. There are now nine weather radars in operation: the two newest are in Hurum, south of Oslo (2010), and Berlevåg in Finnmark (2012). A new weather radar at Sømna in Nordland will come into operation in 2014. The newest weather radars provide better estimates of precipitation intensity and can distinguish between snow and rain. Work is in progress to improve the quality of radar data on precipitation and to combine radar data with actual land-based measurements of precipitation.

The national centre for climate services will provide a better basis for practical work on climate change adaptation. Climate projections for Norway need to be updated regularly as new results become available from the global climate models.

The expertise developed by the centre for climate services will also be relevant in other contexts, for example as a basis for integrating climate considerations more fully as an element of development policy.

Other sources of relevant information

Many other research institutes, universities and directorates also have relevant expertise and provide information on how the projected climate change will affect Norway. They include the Climate and Pollution Agency, the Public Roads Administration, the Institute of Marine Research, the Norwegian Polar Institute, the National Rail Administration, the Norwegian Institute for Air Research, the National Institute of Nutrition and Seafood Research, the Norwegian Forest and Landscape Institute, and Cicero (Center for International Climate and Environmental Research). Information is already being shared with others to some extent. A great deal of information is collected together on the website Klimatilpasning.no, which is part of the Norwegian Government portal. The website provides targeted information from a wide range of institutions with relevant expertise. Up till now, it has been run by the national secretariat for climate change adaptation in the Directorate for Civil Protection and Emergency Planning.

The Climate and Pollution Agency is Norway's national focal point for the IPCC, and is responsible for coordinating all processes relating to the IPCC's work and for providing information on the results. The IPCC assesses scientific information on the climate system and ways of mitigating climate change and adapting society to both gradual climate change and extreme weather events. The Climate and Pollution Agency is therefore in a good position to assisting in the development of the Norwegian knowledge base for climate change adaptation.

The Climate and Pollution Agency is responsible for performance monitoring of Norway's work on reducing greenhouse gas emissions and for international reporting. The Agency is also responsible for ensuring climate change adaptation in the sectors for which it is responsible, for example water supply and sewerage and landfills. This puts the Agency in a good position to consider the links between mitigation and adaptation. The Climate and Pollution Agency is also responsible for assessing whether climate change affects other pollution and environmental pressures, and must adjust regulation in other sectors to avoid negative effects.

The national centre for climate services must be developed in close cooperation with relevant authorities. It should also be considered whether more agencies and research institutes should be linked to the centre, in addition to those that are already cooperating on its development at present.

5.3 Maps and spatial information

Planners and politicians need information on the characteristics of different areas and their value to society in order to assess risk and ensure sound planning. Good maps that provide precise geographical information are therefore an essential basis for assessing the risk posed by climate change in different sectors.

Information is needed in many different areas, for example on buildings and other infrastructure, land use, river systems, sea level and topography.

Norway has good general map data in many fields, particularly for areas that are being developed, and where the data is kept up to date through co-financing. Nevertheless, more continuous and precise mapping is needed to provide a satisfactory basis for risk and vulnerability analyses and for mapping flood, landslide and avalanche risk. There will also be a growing need for better information for general and emergency planning, and it is important to be able to collate information from different sources quickly and effectively.

Sea level monitoring

Monitoring sea level is an international task. The Norwegian Mapping Authority is the competent authority in Norway. The monitoring system includes measurements from tidal gauges along the entire coast and a number of geodetic monitoring programmes. Now that the Mapping Authority's geodetic observatory at Ny-Ålesund has been modernised, Norway is making a substantial contribution to international cooperation on sea level monitoring.

Measuring actual changes in sea level involves considerable scientific and technological challenges. Very precise and reliable measurements are needed to make comparisons possible over long distances all round the world. Modelling future changes in sea level at regional level is a very complex process, since these changes are strongly influenced by the earth's gravitational field and its variations. In addition, postglacial rebound means that sections of the Scandinavian coastline are still rising. The Norwegian Mapping Authority has therefore attached special importance to strengthening its geodetic expertise, and will continue this process so that it can provide the necessary support for Norwegian and international climate research.

Detailed topographical data

There is a pressing need for better maps as a basis for statutory risk and vulnerability assessments in municipal planning processes. Topographical variations that are not revealed by smaller scale maps may be very important for planning in some areas, for example where smaller streams pose a high flooding risk or may do in the future.

In a 2012 white paper on the risk of flooding, landslides and avalanches (Meld. St. 15 (2011–2012), the Government gave an account of efforts to prevent loss of life and damage to property. Assessing and mapping flood, landslide and avalanche hazard and risk requires a great deal of information and high-quality underlying data. For analyses relating to flooding, landslides and avalanches, it is particularly important to have detailed topographic data that can be used as a basis for analyses of the terrain and geological structures.

The most cost-effective way of obtaining topographical data is by airborne laser scanning. So far, a total area of about 100 000 km^2 has been scanned at different levels of detail in Norway. Central government agencies and municipalities are cooperating on this work by organising local projects within a framework called Geovekst.

Data on the power grid and other infrastructure

Climate change will make installations that are exposed to wind, flooding, landslides and avalanches more vulnerable. This includes lines and cables that are part of the electricity and ICT infrastructure. Some types of cables can be laid underground to give protection against wind and weather, and it is likely that this solution will be more widely used in the future. Underground cables are protected, and will generally have a longer lifetime. The disadvantages are the limited space when many different actors need to use the same area for their installations, and that maintenance is more difficult and more expensive. There are several other considerations to take into account for electricity infrastructure, including costs and how long it takes to make repairs. As a general rule, underground cabling will be used

Box 5.5 Climate change and adaptation needs: power and ICT infrastructure

- Closer focus on climate change adaptation, accessibility, reliability, civil protection, emergency planning and vulnerability.
- More infrastructure needs to be laid underground: involves more use of undeveloped areas, costs of maintaining and moving cables are high.
- Public authorities and private actors are becoming more and more dependent on each other.
- Closer coordination and better cooperation between national authorities is needed.
- Better rules on cables and other infrastructure are needed (requirements to register infrastructure, documentation, standardised surveying methods, management and exchange of data).
- Poor coordination creates unnecessary conflicts between public road authorities, road owners and actors responsible for cables, etc in connection with excavation.

more for electricity transmission at lower voltages (grid voltage up to 22 kV), while a more restrictive practice will be followed for high-voltage lines.

Society is so dependent on underground infrastructure that requirements for easy access for maintenance and upgrading are becoming increasingly strict. The requirements for security of supply and reliability, combined with the fact that Norway has a large number of grid owners who have to communicate with different municipal, county and central government owners of roads, makes the situation very complicated.

Knowing what has been installed underground and precisely where is essential for effective cooperation. A notification system has been established requiring information to be reported before any excavation starts. Information on the location of electricity infrastructure is often confidential, so that it is not marked on public maps, but the information is available to anyone who has a professional need for it. A lack of awareness in this area results in unnecessary damage during excavation, lengthens the process and makes it difficult for actors to cooperate. The Ministry of the Environment, together with a number of industry organisations, has established a cooperation forum to gain an overview and assess how problems can be solved. The Government wishes to continue this cooperation with a view to improving coordination.

Cooperation on the establishment and management of spatial information

Geographical information and geographical information systems (GIS) are intended to cover the needs of a wide range of sectors. Precise geographical information is essential for assessing climate-related risks and the effects of risk-reduction measures. Information on vegetation cover, soils, geophysical conditions, sea level, tides and post-glacial rebound in needed to document trends and changes resulting from natural geophysical processes and from climate change. The Norwegian Mapping Authority is responsible for climate change adaptation within its own sphere of responsibility, and contributes to the work of other sectors. Up-to-date and easily accessible map data and spatial information are needed for land-use management, forestry and agriculture, transport and communications and risk and vulnerability analyses, for use both as management and analytical tools and as tools for documenting change. Detailed geographical information, together with downscaled climate projections, will provide a better basis for climate change adaptation in a number of sectors.

Norway's 2012 Spatial Data Act requires central government authorities and municipalities to share spatial data and make it available in electronic form. In the long term, this will provide a better overview and access to basic data and thematic data that the public administration needs for land-use planning, nature management, risk and vulnerability analyses, climate change adaptation and other purposes.

The Norwegian Mapping Authority is coordinating cooperation on an infrastructure for spatial information both at central government and at county level. The Authority has established a secretariat for this purpose. A coordination committee has been set up in each county including representatives of each of the parties, and these will give advice on priorities for mapping projects and draw up spatial data plans.

6 Risk reduction and natural hazard management

The Government:

- Will appoint a committee to evaluate the current legislation and as appropriate make proposals for amendments to provide a better framework for the municipalities, which will have to deal with increasing volumes of stormwater as a result of climate change.

Climate change adaptation is often considered through a sectoral lens. To gain an overall picture of responsibilities for dealing with climate change, it is important to use a different starting point: the types of phenomena and events on which climate change is expected to have a strong influence. In Norway's case, the main problems are expected to be water-related – in particular flooding, landslides and avalanches, stormwater and sea level rise.

6.1 Civil protection and emergency planning

The purpose of civil protection and emergency planning work is to safeguard life, health and property against various kinds of risks and threats. Climate change will alter the level and nature of the risks we face in a number of ways. More frequent and more intense extreme weather events, changes in patterns of flooding, landslides and avalanches, and a greater risk of forest fire in certain parts of the country will make it necessary to improve risk reduction and emergency planning. It is therefore essential for a safe and secure society that the changing climate is taken into account in this work. A white paper on civil protection published in 2012 (Meld. St. 29 (2011–2012) *Samfunnssikkerhet*, in Norwegian only) is intended to strengthen efforts in this field. The Government is also taking steps to ensure that efforts to boost Norway's risk reduction capacity and capacity to manage extreme weather events are incorporated into overall civil protection work.

Extreme weather events pose a risk to life and health and may disrupt critical infrastructure, for example electricity and transport infrastructure. And disruption of critical infrastructure such as roads, telephone systems and the electricity supply system may in itself be a threat to life and health. The projected rise in precipitation and more intense precipitation events may alter the nature and level of the risks people face. Types of flooding and slides that people in Norway are not accustomed to may become more common, for example pluvial (rain-related) flooding. Changes in precipitation and flooding patterns may entail a risk of flooding and slides in areas that have not previously experienced such events.

In the 2012 edition of the annual national risk review published by the Directorate for Civil Pro-

Figure 6.1 Results of a rockfall in Lærdal in Western Norway

Photo: Directorate for Civil Protection and Emergency Planning

Figure 6.2 Rockfall barrier along a road

Photo: Espen Bratlie/Samfoto/NTBscanpix

tection and Emergency Planning, the risk of natural hazard events such as flooding associated with extreme weather events is assessed as high in Norway.[1] Climate change is expected to reinforce this picture. The Directorate emphasises that the consequences of different types of climate-related events will depend on how well Norway is prepared. The review highlights steps to make infrastructure more resilient and strengthen early warning systems as important ways of reducing loss and damage. There are close links between the preventive aspect of civil protection and climate change adaptation.

Division of responsibilities

A variety of tools and instruments can be used in civil protection and emergency planning work. In Norway, this work is based on the principle that those responsible for a particular field under normal circumstances are also responsible for dealing with crises; the principle of subsidiarity (meaning that crises should be dealt with at the lowest possible administrative level); and the principle that the organisational structures set up to deal with crises should be as similar as possible to those used in normal circumstances. In the 2012 white paper on civil protection, the Government introduced a fourth principle, that crisis management must also be based on cooperation. This was intended to clarify the Government's overall responsibility for civil protection and emergency planning across sectors. In accordance with these principles, civil protection and emergency planning is an integral part of the work of all sectors in Norway. The authorities in each sector are therefore required to develop their own civil protection and emergency plans and instruments for their area of responsibility, and that the municipalities have overall responsibility for civil protection and emergency planning at local level.

The Ministry of Justice and Public Security has the overall responsibility for ensuring policy coherence in the field of civil protection. In addition to initiating and carrying out measures, the Ministry takes initiatives vis-à-vis other government agencies and is responsible for coordinating policy and for performance monitoring in all sec-

[1] Nasjonalt risikobilde 2012, Directorate for Civil Protection and Emergency Planning (National Risk Review for Norway 2012, in Norwegian only)

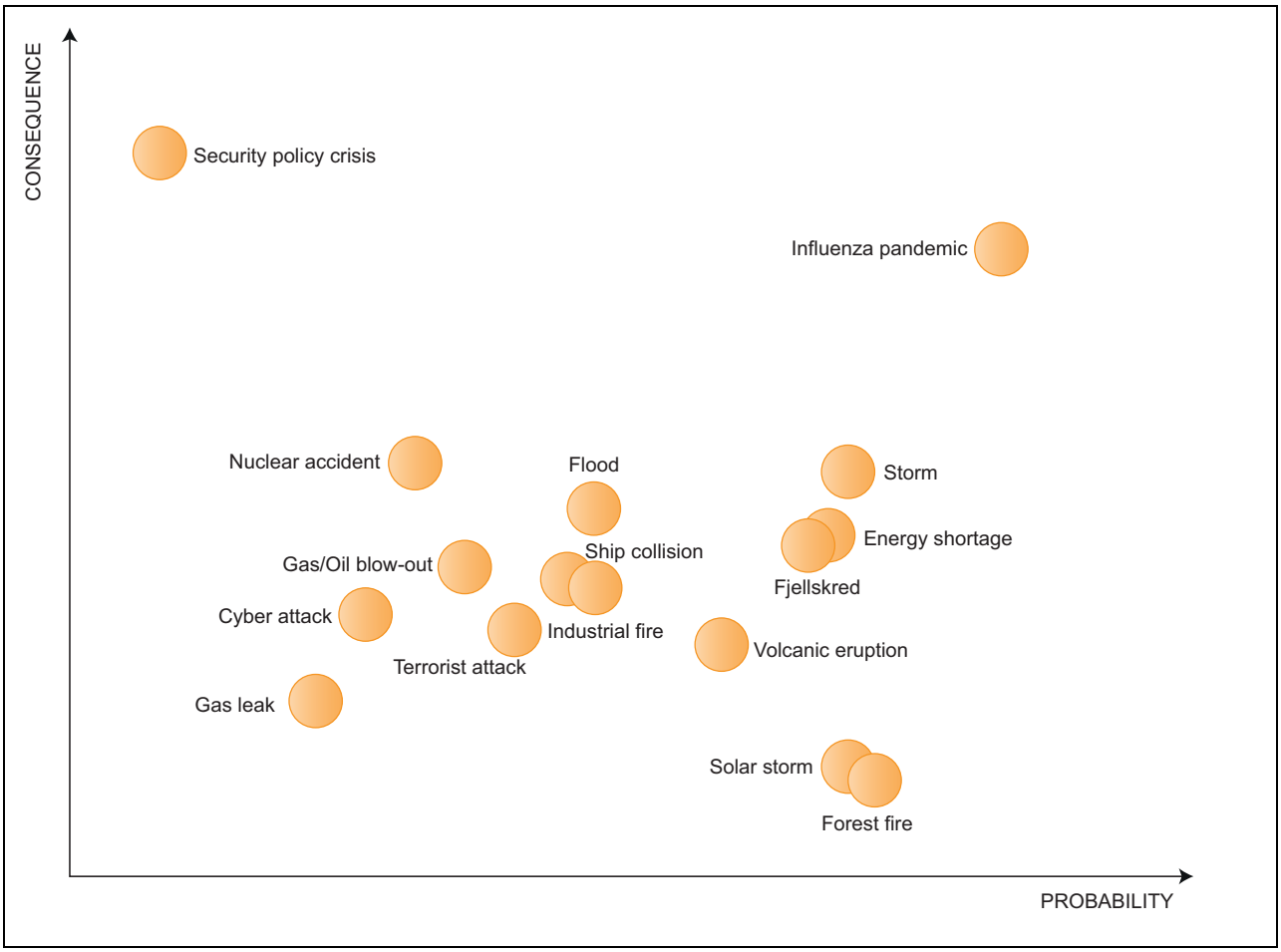

Figure 6.3 Risk matrix showing the probability and consequences of particularly serious events, from the 2012 edition of the national risk review for Norway

Source: *Nasjonalt risikobilde 2012*, Directorate for Civil Protection and Emergency Planning (National Risk Review for Norway, in Norwegian only)

tors. The Ministry is also responsible for contributing to close international cooperation.

The Directorate for Civil Protection and Emergency Planning is the competent authority under the Ministry, and maintains an overview of risk and vulnerability in Norway. The Directorate has the overall responsibility for coordinating risk reduction and natural hazard management. Norway's national platform for disaster risk reduction was established in 2011as a forum for cooperation between bodies that have responsibilities relating to natural hazards and natural hazard events. One of its tasks will be to improve the risk overview for Norway by developing more scenarios, analysing trends and generating more knowledge about vulnerability. The establishment of the national platform was also an important step in following up Norway's commitments under the International Strategy for Disaster Reduction.

The Norwegian Civil Defence is the most important resource that can be deployed to give

Figure 6.4 From a major forest fire in Froland, Aust-Agder county

Photo: Nicolai Prebensen/VG/NTBscanpix

operational support during emergencies. Its responsibilities include many types of climate-related events, and it is an important part of the emergency services in this area. For example, the Civil Defence is used to reinforce municipal resources for fighting forest fires.

After major natural hazard events, extensive clean-up may be needed. In special cases, expertise and construction resources can be obtained through the Council for Emergency Preparedness in the Construction Sector, which is appointed by the Ministry of Trade and Industry.

Civil protection in municipal planning processes

Norway's Civil Protection Act sets out the duties of the municipalities in the field of emergency preparedness, and is designed to ensure that civil protection and emergency planning are incorporated into general planning processes and in connection with specific planning proposals. Under the Act, municipalities are required to carry out an overall risk and vulnerability analysis. This must identify the types of incidents or emergencies that may arise, including impacts of climate change. The analysis must be followed up by the preparation of an overall emergency plan for the municipality, and exercises must be held to test the system. Emergency plans must include an overview of the measures the municipality has implemented for crisis management.

Thus the importance of incorporating climate change considerations into municipal civil protection and emergency planning work, in line with other considerations of civil protection, is strongly emphasised in Norway.

The county governors are the supervisory authorities and ensure that the municipalities comply with their emergency preparedness duties. They are also responsible for coordinating civil protection and emergency planning and maintaining an overview of risks and vulnerability at county level, and function as contact points and receive reports in the event of incidents and emergencies.

Box 6.1 Goals for civil protection

Norwegian society has to deal with a varied and complex set of risks and threats. The Government's goal for civil protection is to provide the population with a strong sense of safety and security by:

- effectively reducing the risk of and if possible preventing incidents that may threaten life, health, key assets, functions of the public authorities or other critical societal functions;
- ensuring effective emergency planning and the necessary response capacity to deal with serious crime, emergencies and accidents;
- ensuring the capacity to restore critical societal functions quickly if it is not possible to prevent an incident or emergency;
- ensuring that lessons are learned from incidents and exercises.

Source: Meld. St. 29 (2011–2012) *Samfunnssikkerhet* (2012 white paper on civil protection, in Norwegian only)

6.2 Stormwater management

Stormwater means runoff on impermeable surfaces such as roofs and roads that originates from precipitation, a storm surge or meltwater. Climate projections indicate a trend towards more, and more intense, precipitation in Norway, which will result in more stormwater runoff in urban areas and may lead to urban flooding. This may cause serious damage to buildings and other infrastructure and entail a threat to life and health. The report *Adapting to a changing climate* (NOU 2010: 10) stresses that climate change, with higher total

Figure 6.5 A street drain

Source: Milich Zoran/Masterfile/NTBscanpix

precipitation and more frequent intense precipitation events, will make stormwater management a more challenging task.

Urban sewer systems are not generally designed to cope with large volumes of stormwater. Norway follows the principle that stormwater should be managed by infiltration into the ground, and this is a statutory requirement in the Water Resources Act. According to section 7, land should as a general rule be built up or otherwise developed in such a way that precipitation can continue to drain away by infiltration into the ground. The greater the permeability of the surface, and the greater the porosity of the soil, the greater the infiltration capacity of an area. Urban areas contain a high proportion of impermeable surfaces – for example car parks, roads, yards and footpaths – that prevent stormwater from infiltrating naturally into the ground. Urban stormwater is therefore largely channelled through the municipal sewer system, either in separate stormwater drains that may discharge directly into nearby river systems, or via the sewer systems for waste water, which discharge to waste water treatment plants. During intense rainfall, the volume of stormwater entering the sewer system is often so high that some of the mixed stormwater and waste water has to be discharged directly to the sea or a river system instead of being treated first. This can contaminate bathing beaches and drinking water and pose a risk to public health and the environment. Excessive volumes of stormwater can also flood buildings, damage infrastructure and seep into drinking water pipelines, resulting in substantial costs and possibly threatening life and health. Failure to manage stormwater properly through the existing sewer systems is already resulting in major damage.

The damage is caused when sewer systems receive far greater volumes of stormwater than those they are designed for. Stormwater volumes have risen considerably, both because of increasing precipitation intensity and because the loss of green structures, expansion of impermeable surfaces and general densification in urban areas means that natural infiltration into the ground is no longer sufficient to remove the surface water. Climate change will exacerbate these problems and make it even more important to find good systems for stormwater management.

The intensity of precipitation and the severity of flooding and storm surges is expected to increase. To prevent this from resulting in stormwater damage, the municipalities need a framework that enables them to manage stormwater at source to a greater degree, in other words without it entering the sewer system. This consideration should be taken into account both in municipal planning processes and for existing built-up areas. A wide range of source control measures may be appropriate:

- To increase the proportion of stormwater that infiltrates the ground, it may be necessary to reduce the area of impermeable surfaces and expand green structures, or ensure that water is drained to local streams and rivers.
- Green roofs and green walls can be established to retain water.
- Drains, gullies, screens and other part of the drainage system for removing water from roads must be properly maintained.

Box 6.2 Norwegian Water's views on stormwater management

Stormwater can be managed through source control or channelled through the sewer system. Source control makes use of natural soil infiltration or drainage via open waterways and ponds. Developments involving large areas of impermeable surfaces and rapid drainage via storm drains tend to intensify flooding in river systems, which can cause more damage further downstream.

Integrated planning and management of urban river systems and stormwater is needed. This approach requires close links between stormwater management and land-use and landscape planning. The most usual, and conventional, approach is to drain surface water rapidly into underground storm drains and sewers, which convey the water away. For many years, stormwater has been viewed merely as a problem, but it can also be seen as a recreational resource and a positive element of the local environment. Conventional solutions have not always functioned satisfactorily and can be expensive. Moreover, there has been a substantial rise in insurance payouts for flood damage to buildings and other infrastructure.

Norwegian Water is an association of drinking water suppliers and wastewater works in Norway.

Source: Norwegian Water Report No. 162/2008 Veiledning i klimatilpasset overvannshåndtering (Climate-resilient stormwater management)

– Retention ponds and rain gardens can be established for temporary water storage.
– Parts of culverted streams and rivers can be reopened.

Key legislation

Stormwater management is a municipal responsibility. However, several different authorities administer the legislation and determine the framework for municipal stormwater management in urban areas. The most important legislation is described below.

The *Planning and Building Act* is the most important tool for the municipalities in their efforts to ensure that land use plans and individual building projects take into account the need to manage increasing volumes of stormwater. The Act is divided into two parts: the Ministry of the Environment is the administrative authority for the planning part, while the Ministry of Local Government and Regional Development is responsible for the part on building matters. The Regulations on technical requirements for building works under the Act set out various requirements that developers must meet: for example concerning local infiltration of stormwater and maintenance of drainage systems, protection against natural hazards, upgrading and maintenance of water supply and sewerage systems and requirements for resolving water seepage problems between neighbours. As a general rule, these provisions apply to new building projects and substantial modification of existing buildings. The Norwegian Building Authority administers the regulations on behalf of the Ministry of Local Government and Regional Development.

