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ESPON Climate:
Climate Change and Territorial Effects on Regions and Local Economies

Applied Research Project 2013/1/4

Final Report

Annex 5

Case Study Bergen

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1 Introduction

Bergen city is situated at the West coast of Norway, and is the capital of Hordaland County. It is a city in close proximity to the sea and the mountains, and the Bergen region is characterised by fjords, mountains and islands, cf. figure 1.1.

Figure 1.1 *The Bergen region – geographical characteristics*

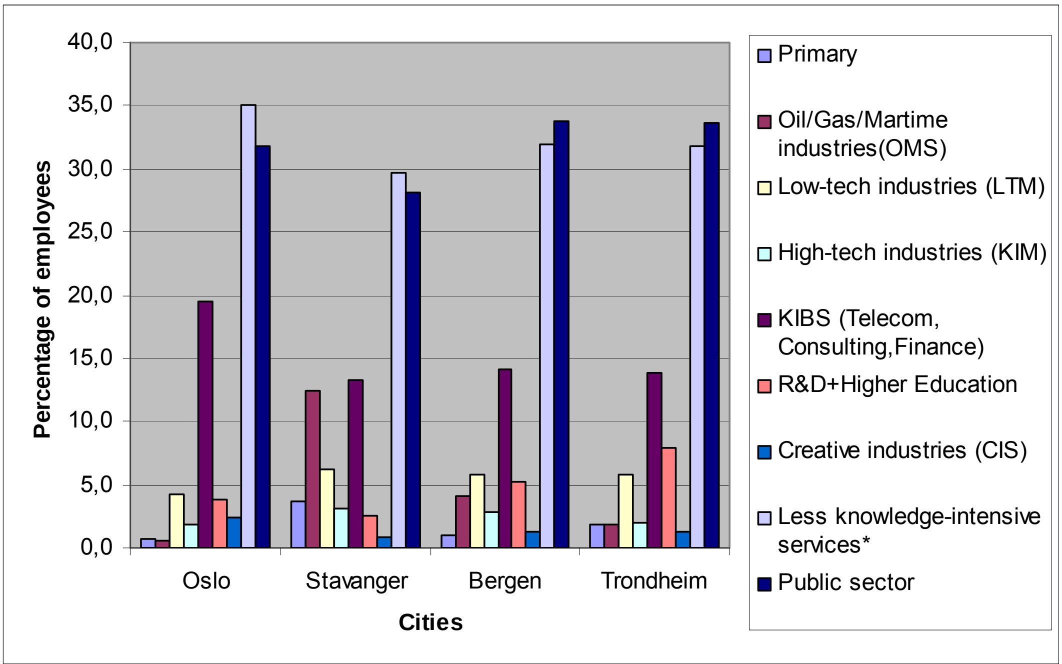
Bergen is the second largest city in Norway with approximately 256,000 inhabitants in 2009 (Statistics Norway 2010). As a result of a positive birth rate and migration the population is expected to grow in the coming decades, in Bergen city but particularly in the surrounding municipalities which constitutes the city region. It is estimated that the city of Bergen will have 317.000 inhabitants in 2030 and approximately 500 000 inhabitants in 2071 (www.bergen.kommune.no).

The functional Bergen region consists of 14 municipalities of a very different size. The total number of inhabitants in the region is approximately 380 000 in 2010 (Statistics Norway). Bergen is in its own class in the region with 256 000 inhabitants where most of the other municipalities are rather small. Fedje for instance is the smallest one with only 600 inhabitants. The population density is 77 cap/km^2 in the total region but in the Bergen city it is 2400 cap/km2. An ageing population is also evident in the region, app. 13% of the population is over 65 year in the County of Hordaland but in some of the smaller municipalities the figure is close to 20 %. And the share of elderly people is expected to increase in the years to come (Statistics Norway 2010).

Like most other Norwegian cities private and public services are the main economic sectors in Bergen, cf. figure 1.2, 1.3 and 1.4.

The economic structure is very different within the region, Bergen is specialised in oil and gas manufacturing and knowledge-intensive services, particularly in financial and business services. In many of the small municipalities in the region the primary sector, farming and fisheries, still plays an important role.