The *Water Resources Act* includes provisions on the flow of water in river systems and infiltration into the ground. Section 7 of the Act states that when land is built up or otherwise developed, this should as a general rule be done in such a way that precipitation can continue to drain away by infiltration into the ground. The water resources authorities (the municipalities) may order measures to improve infiltration into the ground provided that this can be done without unreasonable costs. The Norwegian Water Resources and Energy Directorate administers the Water Resources Act on behalf of the Ministry of Petroleum and Energy.

The *Pollution Control Act* sets out provisions on pollution from waste water, and there are more detailed rules in the Pollution Regulations under the Act. These implement the EU Urban Waste Water Directive, which has been incorporated into the EEA Agreement. There are different requirements for discharges of municipal waste water from larger urban areas, where the county governor is the pollution control authority, and for smaller urban areas, where the municipality is the competent authority. These provisions are also relevant to stormwater management, since requirements for the design capacity of sewer systems, storm drains and waste water treatment plants depend on the quantity of stormwater entering the system. The Climate and Pollution Agency administers the Pollution Control Act and Pollution Regulations on behalf of the Ministry of the Environment. The Agency also administers the Act relating to municipal water supply and sewerage systems, which together with the relevant provisions of the Pollution Regulations provides the legal authority for the municipalities to finance water supply and sewerage systems through fees paid by customers. The water and waste water fees may not exceed the necessary costs incurred by the municipalities in these sectors. If stormwater is transported through the sewer system, the municipality may also include these costs in the fees.

Municipal planning processes

The Planning and Building Act provides the municipalities with the authority to set a framework for sound stormwater management in planning processes and for new developments in urban areas. Municipalities should draw up overall strategies for stormwater management in such areas. Projected climate change and the accompanying increase in precipitation will make this even more important. A stormwater management strategy should give an account of expected precipitation and runoff, evaluate the acceptable level of flood risk, and identify priority steps towards sustainable stormwater management. Key elements of the strategy should then be into the land-use element of the municipal master plan. This will make it possible for municipalities to include sound stormwater management as a factor in preparations for zoning plans and in individual decisions on building matters. In this context, Chapter 7 on climate-resilient municipalities and the policy instruments discussed there are also relevant.

The Government considers it important for the municipalities to make use of the authority provided Planning and Building Act and the Regulations on technical requirements for building

works to plan and lay down requirements for sustainable stormwater management.

Improving the framework for stormwater management

In connection with the consultation process on the report *Adapting to a changing climate* (NOU 2010: 10), the municipalities pointed to a need for clearer rules and a better framework for municipal stormwater management, particularly in already built-up areas.

As mentioned above, the Planning and Building Act and the Regulations on technical requirements for building works primarily authorise the municipalities to include stormwater management as a consideration in land-use planning processes and when processing applications for new developments. However, it must be considered whether these rules for new developments need to be strengthened so that the municipalities have wider powers to set requirements for stormwater management. The municipalities' authority to order measures to improve infiltration into the ground under section 7 of the Water Resources Act is also mainly intended to be used in connection with land-use planning (zoning plans and building development plans).

Thus, the current legislation only gives the municipalities limited authority to require changes in stormwater management in existing built-up areas – which could include replacing impermeable surfaces such as asphalt with porous materials, channelling water to streams or to areas where natural infiltration can take place, re-opening parts of culverted rivers and streams, or establishing green roofs. Further consideration should be given to widening the municipalities' powers to require improvements to stormwater management in existing built-up areas.

At present, the rules on municipal water supply and waste water fees limit the possibilities for financing stormwater management measures through these fees. Fees may only be imposed if stormwater is channelled through municipal sewers and pipelines. Changes to the rules should be considered, including how the criteria for imposing fees should be formulated.

During the consultation process on the report *Adapting to a changing climate*, a number of organisations also identified a need to clarify the duties and responsibilities of the municipalities in their capacity as providers of waste water treatment services, and what residents are entitled to expect. This also raises the question of whether clearer guidelines are needed for determining which conditions the municipalities may impose on residents.

In future, increasing volumes of stormwater will also make it necessary to consider pollution from different types of stormwater, and what the implications may be for the provisions on waste water in the pollution control legislation. For example, it may be necessary to amend requirements for treatment of stormwater, design specifications for sewers, define waste water to distinguish it from unpolluted surface water, or alter guidelines or amend other parts of the legislation.

In the Government's view, the changing climate, accompanied by increasingly intense precipitation events and more severe flooding and storm surges, makes it essential to provide the municipalities with a sound legislative framework that will enable them to prevent stormwater damage in urban areas.

As described above, the current framework includes legislation in several areas, which needs to be considered as a whole and has major implications for a range of interest groups. This field involves complex issues, and evaluating them requires specific expertise.

The Government therefore considers it important to ensure that the different interest groups are involved in an evaluation of the current framework and whether the legislation needs to be amended. To ensure that this is a thorough, inclusive process, the Government will appoint a committee to evaluate the legislation and key parts of the framework for effective municipal stormwater management.

6.3 Flooding, landslides and avalanches

Flooding, landslides and avalanches are natural processes that are influenced by the climate and thus by climate change. The Government's aim is to improve Norway's ability to reduce the risks posed by these phenomena. Work is in progress to identify hazard zones, avoid developments in these zones, and protect buildings and settlements at risk. This was described in more detail in a 2012 white paper on flooding, landslides and avalanches (Meld. St. 15 (2011–2012) *Hvordan leve med farene – om flom og skred*, in Norwegian only).

The consequences of flooding, landslides and avalanches may become worse with climate change, since these events are expected to occur

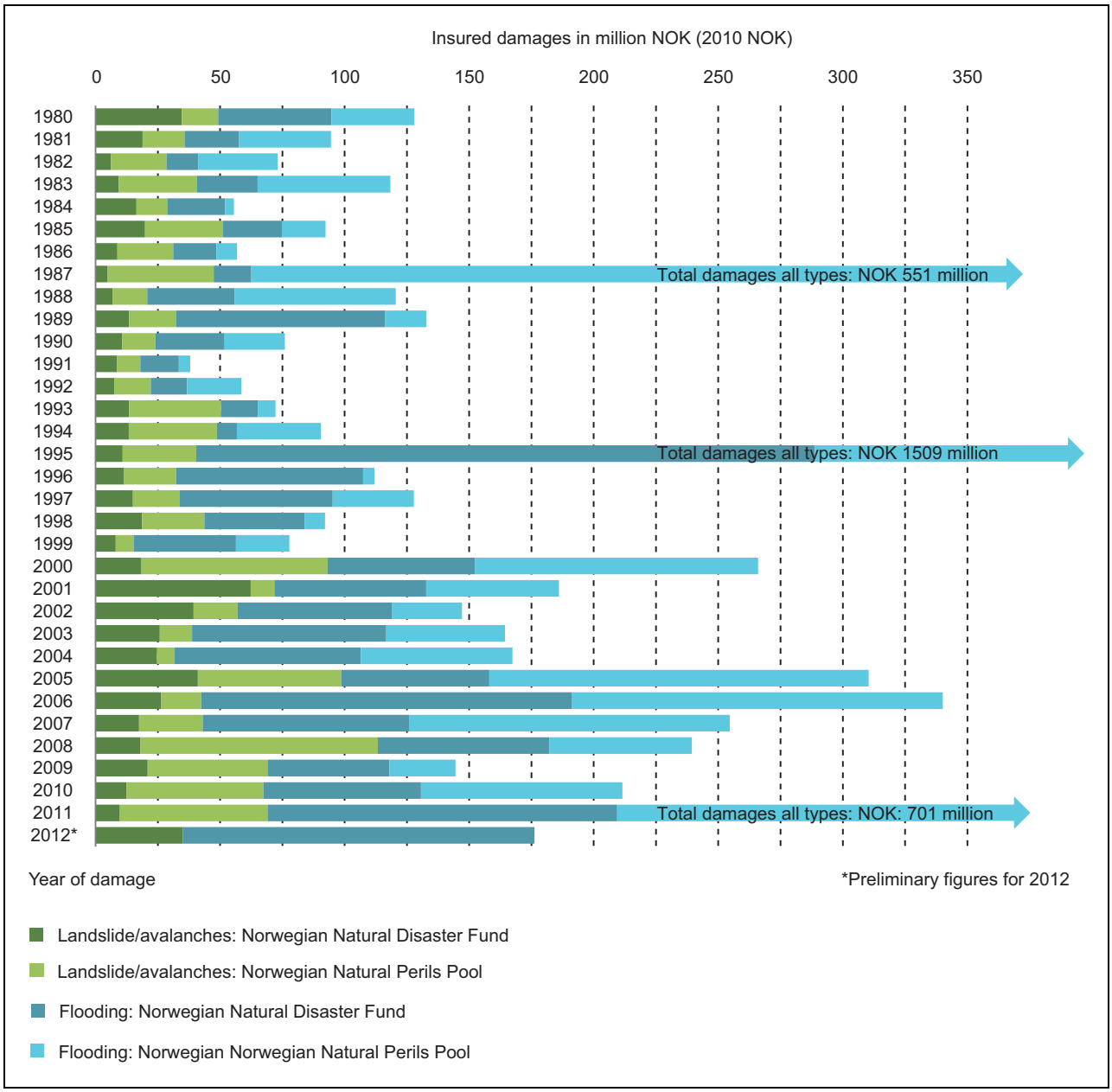

Figure 6.6 Monetary value of damages related to flooding, landslides and avalanches registered in Norway from 1980 to 2012.

Source: Norwegian Natural Disaster Fund/Norwegian Natural Perils Pool

more frequently, become more severe and occur in other areas than today. Climate projections indicate that episodes of locally intense precipitation will occur more frequently. This will cause particular problems in small, steep river valleys and in urban areas, where there are large areas of impermeable surfaces. Rising temperatures and a general rise in precipitation will result in changes in patterns of flooding, see Chapter 2.2. Current climate projections indicate that in some areas the size of floods will rise by more than 20 %. Sea level will probably rise, resulting in higher storm surges. This will directly affect areas close to the sea, and the consequences of flooding will become more severe near river mouths.

Mapping of current flood hazard shows that there are 22 000 residents and 7500 buildings in areas exposed to a 1 in 200-year risk of flooding, with the largest numbers of both people and buildings in Hedmark and Buskerud counties. These figures are based on areas that have already been mapped. In addition, there will be residents and buildings in flood-prone areas where the flood risk has not yet been mapped.

Landslides and avalanches are often triggered by meteorological conditions, and both ava-

lanches and soil slides may be caused by extreme weather events. There are clear links between precipitation, temperature and wind conditions and different types of avalanches. Higher temperatures will reduce the risk of dry snow avalanches at altitudes below 500–1000 metres, but will increase the risk of wet snow avalanches and slush flows. A higher frequency of intense precipitation events will increase the risk of landslides and flood-related debris flows. Quick clay slides are often triggered by human activity, but may also be triggered by prolonged heavy rain and high water flow. Changes in precipitation patterns may increase the risk of debris flows and slush flows in areas that have not been at risk previously. The vulnerability of an area to landslides and avalanches depends on the infrastructure, buildings and types of buildings within it. The siting of residential buildings and other infrastructure, the choice of building type, control and enforcement routines, and maintenance are all very important issues in areas where there is a landslide or avalanche hazard. The risk of rockfall and avalanche susceptibility and hazard has been mapped for most municipalities in coastal and mountain areas of Western Norway and North Norway, and maps of susceptibility to quick clay slides have been produced for 70 municipalities.

At present, 72 000 people (24 000 households) live in areas that are susceptible to rockfalls and avalanches, and there are 64 000 people and 17 000 buildings in areas that are susceptible to quick clay slides.

Division of responsibilities

Many different actors are responsible for reducing the risk of damage from flooding, landslides and avalanches. Individual people are responsible for their own safety, and should take precautions on their own property, when out and about in the countryside and during other activities in areas where there is a flood, landslide or avalanche hazard.

Under the Planning and Building Act, the municipalities are responsible for ensuring that natural hazards, including flood, landslide and avalanche hazards, are assessed and taken properly into account in land-use planning and processing of building applications. The municipalities also have responsibilities as the owners of land, buildings and other infrastructure such as roads and water supply and sewerage systems.

The counties are the regional planning authorities, and are responsible for drawing up the regional plans required by the Planning and Building Act. They are also major infrastructure owners – for example, they are responsible for county roads.

The Ministry of Petroleum and Energy has overall administrative responsibility for managing flood, landslide and avalanche risk in Norway. Operational responsibility for risk reduction in this field has been assigned to the Norwegian Water Resources and Energy Directorate, whose tasks include:

- mapping hazard areas and providing information on them;
- ensuring that flood, landslide and avalanche hazards are taken into account in municipal land-use plans;
- providing the municipalities with technical and financial support for planning and carrying out risk reduction measures;
- monitoring the situation and providing flood, landslide and avalanche warnings;
- providing municipalities, the police and other emergency services with technical support during emergencies;
- generating and spreading knowledge about flooding, landslides and avalanches.

However, every central government body has an independent responsibility for risk reduction and response to flooding, landslides and avalanches within its own sphere of responsibility, whether as the authority responsible for legislation and guidelines in a sector, as a service provider, or as the manager of its property and infrastructure.

The county governors' responsibilities include coordinating civil protection work at county level and promoting and providing advice on civil protection and emergency planning.

Mapping flood, landslide and avalanche hazard areas

The Norwegian Water Resources and Energy Directorate is to draw up a plan for flood hazard mapping to clarify the priorities for initial mapping of new areas and for updating existing maps, and that will include all elements and levels of the mapping programme. A rolling plan is required to make it possible to incorporate new needs that arise as a result of climate change, new technology or other changes that have implications for the mapping process.

The Directorate will continue flood hazard mapping in flood-prone areas. Existing maps are to be updated on the basis of specific criteria, one of which is that rivers will be included if climate projections indicate that there will be major

Box 6.3 Landslides and avalanches can kill

Flooding, landslides and avalanches, together with storms, are the climate-related natural hazards that do most damage and are responsible for the largest numbers of deaths in Norway. Since 1900, about 1100 people have died in more than 500 registered landslides and avalanches. Of these, almost 500 people were in built-up areas, about 70 on roads, 200 were engaged in outdoor recreation and about 250 were travelling in connection with work (including military service). Avalanches have killed about 600 people in Norway since 1900.

In the first half of the 20th century, three large rockfalls in Loen and Tafjord in Western Norway triggered tsunamis in lakes and killed a total of 175 people. Quick clay slides can also kill many people. The largest quick clay slide in Norway's recent history was in Verdal in Nord-Trøndelag in 1893, where 116 people died. Flooding causes few deaths in Norway.

Figure 6.7 Avalanche in Western Norway

Photo: Directorate for Civil Protection and Emergency Planning

changes in the areas exposed to a 1 in 200-year risk of flooding in their catchments.

All municipalities should map tributaries and streams where the damage potential is high. Projections of more frequent local flooding caused by heavy rainfall and thus of a higher risk of damage along smaller rivers and streams indicate that higher priority should be given to mapping hazard areas in their catchments and for stormwater flooding. Flood hazard mapping of Norway's smaller rivers has not received much attention so far. In addition to causing problems in urban areas, flooding in small river systems and streams can have serious consequences for the road and railway systems. Their safety is partly dependent on adequate design specifications for the very

large numbers of culverts and bridges where roads and railways cross streams and small rivers.

The Water Resources and Energy Directorate will draw up guidelines for municipal mapping to ensure that sound, uniform procedures are followed. The Directorate can also provide grants for municipal mapping of river systems, within the framework of the government programme for hazard mapping. The municipalities should coordinate flood hazard mapping with mapping stormwater-related hazards and planning safe flood channels. State infrastructure owners need to maintain an overview of the status of culverts and bridges, and regularly assess the need for upgrading. Where feasible, mapping by municipalities and central government agencies should be coordinated, particularly collection and analysis of hydrological data.

The frequency of landslides and avalanches triggered by intense rainfall/flooding and snowfalls may rise in parts of Norway as a result of climate change. As in the case of flood hazard mapping, the impacts of climate change must be taken into account in landslide and avalanche hazard mapping wherever relevant, in a way that is adapted to the use of the data.

Assessing and mapping flood, landslide and avalanche hazard and risk requires a great deal of information and high-quality underlying data.

For analyses relating to flooding, landslides and avalanches, it is particularly important to have detailed topographic data that can be used as a basis for analyses of the terrain and geological structures.

The importance of municipal land-use planning

Under the Planning and Building Act, the municipalities are chiefly responsible, through their planning activities, for shaping the physical environment, maintaining its quality, and finding a balance between development and conservation on the basis of its characteristics and local factors. The importance of municipal land-use planning in natural hazards risk reduction and climate change adaptation was highlighted in a 1997 white paper on flood control and protection measures (St.meld. nr. 42 (1996–97) *Tiltak mot flom*, in Norwegian only), the 2012 white paper on civil protection, and the report *Adapting to a changing climate* (NOU 2010: 10).

The increasing flood hazard must be taken into account in land-use planning. There can be major benefits in taking an integrated approach to planning that also includes ecosystem services and species and habitats. Particular caution must be exercised along steep rivers and streams where the water may find a new course or wash out soil and debris. Maps of potential flood channels can provide a good basis for municipal mapping of high-risk areas. It is particularly important to take into account the role of wetlands in flood control, see Chapter 8.1. Mires and other wetlands store water and release it slowly, which slows down the speed of floodwater. As a general rule, mires and other wetlands should not be drained or developed. Natural riparian vegetation provides good protection against flood damage and erosion of riverbanks, and should be safeguarded in municipal land-use plans.

In its climate change adaptation strategy, the Norwegian Water Resources and Energy Directorate states that if climate projections show that flooding will increase by more than 20 % in the next 100 years, the projected figures should be used as a basis for land-use planning. This is already being implemented in practice.

The frequency of landslides and avalanches triggered by intense rainfall/flooding and snowfalls may also rise in parts of Norway. So far, little is known about how this will influence the delimitation of hazard zones for landslides and avalanches using the probability limits that are the basis for land-use planning. Even using today's climate as a basis, the level of uncertainty associated with the delimitation of hazard zones for landslides with an annual probability of less than 1/1000 is so great that there is no reason to add an extra margin of error to take account of climate change.

In addition, it is clear that sea levels will rise. However, there will be regional variations, and in several areas the rise in sea level will be reduced by glacial rebound. In 2011, the Directorate for Civil Protection and Emergency Planning published guidelines on how to take sea level rise into account in municipal planning, in cooperation with several other agencies.

The Ministry of the Environment, in cooperation with the Ministry of Local Government and Regional Development and the Ministry of Petroleum and Energy, intends to develop recommendations or guidelines on how to include the effects of climate change on flooding, landslides and avalanches, and storm surges/sea level rise in municipal planning. Municipal plans must be based on environmental criteria designed to ensure that the natural environment and water quality are taken into account when planning and implementing climate change adaptation measures.

Flood defences and landslide/avalanche protection

When upgrading or major repairs to older flood control or landslide/avalanche protection are being planned, environmental improvements are also considered. For example, flood defences can be moved further away from river banks and closer to the buildings they are primarily intended to protect. In addition to being environmentally beneficial, this can reduce costs and the impact of the flood defences on downstream flooding.

Ideally, when selecting design specifications for flood defences or landslide/avalanche protection, it should be possible to achieve as good a level of protection for existing buildings and infrastructure as for new projects, and this also applies to adaptation to climate change. This aim will be used as the basis for planning such measures, but in practice it may often be difficult to achieve an equivalent level of protection, and the costs may be unreasonably high. As for other projects, cost-benefit analyses must be used to assess steps to protect existing buildings and other infrastructure.

The Norwegian Water Resources and Energy Directorate will draw up a manual for landslide/avalanche protection, based on established practice and experience in other countries.

Flood, landslide and avalanche warning

Climate change will involve a general increase in precipitation and more frequent episodes of locally heavy and intense rain followed by flooding in small, steep river catchments. In the longer term, it will therefore be important to establish more flow monitoring stations in such rivers. This must be combined with modelling with better time resolution to give more precise forecasts, particularly for small catchments.

Certain landslide and avalanche types are influenced by climate change, especially by higher and more intense precipitation. Norway's 2013 budget includes an extra allocation of NOK 9 million to establish an operative forecasting service for landslides and avalanches. The avalanche forecasting service has been in operation since 14 January 2013.

Knowledge needs

In connection with the preparation of the 2012 white paper on flooding, landslides and avalanches, an assessment was made of R&D needs in this field, based on input from key research institutes and bodies in the public administration. Knowledge needs were noted in the following areas:

- the climate system and hydrological and geological processes;
- extreme precipitation, modelling of small catchments and urban stormwater management;
- better models and calculation tools that can be used in producing warnings and in mapping flood, landslide and avalanche hazard areas;
- interdisciplinary research on the impacts of flooding, landslides and avalanches, and on the design and effects of protection and risk reduction measures, including more knowledge about the role of ecosystem services in mitigating flooding, landslides and avalanches.

The research institutions also highlighted the need to give priority to improving research infrastructure.

6.4 Sea level rise

Sea level rise associated with climate change will lead to new challenges in some areas. Individuals, private companies, public bodies and local and central government authorities all have a responsibility for taking steps to safeguard their own property. Under the Planning and Building Act, the municipalities are responsible for ensuring that natural hazards are assessed and taken properly into account in spatial planning and processing of building applications. This includes the responsibility for taking sea level rise and the resulting rise in storm surge levels into account.

Advice and guidance on sea level rise and storm surges

The website Klimatilpasning.no offers advice and guidance on dealing with a rising sea level, based on a report on sea level rise with estimates of the rise expected in coastal municipalities in Norway (*Havnivåstigning. Estimater av framtidig havnivåstigning i norske kystkommuner*, in Norwegian only). The report, which was published in 2008 and revised in 2009, was drawn up by the Bjerknes Centre for Climate Research and the Directorate for Civil Protection and Emergency Planning. The recommendations in the report are based on projections from the Bjerknes Centre, which used calculations by the Norwegian Mapping Authority in taking glacial rebound into account. The recommendations are also based on the Fourth Assess-

ment Report from the Intergovernmental Panel on Climate Change (IPCC), but corrected for the contribution to sea level rise from the large ice sheets in Greenland and Antarctica, which the IPCC report did not include. The risk of an increase in the rate of melting has been included in accordance with the precautionary principle, even though there is a great deal of scientific uncertainty as to how much this will contribute to sea level rise in the period up to 2100. The Dutch and British authorities, and more recently the Danish authorities, have made similar recommendations.

It is very uncertain how much and how quickly sea level will rise. Knowledge about how climate change is influencing sea level is constantly being developed, so that current information rapidly becomes outdated. Advice should therefore be updated regularly.

6.5 Compensation and insurance cover for natural hazard damage

Cover against natural hazard damage is provided in three different ways in Norway. Any property that can be insured against fire is covered by private natural hazard damage insurance, which is a mandatory part of all fire insurance policies. If it is not possible to take out normal insurance to cover the property against these risks, the Norwegian Natural Disaster Fund can provide compensation for natural hazard damage. For property that is not covered by either of these regimes, the owner carries the risk and liability, or must take out special insurance cover.

The Norwegian model, including both public and private arrangements for insurance against natural hazard damage, provides major benefits for society, since it gives effective protection against the financial risk associated with extreme weather events. This is very important for people who are directly affected by such damage.