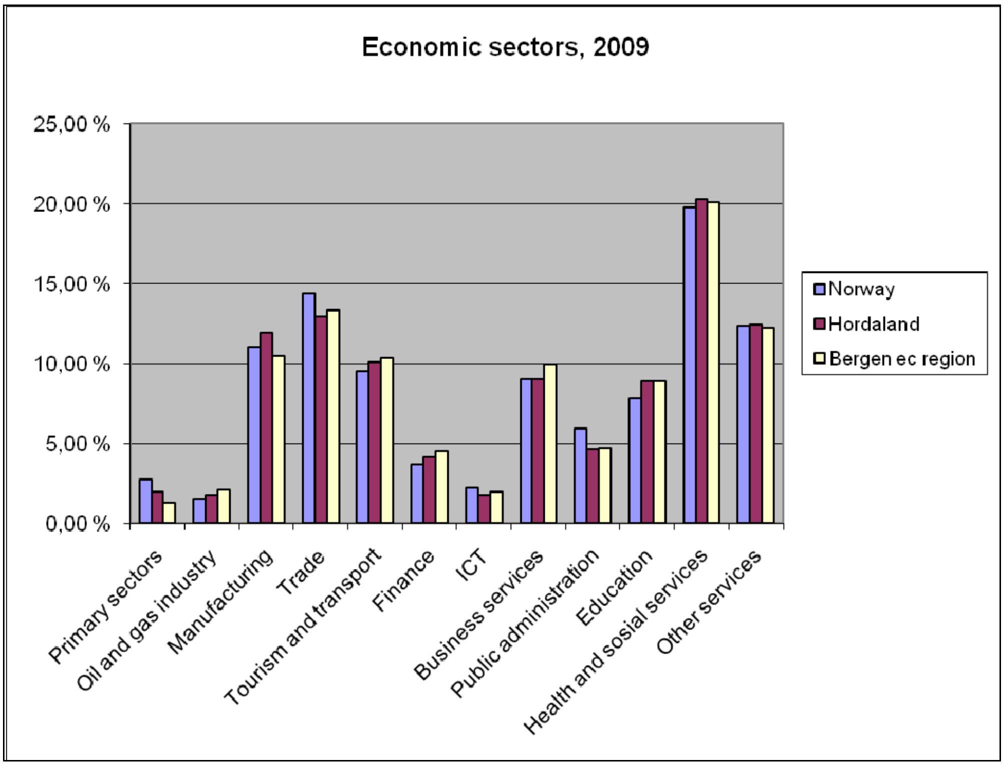
Figure 1.2 *Percentage of employees in different industries in larger Norwegian cities (2008)*



Source: Statistics Norway

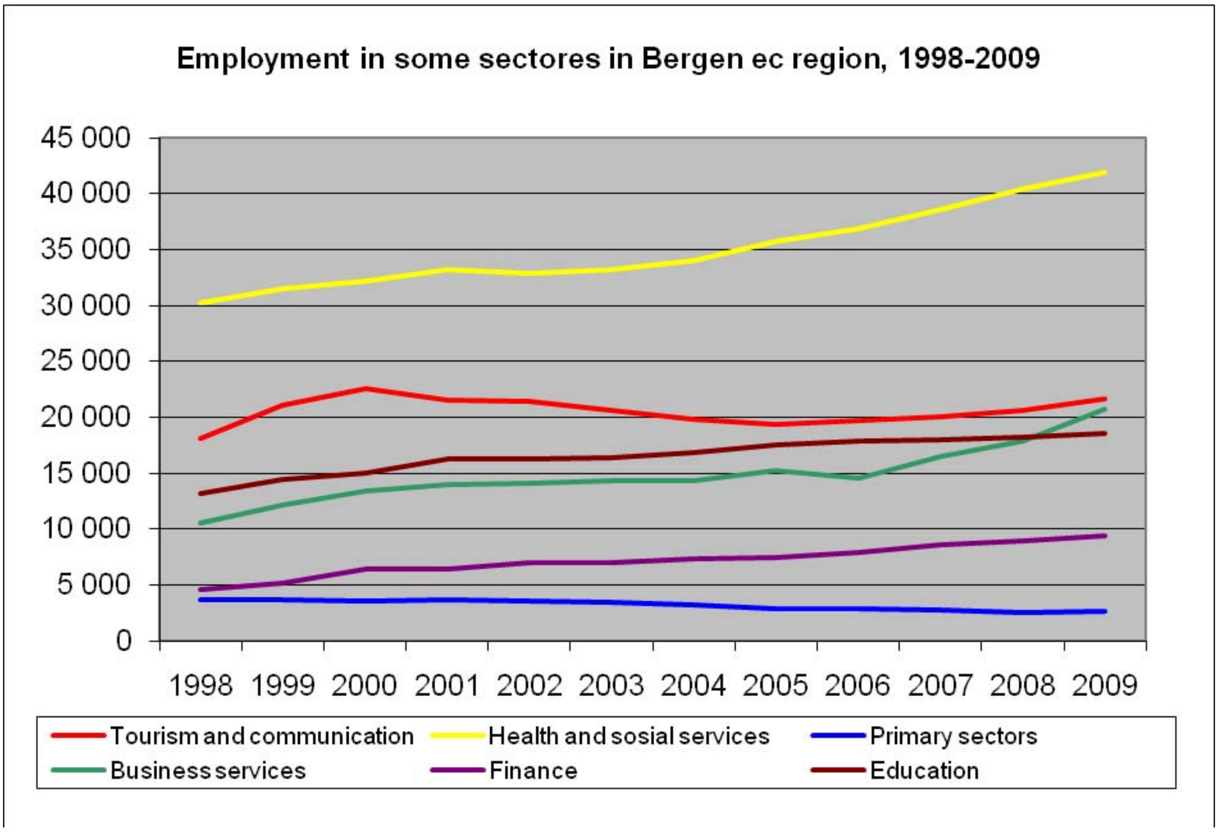
The vulnerability assessment for Bergen is related to sea level rise, flooding, wind, precipitation and extreme weather events. Secondly, there will be a statistical mapping of selected sectors which may be affected by climate change. This part of the study will be based on regional and local statistical sectoral analyses with data on LAU 2 level but it will also draw on an ongoing scenario project for Bergen which is focusing on climate impacts for the following industries: marine industries, maritime sector, tourism, energy and energy-intensive industries. Thirdly, the case study will also look into mitigation and adaptation measures taken on local/regional level in order to see what plans have been adapted and what actions have been taken. One should bear in mind that the adaptive or institutional capacity of the municipality or region is very decisive for the possible actions that will/can be carried out (this section will be changed in accordance with the following content, cf. template for case study reporting).