Climate change will have implications for these insurance arrangements. More frequent and more severe extreme weather events and more intense precipitation could result in increasing damage caused by water penetrating into buildings. Higher precipitation will also worsen problems relating to building decay. Moreover, there will be a higher risk of flooding that could damage bridges, roads, forest, agricultural areas, buildings and other infrastructure.

In certain vulnerable areas that have already been built up, climate change may result in a considerable rise in the risk of damage and perhaps in higher insurance premiums and insurance payouts. If events that are considered to be extreme today become common, it may not be possible to obtain insurance cover at all. A study by the insurance company Gjensidige indicates that by the end of the present century, higher precipitation could result in a 50 % increase in the number of cases of water damage in certain counties.[2]

The insurance companies play an important role in reducing the economic risk borne by companies and private households. Under Norwegian legislation, insurance companies must determine insurance premiums on the basis of risk levels. This means that they can for example offer lower premiums to customers who take steps to prevent climate-related damage. In this way, they can play an important part in reducing overall damage caused by climate change.

Private insurance schemes

The private regime for insurance against natural hazard damage is regulated in the Natural Hazard Insurance Act, according to which all property that is insured against fire must also be insured against natural hazard damage. As part of this system, the insurance companies coordinate their liabilities through the Norwegian Natural Perils Pool, which settles compensation for damage caused by natural hazards between insurance companies that provide fire insurance in Norway. Membership of the Pool is mandatory for all companies that provide fire insurance in Norway. Anyone who for example takes out house insurance pays a share of the premium to the Pool: in 2012, this was 0.007 % of the amount for which the property was insured. This means that if a house is insured for NOK 1 million, the premium for natural hazard insurance is NOK 70. The rate was reduced from 0.008 to 0.007 % of the insured value from 1 January 2012 in response to a favourable long-term trend in insured losses. An excess of NOK 8000 is payable for each claim for natural hazard damage. The Norwegian Natural Perils Pool is administered by Finance Norway.

Forest owners can take out fire and/or storm damage insurance for productive forest on their properties through the company Skogbrand. This is ordinary insurance, even though compensation

[2] Orskaug, E and Haug, O (2009) Skadeprediksjoner basert på ECHAM4 klimamodelldata (Predictions of damage based on data from the ECHAM4 climate model, in Norwegian only). Technical report, NR-notat SAMBA/29/09, Norwegian Computing Center

for fire or storm damage to forest is not covered either by the Natural Hazard Insurance Act or by the Natural Hazards Act. However, regulations under the Natural Hazards Act provide for the Norwegian Natural Disaster Fund to act as reinsurer if the total storm damage to forest exceeds NOK 200 million in a specific case. This ceiling is considered in relation to the area of forest insured as a proportion of the total area of forest in Norway. The insurance companies provide compensation for insured areas up to this relative ceiling, and the Fund provides compensation for damage in excess of this for forest owners who have insurance.

Compensation from the state for natural hazard damage

The Natural Hazards Act regulates the state compensation scheme and the responsibilities of the Norwegian Natural Disaster Fund. The Act is administered by the Ministry of Agriculture and Food, except for Chapter 3 on measures to prevent natural hazard damage, which is the responsibility of the Ministry of Petroleum and Energy.

The task of the Norwegian Natural Disaster Fund is to provide compensation for natural hazard damage in cases where insurance is not available through normal insurance arrangements. The scheme typically covers for example private roads and bridges, forest (flooding and landslide/avalanche damage), agricultural land, quays and breakwaters, sports facilities, tourism and industry.

The Natural Hazards Act gives the injured party a statutory right to compensation under certain conditions. It is only the owner of the object or property that has been damaged who is entitled to compensation. The scheme is intended to make it possible for private landowners to restore their property after natural hazard damage, so that they can continue their activities. This is achieved through a permanent, general compensation regime with objective criteria and prescribed conditions, which gives people a predictable entitlement to a state benefit when property that cannot be insured suffers natural hazard damage. Damage to public property is not covered by the compensation scheme.

The Natural Hazards Act also contains provisions that can reduce the risk of future damage to property that has already suffered natural hazard damage. As a general rule, any compensation provided must be used to repair the damage, but the board of the Natural Disaster Fund may make it a condition for payment of compensation that this is done in a way that reduces the risk of natural hazard damage in the future. For example, if a damaged building or other structure is on a site where the risk of damage is particularly high, the board may require it to be moved to a less vulnerable site. The board may also make it a condition that compensation is used to acquire a different property outside the high-risk area. In such cases the board may require the judicial registration of a declaration that the property is at risk of natural

Box 6.4 The most common types of natural hazard damage and insurance cover

Storms and gales – The lower limit for compensation for storm damage is a strong gale (wind speed from 20.8 m/s). Meteorological measurements are used as a basis for determining whether the wind has been so strong that the damage can be defined as storm damage.

Flooding – For flooding to trigger insurance payouts, there must be extraordinary precipitation or rapid snowmelt that results in an abnormally high water level and damaging inundation. Extraordinary levels of natural runoff that cause water to find new channels in sloping terrain will also trigger insurance payouts. It is a condition that the situation results in extraordinary damage.

Landslides and avalanches – These are the sudden movement of earth, rocks, clay, or snow in the case of avalanches. Rockfalls are also included here. Frost heave and other gradual changes in pressure in the soil are not covered by insurance, nor is settling or subsidence.

Since all fire insurance for buildings and other property in Norway includes insurance against natural hazard damage, one form of insurance is in many cases sufficient.

Anyone who is insured has a duty to take steps to prevent or limit damage. If they do not, the insurance company's liability may be reduced or cease to apply. Similar rules for the reduction of claims apply under the state arrangements for compensation for natural hazard damage if someone has failed to take reasonable steps to prevent or limit damage.

Source: Finance Norway

hazard damage. An injured party may also receive a grant towards the extra costs of reducing the risk of future damage.

The third chapter of the Natural Hazards Act sets out provisions on protection against natural hazard damage, and specifies the municipalities' rights and duties in this area. The formal responsibility for these provisions, and the corresponding budgetary funds, were transferred to the Ministry of Petroleum and Energy in 2009, when the Norwegian Water Resources and Energy Directorate was given administrative responsibility for risk reduction measures for all types of landslides and avalanches, based on the same model as that already established for flood risk management. Thus, the Norwegian Natural Disaster Fund is no longer responsible for the payment of grants for protective measures.

The Norwegian Water Resources and Energy Directorate has drawn up guidelines on assistance in assessing, planning and carrying out protective measures. The 2012 white paper on flooding, landslides and avalanches announced that the Ministry of Petroleum and Energy, as the competent authority under the provisions of the Natural Hazards Act, would carry out a complete review of responsibilities for flood control and landslide/avalanche protection, taking the provisions of the Natural Hazards Act as a starting point.

Risk reduction

Climate change may result in an increase in both the scale and the frequency of different types of natural hazard damage. This makes it appropriate to consider how the Norwegian model for natural hazard insurance can be adjusted in a way that encourages greater caution and promotes risk reduction. A higher risk of damage in itself indicates that efforts to prevent damage should be intensified. Action that is being taken includes stepping up mapping of flood, landslide and avalanche hazard and intensifying risk reduction measures, as described in the 2012 white paper. Protection measures, sound land-use planning and appropriate building techniques are all important in limiting the damage caused by natural hazards. Various planning tools are available for use in climate change adaptation, for example the flood hazard maps produced by the Norwegian Water Resources and Energy Directorate, the website skrednett.no, which provides maps and information on landslide and avalanche risk, and risk analyses.

Box 6.5 Climate change adaptation in the Nordic insurance industry

The Nordic insurance industry has undertaken to take action to meet the challenge of climate change by:

- developing and offering climatically sustainable products within life and non-life insurance;
- incorporating climate aspects into investment strategy considerations;
- using climatically sustainable methods in loss prevention and claims settlement;
- organising and conducting their business in climate-smart ways.

Source: Finance Norway

The Norwegian Agricultural Authority reviewed the state compensation scheme for natural hazard damage in 2008.[3] Climate change and the accompanying probability of increasing damage in the future were an important element of this review. The Ministry of Agriculture and Food used the report as a basis for the consultation documents published on 11 September 2009 proposing a number of amendments to the Natural Hazards Act in order to simplify it, make it more robust and ensure more rapid processing of claims for compensation. The proposals are being considered by the ministry after the consultation round.

Climate-related events may play an increasingly role in insurance payouts, and the insurance industry plays a key role in society's response to extreme weather events. The insurance companies have detailed information on climate-related damage. This information is part of the evidence that makes it possible to state that cases of damage caused by sewage backup have risen in number and scale in recent years. This rise can be linked to climate change and observed extreme weather events.

3 Utredning ny naturskadelov 2008 (Proposal for a new Natural Hazards Act 2008, in Norwegian only), Norwegian Agricultural Authority

7 Climate-resilient municipalities

The Government

- Intends to draw up central government planning guidelines describing how the municipalities and counties should integrate climate change adaptation into their land-use and general planning processes. The new guidelines on adaptation will be incorporated into the existing guidelines for climate change mitigation and energy planning.

Norway's climate is varied, with considerable differences between different parts of the country. The industrial structure, settlement patterns and infrastructure also vary from place to place and will largely determine the local impacts of climate change. Thus climate change in a coastal municipality in Western Norway will not take the same form as in an inland municipality in Eastern Norway. Adaptation will therefore require a different approach in different geographical areas, and it is important to base specific measures on local needs. The local character of the impacts of climate change puts the municipalities in the front line in dealing with climate change.

Climate change and social change are taking place simultaneously, and social change will largely determine our vulnerability to climate change, particularly in towns. A growing proportion of the Norwegian population lives in urban areas, and the growth of Norwegian towns is expected to continue. All Norway's largest towns are either on the coast or close to lakes or rivers. Higher and more intense precipitation will require more efficient stormwater management systems in towns, which contain large areas of impermeable surfaces such as roads and pavements. Challenges will also arise in connection with the development of port facilities and densification of urban areas, both because of sea level rise and because the growing number of roof surfaces will result in larger volumes of local runoff. In addition, much of the urban infrastructure is vulnerable; for example rail and metro tracks can be damaged by erosion and landslips, and tunnels are particularly at risk of becoming filled with water. The electricity grid and ICT infrastructure are more heavily used in densely populated areas, and this infrastructure is therefore more vulnerable to unforeseen incidents.

The municipalities are Norway's local administrative level, and have the overall responsibility for social development, planning and provision of services within their geographical catchment areas. They provide local welfare services, are involved in community development, exercise statutory authority and have important democratic functions. Many of these tasks will be affected by climate change, and plans and decisions adopted by municipalities today will have consequences for many decades. Climate change will intensify existing problems and create new ones. On the other hand, it will also provide opportunities for business development and bring advantages to local communities.

To enable the municipalities to ensure that Norwegian communities are resilient and sustainable in the future, adaptation to climate change must be made an integral part of municipal responsibilities.

7.1 Climate change as part of the framework of society

The climate has always been an important part of the framework for Norwegian society. In previous times communities were more dependent on the natural environment than they are now, and the climate was a key factor behind settlement patterns and the industrial structure. It is still an important factor in business development and social development planning. However, the committee responsible for the report *Adapting to a changing climate* (NOU 2010: 10) pointed out that climate considerations are often sacrificed to other important priorities, and that this can make us more vulnerable to climate change.

Today's climate already puts us at risk. Flooding, landslides, avalanches and other extreme weather events are causing disruption of infrastructure, threatening life and health and entailing

huge costs. Stormwater runoff in urban areas also causes substantial damage every year to buildings and other infrastructure. Climate change could intensify existing problems and result in a higher frequency of natural hazard events that inflict major damage, even in places where such events used to be rare.

Areas that could previously be developed safely may become unsuitable because they are exposed to a higher risk of flooding, landslides and avalanches, or rising sea levels. In built-up areas the higher risk of climate-related damage could make it necessary to impose requirements for preventive measures or altered use. Thus climate change could involve major costs in exposed locations and limit the availability of suitable areas for development.

For the municipalities, which are responsible for civil protection at the local level, climate change will influence the risk profile used as a basis for community development. It can be a challenging task to identify how climate change is likely to alter the risk profile and thus to adjust the preventive aspects of municipal planning appropriately.

However, climate change may also provide opportunities for positive development in local communities. For example, higher precipitation will make it more important to maintain and further develop the green structure that is such a valuable resource in urban areas. In towns especially, where much of the available area has already been allocated, there are a number of examples of innovative stormwater management measures to prevent damage, such as improving green spaces and reopening natural waterways. Such measures will also benefit health, recreational activities and the environment.

Water, sea and land temperatures are rising as a result of climate change. Higher temperatures are leading to environmental changes that will gradually alter the framework for business development, especially in tourism and the primary industries. While this could open up new opportunities for local development, it could also pose problems for existing business activities. Changes in the natural environment will create new conditions for sports and outdoor recreation. For example, in areas that are now on the outskirts of regions with stable winter weather conditions, higher temperatures will gradually limit opportunities for winter activities.

In 2011 a survey was made of climate change adaptation work in Norwegian counties and municipalities was made, as a follow-up to a similar survey in 2007, and eight out of ten municipalities answered that they expect climate change to have impacts in their communities. Many of those that have already taken steps to adapt to climate change have done so after being struck by a natural hazard event. A combination of information, guidance and cooperation with other municipalities has been shown to produce good results. The adaptation efforts made in response to natural hazard events and as a result of participation in projects are a positive development. However, in the long term climate change may have major impacts beyond those affecting municipalities today. In the long run, regular evaluation of adaptation measures based on actual events will not be enough to ensure secure and sustainable local communities.

Furthermore, adaptation efforts compete for attention with many equally important local government tasks, and it can be difficult for a municipality to give sufficient priority to adaptation over other necessary activities.

The 2011 survey of municipal adaptation efforts also showed that there are large differences between municipalities, and that many small municipalities are finding it difficult to address the challenges of climate change. It is an important goal of the national adaptation work to ensure that climate change does not increase disparities between municipalities.

7.2 The municipalities' responsibility for climate change adaptation

The municipalities have the overall responsibility for community development within their geographical catchment areas. They have obligations and exercise authority under various acts of legislation, and their responsibility for planning is regulated by the Planning and Building Act.

The future consequences of climate change for the municipalities will be partly determined by decisions taken today, for example on land use and the development of municipal infrastructure. The Government will therefore require municipalities to use relevant knowledge about current and future climate change as a basis for their planning activities and exercise of authority. This will be necessary for example in their application of legislation relating to civil protection and nature management, where they have vital tasks. The local authorities must also take climate change into account when applying the rules on the construction of housing, roads and other infrastructure.

Box 7.1 Climate change adaptation and water supplies

Providing water supplies is a municipal responsibility, and the authorities have several ways of preventing a reduction in the quality of drinking water as a result of climate change. Measures for preventing disruption of the drinking water supply resulting from extreme events or other impacts of climate change can be included in municipal emergency preparedness plans. Owners of water works can assess the probable impacts of extreme weather events such as intense precipitation and flooding, and identify ways of reducing pollution of water sources or improving water treatment. The location of potential sources of pollution, such as landfills, industrial plants, contaminated soil and livestock for food production, can affect raw water quality. On the other hand, intact wetlands, peatlands and ecotones play a part in water purification. The authorities can also identify stretches of pipeline where there is a higher risk of waste water seeping into the drinking water supply or that are vulnerable to flooding. Another measure would be to prevent discharges of chemical and biological pollutants into the water source by extending restricted areas or imposing other restrictions around water sources.

The municipal authorities can also take steps to improve their emergency preparedness plans for the water supply system in order to prevent or contain acute changes in water quality. These could include for example establishing an additional hygienic barrier at water works with flood-prone groundwater sources. Installing flood defences for the technical infrastructure and strengthening existing barriers, for example by increasing the UV sterilisation capacity at water works equipped with this technology, are other possibilities. The extra safety measures can be activated in the event of a risk that floodwater will contaminate raw water sources.

Establishing reserve water sources that are not flood prone or systems for manual distribution of drinking water may be appropriate in cases where the drinking water source is particularly vulnerable to contamination and it is not possible or financially viable to protect the main source of drinking water.

Climate change will also affect a number of other municipal services, such as provision of drinking water and waste water and waste management. Climate change considerations are particularly important in long-term planning for the development of municipal services and associated infrastructure.

The Government wishes counties and municipalities to take account of climate change and of the vulnerability of society and the environment in their planning activities under the Planning and Building Act and in other areas where they exercise authority. All municipalities should consider how they will be affected by climate change and draw up measures to make themselves more resilient and thereby avoid future costs and a higher risk of loss of life.

All municipal planning is based on the municipal planning strategy. When drafting its planning strategy, which is done at least once during each electoral term, it is very important that the municipality gives prominence to the impacts of climate change. This also applies to any planning programme drawn up when the municipal master plan is revised.

The counties draw up regional planning strategies that are used in deciding which regional planning issues should be addressed by a newly elected county or municipal council. The Government considers that climate change adaptation must be a key premise for this work.

The municipal master plan is more concrete, and the municipalities need to decide how the impacts of climate change in their particular municipality should be addressed in the social, land-use and implementation elements of the master plan. The social element addresses long-term challenges, goals and strategies for development of the community as a whole, including strategies for social development, sectoral activities and long-term land-use needs. It should be focused and action-oriented, and identify priority areas that need to be addressed. The assignment of priorities will largely depend on a vulnerability assessment for the various areas. The assessment should cover environmental status, water quality, nature management, buildings, transport, health and pollution. The vulnerability assessment and priorities in the social element of the master plan are important, since the social element serves as

Box 7.2 Information about climate change useful in many areas

General information about the most important trends in climate change is sufficient in many cases. However, in some areas, like the following, there is a need for more detailed knowledge about present and future climatic conditions:

- Design of urban waste water treatment systems (up-to-date data on short-term precipitation under current climatic conditions in order to calculate intensity-duration-frequency (IDF) curves and future IDF estimates).
- Flood protection near rivers and lakes and for urban areas (up-to-date flood frequency analyses under current conditions and estimates of future changes).
- Design of roads and railways, including safety systems.
- Design of coastal infrastructure that is affected by sea level, waves and storm surges.
- Design wind loads (improved monitoring and modelling of extreme wind conditions).
- Icing on terrestrial and maritime infrastructure.
- Mapping of various types of landslides and avalanches and assessing how climate change will affect them.
- Agriculture and forestry, reindeer husbandry.
- Fisheries, including aquaculture.
- Ecology and biodiversity (new species, new plant diseases).

The authorities intend to develop a national centre for climate services, which will provide information on the climate of the future in user-friendly form, see Chapter 5.2.

the basis for the municipal sector plans and activities.

The social element of the master plan is concerned with community development; it describes the needs of the community and provides land-use guidelines. A land-use plan for the entire municipality is also required, linking land use with future social development. In many municipalities, the land-use guidelines will be strongly influenced by the need for adaptation in various areas. Thus by including adaptation measures in their land-use planning, municipalities will be able to reduce the scale of the damage done by climate change.

The implementation element of the master plan contains an action programme based on the adaptation needs identified in the social and land-use elements, and is coordinated with the finance plan that is required by the master plan. The implementation element and the finance plan are the most important tools available to the municipalities for ensuring efficient implementation and sound economic management.

7.3 Central government planning guidelines for climate change adaptation

The Government intends to draw up central government planning guidelines describing how climate change adaptation should be addressed in planning processes and decision-making in different sectors.

The central government planning guidelines will be designed to assist coordination across sectors and administrative levels. They will make it easier for counties and municipalities to include climate change adaptation in their planning under the Planning and Building Act and take it into account in the exercise of their authority and the fulfilment of their obligations.

To enable the counties and municipalities to ensure that Norwegian communities are resilient in the future, adaptation to climate change must be made an integral part of their responsibilities. Climate change adaptation, which is a long-term, cross-cutting issue, needs to be integrated into the municipalities' existing tasks. The purpose of the guidelines is to encourage municipalities to use their long-term planning activities, particularly their land-use planning, to reduce vulnerability to climate change. They will also provide information and guidance on where and how the local authorities can obtain adequate knowledge about the impacts of climate change and which knowledge is most applicable to their particular region.

The new guidelines will also set out national goals and expectations, together with clear guidelines, concerning municipal planning of climate change adaptation. They will apply both to overall regional and municipal planning strategies and to more specific municipal planning, in other words

to the social, land-use and implementation elements of the municipal master plan.

A key part of the central government guidelines will be to specify the considerations and assessments that must be taken into account in order to ensure that the impacts of climate change are given sufficient priority in planning and other municipal activities and in the exercise of their authority.

The local government authorities must also take into account the fact that the impacts will differ from one part of the country to another.

In addition, the central government guidelines will provide a more detailed overview of the measures that should be evaluated and implemented in the long-term social element of the municipal master plan, in the land-use element and in zoning plans. Specific, action-oriented guidelines will be given for various sectors: for drawing up risk and vulnerability assessments, incorporating environmental considerations and identifying how the natural environment can be used to prevent damage, and for building technology, road construction and so on.

The central government guidelines will provide general, overall directions, and will also be more specific and detailed in certain areas. They will be incorporated into the existing central government guidelines for climate change mitigation and energy planning by counties and municipalities. They are also intended to serve as a basis for individual decisions made by central government, regional and municipal bodies under the Planning and Building Act and other legislation.

7.4 Information, cooperation and advice

Regardless of how the municipalities organise their adaptation efforts, knowledge of the local impacts of climate change will be essential. For example, without information about sea level rise, precipitation trends and the resulting changes in the risks associated with flooding, landslides and avalanches, local authorities will not know which changes they need to adapt to. Priority will be given to improving dissemination of information on climate change to the counties and municipalities.

Today there is a great deal of information available from studies and the central government administration on climate change and the practical results of various adaptation efforts. In 2009 the Ministry of the Environment set up the website www.klimatilpasning.no to coordinate this type of information and make it easily accessible for regional and municipal authorities. The website, which is managed by the Norwegian Climate Adaptation Programme, is also intended as a tool for municipalities and others who find it difficult to start on adaptation work, and contains a set of practical guidelines. These include background information, tools and advice on how to include climate change considerations in planning processes. The website has so far been a success, but if it is to continue to be relevant and serve as a key knowledge base and communication channel, it will require regular maintenance, development and updating. Priority will be given to maintaining the role of klimatilpasning.no as a knowledge platform for adaptation efforts in Norway.

In order to be of practical use in planning, knowledge about climate change adaptation must be further developed through collaboration between municipalities and resource centres that can interpret climate modelling and projections to provide locally adapted information.

Studies can form a sound basis for adaptation efforts, but the practical measures must be developed by the municipalities themselves. Networks and regional cooperation have been shown to be effective learning tools for strengthening the adaptive capacity of municipalities and enabling them to exchange experience. This is important in an area like climate change adaptation, which is new to many people and where experience is limited. Networked learning is also very effective. Cooperation with central government agencies, suppliers of climate projections and other knowledge centres can save municipalities time and money. For example, the cooperation within river basin districts under the Water Management Regulations is an important arena for intermunicipal collaboration and knowledge-building and also relevant to adaptation measures to maintain or improve the environmental status of inland and coastal waters.

Several types of networks for cooperation and sharing experience have been set up. While Cities of the Future involves the largest towns and their adjacent municipalities, regardless of geographical location, the networked learning for which the counties and county governors are responsible is linked to specific geographical regions. Both models have their strengths. Cities of the Future provides a forum for exchange of experience between urban areas on specifically urban problems, such as stormwater. The county networks link the municipalities within each regional administrative

Box 7.3 Cities of the Future

Cities of the Future is an example of an ongoing cooperation focusing on climate change adaptation. In 2008, Norway's 13 largest cities and urban areas were invited by the Ministry of the Environment to join together to reduce greenhouse gas emissions and create cities that will be better places to live. In addition to the cities and the Ministry of the Environment, which heads the cooperation, three other ministries are involved: the Ministry of Local Government and Regional Development, the Ministry of Petroleum and Energy and the Ministry of Transport and Communications, together with the Norwegian Association of Local and Regional Authorities and the business sector. The practical cooperation takes the form of a network. Adaptation to climate change is also an important element of the cooperation. The focus area is adaptation to climate change.

So far 10 of the cities have included specific objectives or strategies relating to adaptation in the social element of their municipal master plans and 10 have included provisions concerning climate change adaptation in the land-use element. All 13 have developed action programmes that will play a part in climate change adaptation.

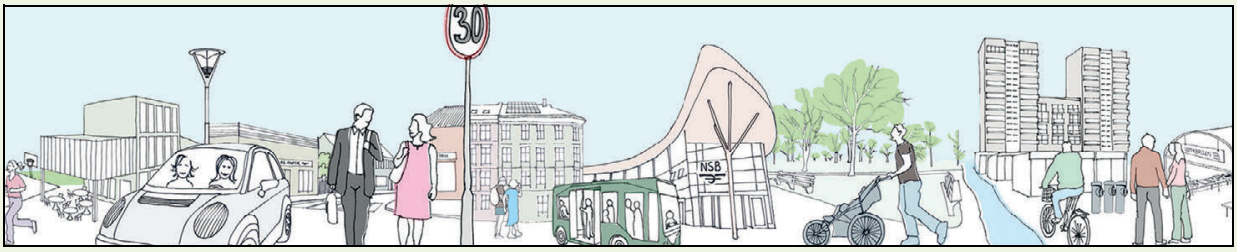

Figure 7.1 Cities of the Future

Source: *Gjennomgang av klimatilpasning i kommunale planer – kommuner i Framtidens byer* (Review of climate change adaptation in municipal plans – municipalities in Cities of the Future, in Norwegian). Report drawn up by Rambøll Norge for the Directorate for Civil Protection and Emergency Planning, January 2012.

structure, which enables county authorities, county governors and key state agencies with a regional presence, such as the Norwegian Public Roads Administration and the Norwegian Water Resources and Energy Directorate, to provide clear and coordinated guidance to the municipalities. This form of cooperation also promotes intermunicipal collaboration on joint vulnerability assessments and regional challenges. The Government considers that intermunicipal cooperation will be an effective means of implementing central government guidelines on adaptation.

Regional networks and the provision of guidance and advice to the municipalities should be considered together. The county authorities and county governors have a number of tasks and functions at the regional level that are relevant to municipal adaptation efforts.

The counties are the regional planning authorities, with overall responsibility for regional planning strategies, regional master plans and regional planning provisions. Their planning activities are intended to implement political objectives for economic, environmental, social and cultural development within each county and to provide guidance and assistance on planning to the municipalities. In their planning guidance for the municipalities, the county authorities include input on regional interests in the planning area and guidance on processes and requirements regarding planning documents. This means that the county authorities have an important advisory role as regards municipal climate-related work in land-use planning.

The county governors' offices are responsible for ensuring that national policies are implemented locally and coordinate central government policy signals to the municipalities. Under the Planning and Building Act, they also provide advice and guidance on following up government guidelines and act as appeal and supervisory bodies. They coordinate civil protection and emergency planning at the regional and municipal levels, and are responsible for county-level risk and vulnerability assessments. They have also been made responsible for maintaining an overview

and providing guidance to the municipalities on climate change adaptation within their spheres of responsibility. Under the Planning and Building Act, the county governors will be responsible for ensuring compliance with the central government guidelines on climate change adaptation, and for providing guidance to the municipalities. The county governors' offices cooperate with the county authorities in these tasks.

8 Climate change adaptation in different sectors

There is nothing new about the idea of taking weather and climatic conditions into account in planning processes. However, climate change will make it more challenging to deal with the climate-related problems Norway already faces, and there will be new challenges to deal with in addition. Plans will have to be adjusted to take account of more frequent and more intense extreme weather events and gradual changes in the natural environment. Planning for a different climate means that current planning processes have to address both today's climate and the projected future climate.

It is particularly important to take climate change adaptation into account in all investments with a long time horizon, regardless of sector. However, some sectors will be more strongly affected by climate change than others. Several of these, such as the electricity supply and transport sectors, have already started to address climate change adaptation through surveys, analyses and policy development in their own fields. It is important to ensure that this work is systematically incorporated into planning and decision-making processes in the different sectors.

In recent years, sectoral authorities have begun reviewing the situation and implementing the first steps towards climate change adaptation. The Directorate for Nature Management and the Norwegian Water Resources and Energy Directorate have for example both carried out reviews and presented action plans and strategies for climate change adaptation. In 2010, the Norwegian Public Roads Administration completed a three-year review of the impacts of climate change on transport infrastructure. The Norwegian Building Authority has also carried out major research projects and studies relating to the construction sector in cooperation with SINTEF Building and Infrastructure. In 2009, the Government presented a white paper on climate change and the agriculture and forestry sectors, which discussed both mitigation and adaptation (Report No. 39 (2008–2009) to the Storting, *Klimautfordringene – landbruket en del av løsningen* (Climate challenges – agriculture part of the solution. Summary in English). There is considerable variation in how far the different sectors have progressed in their work on climate change adaptation. Some actors are already carrying out practical work, whereas others have barely started. The main focus is on reviews and surveys, and most of the work has been organised in the form of projects.

8.1 Nature management

Climate change has impacts on both species composition and biomass production in ecosystems, and will have positive effects on some species and adverse effects on others. This section discusses how nature management in Norway can be adapted to climate change.

The report *Adapting to a changing climate* (NOU 2010: 10) points out that nature's capacity to adapt to rapid climate change is limited, but that there are ways of strengthening the adaptive capacity of ecosystems and species. High species diversity and wide genetic diversity combined with many different habitats and niches make ecosystems resilient, in other words capable of withstanding and adapting to environmental change. High biodiversity and resilience is therefore important for adaptation to climate change. One example is the importance of a wide variety of pollinators for some types of plant production. Healthy ecosystems can also reduce the impacts of climate change on human society. For example, forests can prevent landslides and erosion, and riparian vegetation can reduce inundation during smaller flooding events. Thus, the natural environment can fulfil an important function in adaptation of human society to climate change.

Much of the nature management work being done today consists of important measures to ensure that biodiversity is resilient, which can also be classified as climate change adaptation. The overall goal of climate change adaptation in the field of nature management is to maintain the adaptive capacity of natural systems. This goal must be achieved by finding a balance between conservation and sustainable use, and must be incorporated into the management of species and

habitat types that may be exposed to climate change, for example by designating priority species and selected habitats under the Nature Diversity Act. It is also important to maintain the range of ecosystem services provided by habitats such as wetlands, forest and river systems. As part of the work of following up decisions under the Convention on Biological Diversity, Norway is seeking to reduce the negative impacts of climate change on biodiversity through conservation and sustainable use strategies that maintain biodiversity.[1] This work involves finding good ways of integrating climate change considerations into nature management.

Activities in many different sectors and administrative areas have impacts on the natural environment. This makes it essential to take an integrated approach to environmental management and to consider climate change in conjunction with other environmental pressures. The report *Adapting to a changing climate* highlights the importance of ecosystem-based management for strengthening the adaptive capacity of the natural environment, and this is also emphasised in decisions under the Convention on Biological Diversity. The same approach is being used in Norway as a basis in adaptation efforts in nature management, in the form of a good balance between conservation and sustainable use.

The Nature Diversity Act sets out principles for sustainable use, and is an important tool for promoting ecosystem-based management. The authorities must use these principles as a basis when evaluating and designing measures and new policy instruments. One of the fundamental requirements of the Act is that all decisions must, as far as is reasonable, be based on scientific knowledge of the population status of species, the range and ecological status of habitat types, and the impacts of environmental pressures (section 8). Any pressure on an ecosystem must be assessed on the basis of the cumulative environmental effects on the ecosystem now or in the future (section 10). In the absence of adequate information on biological, geological or landscape diversity or cumulative environmental effects on the ecosystem, the aim must be to avoid possible significant damage, in accordance with the precautionary principle (section 9). The costs of avoiding environmental degradation must be borne by the project owner (the user-pays principle, section 11), and methods, techniques and siting of activities must be chosen to give the best results for society as a whole (section 12). There are similar provisions on the management of marine species in section 7 of the Marine Resources Act. At the same time, section 14 of the Nature Diversity Act requires measures under the Act to be weighed against other important public interests.

The capacity of the natural environment to withstand extreme weather and to moderate the negative impacts of climate change are important ecosystem services. Research shows that including more aspects of the value of biodiversity in planning and management of the natural environment in order to enhance ecosystem services can bring major benefits. At national level, Norway needs more knowledge and a better overview of ecosystem services and their importance for economic development and human well-being, and also the possible impacts of the loss and degradation of ecosystems. Norway's follow up of the Economics of Ecosystems and Biodiversity (TEEB) study will be able to provide a valuable contribution here. The Government has appointed a committee to review the values associated with biodiversity and ecosystem services in Norway so that we are in a better able to integrate this knowledge into decision-making processes. The committee has been asked to focus particularly on ecosystem services that will be important in dealing with climate change.

The Conference of the Parties under the Convention on Biological Diversity in Nagoya, Japan, in 2010 adopted the Aichi targets, 20 targets for the conservation of biodiversity and maintenance of ecosystem services. According to these, the countries that are parties to the Convention are to update their national biodiversity action plans by 2015, in line with the new targets. Norway is preparing a national action plan for biodiversity that will meet its obligations. Climate change considerations and the capacity of ecosystems to help society adapt to change will be integrated into the action plan.

Conservation and climate change adaptation

Substantial work has been done over many years to implement Norway's nationwide national park plan and various thematic conservation plans. This work is now nearing completion, and large areas, particularly in the mountains, have been safeguarded. However, some lowland habitat types still have little statutory protection, and many protected areas are small. Climate change may increase the vulnerability of such areas to cli-

[1] Convention on Biological Diversity, COP10, Decision X/33

mate-related factors such as strong winds and intense precipitation. Steps are already being taken to integrate climate change considerations into the management of protected areas, for example by increasing the size of protected areas and adjusting their boundaries. The connectivity of terrestrial habitats is important, since it enables animals and plants to move to other, more suitable areas over time if ecological conditions change as the climate changes. This intensifies the need for good land-use and general planning, so that networks of natural habitat can be maintained and allow species to move when necessary. Areas that stretch from sea level to the mountains or through several vegetation zones can be particularly important in this connection.[2, 3]

In the vicinity of urban areas, the Government will make active use of land-use planning under the Planning and Building Act and the Nature Diversity Act to safeguard areas of natural environment that moderate the impacts of flooding and extreme weather events on housing and other infrastructure. Establishing protected areas can also be an appropriate tool to use in this work.

Invasive alien organisms and climate change adaptation

Alien organisms are species, subspecies or populations that have been introduced outside their natural past or present distribution by human agency (populations established in Norway before 1800 are considered to be indigenous). Some of them are invasive, meaning that they displace native species and disturb local ecosystems. Climate change is expected to make it easier for alien organisms to become established in Norway and some of them may pose a threat to native biodiversity. The Norwegian Biodiversity Information Centre's report *Alien species in Norway – with the Norwegian Black List 2012* includes ecological risk assessments of species that do not occur naturally in Norway. These provide an important basis for eradicating, containing and controlling invasive alien organisms in Norway.

Chapter IV of the Nature Diversity Act deals with the import and release of alien organisms. Its provisions will be further elaborated in two sets of regulations. The regulations relating to the planting or sowing of foreign tree species for forestry purposes enter into force on 1 July 2012, and require anyone who wishes to plant or sow foreign tree species to obtain a permit. Applications are processed by the county governors. Regulations relating to the import and release of alien organisms are being drawn up. Risk factors are expected to change as a result of climate change, and these regulations may help to protect Norway's native biodiversity by preventing the introduction and spread of invasive alien organisms. A similar provision prohibiting the release of alien organisms is set out in section 7 of the Marine Resources Act. Cooperation between sectors will play a key role in action against invasive alien organisms that become established and spread more rapidly as a result of climate change. The Government's *Strategy on Invasive Alien Species* contains a programme of measures to prevent the spread and establishment of invasive alien species, which includes both measures to be taken by the individual sectors and joint measures on which they are to cooperate. The strategy was drawn up in cooperation between ten different ministries.

To ensure good control of the spread of invasive alien organisms, it will be important to ensure that the new legislation is properly enforced and applied, and to develop early warning and rapid response systems for new invasive alien organisms. Many counties have already established or are implementing action plans for dealing with alien organisms. This work must be continued, since it is part of Norway's efforts to meet its international commitments to introduce measures to eradicate, contain and control invasive alien organisms. Policy instruments for eradication, containment and control, information work and mapping of alien organisms must also be coordinated between sectors.

Climate change adaptation and outdoor recreation

Making sure that everyone has the opportunity to take part in outdoor recreation on an everyday basis is an important objective of the Government's efforts to promote active outdoor recreation in Norway. The Government is drawing up a national action plan for state involvement in the provision of outdoor recreation areas and on arrangements for public access, which is to be completed in summer 2013. Its overall objective is to identify which areas should be set aside for out-

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2 Framstad et. al. Naturfaglig evaluering av norske verneområder. Verneområdenes funksjon som økologisk nettverk og toleranse for klimaendringer (Assessment of Norwegian conservation areas. Their functions as ecological networks and tolerance to climate change. Summary in English) NINA report 888, 2012

3 IPCC Fourth Assessment Report, Climate Change 2007 – Impacts, adaptation and vulnerability, Chapter 4.6

door recreation and what arrangements are needed for access, for example low-impact facilities that make access easy for as many people as possible. The action plan will focus particularly on the need to set aside areas and make arrangements for public access near urban areas. It will also discuss the need for adaptation to the changing climate. More public information may have to be provided, such as more information about the rules on open fires as the risk of forest fire increases, and more information on sheep ticks as their distribution area expands.

Climate change adaptation in different ecosystems

Many of the current policy instruments for management of *mountain* areas were not primarily established with climate change adaptation in mind, but may nevertheless be important in safeguarding species and habitats in a changing climate. About 75 % of the total area of Norway's national parks is in the mountains, and the corresponding figures for protected landscapes and nature reserves are 71 % and 22 % respectively. When the national park plan has been completed, about 27 % of Norway's mountain areas will be protected under the Nature Diversity Act.

Montane forest is the term used to describe forest growing so high up that the trees clearly show the effects of the harsh climate. In general, Norway's montane forests are less influenced by forestry operations and have a higher proportion of old-growth forest than those in lowland areas. Many threatened species are associated with old-growth forest, and montane forests are therefore important for their survival. Climate change may allow forest to become established in areas that are currently above the treeline. This could have positive effects on forest species, but will reduce available areas of habitat for alpine species, creating future conservation challenges. On the other hand, montane forests in many areas are under severe pressure because of holiday cabin developments, and species that live in these habitats may therefore be particularly vulnerable to further pressure such as climate change.

Climate change is one of the greatest threats to wild reindeer and other species that are adapted to alpine habitats. To help these species to survive, it is therefore important to reduce other negative factors such as habitat loss and fragmentation. To safeguard vulnerable habitats and threatened species in the mountains, the Government will focus on strengthening an integrated land-use planning regime for mountain areas, including montane forest, and will incorporate climate change considerations into planning processes. The Government will consider whether current policy instruments are sufficient to ensure integrated land-use planning incorporating climate change considerations in mountain areas. The need for new national guidelines for planning and designing holiday housing in the mountains will be considered. One of the objectives of the regional plans for Norway's national conservation areas for wild reindeer is to safeguard continuous areas of wild reindeer habitat. These plans are to be completed by the end of 2012, and their implementation through decisions at county and municipal level will play a key role in ensuring continuous areas of wild reindeer habitat in the future.

Climate change may also alter food availability for many species, including mountain and forest game species. Populations must be regulated in a way that takes other pressures and climate change into account. As one element of a sustainable wildlife management regime, it may be appropriate to consider adjustments of quotas and open seasons for game species to ensure that the vulnerability of different species to climate change is taken into account.

Forest covers about 130 000 square kilometres or about 34 % of mainland Norway. About 50 % of the most seriously threatened species in Norway (1838 species) are associated with forest. Conditions for many of these have improved with increasing environmental awareness in the forestry industry. Forests are also very important as an economic resource and for outdoor recreation and enjoyment of the outdoors – the local outdoor areas most used by many Norwegians are in forest. Forests provide other important ecosystem services too – they store carbon, are a source of renewable energy and building materials, and help to control landslides and avalanches, flooding, runoff and erosion. For example, a buffer zone of riparian forest plays an important part in stabilising river banks.

The way forests are managed strongly influences their productivity, the species composition and age distribution of trees, forest health, species diversity and the capacity of forests to deliver ecosystem services. Climate change intensifies the need for adaptation in the forestry industry, including the development of seeds and plant material that are better adapted to the climate. Climate change will also make it more important to continue current practices such as ensuring that forestry roads follow appropriate routes and tak-

ing other steps to prevent erosion, particularly in steep terrain and flood-prone areas.

Forestry conservation areas that cover several vegetation zones can enable some species to spread more readily, and thus facilitate climate change adaptation in forest habitats. In privately-owned areas, forest conservation is largely voluntary, involving cooperation between landowners and the environmental authorities. In addition, publicly owned areas of forests are protected. It is essential to ensure that areas of the highest conservation value are protected.

Responsibility for forest management in Norway is shared: the Ministry of the Environment is responsible for biodiversity and outdoor recreation interests, and can make use of the Nature Diversity Act, the Planning and Building Act, the Oslo Forest and Countryside Act and funding for protection of forest areas on a voluntary basis. The Norwegian Agricultural Authority administers the Forestry Act, the Natural Hazards Act and various regulations and grant schemes for the Ministry of Agriculture and Food. Forums for cooperation between the agricultural and environmental authorities have been established. This cooperation is also intended to facilitate climate change adaptation in the forest sector.

Climate change may result in changes in species and habitat diversity in the *cultural landscape*. For example, with higher temperatures and a longer growing season, scrub and woodland will encroach more quickly on open landscapes unless steps are taken to counteract this. Various arrangements and grant schemes have been established for the maintenance of cultural landscapes. Many of these form part of the national and regional environmental programmes under the Agricultural Agreement, which have total almost NOK 5 billion per year. The national environmental programme includes general support for maintaining agricultural areas and cultural landscapes, while the regional environmental programmes contain more specific measures to safeguard cultural landscapes, the cultural heritage and biodiversity, and also pollution- and climate-related measures. The environmental authorities are cooperating with the agricultural sector to ensure that economic and other types of instruments counteract negative effects such as overgrowing of open landscapes.

The Nature Diversity Act provides the legal authority to designate priority species and selected habitat types, which makes it possible to adopt regulations to safeguard species and habitats that are at particular risk. So far, five selected habitat types and eight priority species have been designated, several of which are associated with the cultural landscape. Various arrangements, including the scheme for specific environmental measures in agriculture and the regional environmental programmes, include grant schemes for management and restoration of habitats such as wetlands, hay meadows and coastal heaths, and for ditching and drainage of cultivated land. There are regional water management plans that provide a basis for targeted measures to reduce runoff and nutrient loss from agriculture along rivers and lakes. These help to improve the ecological status of rivers and lakes, in accordance with the EU Water Framework Directive.

The Government considers the instruments used by the agricultural sector for conservation of the agricultural landscape and associated species and ecosystems to be important in addressing climate change. They improve management of the agricultural landscape and make vulnerable habitat types more resilient to climate change. Climate change may also make it necessary to make adjustments to ensuretargeted and efficient use of agricultural policy instruments. It is also essential to ensure close coordination of the use of policy instruments by the agricultural and environmental authorities.

About 10 % of mainland Norway is covered by *wetlands*, mostly peatland – bogs or mires. Many of these areas can play a part in flood control, groundwater recharge and moderating water flow[4]. However, the capacity of wetlands to retain water varies greatly, and depends on hydrological processes. Floodplains and riparian ecosystems are generally recognised as one of the most important defences against flood damage and erosion of riverbanks. This means that safeguarding and restoring such wetlands can be a win-win solution, which reduces vulnerability to climate change, enhances carbon storage and maintains habitats for many different species.

The fact that the ecosystem services wetlands provide are public goods that benefit society as a whole, whereas the value for those responsible for managing a specific area is not as obvious, creates major challenges in wetland management. Many wetlands have been severely degraded by processes such as straightening and channelling stretches of river, culverting, road-building alongside rivers, and more recently also the spread of

[4] Rusch, G. M. (2012): Climate and ecosystem services. The potential of Norwegian ecosystems for climate mitigation and adaptation. – NINA Report 791.

alien species. Sound knowledge and information about the importance of ecosystem services from wetlands is therefore needed, so that drainage and development of peatlands and other wetlands can be avoided through integrated land-use planning.

Some wetlands have been protected, but there are several types that are not included or are under-represented in Norway's system of protected areas. Particularly in highly productive lowland areas, wetlands are under severe and growing pressure from development projects for housing, industry and infrastructure. Many wetlands have also been drained, have become overgrown or have changed in other ways, reducing their capacity to buffer flooding or drought resulting from climate change.

A survey has shown that about 350 of Norway's wetlands need restoration to maintain their conservation value. A national plan for the restoration of priority wetlands is being drawn up. The purpose is to improve conditions for threatened species, safeguard threatened habitat types and enhance ecosystem services. Efforts to restore and maintain wetlands so that they can continue to deliver ecosystem services will be continued.

Freshwater habitats and species may be affected by more frequent and larger changes in water flow, temperature changes and an increase in runoff and accompanying pollution as a result of climate change. The integrated, cross-sectoral system of water resource planning under the Water Management Regulations makes an important contribution towards ecosystem-based management of freshwater. This system applies to all of Norway's groundwater, freshwater bodies and coastal waters to one nautical mile outside the baseline. The overall objective is for all water bodies to achieve good ecological and chemical status.

Norway has been divided into eleven national river basin districts and five[5] river basin districts that are shared with Finland and Sweden. These divisions are based on the natural boundaries of river basins and are independent of county and municipal boundaries. Management plans are being drawn up for each region in accordance with the requirements of the Water Management Regulations. They include both monitoring programmes and programmes of measures to achieve the environmental objectives. Measures have to be implemented under legislation administered by various authorities, particularly the Pollution Control Act, the Water Resources Act, the Watercourse Regulation Act, the Aquaculture Act, the Planning and Building Act and the Nature Diversity Act. Economic instruments are also important, including grants from the agricultural authorities that encourage the implementation of measures to reduce runoff, for example establishing buffer zones, grassed waterways and hydrotechnical installations.

Under the Common Implementation Strategy for the Water Framework Directive, a guidance document has been drawn up on river basin management in a changing climate. Climate change adaptation is an important consideration in developing both monitoring programmes and programmes of measures as part of these plans.

To reduce the vulnerability of freshwater species to climate change, the Government will seek to ensure that populations are as resilient as possible by regulating harvesting and other removal, carrying out stock enhancement measures where appropriate, maintaining areas with specific ecological functions, removing barriers to migration created by physical disturbance or alteration, and taking steps to prevent new developments from creating such barriers. Cross-sectoral cooperation is also need to ensure stable flow and good water quality even if precipitation patterns change.