Figure 1.3 *Percentage of employments in economic sectors in Bergen, Hordaland County and Norway 2009*



Source: Statistics Norway

Figure 1.4 *Employment development in selected sectors in the Bergen region*



Source: Statistics Norway

The case study will first focus on relevant vulnerability dimensions, cf. Section 2. It first gives an overview of relevant exposure indicators (2.2) followed by sensitivity and analysis (2.3), and an overview of potential impacts (2.4). Then, the adaptive capacity is outlined (2.5) and vulnerability analyses are summarised (2.6). In Bergen, vulnerability is primarily related to sea level rise, flooding, wind, precipitation and extreme weather. Finally, this section presents a modified CBA for Bergen (2.7). Section 3 gives description of strategies and policy development for Bergen with regard to climate change adaptation measures.
Section 4 concludes the study by discussing future aspects specific to Bergen case study and the validity of European-wide analyses from a regional perspective, and the transferability of results to other regions.

2 Vulnerability assessment

2.1 Main effects of climate change on the case study region

The main effects of climate change in the Bergen region relate to damages on infrastructure, build environment and economic activities due to flooding, sea level rise and landslide, cf. sections 2.4.Impacts. The main exposure indicators for which data is available for the Bergen case study is temperature, precipitation and sea level rise.

2.2 Exposure indicators

There are significant natural climate variations in Norway, both in time and space/geography. The annual mean temperature is approximately + 1°C but it vary from + 6°C at the West coast to below - 4°C in the mountains. Annual mean precipitation in Norway is 1486 mm per year but with more than 5000 mm in some areas at the West coast of the country. This section presents regional climate scenarios and the most important exposure indicators for Western Norway and the Bergen region based on the report *Climate in Norway 2100* (Bauer et al 2009).

The results in this chapter are based on climate simulations from several national and international research projects (RegClim, GeoExtreme, NorACIA, NorClim og PRUDENCE). Sorteberg og Haugen (2009) has made a compilation of 22 different prognoses for temperature and precipitation based on dynamic methods («dynamic ensemble»). This comprise both prognoses produced with a regionalised climate model (Bjørge et al, 2000; Haugen and Haakenstad, 2006; Haugen and Iversen, 2008) and prognoses based on a global model (Barstad m.fl., 2009). All prognoses are scaled so as to be valid for changes in the period 1961–90 to 2071–2100. These results are the available data and prognoses for the Bergen case study.

Table 2.1 *Overview of example prognoses used in further calculations*

Betegnelse	Globalmodell/ Regionalmodell	Kontroll- og framtids-periode	Ut-slipps-scenario	Horisontal oppløsning	Vertikale lag
M92	ECHAM4 AOGCM (T42)/HIRHAM1	1980–1999 2030–2049	IS92a	50 km	19
MB2v1	ECHAM4 AGCM (T106)/HIRHAM1	1961–1990 2071–2100	SRES B2	50 km	19
MB2v2	ECHAM4 AGCM (T106)/HIRHAM2	1961–1990 2071–2100	SRES B2	25 km	19
HA2	HadAM3H AGCM/HIRHAM1	1961–1990 2071–2100	SRES A2	50 km	19
HB2	HadAM3H AGCM/HIRHAM1	1961–1990 2071–2100	SRES B2	50 km	19

Source: Bauer et al 2009, Klima i Norge 2100

Temperature

The temperature will increase in all Norwegian regions and in all seasons towards 2100. The annual mean temperature is estimated to rise with 2.3 to 4.6 °C within 2100, see figure 2.2. The increase will be strongest in the North (Finnmark) whereas the figures for Western Norway are 1, 9 and 4, 2. Figure 2.3 shows that there were no significant changes in the temperature from 1900 until 1980 but that there will be a strong increase in the annual mean temperature in Western Norway from the late 1990s to 2100. Figure 2.4 and 2.5 show the deviation from “normal” temperature in Western Norway for winter and summer respectively. And, as can be seen, the increase is significantly bigger in the winter (M = 3.8) than in the summer (M = 2.3). Figure 2.6 shows changes in annual mean temperature specifically for Bergen at the late part of the century, the period 2071 – 2100 (red line) compared to the “normal” for the period 1961-1990). All projections in the scenario show that the weather will be warmer, and that in the winter time the temperature will increase from close to zero to 4-5 °C. This implies amongst other that the agricultural growth season will be significantly extended with 1-3 months towards 2100.