The overall framework for management of *Norwegian sea areas* has been laid down in the integrated management plans for these areas, while the Water Management Regulations and the Planning and Building Act are important for integrated management of the *coastal zone*. An important element of both systems is a monitoring programme for selected indicators to give an overview of status and trends for ecosystems. The Marine Resources Act provides the legal basis for management of Norway's living marine resources. The countries around the Northeast Atlantic have extensive monitoring programmes for ecosystems and fish stocks. The International Council for the Exploration of the Sea (ICES) uses the monitoring results in drawing up its advice on fish stocks, which is a key part of the basis for resource management. Quota recommendations from ICES are based on updated information on stocks, ecosystems and climatic and environmental factors, and decisions on quotas for stocks that are harvested are based on this advice. This system is essential for ensuring that harvesting levels are in accordance with the goal of maintaining resilient marine ecosystems. Scientists consider that most Norwegian stocks are being harvested within safe ecological limits.

[5] Corrected from six in the original Norwegian text.

Box 8.1 Restoration and climate change adaptation

A number of Norway's river systems have been physically altered, for example by channelling for timber rafting, in connection with construction of buildings or other infrastructure, or to build flood defences. One example is the river Enningdalselva, which runs from lake Bullaren in Sweden to the sea in Iddefjorden near Halden in Østfold[1]. The river bed was cleared and the river channelled over a long period, which had negative impacts on aquatic organisms. Retaining walls were built along sections of river bank and vegetation and eddies and backwaters removed, with the loss of breeding sites and shelter for species such as freshwater pearl mussel and salmon. A large-scale restoration project has been initiated and a joint management plan drawn up to improve the situation. In addition to providing better ecological conditions for a number of species, the restoration project will also mean that sand and gravel deposits near the river can function as retention basins and control flooding in the river. With good planning and close cooperation, such solutions generally result in win-win situations.

[1] Part of one of the river basin districts shared between Norway and Sweden.

It is becoming increasingly important to adapt the marine management regime to ensure that the cumulative environmental effects of rising sea temperature, ocean acidification and human activity do not cause any degradation of ecosystem services from the marine environment. This is essential to the maintenance of resilient ecosystems. Cumulative environmental effects on marine ecosystems are taken into account in the management plans for Norway's sea areas. In the updated management plan for the Barents Sea–Lofoten area (Meld. St. 10 (2010–2011)), the Government emphasised the need to build up knowledge about ocean acidification and climate change, for instance by putting in place a long-term programme with adequate coverage to monitor changes in ocean acidity and the impacts of these changes. This is needed both to gain an overview of the scale of the problem and to provide projections of future trends.

New challenges will arise as regards the management of previously ice-covered areas that become ice-free as a result of climate change. This is further discussed in Chapter 9 on the Arctic.

Further development of the knowledge base

The impacts of climate change on the natural environment are increasing the need for knowledge-building and close monitoring of changes. Research on adaptation and vulnerability and systematic collection of data through mapping and monitoring of environmental change are crucial for our ability to establish sound, effective adaptation measures. The knowledge base for climate change adaptation in nature management needs to be further developed through research, mapping and monitoring. The municipalities, the business sector and other relevant actors also need better advice and information on the important role nature plays in making human societies resilient to climate change.

Over the years, a large volume of data on both terrestrial and marine ecosystems has been collected through mapping and monitoring programmes. In recent years, some monitoring programmes have been modified to incorporate the impacts of climate change. If this information is to be used, it is essential for all decision makers to have access to good data. Several systems have therefore been developed to provide access to data from mapping and monitoring programmes. These include the database «Naturbase» run by the Directorate for Nature Management, and the Species Map Service run by the Norwegian Biodiversity Information Centre. A map-based web application called Vann-Nett provides data on ecological status and trends in water bodies, and the MAREANO programme is mapping the seabed in Norwegian waters and making the data available. The website www.miljostatus.no publishes the results of environmental monitoring programmes, and the new portal www.barentswatch.no will provide access to data from a range of bodies and institutions involved in monitoring of Norwegian sea areas.

Monitoring of changes in the status and distribution of species that are vulnerable to climate change, such as Arctic and alpine species, will be continued. Knowledge about alien species, including their environmental impacts, pathways of introduction and the effects of climate change, needs to be improved through mapping, monitoring and research. The rising volume of shipping in northern waters and the potentially higher risk

that new alien species will be introduced will intensify the need for knowledge. It will also be important to follow up the new Norwegian Black List from 2012 and establish a good overview of measures already in use to eradicate, contain and control the most invasive alien species and identify where action needs to be taken.

The Norwegian Nature Index measures the status and trends of biodiversity in nine major ecosystems in Norway, and the first edition was published in 2010. It is based on monitoring data and expert assessments. The first edition was only the beginning of a long-term process of following environmental change to provide a constantly improving basis for deciding on priorities for environmental measures and for mapping and monitoring. One aim is to replace the large numbers of assessments by experts with monitoring and modelling based on monitoring data in the next edition of the Nature Index.

Systematic, long-term monitoring is an essential basis for evaluating the impacts of climate change on the natural environment. It is particularly important to develop long time series of monitoring data. The Nature Index has identified a number of major gaps in our knowledge, especially as regards coastal waters and certain groups of organisms, including plants and invertebrates.

Although many mapping and monitoring projects are already in progress, further development of the knowledge base is still needed, and relevant actors need sound advice and information on climate change adaptation in nature management and the important role nature has to play in making human societies resilient to climate change. This can be provided through better use of already existing information channels, for example www.miljøkommune.no, which provides information and advice to the municipalities, and by strengthening cooperation between different levels in the public administration.

A number of research projects have been initiated to learn more about the effects of climate change on the natural environment and the value of ecosystem services in climate change adaptation. These efforts are being continued. It is particularly important to focus on the pace and impacts of climate change in Arctic areas and how these developments contribute to the cumulative environmental effects on ecosystems, and on ocean acidification and climate change and the synergistic effects they may have. Norwegian waters will be some of the first areas in the world to be affected by ocean acidification, and it is therefore important to continue the current monitoring programmes for marine ecosystems.

8.2 Agriculture and forestry

The agricultural and forestry sector in Norway includes a wide range of activities, including reindeer husbandry and other activities based on farming and forestry resources. Adaptation of these activities to climate change is essential to prevent or limit damage both from extreme weather events and from more gradual processes of change, and at the same time ensure that potential production gains resulting from climate change are realised. Well-functioning ecosystems need to be maintained to prevent forest fire, landslides/avalanches, flooding and other problems caused by climate change. Soil structure will need to be improved and more climate-resilient production systems developed. The agricultural and forestry sector is responsible for managing large areas of Norway, and sound management here can reduce the risk of damage in other sectors. A dynamic agricultural and forestry sector is therefore a vital basis for addressing the challenges of climate change.

Climate change adaptation in the agricultural and forestry sector has been reviewed in connection with the 2009 white paper *Climate challenges – agriculture part of the solution* and the report *Adapting to a changing climate* (NOU 2010: 10). Another white paper dealing with agriculture, forestry and food policy more generally was published at the end of 2011 (Meld. St. 9 (2011–2012) *Landbruks- og matpolitikken. Velkommen til bords.* In Norwegian only).

Management of land resources

The large areas of land managed by the agricultural and forestry sector provide vital common goods and ecosystem services for society as a whole. Farmland, forest and other areas that have not been developed can act as important buffers against climate-related events such as landslides, avalanches and flooding. If such areas are developed for buildings, roads and other infrastructure, parts of the surface are made impermeable, resulting in more surface water runoff and stormwater management problems.

Climate change will result in a longer growing season and make it possible for primary production to increase, but will also speed up the spread of forest and scrub in open landscapes. Cultivated

land must be used actively and grazing pressure in uncultivated areas must be maintained to prevent overgrowing, which displaces species and habitats associated with agriculture and causes the loss of agricultural and cultural heritage and landscapes. The visual impact of the cultural landscape is of great value in connection with tourism. On the other hand, the growth of trees and scrub on open agricultural landscapes may enhance carbon storage and offer niches for new species, and may in certain cases help to prevent landslides, avalanches, drifting snow, etc. Grant schemes have been established to ensure that active use of farmland continues, including its use as pasture. Cooperation between the environmental and agricultural authorities is needed to maintain hay meadows and other traditional types of farmland that are no longer used for production.

According to the Government expectations for regional and municipal planning adopted by Royal Decree on 24 June 2011, the Government expects the counties and municipalities to take steps to prevent development of and building on valuable designated agricultural areas, areas of natural environment and outdoor recreation areas. Regional plans should identify valuable agricultural areas and through long-term development strategies draw clear boundaries between development areas and agricultural land and green structures.

Grant schemes in the agricultural sector

Over the past 25 years, an increasing proportion of the financial support provided through the Agricultural Agreement between the state and the farmers has been channelled through grant schemes intended to maintain and improve the environment. Many of these are designed to deal with runoff problems and maintenance of the cultural landscape, and are therefore relevant to climate change adaptation. Some grant schemes are key elements of the national environmental programme, and play a part in counteracting overgrowing of open agricultural landscapes (area-based schemes for agricultural production and the cultural landscape, a number-based scheme for livestock kept at pasture outdoors), while others are part of the regional environmental programmes (for example schemes to reduce nutrient runoff from farmland and to maintain the cultural landscape). Other environmental grant schemes are organised at municipal level, for example a scheme for specific environmental measures in agriculture.

From 2013, a climate and environment programme has been established under the Agricultural Agreement. This will provide funding for projects on topics including greenhouse gas emissions, climate change adaptation, reducing runoff, the cultural landscape and biodiversity. Total funding of NOK 18 million has been allocated to the programme for 2013, and will be administered by the Norwegian Agricultural Authority and the county governors. Knowledge development relating to climate change adaptation will be a natural topic to include in the programme.

Well-drained soils with a good soil structure are resilient to high precipitation. In 2013,a new grant scheme for drainage projects was therefore introduced, with an allocation of NOK 100 million. This will encourage more ditching and draining, and will increase the adaptive capacity of the agricultural sector and reduce erosion and runoff from cultivated areas.

The state compensation scheme for crop damage is important in reducing the risk borne by farmers. On the other hand, it is important to ensure that it does not discourage necessary adaptation to climate change. At present, there is a deductible for any claim, so that farmers bear part of the risk themselves. This means that it is not profitable for farmer to continue producing a specific crop or variety if there is extensive crop damage for several years in a row. In this way, the scheme encourages necessary adaptations to climate change, while protecting farmers' financial position in the short term.

National emergency stocks of seed

In 2011, high rainfall reduced seed corn production in Norway, making it necessary to import larger quantities in 2012. In the longer term, it may become difficult to obtain GMO-free seed. During negotiations on the 2011 Agricultural Agreement, it was therefore decided to establish a grant scheme from 2012 for the maintenance of contingency stocks of seed corn. The Ministry of Agriculture and Food adopted regulations for the scheme in October 2012. A complete review of the situation as regards crop seed (both grain and other crops) is also needed, to consider possible measures for ensuring stable supplies of seed in the future. In the first instance, the Ministry has asked the Norwegian Agricultural Authority to review the problems associated with ensuring stable supplies of seed, for example clover and grass seed. In response to the recent food crises, the Ministry of Agriculture and Food has also started

an assessment of whether to re-establish national contingency stocks of seed corn, as announced in the 2011 white paper on agricultural, forestry and food policy.

Genetic resources in agriculture and forestry

To adapt agriculture and forestry to climate and environmental change and changes in production conditions, it is essential to safeguard the genetic resources in crops, livestock and trees. Unless this is done – whether resources are actively used by individual farmers or maintained by breeding programmes, by companies, in gene banks or in situ – genetic diversity will be lost. According to the Food and Agriculture Organization of the United Nations (FAO), about 75 % of crop genetic diversity was lost between 1900 and 2000[6]. Breeding livestock and crops that are adapted to a changed climate requires a long-term strategic effort and access to varied genetic material. The Nordic countries are cooperating on the management of Nordic genetic resources through NordGen (the Nordic Genetic Resource Centre). The Norwegian company Graminor AS has national responsibility for plant breeding in areas where the Norwegian market does not have sufficient supplies of foreign varieties. Grants are available through the Agricultural Agreement for plant breeding and the development of new varieties to ensure that Norwegian agriculture and horticulture has access to a range of disease-resistant crop varieties that are adapted to the climate. The overall responsibility for breeding and seed of Norwegian forest plants lies with the Ministry of Agriculture and Food. A foundation called the Norwegian Forest Seed Center is responsible for practical aspects of this work under an agreement with the Ministry.

The Norwegian Genetic Resource Centre initiates and coordinates activities relating to the conservation and sustainable use of Norway's genetic resources. Norway is involved in international cooperation in the FAO Commission on Genetic Resources for Food and Agriculture to draw up global status reports and action plans to ensure the conservation and sustainable use of these resources. The International Treaty on Plant Genetic Resources for Food and Agriculture and the Nagoya Protocol to the Convention on Biological Diversity provide the international framework for access to genetic resources and fair and equitable sharing of the benefits that arise from their use.

Water pollution

A wetter climate will exacerbate water pollution resulting from nutrient runoff and the use of chemical pesticides in agriculture, and may result in eutrophication, algal blooms and pollution of drinking water. Climate change may also result in changes in the degradation of chemical pesticides and their environmental impacts. For example, frequent, intense precipitation events may increase runoff and leaching of pesticides. In particular, more rain-related flooding just after crops have been sprayed will increase the risk of pollution of drinking water.

The Norwegian Agricultural Environmental Monitoring Programme measures soil erosion, nutrient runoff and pesticide loss from agricultural areas. Data from the programme are used to further develop and target environmental instruments in the agricultural sector, in implementing the Water Management Regulations and in national and international reporting.

Amended soil management (no autumn tilling) is the most important measure for reducing runoff of nutrients and particulate matter to river systems. In autumn 2011, about 60 % of all cereal acreage was left under stubble. Although this is a good way of reducing runoff from agriculture, research indicates that fungi and weeds are a greater problem in these areas than in areas that are tilled in autumn. As a result, farmers tend to use more pesticides. The Ministry of Agriculture and Food has adopted an action plan to reduce the risk of damage to health and the environment associated with the use of pesticides and make Norwegian agriculture less dependent on chemical pesticides.

Higher precipitation will increase problems related to the loss of nutrients and runoff to lakes and rivers. The Water Management Regulations require the implementation of measures to achieve good ecological status in river systems by 2021. In the long term, climate change may increase runoff from agricultural areas, and this must be taken into account in future agricultural policy. The situation will be particularly challenging in parts of the country where livestock density is high or that are vulnerable to erosion. There are wide variations in natural conditions, climate and farming methods in Norway, and priorities for measures to prevent pollution and nutrient runoff, and thus losses to farmers, must therefore be var-

[6] Corrected from 'the past 50 years' in the original Norwegian text.

ied accordingly. Measures of these kinds are covered by grant schemes under the Agricultural Agreement. They will also be included in programmes of measures under the Water Management Regulations. The system of management cycles and rolling six-year management plans under the regulations makes it possible to adapt measures to climate change and its consequences.

Plant and animal health

A milder climate and higher precipitation may increase the problems associated with plant and animal diseases, pests and weeds. Plant pests will be able to reproduce more rapidly, spread more widely and survive the winter better. Further development of the «VIPS» forecasting system will be an important way of preventing crop losses and poor crop quality. The system provides forecasts of the risk of damage from plant diseases, pests and weeds for important agricultural and horticultural crops, and helps farmers assess the need to use pesticides. Fungal diseases are particularly likely to become more of a problem as precipitation rises. Researchers have observed more widespread occurrence of fungi that produce mycotoxins, which can be harmful to both people and animals. Growing problems associated with plant diseases, pests and weeds may result in

Box 8.2 The Svalbard Global Seed Vault

The Svalbard Global Seed Vault was established by the Norwegian Government in 2008 to provide a safe repository for seeds from the world's seedbanks. The seed vault is in a cavern excavated into a mountain in the permafrost, and the temperature is maintained at -18 °C. Even in the event of a power cut, the samples will remain frozen. This means that gene banks can feel confident about depositing duplicates of their valuable collections here. Five years after the seed vault opened, it has received more than 750 000 seed samples from 53 gene banks in Norway and other parts of the world.

Figure 8.1 Svalbard Global Seed Vault, Longyearbyen

Source: Håkon Mosvold Larsen/NTB scanpix

more use of pesticides, making it even more important to continue efforts to make agriculture less dependent on chemical pesticides and reduce the risks associated with their use.

In order to address the challenges associated with climate change, it is important to maintain an effective and clearly targeted inspection and enforcement regime and ensure that active monitoring and emergency preparedness activities are part of the Norwegian Food Safety Authority's responsibilities in the field of animal health. These activities must be based on ongoing research and knowledge development by the Norwegian Veterinary Institute. We need to know which serious animal diseases are expected to show a higher risk of introduction, spread and establishment in Norway, and what implications this will have for agriculture and food production.

The results of monitoring and control programmes are vital to an understanding of the situation at any given time. Monitoring programmes, contingency tools and plans for combating animal disease must be in accordance with current legislation and updated risk assessments.

The effects of climate change on the animal health situation, including the expected increase in the number of disease-causing organisms, will make it necessary to step up efforts to combat disease. Environmental change and a change in the balance between pathogens and hosts, together with the possible increase in the incidence of zoonoses, must be met with sound emergency planning and preventive measures.

Reindeer husbandry and climate change adaptation

Reindeer husbandry will be strongly influenced by climate change. The Norwegian Reindeer Husbandry Act is intended to facilitate sustainable use of reindeer grazing resources to benefit both those involved in reindeer husbandry and society as a whole. Reindeer husbandry is to be maintained as an important basis for Sami culture, in accordance with Article 110a of the Norwegian Constitution and the provisions of international law on indigenous peoples and minorities.

Reindeer husbandry in Norway is organised in the traditional way, with migration between seasonal grazing grounds. It is therefore vulnerable to climate change, which adds to the pressure from other commercial interests, land-use conflicts and predators. Such external pressures have implications for use of grazing resources, migration routes and the timing of migration. The 2007 Reindeer Husbandry Act gave the reindeer husbandry districts greater responsibility for management of grazing resources. Reindeer numbers need to be kept stable at a level that allows flexibility in the way different areas are used. For example, reindeer owners need to be able to move to other areas if the normal winter grazing grounds are inaccessible because of deep snow or the formation of a hard ice crust («ice-locked»). A system of emergency groups with representatives of the authorities and the reindeer husbandry industry has been established, and a group can take action if large areas of reindeer grazing are inaccessible because of weather conditions.

More knowledge is needed about interactions between different impacts of climate change, and how this will affect different reindeer grazing areas. New knowledge about the consequences of climate change for reindeer husbandry may make it necessary to review adaptation measures in the industry at regular intervals. The Norwegian Reindeer Husbandry Association already makes regular assessments of the need for measures to mitigate the impacts of factors such as overgrowing of grazing areas and changes in the management regime.

The forestry industry and climate change adaptation

Forest plant breeding programmes in Norway need to be stepped up to obtain the climate-related benefits described in the 2012 white paper on Norwegian climate policy (Meld. St. 21 (2011–2012)), and to ensure that Norwegian forests are adapted to future climate change, as discussed in the 2011 white paper on agricultural, forestry and food policy (Meld. St. 21 (2011–2012)). Forest plant breeding with a view to adaptation makes use of the wide genetic diversity in Norway's forest trees to produce plant material that is more resilient to climate change. Forest plant material produced through breeding programmes can be used across wider climatic gradients than material produced by natural reproduction. Climate change adaptation is an important element of the strategy for forest plant breeding for 2010–40 drawn up by the Norwegian Forest Seed Center.

Improving the resilience of forests is an important element of the adaptation of a sustainable forest management regime to climate change. Appropriate measures include good forest hygiene, the choice of tree species, the choice of resilient seed trees and stand boundaries, appropriate programmes for tending young-growth stands, and caution when thinning at a late stage and during selection cutting. Existing tools for stand manage-

ment should be adapted to incorporate climate change considerations, and steps must be taken to ensure that the existing legislation takes forest hygiene properly into account.

Higher temperatures and a longer growing season will increase the production capacity of forests. It will be important for the forestry industry to make use of the opportunities this offers through forest plant breeding, promoting regeneration and forest management. Such opportunities should also be considered in forestry planning and in economic calculations where forests are classified according to site quality.

Climate change may also have indirect consequences for forest health. There is particular concern about the possible establishment of forest pests or diseases whose natural distribution is in milder climates outside Norway. New diseases affecting ash and elm trees in Norway are examples of the spread of climate-related diseases.

The Norwegian Scientific Committee for Food Safety, which carries out independent risk assessments relating to plant health, has detected traces of plant pests that could have very serious impacts in the form of forest disease or death if they become established in Norway.

The risk has increased considerably in recent years with the growing trade in timber and timber products. Some pests would be capable of establishing themselves in Norway in the current climate, but damage will only become apparent at higher temperatures. More knowledge of how to control forest pests that already occur naturally in Norway is also needed, since they are expected to become more widespread in a warmer climate.

In addition to developing contingency strategies and plans, it may therefore be necessary to strengthen monitoring programmes and certain preventive measures, for example for forest near Norway's main import nodes, as mentioned in the 2011 white paper on agricultural, forestry and food policy.

Norway's regulations on forest tree seed and plant material date from 1996. They are to be revised in keeping with new knowledge and new legislation, for example the new regulations on foreign tree species for forestry purposes. These new regulations must be implemented in a way that takes both biodiversity considerations and adaptation of Norwegian forests to climate change into account. Rules on plant quality and on the import and export of genetic material must also be improved when the regulations are revised.

Climate change adaptation is being considered in connection with an ongoing revision of standards for forest and farm roads. Guidelines have been issued on the risk of soil slides when forest roads are built in steep terrain, and how they can be prevented by using appropriate construction techniques and suitable design and specifications for ditches, culverts and drains. The Ministry of Agriculture and Food has begun revision of the legislation on planning and constructing forestry and farm roads, and will consider these in the context of relevant provisions in the Planning and Building Act and the Nature Diversity Act. The legislation is intended to promote good overall solutions that ensure the necessary infrastructure for the forestry industry and at the same time take into account safety, important environmental considerations and the risk of flooding, landslides and avalanches.

Access to forest resources is essential not only for forestry operations, but also in connection with forest fires and forest hygiene measures, such as the removal of damaged trees that could provide suitable breeding sites for various insect pests. Both the forest road network and the public roads system are of crucial importance for clean-up operations and the removal of timber after large-scale forest damage. When damage has occurred, effective application processes are needed. Coordination between the ministries involved and the public roads authorities must be improved so that clean-up operations can rapidly be initiated.

There have been a number of major forest fires (for example in Froland in Aust-Agder in 2008) and storms that have caused damage (for example «Dagmar» in 2011) in Norwegian forests in recent years, which have been challenging to deal with. Better coordination is needed between the public and private sectors in contingency plans for the forestry sector, so that all parties involved can work together efficiently during emergencies. In 2008, a government-appointed working group delivered a report on emergency preparedness and response to forest fires in Norway, and its conclusions need to be followed up further. For example, the report pointed out the importance of deploying resources fully at an early stage to prevent small forest fires from developing into large-scale incidents that are difficult to deal with and involve several sectors (such as the Froland forest fire).

Responsibility for cover against natural hazard damage, including damage directly caused by events such as landslides, avalanches, storms and flooding, is shared between the Norwegian Natural Disaster Fund and private insurance compa-

nies. About 50 % of the total area of forest in Norway is not covered by private insurance arrangements and is therefore not eligible for compensation from the Fund. In view of the climate change projected for Norway, the Ministry of Agriculture and Food will look more closely at how it would be possible to provide protection against financial losses resulting from climate-related damage for a larger proportion of Norwegian forests. Information on forest owners' own responsibility for preventive measures and for obtaining insurance against storm damage and the like must be improved.