Figure 2.1 *Change in annual mean temperature 1961-1990 to 2071-2100*

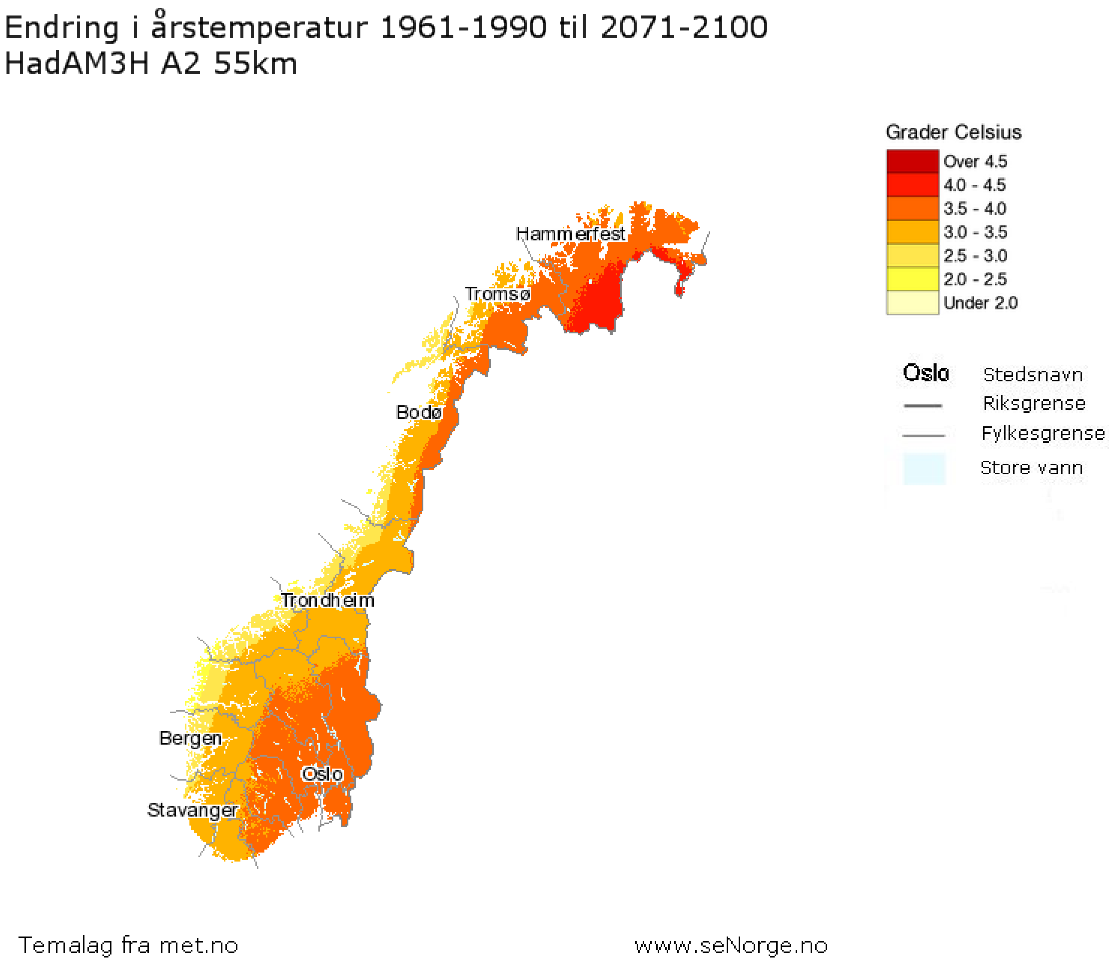


Figure 2.2 *Annual mean temperature in Western Norway, deviation from "normal"*