Forest that provides protection against natural hazards such as landslides, avalanches, windthrow and flooding is managed in accordance with Norwegian forestry law. The same applies to forest that protects other areas of forest, farmland or built-up areas. The county departments of agriculture are responsible for mapping theses areas, and the municipal councils determine their boundaries, which are also shown in municipal master plans. Owners are required to provide notification before any logging in such areas, and the county governors can issue guidelines for logging in protective forests. Protective forests can provide important ecosystem services in connection with climate change adaptation.

Knowledge production

Climate change will influence biological production systems, including agriculture and forestry. These sectors are therefore vulnerable both to gradual climate change and to extreme weather events. Research and development projects, monitoring programmes, international cooperation and dissemination activities are designed to identify the impacts climate change will have on agriculture and forestry in Norway and how different production types in different parts of the country best can be adapted. The Ministry of Agriculture and Food is giving priority to funding four research areas:

1. Innovation and competitiveness in the agricultural, forestry and food sector

Climate change will make it more difficult for the global food system to provide enough food to meet growing demand. However, in northern latitudes the growing season is expected to become longer, making it possible to increase yields and grow new types of crops. To make use of these opportunities, more knowledge will be needed about:

- plant material (new varieties and adaptation of existing varieties by means of breeding programmes);
- farming techniques (e.g. more use of grazing resources);
- cultivation techniques (potentially longer growing season, frost damage, water issues);
- social and economic impacts of changes in the crops and livestock produced and in the areas used on production and food quality (e.g. preventing any increase in fungal infection pressure from resulting in the presence of toxins in food and animal feedstuffs).

Biotechnology makes use of natural biological processes and offers unique opportunities for environmentally sound, climate-friendly innovation. According to the report *The Bioeconomy to 2030: Designing a Policy Agenda*, published by the OECD in 2009, agricultural and industrial applications of biotechnology are expected to show the greatest growth up to 2010. The report estimates that in 2030, 36 % of all applications of biotechnology will be in the agricultural sector, often based on new research findings.

2. Sustainable production of sufficient quantities of safe food

A warmer climate will allow pests and diseases to become established and spread to new areas. In future, threats to animal, plant and human health and to biodiversity may to a considerable degree come from as yet unknown diseases and pests (weeds, insects, bacteria, viruses, fungi, nematodes). This will require more knowledge in various fields, including the following:

- diagnosis, prevention, treatment, pathogenic agents and control of infection;
- zoonoses (diseases that can be transmitted between animals and humans);
- breeding of more resistant plant varieties;
- environmental impacts of pesticides, and alternatives to chemical pesticides;
- adaptation of farming and cultivation techniques;
- impacts of climate change on grazing resources and on reindeer parasites/diseases.

3. Emissions reductions, adaptation and renewable energy

Norway's forestry policy promotes wider use of timber in a variety of products and for energy purposes, and active utilisation of forests for commercial purposes and for climate change adaptation and mitigation. More knowledge is needed about:

- interactions between precipitation, soils and technology, and conservation of genetic diversity to develop more resilient forest production systems;
- choice of tree species, management, and links between forest management and the risk of damage;
- monitoring and development of preventive measures against alien pest organisms;
- existing forestry monitoring and mapping programmes, which need to be reviewed to clarify whether any changes are needed in connection with climate change adaptation.

4. Knowledge development for the public administration

The public administration makes use of a variety of policy instruments to ensure that the agricultural, forestry and food sector can fulfil its functions, and needs more knowledge about the following:

- the role of agricultural areas in climate change adaptation and in preventing damage in other sectors, for example from flooding, fire and landslides/avalanches;
- the responsibility of the agricultural and forestry sector for water pollution as a result of runoff and loss of nutrients to river systems.

International research cooperation

There has been a great deal of instability in the wider world around Norway in recent years, triggered by the food crisis and financial crisis, and not least by the impacts of weather and climate change. Import protection and higher prices for key foods mean that Norway is currently to some extent shielded from price fluctuations on the world market resulting from these crises, but it is not unaffected. Agricultural and food policy is being developed in a way that takes such factors into consideration.

Climate-related research should therefore investigate these complex relationships through a cross-sectoral approach and cooperation. Norway should take part in international cooperation in order to resolve shared challenges, expand the scope of research, revitalise Norwegian research and be able to understand and make use of research results from other countries.

Box 8.3 Programmes, infrastructure and institutes

There are five agricultural research institutes in Norway: Bioforsk (the Norwegian Institute for Agricultural and Environmental Research), the Centre for Rural Research, the Norwegian Forest and Landscape Institute, the Norwegian Agricultural Economics Research Institute and the Norwegian Veterinary Institute). They have a substantial research and development portfolio in agriculture, forestry, food and feedstuff production. This must be maintained and further developed. Since there is a great deal of uncertainty about climate change, broad-based research is needed on how agriculture will be able to respond to different climate change scenarios.

The Research Council of Norway has issued several calls for proposals related to climate change adaptation in agriculture as part of the research programme BIONÆR (on sustainable innovation in food and bio-based industries) and the NORKLIMA climate research programme. Many of the issues discussed in the section above are included in the plans for the BIOKLIMA project, which aims to develop a national infrastructure for studying climate effects in natural and agro-ecosystems. A pre-project has started up to look at the feasibility of developing a research infrastructure offering a climate-controlled facility for experimental studies of soil, water, plants and greenhouse gases, and where it is also possible to study the effects of frost. Norway is also playing an active part in international programme cooperation related to climate change adaptation in agriculture and forestry.

8.3 Fisheries and aquaculture

The projected impacts of changes in water temperature, higher water levels and wilder weather will require adaptations in all areas of responsibility under the Ministry of Fisheries and Coastal Affairs. Adequate information about the impacts of climate change and ocean acidification on marine ecosystems is needed so that fisheries and coastal management can be adapted to new conditions. Chapter 8.5 on infrastructure discusses assessments by the transport agencies of the risks associated with the consequences of climate change, for example extreme weather events and storm surges.

A concerted research effort has been launched to learn more about the role of the oceans in the climate system and the impacts of climate change on marine ecosystems and resources. Projects have shown that a range of climate factors will have effects on marine organisms at both individual and population level. Climate change will entail management challenges for the Ministry of Fisheries and Coastal Affairs.

The Ministry has drawn up a climate change strategy for its own areas of responsibility. Its goal is to put the fisheries and coastal administration in the best possible position to meet challenges related to climate change, and to reduce greenhouse gas emissions from the sector. One important measure for adaptation measure is the continuation of important monitoring series. Following developments in factors such as temperature, acidification, populations, fish health and food safety closely gives a good basis for taking the necessary action. The Institute of Marine Research is responsible for most climate-related monitoring in the marine environment. Rising levels of CO_2 in the atmosphere lead to higher CO_2 uptake in seawater. The Institute of Marine Research started monitoring of ocean acidification in 2010. A number of projects have been started to investigate the impacts of acidification on species at different levels in food chains, such as the copepod *Calanus finmarchicus*, lobster, mackerel, cod and scallops. The National Institute of Nutrition and Seafood Research is responsible for research and development on environmentally sound feed for farmed fish and on seafood safety and quality.

As regards the reduction of greenhouse gas emissions, the Ministry of Fisheries and Coastal Affairs has taken the initiative for the development of a Norwegian standard for calculating the carbon footprint of seafood under the auspices of Standards Norway. The work is expected to be completed in spring 2013.

Box 8.4 Hav21

The HAV21 strategy committee was established by the Government in autumn 2011 with a mandate to draw up a proposal for an integrated marine research strategy to ensure effective and targeted use of marine research resources. The committee presented its report, *An R&D strategy for a marine nation of substance*, on 7 November 2012.

In the strategy, the committee identifies research and knowledge needs that must be met in order to develop the marine sector in accordance with the Government's vision that Norway should be the world's leading seafood nation, maintain clean, rich seas for future generations, and maintain an integrated, ecosystem-based marine management regime. The report also concludes that it is prudent for Norway to continue investing in the marine sector, which is a sector in which it excels.

The kind of knowledge needed in the marine sector has become increasingly complicated. More and more, complex, interdisciplinary research and development is required. The committee recommended the use of interdisciplinary and cross-sectoral projects involving science and technology, social sciences and the humanities, drawing on Norway's extensive knowledge base in the offshore and maritime sectors.

The strategy notes that Norway takes a broad-based approach to marine research and development, which should be continued. This is the point of departure for the strategy committee's recommended priorities: social and legal perspectives, management and use; knowledge of ecosystems; the Arctic and northern areas; harvesting and cultivating new marine raw materials; fish health and sustainable, safe and healthy seafood; food and markets; and technology. These priorities have not been ranked.

8.4 Health

Many types of health risks are influenced by climate change. Climate change may result in a negative trend in drinking water quality. Food- and water-borne infections are among the commonest infections in the world and are sensitive to climate change. Climate change can entail a higher risk of vector-borne diseases carried by organisms such as mosquitoes, ticks and snails. The climate-related natural hazards that are responsible for the greatest number of deaths in Norway are storms, flooding, landslides and avalanches. Climate-related accidents and diseases are a general risk factor in Norway, but climate change is not expected to cause any large changes in mortality. Norway is a safe country, and public health is generally good. This means that we have a sound basis for dealing with the challenges of climate change.

Confidence that life and health will always be safeguarded is a fundamental value of our society, and contributes to a high quality of life. This means that measures are taken to prevent disease and injury and to ensure adequate medical care and emergency services. In the event of an incident involving a risk to life and health, substantial resources are mobilised, and priority is given to ensuring that every inhabitant feels safe, regardless of the geographical region in which they live. All sectors and enterprises have a duty to safeguard life and health within their respective spheres of responsibility.

The Norwegian health services are the responsibility of the Ministry of Health and Care Services. The ministry administers the health sector by means of legislation and annual budget allocations and through government agencies and enterprises. The ministry is also responsible for treatment, research and monitoring activities in the sector. Sound organisation and a clear division of responsibility are essential, and these factors will also be fundamental in addressing the challenges associated with climate change.

Individual food producers and water works are responsible for ensuring that their products are safe to eat and drink. The Norwegian Food Safety Authority is the supervisory authority for the legislation governing food and drink. The health authorities have a number of procedures for monitoring the health of the population, including the occurrence of diseases associated with climate change. For example, physicians have a duty to report every case of more than 50 communicable diseases by means of a dedicated reporting system operated by the Norwegian Institute of Public Health. The Directorate of Health is responsible for defining critical vulnerabilities, taking appropriate adaptation action, and identifying challenges to the health sector. The Institute of Public Health is responsible for assessing the health impacts of changes that may occur in Norway, for example in temperature, water quality and the prevalence of vectors.

Climate change and drinking water supplies

The importance of drinking water as a source of water- and food-borne infections is probably greater in Norway than in other developed countries, partly because such a large proportion of drinking water is surface water.

Sections 5 and 9 of the Norwegian Public Health Act, which entered into force on 1 January 2012, provide the authority to require new measures to be planned, initiated and implemented so that climate change considerations are more fully incorporated into relevant decision-making processes. The precautionary principle is one of the fundamental principles underlying the Act and should therefore underlie municipal risk and vulnerability assessments and emergency preparedness plans (see section 28 of the Act), which should take into account the potential impacts of climate-related hazards.

It is relatively straightforward to take steps to improve raw water quality and prevent contamination of water treatment plants, and to intensify monitoring of water quality. The most vulnerable treatment plants are also relatively easy to identify. However, it is more difficult to predict where there is a risk of waste water seeping into the drinking water supply, because there is insufficient information about the state of the pipeline network. It is also more difficult and more costly to prevent contamination of the pipeline network by waste water, making these types of adaptation measures more difficult.

The Norwegian Food Safety Authority has pointed out the need to maintain and upgrade drinking water supply systems. The responsibility for ensuring that drinking supplies are safe lies with the municipalities and other owners of water supply systems.

In 2012 the Norwegian Food Safety Authority conducted a national inspection campaign focusing on the distribution system for drinking water. Drinking water was also one of the elements of an emergency preparedness exercise conducted in 2012 in the counties of Buskerud, Vestfold and

Telemark, in which drinking water was used to train cooperation with county governors and between municipal medical officers. The exercise revealed a need to discuss and clarify roles and responsibilities with the county governors' offices.

A working group of the relevant ministries and government agencies has been appointed to consider potential problems related to drinking water and the distribution network.

Vectors

The Norwegian Institute of Public Health and the National Veterinary Institute run the project www.flattogflue.no, which registers data on the distribution of sheep ticks (*Ixodes ricinus*) and deer keds (*Lipoptena cervi*) based on information reported by hunters. Data are registered for each hunting season, and it is planned to continue the project in the years ahead. The Norwegian Institute of Public Health has collected sheep ticks within and outside the known area of distribution of the virus disease tick-borne encephalitis (TBE) and analysed them for TBE. This is the vector-borne disease that is most likely to become more common as a result of future climate change.

International cooperation

Norway takes an active part in the work in the environment and health field under the auspices of the World Health Organization. This includes implementation of the Protocol on Water and Health, where Norway is chair of the Bureau of the Protocol on Water and Health for the period 2011–13. The protocol provides guidance on addressing the impacts of climate change on drinking water.

Norway is a party to the Parma Declaration on Environment and Health, which was adopted at the WHO Fifth Ministerial Conference on Environment and Health in 2010, and is promoting its implementation. The declaration identifies the key environment and health challenges in Europe and presents ways to address them, politically, technically and through participation by involved groups. Protecting children's health and protecting health and the environment from climate change are two of the commitments undertaken by the parties.

Norway participates in several European expert networks, including meetings on environment and health and ECDC/VBORNET, a network on vector surveillance.

8.5 Buildings and other infrastructure

Transport

Norway's transport systems are vulnerable to climate change. Higher precipitation and more intense precipitation events are expected to create problems for roads and railways in particular, in the form of greater wear and tear, more damage and traffic disruption. Maritime and air transport will also be vulnerable to more extreme weather events, rising sea levels, storm surges and generally more difficult climatic conditions.

Society is dependent on a well-functioning transport system, and traffic disruption can easily have major consequences. The goal of the Government's transport policy is to provide an efficient, safe and environmentally sound transport system that meets society's needs and promotes regional development.

Climatic conditions and extreme events frequently cause disruption of the transport system and pose considerable risks to the sector even in today's climate. The transport authorities therefore attach great importance to including climatic factors and climate change projections in their planning processes. For many years the manuals, guidelines and standards for the maintenance of existing infrastructure and the construction of new infrastructure published by the various transport agencies have been revised as more knowledge of climate change becomes available.

The Ministry of Transport and Communications is responsible for the transport sector, and lays down the overall framework for policy development for the various transport sectors. This does not apply, however, to maritime transport, which is the responsibility of the Ministry of Fisheries and Coastal Affairs. The national transport plan, which is a 10-year rolling plan that serves as a platform for development of the sector as a whole, is the most important strategic document. The guidelines for the various transport authorities drawn up in connection with the preparation of the 2014–23 National Transport Plan state that the proposed plans and priorities must take into consideration today's climate and projected climate change.

In 2007 the Ministry of Transport and Communications presented a risk and vulnerability assessment for the transport system from a cross-sectoral perspective (SAMROS I). The results of a follow-up project, SAMROS II, will be presented in the first half of 2013, and will provide an updated overview together with the most recent knowl-

edge concerning the risks facing the transport sector. The projects have identified critical assets in the transport and ICT sectors, such as stretches of road or rail, terminals and control centres, the disruption of which would have particularly serious implications for the transport and communications system. Specific measures have been proposed for protecting these assets, together with emergency plans in the event of disruption. The goal is to ensure that critical assets in these sectors are sufficiently resilient to different types of stress, including extreme weather events and climate change. In the field of maritime transport, risk and vulnerability assessments are being conducted for exposed fairways and navigation infrastructure. The Norwegian Coastal Administration will consider the need to install more buoys to measure wind speed, currents and wave height, and will publish the resulting data.

Surveys and research are a key part of adaptation work by the Norwegian transport authorities. In close cooperation with the National Rail Administration, the Public Roads Administration has conducted an R&D project called «Climate and transport», which proposed measures in four areas: new transport infrastructure, existing road and railway networks, emergency preparedness and development of a knowledge base for climate change adaptation. The project has provided substantial information on the impacts of climate change and on how the transport sectors can take account of climate and climate change considerations. Coordination, exchange of experience and cooperation with other agencies will enable the transport authorities to carry out more effective safety measures and develop better preparedness systems against extreme weather events. The National Rail Administration has developed a system of preparedness levels and early warning procedures for extreme weather events and flooding, and the Public Roads Administration is doing the same. The transport authorities cooperate closely with the Norwegian Water Resources and Energy Directorate, among other things on a national warning system for landslides and avalanches. However, further knowledge-building is still needed.

The Public Roads Administration, the National Rail Administration and the Water Resources and Energy Directorate have started an R&D project, «Natural hazards – infrastructure, flooding, landslides and avalanches», that is partly based on the «Climate and transport» project. The aim is to make infrastructure more resilient and improve coordination when natural hazard events occur. The project focuses on areas where closer cooperation between the various agencies is essential for improving preparedness, risk management and management of extreme events, particularly in relation to landslides, avalanches and flooding. The project includes risk and vulnerability assessments, stormwater management, mapping, early warning and safety measures in connection with landslides, avalanches and flooding, and quick clay. The project was launched in 2012 and will last for four years.

Avinor has made substantial efforts to assess the probable impacts of climate change on airports in Norway. A major project is being started in 2013 to provide a more systematic overview of vulnerability to climate change.

The new knowledge that is being generated is used to develop specific measures. The transport authorities ensure that the new knowledge and lessons learned from ongoing projects are systematised and disseminated to all administrative levels in the transport sector. Thus the Norwegian Public Roads Administration has made changes in its rules and manuals as a result of the «Climate and transport» project. Other developments include stricter requirements for including climate considerations in road and railway planning and in risk and vulnerability assessments, stricter requirements for the choice of design values for flooding and runoff, measures to increase drainage capacity, and new guidelines for landslide and avalanche risk management and safety measures. In addition to amendments to the legislation, proposals are being discussed for adaptation measures in connection with management of the road network. In 2013 the Norwegian Coastal Administration is to revise its guidelines for breakwaters to include climate change considerations.

It is especially important to ensure that there are adequate rules and sufficient expertise and capacity at municipal level to ensure that the consequences of climate change are taken properly into account in connection with local road building. The changes in the rules set out in the manuals of the Norwegian Public Roads Administration are applicable to all administrative levels. Higher precipitation and more intense precipitation events often have even more severe impacts on municipal roads than elsewhere. This is because there are often larger areas of impermeable surfaces, they are affected by streams with a short response time, and in some places the infrastructure is poorly maintained, making it difficult to drain away stormwater effectively.

The road and railway maintenance backlog is increasing the vulnerability of this infrastructure to climate change, and reducing the backlog will be an essential step in adaptation.

Buildings

The building sector is large, complex and fragmented. Buildings are vital to everyone's lives, and the sector includes the construction industry, a major industry with a strong influence on other sectors. The Government's overall goal is for buildings in Norway to be well designed, safe, energy efficient and healthy.

The impacts of climate change in Norway will have major implications for the requirements that will have to be set for siting buildings and for building technology to take account of the higher risk of landslides, avalanches and flooding, larger volumes of stormwater and rising sea levels.

The building sector is the responsibility of the Ministry of Local Government and Regional Development, which establishes the overall framework for legislation, budget funding, research, organisation and information. The Norwegian Building Authority plays a central role in administering and developing the technical building requirements, ensuring that up-to-date knowledge is available and providing guidelines and information. The building sector is made up of many different actors with important roles in building policy, including the construction industry, owners of public and private buildings, county governors, counties, municipalities and a number of government agencies.

The sector has given high priority to improving knowledge about the impacts of climate change on buildings. Knowledge-building is an essential part of the first phase of adaptation. SINTEF Building and Infrastructure was commissioned by the Norwegian Building Authority to conduct a risk and vulnerability assessment for a number of climate parameters. The assessment provides an overview by county, and is intended to provide a better foundation for deciding on appropriate measures. On the basis of the assessment, SINTEF Building and Infrastructure has proposed a number of measures for reducing the vulnerability of the construction industry to climate change and increasing its adaptive capacity. With regard to the risk of decay in the event of a more humid climate, R&D is being conducted under the auspices of the Norwegian Institute of Wood Technology and the Norwegian Forest and Landscape Institute to find ways of improving protection of wooden structures against moisture. These involve appropriate structural design, development of new, environmentally friendly impregnation agents, preservatives that can be brushed or spread on the wood surface, use of the correct type and quality of wood, and new protection methods such as the use of electrodes. Many of the projects have been supported by the innovation programme for wooden materials under Innovation Norway.

The Planning and Building Act and the technical regulations under the Act are key instruments for the planning and building authorities in preventing the harmful effects of climate change. Clear, up-to-date and effective legislation provides guidelines for adaptation efforts in the construction industry. This is emphasised in a white paper from the Ministry of Local Government and Regional Development on building policy (*Gode bygg for eit betre samfunn*, Meld. St. 28 (2011–2012), in Norwegian only). The white paper highlights the importance of focusing on climate change and the need for adaptation to future climate change when building today.

According to the white paper, the need to amend legislation in the light of new knowledge about the impacts of climate change will be considered. This applies particularly to amendments to the regulations on technical requirements for buildings. The white paper also states that the Government will promote competence-building in the municipalities and the development of a better factual basis on climate change adaptation and climate risks. The introduction of new tools and methods to make it easier for municipalities to take climate change into account will be considered. For example, tools that ensure good moisture management will be considered to ensure that this is taken seriously throughout building processes.

The white paper also states that the Government will consider the development of local climate indexes and climate zones to clarify which requirements should apply to buildings and in municipal land-use planning. Geographically differentiated climate data and indexes have not previously been available, making it difficult to assess the suitability of particular technical solutions for a particular type of climate. Climate indexes can be an important tool for developing adaptation measures.

The power supply system

The *power supply system* is a critical infrastructure, since the normal functioning of society depends on a secure and stable power supply. Major disruption of the power supply would have significant economic consequences and pose a threat to life and health. Some of the factors that already constitute risks to the power supply may become more pronounced in future as the climate changes. This could increase the need for maintenance and the risk of damage and power cuts. On the other hand, more precipitation may increase the potential for electricity production.

Over 300 public and private enterprises, organised in different ways, are concerned with the generation, transmission and sale of electricity. The Ministry of Petroleum and Energy is responsible for energy supplies, and the Norwegian Water Resources and Energy Directorate administers the electricity resources and the power supply system on behalf of the ministry. The directorate determines the framework for the production, sale, transmission and use of energy, and is responsible for the power supply system, quality of supply, security and emergency preparedness in the sector. The directorate is also responsible for licensing procedures for hydropower developments in rivers systems, electricity production and power lines. The Directorate for Civil Protection and Emergency Planning has been given the responsibility for electricity safety by the Ministry of Justice and Public Security, and is also responsible for monitoring emergency planning by other authorities. The two directorates have a wide range of tools for ensuring security of electricity supply in Norway that also take into account the higher level of risk associated with future climate change.

The Water Resources and Energy Directorate is responsible for assessing the impacts of climate change within its sphere of responsibility and for ensuring that the necessary adaptation measures are taken. There is a need for continual adaptation to avoid incidents that could entail a risk of loss of human life or material damage or disrupt critical infrastructure and societal functions. Adaptation efforts should focus on adequate security of supply and emergency preparedness in the power supply sector and seek to prevent damage from natural hazard events such as flooding, landslides and avalanches.

The Water Resources and Energy Directorate is responsible for ensuring that dams and other installations do not represent a risk of damage or injury to people, the environment or property (third parties). The main elements of this work are control and approval of technical plans and of periodic safety inspections, control of the construction of installations and inspection and auditing of existing facilities and their owners.

The licensing requirements for actors in this sector are an important tool for the Norwegian Water Resources and Energy Directorate, and are mentioned as a particular strength in connection with adaptation work in the power sector in the report *Adapting to a changing climate* (NOU 2010: 10). The licensing system is based on the provisions of the Energy Act, the Water Resources Act, the Watercourse Regulation Act and the Industrial Licensing Act. An enterprise will only be granted a licence in the power supply sector if it meets the safety requirements for the construction, commissioning and operation of the installation or facilities in question. For example, the Energy Act grants wide powers to attach conditions to licences as long as there is an objective link between the conditions and the activity subject to licensing. In the case of hydropower installations, licences may include requirements for measures to reduce the risk of damage from flooding, erosion, sea level rise and so on. The guidelines for flood calculations contain recommendations for assessing the impacts of climate change.[7] The Water Resources and Energy Directorate gives priority to ensuring that the guidelines are

Box 8.5 The Norwegian Water Resources and Energy Directorate and climate change

In order to maintain security of supply, the electricity sector needs to adapt to climate change. The Water Resources and Energy Directorate is following this up through licensing procedures and a greater emphasis on inspection and enforcement. In 2009 and 2012 the directorate conducted surveys of the level of awareness of climate change and adaptation activities in the sector. It has also produced a report on climate-related challenges in the sector up to 2100 (*Klimautfordringer i kraftsektoren frem mot 2100*, in Norwegian only).

[7] Retningslinjer for flomberegninger (Guidelines for flood assessment, in Norwegian), NVE 2011.

followed in the plans for new dams and the control of existing ones.

The regulations relating to dam safety cover all dams that represent a risk of damage to third parties and require safety reviews of all dams at intervals of 15–20 years. One of the purposes is to identify changes in the loads to which the dam is subject, such as changes in flood volumes, wind, waves and ice loads, both under existing conditions and in the context of future climate change. In 2012 the Water Resources and Energy Directorate conducted a survey of the hydropower sector's awareness of climate change.

Monitoring and inspection of dams under normal operating conditions and in emergencies should be adapted to the probable effects of climate change, such as more frequent flooding in winter, and plans for the necessary maintenance and upgrading should be adapted to changes in runoff patterns. The dam safety regulations include requirements for preparedness and emergency planning by dam owners for situations that could represent a risk of damage. Emergency plans must be based on risk and vulnerability assessments, be kept up to date and revised at least every third year, and reflect any increase in risk as a result of climate change.

The Water Resources and Energy Directorate's licensing procedures are required to take security of supply into account. Improving security of supply is often given as a reason for applications for licences for reinvestment and upgrading. Much of the power grid in Norway was constructed during the 1960s, 70s and 80s, and given

Box 8.6 Excerpt from the 2010 climate change adaptation strategy of the Norwegian Water Resources and Energy Directorate

The changing climate makes it necessary to adapt continuously in order to prevent adverse environmental impacts that may entail a threat to human life and damage critical infrastructure and societal functions. Adaptation includes both physical measures and steps to acquire sufficient knowledge about climate change to make effective decisions. The speed of climate change and its impacts will vary between the different parts of the country. Moreover, the Water Resources and Energy Directorate makes decisions with very different time horizons. The climate change adaptation strategy has to reflect these factors in order to enable the directorate to do the right things at the right times. This means that the strategy must be dynamic and be continuously updated as new knowledge becomes available.

A dynamic climate change strategy should be based on the following principles:

- Measures and decisions with a short lifetime should be assessed on the basis of today's climate.
- Measures and decisions with a long lifetime should be assessed to determine whether they should be designed to withstand the climate change projected to occur within their lifetime or on the basis of today's climate but in such a way that necessary adaptations can be retrofitted.
- Measures and decisions should be resilient to climate change, in other words they should function as intended even if actual climate change is rather different from projected climate change.
- Adaptation measures that also contribute to results in other areas (such as nature conservation, flood protection, or security of supply) represent a win-win situation and should be given high priority.
- Adaptation measures that are cost-effective and will function equally well or better if the climate changes as projected should be given high priority.
- Costly adaptation measures whose effects will be reduced by projected climate change should have low priority.

The Water Resources and Energy Directorate must pay special attention to areas of responsibility where climate change is expected to have particularly serious impacts. This may involve amending regulations or clarifying requirements, such as requirements for maintenance, modernisation, emergency preparedness in the power supply sector and dam safety. It may also include support for flood protection and protection against landslides and avalanches, and steps to ensure sound land use planning that reduces risks.

Source: Norwegian Water Resources and Energy Directorate

the normal lifetime of such installations, large-scale reinvestment and upgrading will be needed in the years ahead. Adaptation will be a key element of this work, and power lines must be designed to withstand the projected loads in different types of extreme weather. Safe operation and maintenance under all weather conditions is another vital consideration. Routeing of power lines is important, since appropriate choices can reduce climate-related risks and facilitate control and maintenance. The directorate expects all transmission system operators to place sufficient weight on risk and vulnerability assessments in their planning.

More knowledge is needed about how much the climate is expected to change before appropriate requirements can be set during licensing procedures and in other contexts. The Water Resources and Energy Directorate already imposes strict requirements for impact assessments, but will focus more on climate change in connection with licensing procedures, impact assessments and power system studies. R&D on the challenges associated with climate change is being conducted under the auspices of the directorate, including studies of the hydrological impacts, climate-related challenges in the power sector, changes in the frequency of lightning, the significance of changes in sea level and storm surges, the frequency of storms and the effects of hurricane-force winds, icing on power lines, ice loads on dams and the effects of slide-generated waves on dams.

The legislation administered by the Directorate for Civil Protection and Emergency Planning include safety requirements for electricity infrastructure, which in practice mean that installations must be designed to withstand future climatic conditions.

8.6 The business sector

Climate change will have impacts on the Norwegian business sector. Because the sector is so varied, there will also be wide variations in how climate change affects earning power and profitability. The sector also has a vital role to play in Norway's transition to a low-emission economy and through the introduction of production methods and equipment that are adapted to a changed climate. In addition, the sector supplies products and services that will play a large part in determining Norwegian society's resilience to climate change.

The Ministry of Trade and Industry is responsible for drawing up a future-oriented business policy for all policy areas of importance for value creation. A knowledge-based business sector is necessary to maximise value creation, and this needs to be further developed. The allocations to Innovation Norway, SIVA (the Industrial Development Corporation of Norway) and the Research Council of Norway are among the largest administered by the ministry. One of the areas that the ministry emphasises in its dialogue with Innovation Norway is environment and energy, and Innovation Norway is extensively involved in environmentally relevant networking activities.

Climate change could alter much of the basic framework for parts of the Norwegian business sector. For the primary industries and other industries that are closely linked to the natural resource base, it could necessitate considerable restructuring. Restructuring will also be necessary if climate change imposes new requirements with respect to siting or development. The Norwegian Public Roads Administration has already changed the manuals setting out conditions for road construction, and contractors will have to follow the new rules. The technical regulations for buildings may have to be amended to address the higher risk of water damage and decay, imposing fresh requirements on the industry. Climate change could also make restructuring necessary for local businesses. This applies particularly to outdoor industries, which could be forced to replace their existing activities with new ones. This requires considerable expertise and innovative capacity, and may be a challenging task in small communities with a poorly diversified economy.

Climate change intensifies the need for knowledge-based business development, and restructuring that takes climate change into account will require research and innovation. Since the business sector has an important role to play in adaptation, it is important to promote its involvement in public-sector research and innovation efforts. One way of encouraging businesses to engage in innovation and knowledge development is through intellectual property rights such as patents. Climate-resilient business development will also require new types of knowledge. For example, if new, climate-resilient activities are being planned as part of a local restructuring process, information tailored to local needs about how climate change will affect that particular geographical area will be valuable. If sectors that supply for example infrastructure services are to do so sus-

tainably, they will need reliable data on factors such as precipitation patterns and sea level rise.

While the authorities have an important responsibility for providing information tailored to different needs and a suitable overall framework, companies themselves must also take responsibility for climate-resilient development of their own activities. A good dialogue between businesses and the authorities is essential. In Norway dialogue between these two parties is already well established, and it is important to ensure that it also encompasses climate change. It is also important to adopt a precautionary approach to new business opportunities created by climate change, especially in North Norway.

On 16 December 2011, Norway adopted the Act relating to supply chain preparedness, which emphasises the need for cooperation between the public authorities and the business sector in the field of civil protection and emergency planning. This legislation also applies to problems that may arise as a result of climate change. Issues related to climate change have therefore been raised in the ongoing emergency planning cooperation between the public authorities and the business sector. There are several emergency response organisations under the auspices of the Ministry of Trade and Industry, and the Council for Emergency Preparedness in the Construction Sector in particular has devoted considerable attention to this topic.

Cooperation between the authorities and the business sector is also important for community and local business development. Regional planning is an example of current cooperation in this context. Adaptation needs to be made an integral part of the relevant dialogue between the local and regional authorities and the business sector.

The business sector itself also has an independent responsibility to integrate climate change adaptation into its activities. For example decisions are constantly being made on long-term investments, such as the siting and design of commercial buildings. The business sector also has a wider social mission that requires climate change to be taken into account. This includes a wide range of businesses, for example the construction industry, contractors and consultants supplying services for general municipal planning. Although it is the authorities that determine the framework conditions, businesses must also take responsibility for sustainability through their own activities and operations. This means that businesses must be able meet the adaptation requirements imposed by the authorities on the one hand, and on the other take an active approach by ensuring that their investments are climate-resilient. Thus the impacts of climate change on society's infrastructure in the broadest sense will also have consequences for the business sector. The individual company must consider how disruption, for example of the transport system, will affect its activities and as far as possible take the necessary measures to limit the consequences.

The report *Adapting to a changing climate* (NOU 2010: 10) points out how important it is for industries themselves to ensure competence-building and training to meet changes in requirements in different areas. Knowledge-building will also be necessary for some branches, for example consultancy firms that often advise municipalities on planning and will need expertise if they are to assist municipalities to include climate change adaptation in planning processes.

The travel and tourism industry is one of those that will be strongly affected by climate change. Considerable restructuring will be necessary to take advantage of changed conditions and avoid negative effects of climate change as far as possible. Successful adaptation in this sector will depend on better assessments of how climate change will affect global travel patterns, since this is a global industry and the Norwegian tourism market may be affected by climate change in other parts of the world. In spite of the predictions of higher precipitation, shorter duration of snow cover, melting of glaciers and more rapid spread of forest and woodland in mountainous areas and cultural landscapes, Norway's geographical location is still likely to make it an exotic and attractive tourist destination. Furthermore, drier summers in southern Norway may make this region more attractive to summer tourists.

Climate change may also lead to considerable changes in national travel patterns, particularly in winter, when the direction of traffic flows will be strongly influenced by access to stable snow conditions. Such changes will have considerable effects on tourism. In order for the sector to be able to plan for sustainable adaptation, capacity needs assessments will have to be made for all parts of the tourist industry.

Box 8.7 Sustainable Destination Norway 2025

Sustainable Destination Norway was one of three research projects funded by the Ministry of Trade and Industry and the Research Council of Norway in the period 2008–11 with the aim of strengthening the knowledge base for policy development for a more sustainable tourism industry in Norway. Vestlandsforsking was the main research institute involved. Sustainable Destination Norway developed a computer model to run scenarios based on research in three areas:

- dialogue processes to develop sustainable tourism,
- the links between climate policy, climate change and tourism,
- the links between climate-friendly food and sustainable tourism.

Modelling showed that, all in all, an ambitious climate policy can be combined with rising profitability in the tourism industry and an increase in the number of foreign tourists visiting Norway. An important point made in the final report was that under all the different global socioeconomic development and climate policy scenarios that were used, both profitability and the number of international tourist arrivals will double. However, the report pointed out that stronger policy measures will be needed to reach the goal of a more sustainable tourism industry.

9 The Arctic

The temperature in the Arctic is rising faster than in any other part of the world. Moreover, the physical environment associated with snow and ice is particularly sensitive to a warmer climate. Climate change is therefore the most serious threat facing Arctic species and ecosystems. For the same reasons, communities that depend on the living resources of the Arctic are also vulnerable to climate change. Climate change adaptation in the Arctic will therefore entail special challenges. As the sea ice melts, the Arctic is becoming more accessible for new activities such as oil and gas extraction, mining, shipping, fisheries and tourism. This can open up new opportunities, but may also exacerbate negative impacts on the environment and on traditional ways of using the living resources of the Arctic. Climate change may also intensify the negative impacts of other pressures such as ocean acidification and pollutants on the Arctic environment. In the Government's view, management of the natural environment in the Arctic must therefore be based on an ecosystem approach that will make it possible to adapt management to rapid changes in the climate, environmental conditions and human activity. An approach of this kind is intended both to facilitate value creation through sustainable use and to maintain the high environmental value of the Arctic environment and its biodiversity.

This chapter discusses climate change in the Arctic and the specific challenges that need to be addressed in Norway's most northerly waters and in Svalbard, where climate change is already altering environmental conditions and patterns of activity. The chapter also gives an account of Arctic cooperation on the climate and climate change, and the Government's efforts to strengthen the knowledge base for climate change adaptation in the Arctic. Issues relating to mainland Norway and to Norway's sea areas more generally are discussed in other chapters of the white paper.

9.1 Climate change in the Arctic

In recent decades, temperatures in the Arctic have been rising twice as fast as the global average. The annual mean temperature in the region is 2 °C higher than it was a hundred years ago, and data indicate that the summer temperatures are now higher than at any time during the past 2000 years.

The rising temperatures are causing rapid, far-reaching changes to the physical environment in the Arctic. The transition to an ice-free Arctic Ocean appears to be occurring much faster than the Intergovernmental Panel on Climate Change (IPCC) projected in its Fourth Assessment Report in 2007. The summer sea ice cover has been reduced by about a third in recent years compared with the average for the normal period 1979–2000. In September 2012, the extent of the sea ice reached the lowest level since measurements started, and was 48 % under the average for the period 1979–2000. The extent and duration of snow coverage have also decreased significantly. The estimated annual loss of mass from the Greenland ice sheet has quadrupled since 2000, and the loss of mass from other ice caps and glaciers in the Arctic is also increasing sharply.

The Svalbard archipelago has also experienced rapidly rising temperatures, combined with a rise in precipitation. Since the mid-1960s, the average temperature in Longyearbyen has risen by 0.9 °C per decade. The extent of the sea ice has been showing a clear downward trend both in the Barents Sea and in the Fram Strait between Svalbard and Greenland since satellite monitoring began in 1979. Svalbard's glaciers are also retreating rapidly and their mass balance is negative. In addition, the temperature of the permafrost is rising.

Because of polar amplification, it is expected that temperatures in the Arctic will continue to rise twice as fast as the global average. The estimated rate of temperature rise in Svalbard and the northern Barents Sea is far higher than for areas further south. There are also considerable smaller-scale variations. For Svalbard, the pro-

jected rise in mean air temperature ranges from about 3 °C in the southwestern part of the archipelago to 8 °C in the northeastern part towards the end of the present century. For the sea, the projected temperature rises are more moderate: sea temperature in the northern Barents Sea is projected to rise by 2–3 °C. It is very uncertain how fast the Arctic sea ice will retreat, but both modelling results and the rapid reduction in the area and volume of the ice indicate that the Arctic seas may be almost ice-free in summer by the middle of this century. Melting of the Greenland ice sheet and other ice caps and glaciers is expected to accelerate, but it is uncertain just how rapid the process will be. The thawing of permafrost and the reduction in snow coverage are also expected to continue, and ocean circulation and weather patterns may change considerably.

Future climate change in the Arctic will depend on processes such as melting of sea ice and land ice, and changes in ocean currents and atmospheric circulation, which govern the transport of heat from further south. Some of these processes involve positive feedback loops, which can cause changes to accelerate. Sea ice melt and the release of methane (a greenhouse gas) from melting permafrost are the best known of these feedback mechanisms. Other mechanisms, such as changes in cloud cover as the areas of open sea become larger, and cooling of the surface water as a result of faster melting of the Greenland ice sheet, may moderate the warming process. Many of these mechanisms are difficult to incorporate into climate models, which adds to the uncertainty of climate projections for this region. Climate change in the Arctic and the processes governing it also have major implications for climate change and sea level rise at global level, which adds to the uncertainty of projections of future global change.

9.2 Impacts and adaptation needs

Impacts on the Arctic environment

The rapid temperature rise in the Arctic is expected to intensify many of the same types of impacts that are expected to become apparent further south. Many species and habitats that are characteristic of the Arctic today are expected to have difficulties in adapting to climate change, both because of the rapid pace of change and because many species will be unable to move further north to find new areas of habitat with a suitable climate. Species and ecosystems associated with the sea ice are particularly vulnerable to climate change, and may disappear from larger and larger areas of the Arctic.

Rising temperatures will result in a northward shift in the distribution of species and habitats. The Arctic species and habitats found in the region now are expected to be gradually displaced by species and habitats that are currently found further south. The tundra areas north of the Arctic treeline are some of the terrestrial habitats that are expected to undergo the most dramatic changes.

Marine ecosystems will change as the sea temperature rises. Higher temperatures and the retreat of the sea ice will allow more southerly species to move into Arctic sea areas, and purely Arctic species will meet growing competition, greater predation pressure and a higher risk of disease and parasites. Coastal waters and continental shelf areas along the margins of the Arctic Ocean will be ice-free for longer and longer periods, which will be a serious threat to the drift ice ecosystem and the species it supports. Areas of suitable habitat for the polar bear, ringed seal, walrus, narwhal, little auk, ivory gull, polar cod and a number of other species that are part of the marginal ice zone ecosystem are expected to be greatly reduced. The distribution of commercially important fish species such as cod, haddock and capelin may change. Warmer water and a reduction in ice cover may result in larger quantities of phyto- and zooplankton, but there is no guarantee that fish and other animals will be able to make use of the greater availability of food.

On land, the Arctic treeline is expected to shift northwards and upwards, a trend that is already apparent today. In certain parts of the Arctic, the treeline is expected to move as much as 500 kilometres northwards in the course of this century. Within the same time frame, half of the current area of tundra in the Arctic may be replaced by forest and scrub, which would entail major changes in species diversity.

Since Arctic land areas border on the Arctic Ocean in the north, some Arctic species and ecosystems may disappear completely in the longer term, or become restricted to isolated Arctic islands north of the mainland. Animals and plants on isolated islands are particularly vulnerable because it is more difficult for them to shift northwards to stay in the same climate zone as the temperature rises. At present, the sea ice functions as a bridge that animals can follow between Arctic islands or between islands and the mainland. As the ice disappears, more or less continuous popu-

lations of species such as the Arctic fox, reindeer and polar bear may be split into much more isolated and therefore more vulnerable populations. This could make isolated Arctic archipelagos such as Svalbard even more important in future conservation strategies, but could also make conservation efforts more challenging.

Changes in snow cover will have impacts on soils, vegetation and the fauna. Some migratory species in the Arctic, such as geese, many benefit when the snow melts earlier in spring. On the other hand, if increasing amounts of winter rain result in more frequent formation of a hard ice crust, this may have serious impacts on animals such as reindeer that are dependent on digging through the snow to find food in winter. This phenomenon is already being observed more frequently in Svalbard and elsewhere in the Arctic.

If climate change is already putting pressure on species, for example through habitat loss or poorer food supplies, they will be less resilient to other pressures, both external pressures such as long-range pollutants, UV radiation and ocean acidification, and those caused by local activities, such as harvesting, local pollution, land development and disturbance. Climate change may also intensify other pressures, either directly or indirectly. The declining sea ice cover is making marine and coastal waters in the Arctic more accessible for fisheries, maritime transport, cruise ships and oil and gas activities. In certain areas, a reduction in ice cover may make it easier to start mining activities and extract minerals. The increase in activity levels may lead to more harvesting, infrastructure development, habitat loss and fragmentation, the spread of invasive alien species, disturbance of the fauna, and pollution and the risk of pollution. It is therefore essential to set limits for activities in the Arctic that will keep the risk level and cumulative environmental effects on species and ecosystems within reasonable bounds.

Ecosystem-based management

The speed of climate change in the Arctic highlights the need for an ecosystem-based approach to management of the Arctic environment. This will make it possible to adapt the management regime and environmental standards to rapid changes in the climate, environmental conditions and human activity. An approach of this kind is intended both to facilitate value creation through sustainable use and to maintain the high environmental value of the Arctic environment and its biodiversity.

In the Government's view, the integrated management plans for the Barents Sea–Lofoten area and the Norwegian Sea will be very important tools for overall adaptation of the framework for activities in Arctic seas to changes in the climate, environmental conditions and patterns of activity. The management plans are already contributing to an integrated, resilient management regime that incorporates climate change considerations. A range of measures to protect particularly valuable areas and reduce pressure on the environment and the risk of accidents and pollution have already been adopted within the framework of the management plans, in response to the observed and expected increase in the level of activity in our northern seas.

Human activity in northern sea areas is expected to increase in future, and it is uncertain what cumulative environmental effects we can expect on ecosystems as a result of activities in various sectors, climate change and ocean acidification. The pace of climate change and ocean acidification is higher than previously expected. This may result in more marked cumulative environmental effects in the years ahead, and means that it is important to introduce management measures that increase the resilience of ecosystems. Any pressure on an ecosystem must be assessed on the basis of the cumulative environmental effects on the ecosystem now or in the future, taking into account the structure and functioning of the ecosystem. This principle applies in the Arctic as well. Cumulative effects must be assessed for each ecosystem component, for species and habitats, and for the ecosystem as a whole. The principle that cumulative effects on the ecosystem must be assessed underlies the management plans for Norwegian sea areas, the Svalbard Environmental Protection Act and the Nature Diversity Act. The Marine Resources Act takes the cumulative environmental effects of utilisation of living marine resources into account, and requires the authorities to ensure that they are managed sustainably.

9.3 Adapting nature management in Svalbard to climate change

Climate change will pose considerable challenges for nature management in Svalbard: it will have major impacts on the species, ecosystems and landscapes Norway is seeking to protect, and may result in more traffic and pressure on the islands

from various types of activities. The distribution of species will change. Areas that have been important for ice-dependent species may lose their value as habitats, while other areas become more important. Thus, the distribution of species and ecosystems in space and time will be constantly changing, as will their vulnerability to local activity, and the authorities need mechanisms that make it possible to adapt the management regime to this situation.

The comprehensive protection regime and strict environmental rules set out in the Svalbard Environmental Protection Act and regulations under the Act are a good starting point, because intact ecosystems in themselves make nature more resilient to the impacts of climate change. It is therefore important to maintain the current protection regime. A management regime clearly cannot prevent loss of ice cover and rapidly rising temperatures from altering the physical conditions and species' habitats. But it can help to ensure that the changing climate and the possibility that species and habitats will become more vulnerable are taken into account in local activities.

Important measures have already been introduced in Svalbard in response to the decline in the extent of the sea ice, which has made some areas more accessible and exposed vulnerable species and habitats to more traffic and human activity. To reduce the risk of a shipwreck or grounding causing serious pollution or the loss of human life, ships sailing within the protected areas of Svalbard (which cover most of the territorial waters) are now prohibited from carrying heavy bunker oil, and cruise ships that call in the nature reserves in the eastern part of Svalbard may not carry more than 200 passengers. In addition, compulsory pilotage is being introduced, and charting of the waters around Svalbard is being improved. Climate change adaptation is one of the elements of the management plans that are being drawn up for the protected areas in Svalbard. The protected areas cover 65 % of the land area of the islands and 87 % of the territorial waters. Management plans for these areas will therefore be an important tool for adapting the management regime to a changing climate. Climate change is expected to make it easier for alien species to survive and spread in Svalbard. An action plan to prevent the introduction and spread of invasive alien species in Svalbard is being drawn up.