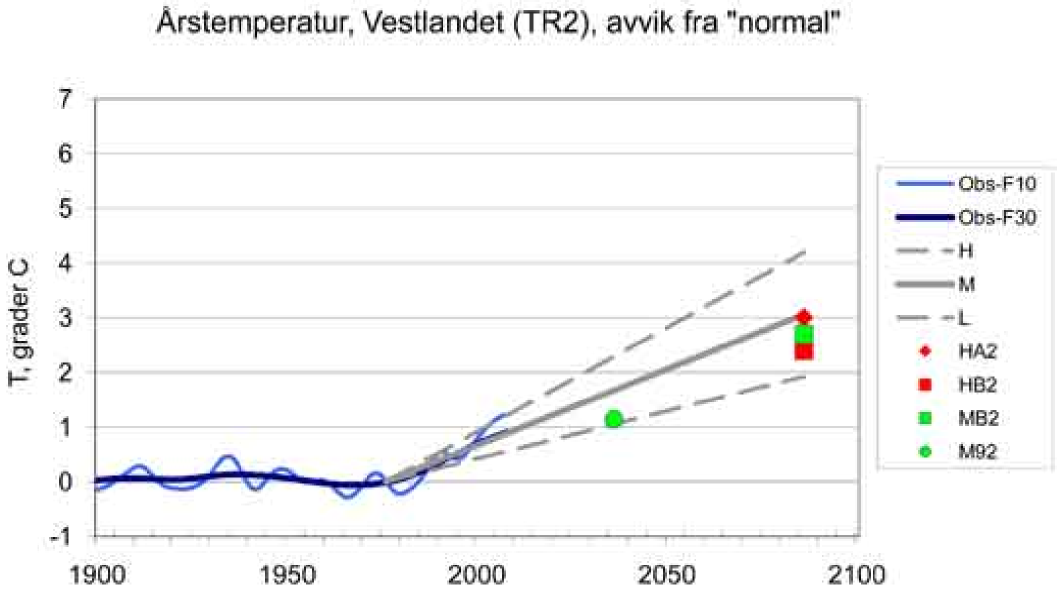


Figure 2.3 *Winter temperature Western Norway 1900-2100, deviation from "normal"*

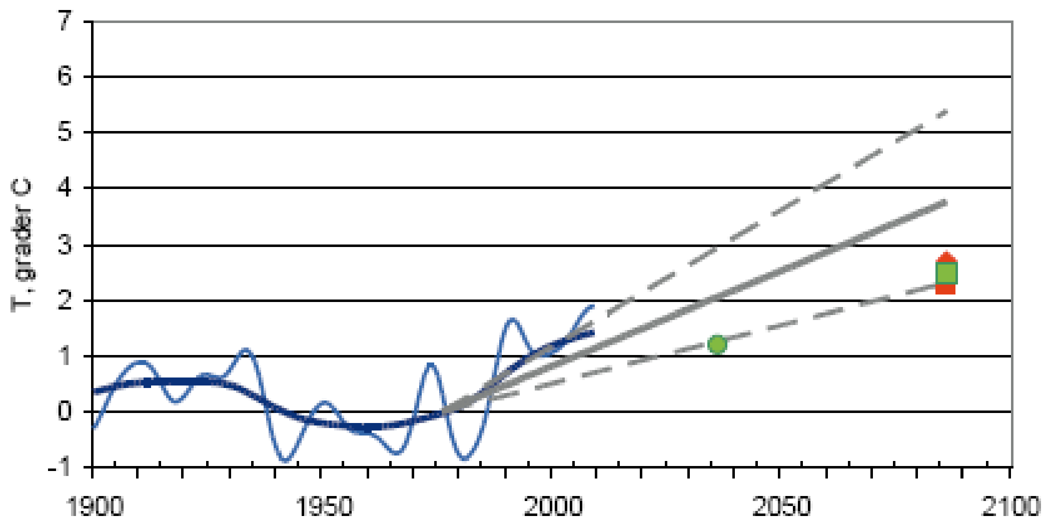
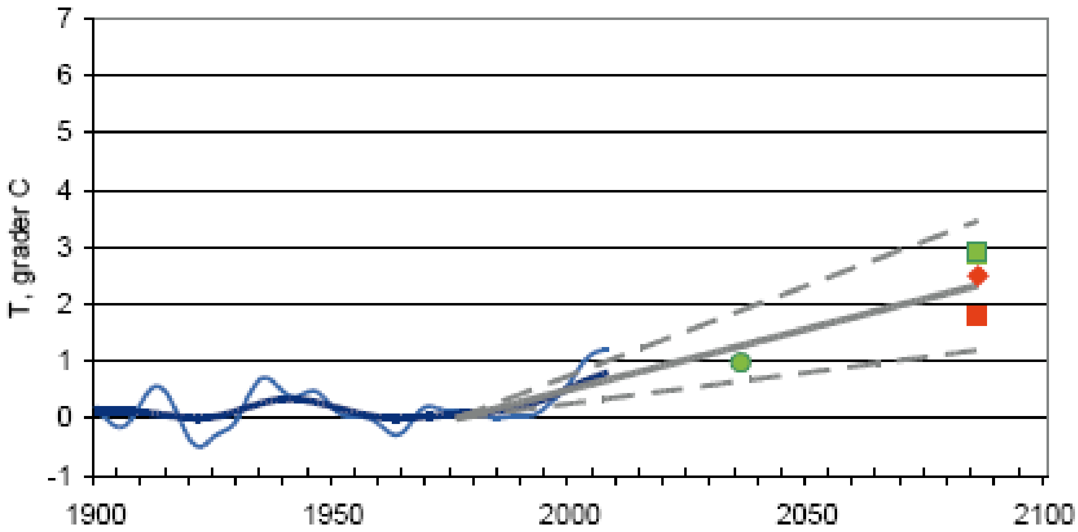


Figure 2.4 *Summer temperature Western Norway 1900-2100, deviation from "normal"*

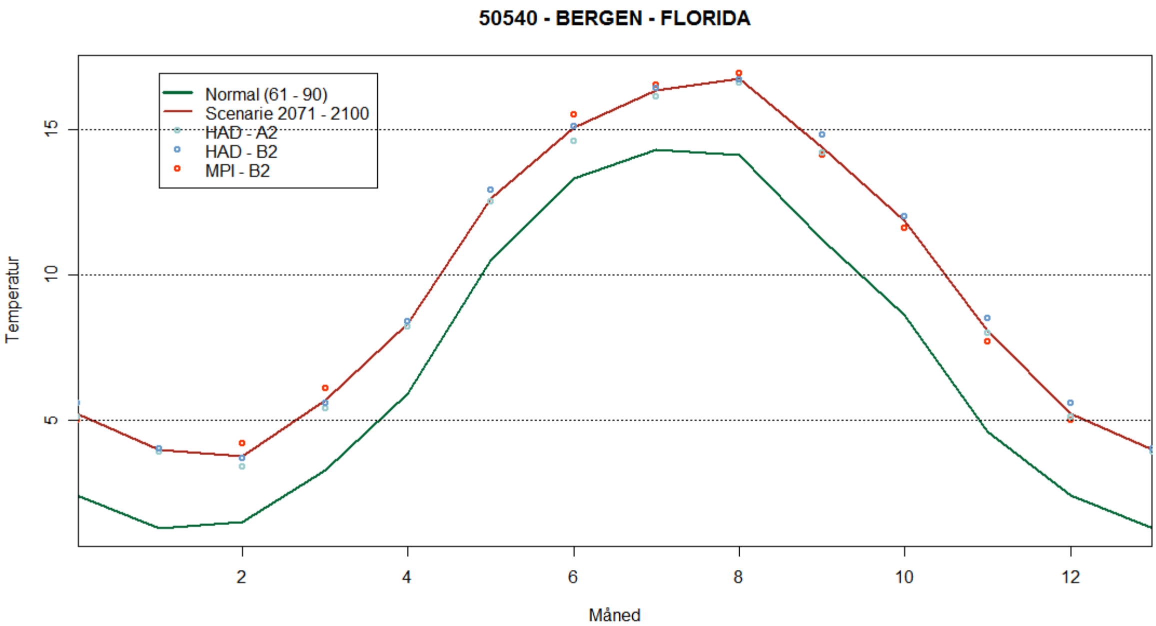


Precipitation

Precipitation will increase in all parts of Norway towards the end of the century. Annual mean precipitation is estimated to increase from 5 to 30 percent, see figure 2.7. Annual mean precipitation in winter months may increase with more than 40 percent in parts of East-, South and Western Norway in this period. There will be more days with heavy rainfall and annual mean precipitation will be higher for all these days and for all parts of Norway.

Figure 2.8 shows a comparison of the normal annual precipitation for the period 1961-1990 (green graph) and estimated precipitation (red graph) for the period 2071 - 2100 for Bergen. The different estimates vary a bit but the main tendency is the same, namely that precipitation will increase, and particularly in autumn and winter. Figure 2.9 shows the changes in days with heavy rainfall in Norway, and the amount of precipitation within a medium, low and high scenario. Annual changes for Norway in the medium scenario indicate that there will be a 75 percent increase of days with heavy rainfall, and that in winter and autumn there will be twice as many days with heavy rainfall. The amount of precipitation in days with heavy rainfall will increase with approximately 10-15 percent. The same tendency is apparent for Western Norway, and the increase in days with heavy rainfall is particularly strong in autumn in this part of the country. Having in mind that this region already has large amount of precipitation, a doubling of days with heavy rainfall will increase the vulnerability related to flooding and landslide.