In the same way as in mainland Norway, it will be necessary to strengthen instruments to safeguard threatened species and habitats that may come under increasing pressure as a result of climate change. This applies especially to species that are heavily dependent on ice-covered areas of sea, such as the polar bear and Arctic seals, since their distribution may change considerably and become much more restricted. Another factor it may be necessary to consider is the increasing isolation and consequent vulnerability of some species and populations as the loss of sea ice weakens links between the Svalbard islands and between Svalbard and Arctic islands and mainland areas further east. These considerations must be incorporated into species and habitat management in Svalbard.

Most animal species in Svalbard are protected, but limited hunting and trapping is permitted. Game species include reindeer, Arctic fox, ptarmigan and certain seabird species. It may be necessary to adjust quotas and hunting seasons to take account of the vulnerability of these species to climate change.

Extensive research, monitoring and mapping of species and ecosystems in Svalbard is in progress, and results are reported through the environmental monitoring programme for Svalbard and Jan Mayen (MOSJ), which includes several indicators of impacts of climate change in Svalbard. The monitoring programme needs to be further developed so that changes can be identified at an early stage and the management regime can be adjusted as necessary. Knowledge of population trends for vulnerable species such as the polar bear is currently inadequate. To make it possible to implemented targeted measures, it is also important to identify areas that will become either more vulnerable or more important as habitats for vulnerable species as the climate changes.

9.4 Settlements and human activity in Svalbard: impacts of climate change and adaptation needs

In Svalbard, as in mainland Norway, climate change may increase the risk of landslides, avalanches and flooding, and result in more frequent and more severe extreme weather events, sea level rise and storm surges. Infrastructure such as roads, buildings and port facilities will be vulnerable to such climate-related events. Only about 2500 people are resident in Svalbard, and infrastructure is limited to a few areas, including the mines, that are not linked together by roads or power lines. Their isolation may make the settlements more vulnerable to climate-related events that disrupt critical infrastructure. Heavy rainfall

in winter has already begun to occur more frequently in Svalbard, and in winter 2012 this resulted in a slush flow in Longyearbyen that damaged the road system. The active layer (the soil layer above the permafrost that thaws each summer) is becoming deeper and deeper, which makes the ground unstable and is a threat to buildings and other infrastructure. Coastal erosion may also become a growing problem for buildings and cultural heritage sites near the shoreline in Svalbard, since wave action will increase as sea ice is lost. See box 3.8 in Chapter 3.6 for more about climate change and Svalbard's cultural heritage. The Governor of Svalbard is revising the risk and vulnerability analysis for Svalbard, which dates from 2009. The work is being carried out in close cooperation with Longyearbyen Local Administration and other members of the emergency planning council. Possible social consequences of climate change are an important element of this analysis, which is expected to be completed in spring 2013. Climate change considerations must also be incorporated into land-use and general planning processes in Svalbard. This work is in progress. During the most recent revision of the land-use plan for Longyearbyen, adaptation to changed conditions, including landslides, avalanches and flooding, was one of the topics that was highlighted. The guidelines on land-use planning under the Svalbard Environmental Protection Act are now to be revised, starting early in 2013, to include a detailed description of how climate change considerations are to be taken into account for the different land-use planning areas in Svalbard. Input on how this should be done should be obtained in close dialogue with relevant actors. Adaptation of land-use management in Svalbard to climate change will require enhanced expertise and knowledge. An important task for the Governor of Svalbard is to provide guidance for Longyearbyen Local Administration and other bodies responsible for planning in Svalbard. Staffing for planning and mapping functions at the Governor's office has been strengthened in recent years.

Much of the infrastructure in Longyearbyen – roads, bridges, buildings – was constructed in the 1970s. Thawing of the permafrost makes the ground unstable and is a threat to buildings and other structures, and this combined with variable maintenance standards, an increase in the population and a generally higher activity level resulting in more wear and tear, means that Longyearbyen now has a maintenance backlog for important and critical infrastructure such as roads, electricity and heating infrastructure, and buildings. Climate-related events may put even more pressure on the already vulnerable critical infrastructure in the Arctic, creating a need for upgrading and adaptation.

Research and the travel and tourism industry are important sectors in Svalbard, and will be affected by climate change. Even today, the increasing length of periods without sea ice in summer is making areas more accessible to cruise ships. At the same time, an earlier spring thaw and a reduction in ice cover on the fjords has resulted in a shorter season for snowmobile-based tourism, and restricted the areas available for such activities. These trends are expected to continue. There will be less opportunity for visitors to observe ice-dependent species such as walruses, ringed seals and polar bears, and this may make some tourism products less attractive. On the other hand, new species that move into the area, such as whale species that are commonly seen further south today, may partly compensate for this. Svalbard also has other important qualities such as its wild landscapes and unspoiled nature, which are likely to make it an attractive destination even with a warmer climate. Thus the travel and tourism industry will have to adapt its activities to a situation in which many species are under stress as a result of climate change, which means that visitors will have to show special consideration, and certain areas will need to be shielded from disturbance and traffic to maintain their value as reference areas for climate research. The industry may also have to comply with new and stricter environmental standards.

Research in Svalbard is generating important knowledge that will be valuable for projections of future changes in the climate, ice cover and environmental conditions. This is key information for planning activities and climate change adaptation both within the region and in a wider context. Focusing on climate research in the Arctic, including Svalbard, is thus an essential part of climate change adaptation. However, climate change also affects research activities themselves, in a number of ways. Much of the research being carried out in Svalbard is climate related, and the opportunity to study climate change in the Arctic is one of the drivers behind the growing interest in research and teaching activities in the archipelago. The great socio-economic value attached to this research is influencing the willingness to invest in research infrastructure and carry out projects and field work in Svalbard. However, in the long term the retreat of the sea ice may con-

siderably restrict opportunities for research on processes, ecosystems and species associated with the sea ice.

Svalbard and the protected areas of the archipelago are not much affected by local activity. This is an important factor, because it makes it possible to distinguish between the impacts of climate change and those of other pressures. The large nature reserves in eastern Svalbard are particularly valuable as undisturbed reference areas for research on the impacts of climate change on Arctic species and ecosystems, and it is important to manage these areas in a way that will maintain their intended function as reference areas. Research field work must, like tourism and fisheries activities, be adapted to an environment where many species are under stress as a result of climate change, and special caution and protection are needed.

The warmer climate and loss of sea ice are also resulting in changes in activity patterns in the waters around Svalbard. Fisheries activity has already increased. Cruise traffic has also grown considerably in recent decades, and activities have expanded to larger and larger parts of the archipelago, partly because the extent of the sea ice has declined. A continued increase in the volume of shipping, both cruise ships and fishing vessels, around Svalbard and in the northern part of the Barents Sea is to be expected. Such changes in activity patterns may make it necessary to upgrade fisheries inspection, maritime safety, oil spill preparedness and response, and search and rescue capacity in these waters. The Governor of Svalbard, the Norwegian Coastal Administration and the Norwegian Coast Guard may all need additional resources and capacity as a result.

Most of the Arctic has already been divided into search and rescue regions (SAR regions), but in certain areas the division of responsibility is unclear or inappropriate. Norway, Denmark (Greenland) and Russia have therefore agreed on a more suitable delimitation of our SAR regions. Norway's SAR region has been extended, so that it now includes the area north of Svalbard and to the North Pole, and its border with the Russian SAR region has been moved slightly further east. This gives a natural division of responsibility between the various countries, and reflects their actual search and rescue capacity. In response to the increase in activity and the wider geographical area of responsibility, it has been decided that the Governor of Svalbard's helicopter service is to be expanded from one large helicopter and one medium-sized helicopter to two large helicopters. In addition, a new search and rescue vessel of a suitable size for the new helicopters will be available from 2014. This will strengthen search and rescue capacity in Svalbard and nearby sea areas.

Since 2010, the Norwegian Space Centre has been running a project to test satellite technology to monitor maritime traffic in northern waters. Moreover, in 2009 the International Maritime Organization (IMO) introduced obligatory long-range identification and tracking of cargo and passenger ships at sea (LRIT), with global coverage. This means that Norway will from now on have access to better information on maritime activity in Arctic waters, which will also be valuable for search and rescue operations. From 1 July 2012, the Pilotage Act and associated regulations were made applicable to Svalbard. This means that the rules relating to the state pilotage service, compulsory pilotage and pilot exemption certificates also apply in the waters around Svalbard. Compulsory pilotage is being introduced gradually in the period 2012 to 2015. It has applied to coal vessels to and from the Svea mine since 2012, and from 2013 includes large passenger vessels (length 150 metres or more). From 2015, the rules for the waters around Svalbard will be the same as for mainland Norway, meaning that vessels of a length of 70 metres or more and passenger vessels of a length of 24 metres or more must use a pilot when sailing inside the baselines. Smaller size limits apply to vessels carrying dangerous cargo.

9.5 Climate change adaptation and Arctic cooperation

The Arctic states, particularly the five states that border on the Arctic Ocean, share important challenges and interests when it comes to addressing climate change and the higher level of human activity in the Arctic. This applies not least to environmental problems and the framework for activities in areas where use of natural resources and maritime transport will become possible as the melting ice makes them more accessible.

There is effective, binding international cooperation in the Arctic, which promotes environmental protection and sound resource management. Even though parts of the Arctic Ocean are covered by ice, the Law of the Sea applies fully in this region, as it does in other sea areas around the world. The international legal framework for all activity in the Arctic Ocean is set out in the Con-

vention on the Law of the Sea, which clarifies questions relating to jurisdiction in the area, as well as rights and duties. Under the Law of the Sea the coastal states bordering the Arctic Ocean have special duties and rights in the area. The melting ice and expected increase in activity in the Arctic will make cooperation on the implementation of existing instruments and the development of supplementary rules in various areas essential. New regulatory measures are being developed to meet growing needs, within the framework of international law.

Although various actors may have differing, legitimate interests in the north, the Arctic is currently a peaceful region in which states display a willingness to cooperate and to resolve contentious issues in accordance with the principles of international law.

The Arctic Council is the most important arena for dealing with common challenges in the Arctic. It is the only political circumpolar cooperation forum at government level, and plays a leading role in generating and communicating knowledge about climate change in the Arctic. Environmental issues are a central part of its work, particularly assessments of environmental status, climate change, sustainable development and environmental protection as activity increases.

The Arctic Council has published a number of reports that synthesise and assess new knowledge on climate change in the Arctic. In 2011, reports presenting the results of the Snow, Water, Ice and Permafrost in the Arctic (SWIPA) assessment were published, bringing together the latest knowledge about the changing state of the cryosphere. The Circumpolar Biodiversity Monitoring Program (CBMP) is building up a coordinated monitoring system with a strong focus on the impacts of climate change. The Arctic Biodiversity Assessment, a major review of the status and trends of Arctic biodiversity and projections for the future, will shortly be published. The impacts of climate change are one of the key topics in this review as well. The project Vulnerability and Adaptation to Climate Change in the Arctic (VACCA), also under the Arctic Council, has conducted and published an initial scoping study.

Two recently started projects are intended to improve understanding of climate change in the Arctic and how climate change together with other drivers and pressures will change the natural environment and human society in the future.

Adaptation Actions for a Changing Arctic (AACA) is a Norwegian initiative that is intended to enable more informed and timely adaptation in a rapidly changing Arctic. It will develop a range of Arctic scenarios for the period up to 2050 as a basis for adaptation strategies and planning. It consists of three elements: identifying relevant information from existing reports and projects; identifying other relevant work on adaptation; and assessing models and scenarios that can improve projections of climate change and other factors of change in the Arctic. The work will be concluded in 2017.

The Arctic Resilience Report is a flagship project for the Swedish chairmanship of the Arctic Council. It is focusing on the risk of reaching tipping points beyond which there may be sudden shifts in Arctic ecosystems and communities, and on resilience to such shifts. Norway is represented on the steering committee and is taking part at expert level. The project is to be concluded in 2015.

Ecosystem-based management of Arctic seas is a priority cooperation topic for the Arctic Council, and is also an important approach in climate change adaptation. The Ecosystem Approach Expert Group is co-chaired by Norway. So far, it has focused on discussing concepts and terminology for ecosystem-based management, and on mapping different marine ecosystems in the Arctic. The expert group will recommend guidelines for ecosystem-based management to the ministerial meeting in 2013. The Arctic Council is also surveying areas of particular ecological and cultural value in the Arctic. The results will be used as a basis for assessing whether any of these areas will need special protection when the volume of shipping in the Arctic rises. The application of ecosystem-based management is also one of the basic principles that is to be followed in developing a revised Arctic Council Arctic Marine Strategic Plan, which is scheduled to be ready for the 2015 ministerial meeting.

Specific cooperation agreements are also being negotiated under the Arctic Council to address the challenges posed by the increase in traffic and activity in Arctic waters. The Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic, which was signed during the ministerial meeting in Nuuk in 2011, was the first legally binding agreement to be negotiated under the auspices of the Arctic Council. During the Nuuk ministerial, the foreign ministers also decided to establish a task force co-chaired by Norway, the US and Russia to develop an international instrument on Arctic marine oil pollution preparedness and response. The purpose of the initiative is to simplify procedures for

international assistance in the event of acute pollution in the Arctic. Negotiations on the instrument have been finalised, and will according to plan be signed at the foreign minister meeting of the Arctic Council in spring 2013. The agreement should make it easier for Norway to draw on relevant emergency resources in the event of serious oil spills in our waters.

The IMO is working on the development of a Polar Code of rules for ships operating in polar waters. This will set out specific requirements for vessels and crews operating in these waters, including ship design, equipment, operations, environmental protection and damage limitation. Norway considers it important to ensure that ship design and equipment are suitable for operations in polar waters and that environmental considerations are taken properly into account.

Climate change in the Arctic and the High North is also on the agenda of the Barents cooperation and Norway's bilateral cooperation with Russia. Cooperation on ecosystem-based management and joint environmental monitoring arrangements are important topics in environmental cooperation between Norway and Russia. As part of the environmental cooperation in the Barents region, a climate change action plan is being drawn up, in which adaptation will be an important element. This work is being chaired by Norway, and the plan is scheduled to be adopted in the course of 2013.

The Government will seek to ensure that cooperation in the Arctic Council and other international cooperation in the High North results in a joint knowledge base for climate change adaptation and ecosystem-based management in the Arctic.

9.6 Knowledge and competence building

The rapid changes in the climate and environmental conditions in the Arctic make great demands on people's knowledge and understanding of climate change and its impacts. Such knowledge is an essential basis for management and planning in the Arctic, a region where activity levels are rising rapidly. In addition, knowledge about climate change in the region is important because changes in the climate system in the Arctic have major implications for global climate change and for sea level rise.

Norwegian institutions have for many years been involved in research and monitoring relating to climate change in the Arctic and its impacts. For example, the Norwegian Polar Institute, the Norwegian Meteorological Institute and the Institute of Marine Research run research and national monitoring programmes that cover land, the sea ice, the atmosphere and the oceans. The Polar Institute's research activities are designed to improve the knowledge base in fields where the environmental authorities have direct management responsibilities in the polar regions. The main priorities are climate change, ocean acidification, hazardous substances and biodiversity. Climate research is coordinated by the Polar Institute's Centre for Ice, Climate and Ecosystems (ICE). The Centre's activities include studies of the physical processes that control the behaviour of the Arctic sea ice. Another priority is research on Arctic ecosystems, focusing on indigenous ice-associated species, which are some of the species that are most seriously threatened by future climate change. There is also extensive research on the Antarctic climate and the impacts that climate change in Antarctica may have on the rest of the world. The Polar Institute is also responsible for and runs the environmental monitoring programme MOSJ, which collects and processes data from the atmosphere, land and sea areas around Svalbard and Jan Mayen.

The Institute of Marine Research also runs extensive research and monitoring activities and provides advice relating to the impacts of climate change on the marine ecosystem. In the present context, research in the northern Barents Sea and the waters west and north of Svalbard on biodiversity, alien species, the northward shift in distribution of commercial and other species, changes in the plankton and benthic communities, changes in biological production (phyto- and zooplankton, fish, seals and whales) and changes in the resilience of the ecosystem to environmental pressures and stress is particularly relevant. Such comprehensive studies are made possible by the annual joint Norwegian/Russian ecosystem surveys, which look at the entire ecosystem «from physics to whales».

Climate and environmental research in the North has been considerably strengthened by the establishment of the Fram Centre (the High North Research Centre for Climate and the Environment), which opened in Tromsø in 2010. This is an umbrella organisation, under which 20 Norwegian institutions, including the Institute of Marine Research and the Norwegian Polar Institute, are cooperating to generate new knowledge.

At the Fram Centre, research is being carried out on climate change and how it affects all elements of Arctic ecosystems. One key research topic is how indigenous peoples and local communities can adapt as quickly and as effectively as possible to climate change in order to maintain their way of life and income base, and thus their local communities and indigenous culture.

The Fram Centre is also preparing to launch an observatory for the ecological impacts of climate change on the Arctic tundra, known as KOAT. The plan is for observations to be carried out in two areas – on the Varanger peninsula in the far northeast of mainland Norway (in the subarctic zone), and in Svalbard (in the arctic zone). The purpose is to build up knowledge of climate-related changes that are relevant to the management of these ecosystems.

Other research at the Fram Centre is looking into how climate change affects the spread of hazardous substances and studying the negative impacts of such pollutants on health and the environment.

Ocean acidification in Arctic waters is another important research topic at the Centre. The impacts on ecosystems are being studied to provide a basis for estimating the economic consequences as regards marine resources. One project, a scoping study called «The Economics of Ocean Acidification», is a first step towards a multidisciplinary approach, which will provide a more integrated understanding of ocean acidification and related adaptation needs.

Changes in the climate and marine environment will result in new patterns of use of the Arctic that require new knowledge and innovative technology. Researchers are looking at the future of the Arctic and at economic and political aspects of change. There are also shipping-related projects on topics such as traffic statistics, transport corridors, regulation of Arctic shipping and the detection, effects and clean-up of oil spills in ice-covered waters.

Climate change will open up opportunities for more commercial activity in the High North and the Arctic. This applies particularly to oil and gas activity and maritime transport, but mining operations may also be expanded as areas become more easily accessible and demand grows. The impacts of developments, disturbance, pollution and waste will depend on the scale of such activities, their geographical distribution and what environmental standards are imposed.

At national level, a number of initiatives have been taken to build up competence and knowledge with a view to promoting more commercial activity in the north. The Government intends to strengthen knowledge about climate change and the environmental impacts of increasing activity in the Arctic and the High North. Knowledge is important for the development of management strategies that can limit negative environmental impacts and ensure that new commercial activities are carried out within environmentally sound limits. This will be an essential element of an integrated approach to developments in the High North. An initiative has been taken to develop a framework for the environmental impacts of increasing activity in the Arctic and the High North as a new priority research area for the Fram Centre in the course of 2013.

The High North and the Arctic are an integral part of Norway's national climate-related monitoring programmes. Norway collects large amounts of data through field work in Svalbard and research cruises in the surrounding Arctic waters, in the Fram Strait and in the Barents Sea. Concentrations of about 30 different greenhouse gases and ozone-depleting substances are monitored from the Zeppelin Observatory in Ny-Ålesund in Svalbard. Ocean acidification is being measured at different times of year in Norwegian waters, among other things along a transect from Tromsø to Longyearbyen. The monitoring programmes make it possible to measure climate

Figure 9.1 Ice research – scientists with an ice core

Photo: Ole Magnus Rapp/Aftenposten/NTB scanpix

change in the Arctic and to predict future changes and impacts that may entail a need for adaptation.

A great deal of work is also being done in connection with the management plans for the Barents Sea–Lofoten area and the Norwegian Sea to collect and collate information that can provide a better basis for ecosystem-based management of Norway's northern sea areas. Much of the knowledge generated is also important for adaptation of the management regime to a changing climate and to the resulting increase in activity. The knowledge base for management of Svalbard's natural environment is being developed and tailored to the needs of the authorities. A key element of this work is obtaining and tailoring the knowledge needed as a basis for management plans for the large protected areas in Svalbard. Much of the work focuses on the impacts of climate change, and is providing the authorities with better knowledge of how climate change considerations can be incorporated into their work.

10 Economic and administrative consequences

Climate change is one of the greatest threats humanity is facing in the present century. Changes in temperature and precipitation patterns and sea level rise are examples of factors that will have increasing impacts on natural and human systems. These changes will become gradually more marked as the atmospheric concentration of greenhouse gases rises, and greenhouse gas emissions will have increasingly serious impacts. Climate change may have significant adverse impacts on nature and on human life and health. The impacts in countries that are more vulnerable than Norway may also influence international politics and trade. This white paper is based on the impacts climate change is expected to have in Norway. No assessment has been made of possible indirect impacts on Norway of the effects of climate change in other countries and regions.

Climate change may have serious adverse impacts on natural and human systems. Changes in precipitation patterns in recent decades have resulted in increasing damage to buildings and roads. In 2011, insurance companies paid out more than NOK 2 billion in compensation for damage caused by water entering buildings. However, the increase in damage costs partly reflects the increase in the value of buildings and contents with the rising incomes and greater prosperity in Norway.

Society's vulnerability is partly related to important infrastructure such as roads, water supply systems and buildings. Climate change will increase the need for maintenance and upgrading of key infrastructure in Norway. The climate is already changing, and inadequate maintenance of roads and water supply and sewerage systems means that parts of Norwegian society are not well adapted to today's climate.

The combined measures and policy instruments proposed in this white paper constitute an active, coordinated approach to making Norway more resilient to climate change. A key purpose of climate change adaptation is to avoid future costs, for example related to accidents, disruption of operations and other damage caused by climate change. Measures such as flood, landslide and avalanche protection, and upgrading of water supply, sewerage and drainage systems are costly. However, unless the sewerage and drainage systems that are being replaced in Norwegian municipalities today are designed for a changing climate, they may not have sufficient capacity to deal with future precipitation levels. This could reduce their lifetime and entail far greater costs for society. Preventing negative impacts of climate change through adaptation can reduce future costs. The cost-effectiveness of adaptation measures must be evaluated on a case-to-case basis.

For a more detailed review of the costs and impacts of climate change in Norway, the reader is referred to the report *Adapting to a changing climate* (NOU 2010: 10).

The municipal, county and central government authorities are responsible for taking into account climatic conditions, including climate change, in relevant areas of their activities. This is not a new responsibility, but the present white paper highlights the authorities' responsibility for taking climate change into account and describes its substance more specifically. The measures proposed here, such as the development of a national centre for climate services, will facilitate adaptation in municipal planning processes.

It is presumed that in many cases, the reduction in future damage costs will compensate for the additional costs involved in incorporating climate change considerations into planning processes. The development of climate services and improvement of the knowledge base, expertise, map data and other practical tools for municipal adaptation work will make it possible for the municipalities and others to fulfil their responsibilities without substantial economic and administrative consequences.

The Ministry of the Environment

r e c o m m e n d s :

that the Recommendation from the Ministry of the Environment concerning climate change adaptation in Norway dated 7 May 2013 should be submitted to the Storting.

Published by:
Norwegian Ministry of Climate and Environment

Internet address:
www.government.no

Cover image: Oslo 20. juli 2012
Photographer: Trond J. Strøm

Printed by:
DSS – 08/2015