Figure 2.5 *Annual mean temperature in Bergen 2071 - 2100*



Florida is the temperature observation point in Bergen

Figure 2.6 *Annual mean precipitation in Norway 1900 - 2100*

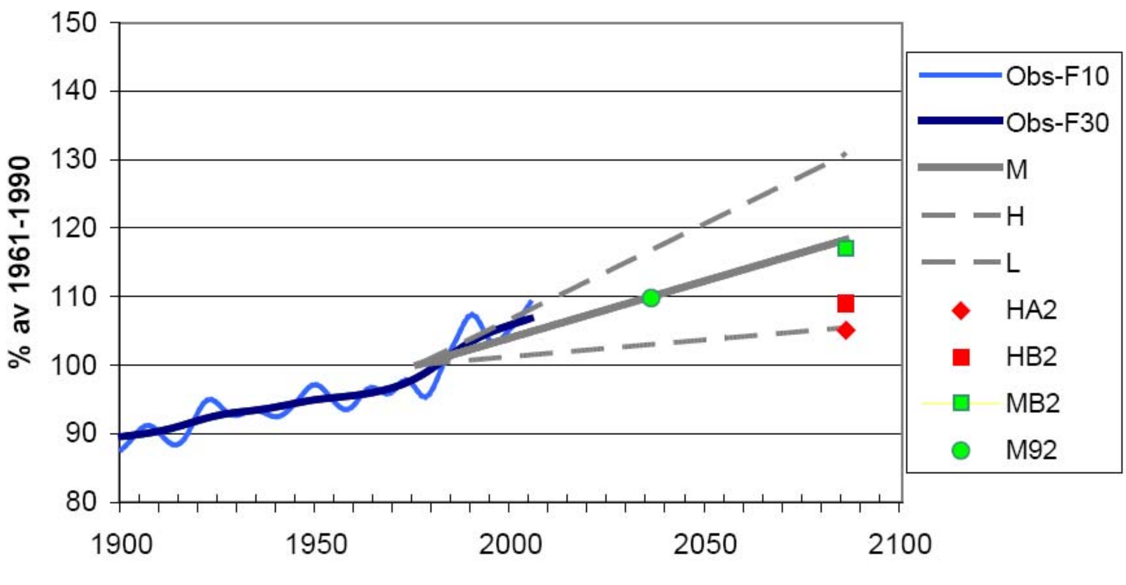
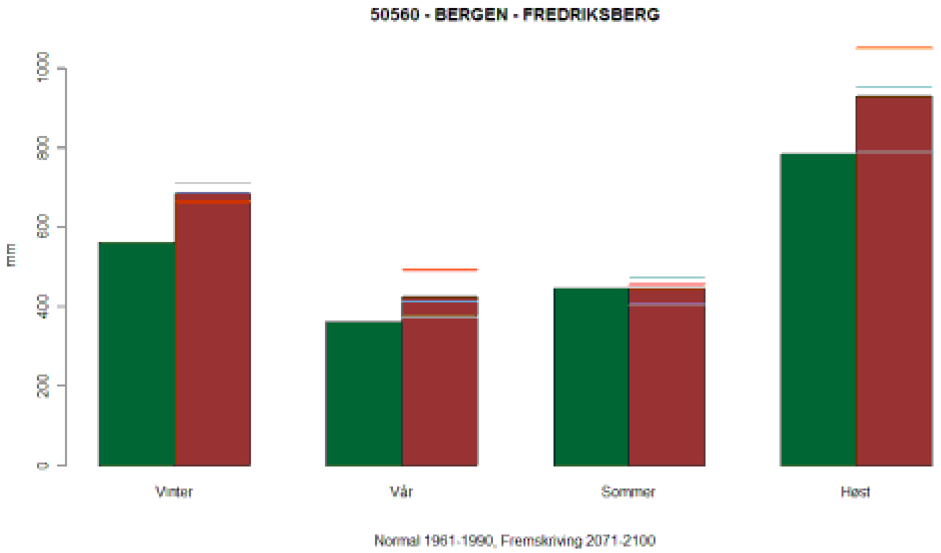


Figure 2.7 *Annual mean precipitation for winter, spring, summer and autumn in Bergen 2071 - 2100*



Fredriksberg is the precipitation observation point in Bergen

Table 2.2 *Relative changes (%) in number of days with heavy rainfall* (column 3,4 and 5) and relative change (%) in precipitation amount in days with heavy rainfall (column 6,7 and 8) in Norway, from the 1961-90 to 2071 – 2100.*

Region	Sesong	1961–90 til 2071–2100: Endring (%) i antall dager med mye nedbør			1961–90 til 2071–2100: Endring (%) i nedbørmengde på dager med mye nedbør		
		M	L	H	M	L	H
Norge	År	75,7	40,6	139,9	15,6	7,2	23,1
	Vinter DJF	126,5	80,0	250,9	16,5	1,9	32,3
	Vår MAM	88,3	41,6	193,1	15,5	5,9	29,1
	Sommer JJA	71,4	30,0	86,9	16,5	6,4	21,5
	Høst SON	110,3	55,9	192,5	17,5	9,7	26,4

* Days with heavy rainfall is defined as days with precipitation amount which in the normal period 1961-90 was exceeded in 0, 5 % of the days. (År = year, Vinter = Winter, Vår = Spring, Sommer = Summer, Høst = Autumn).

Sea level rise

During the 21st century the sea level is expected to rise with approximately 70 cm in Southern and western Norway. Figure 2.10 shows upper and lower level for sea level rise and storm surge for the five largest cities in Norway in 2050 and 2100 respectively. Sea level rise is estimated to be largest in Bergen and Stavanger, both situated on the west coast of Norway. In addition to the sea level rise which is estimated to increase with 75 cm, the storm surge may increase up to 221-276 cm. This will have significant impacts on the city’s infrastructure, transport system and tunnels, buildings and sewage system.

Table 2.3 *Upper and lower level of sea level rise and storm surge in the five largest cities in Norway*

	2050				2100			
	Havstigning (cm)		Stormflo (cm) Relativt NN1954		Havstigning (cm)		Stormflo (cm) Relativt NN1954	
	Min.	Maks.	Min.	Maks.	Min.	Maks.	Min.	Maks.
Tromsø	10	32	229	251	43	98	267	322
Trondheim	–1	21	246	268	22	77	274	329
Bergen	15	37	178	200	53	108	221	276
Stavanger	17	39	143	165	58	113	189	244
Oslo	–1	21	189	211	21	76	216	271

(Havstigning = Sea level rise, stormflo = storm surge)

2.3 Sensitivity

Sensitivity to climate change can be measured by how different exposure indicators lead to a detectable change (positive or negative) in the studied object. Sensitivity is measured by many dimensions in the project. The physical sensitivity refers to settlements and infrastructure which are exposed to river flooding and flooding by sea level rise. The environmental sensitivity refers to protected natural areas or areas of high ecological value, such as wetlands. Social sensitivity refers to population density of the region, coastal population, population in areas prone to heavy rainfall. Cultural sensitivity refers to Wold heritage sites, cultural monuments and landscapes. Economic sensitivity refers to how the region will be affected economically by the others sensitivity dimensions. In the Bergen case study the main sensitivity dimensions are physical sensitivity (infrastructure), cultural sensitivity (world heritage sites) and economic sensitivity (business activities and tourism).

However we only have statistics for social sensitivity measured by dependency rate, see figure 2.8; economic sensitivity measured by dependency on primary sector, see figure 2.9 and 2.10; dependency on hotel and service sectors, see figure 2.11 and 2.12; cultural sensitivity measured by world heritage sites, see figure 2.13 and environmental sensitivity measured by preserved landscape, see figure 2.13.

All the maps are covering the NUTS3 unit Hordaland County, cf. Figure 1.1. Statistics are given for all municipalities (LAU2) within that NUTS3 unit, and the Bergen case is seen in relation to the other municipalities.

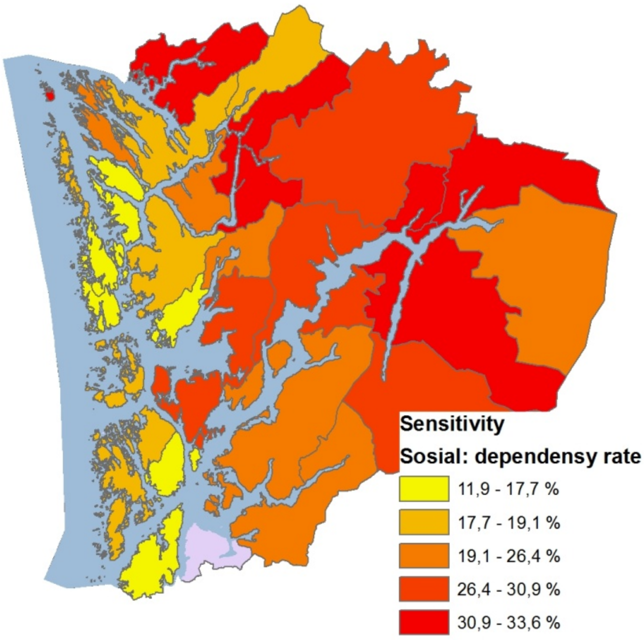
Table 2.4 *Climatic stimuli and sensitivity indicators*

	Change of annual **mean temperature**	Decrease of number of **frost days**	Change of number of **summer days**	Rel. change of mean **winter precipitation**	Rel. change of mean **summer precipitation**	Change of number of **heavy rainfall days**	Rel. change of annual **mean evaporation**	Change of number of **days with snow**	Change in occurrence of **river flooding**	Change of **mean sea level**
Physical sensitivity										
Infrastructure				*	*	*			*	*
Social sensitivity										
Social dependency rate		*	*					*		
Cultural sensitivity										
The World Heritage Sites				*	*	*			*	*
Environmental sensitivity										
Preserved landscape	*			*	*	*				
Economic sensitivity										
Primary sector	*	*			*	*				*
Service sector	*	*	*	*	*					*

Social sensitivity

Figure 2.8 shows the dependency rate, defined as the population over 66 years related to the population 16-66 years. The map shows that Bergen has a fairly low dependency rate but also that the neighbouring municipalities to the city of Bergen have an even lower rate. This can probably be partly explained by families with small children moving out of the city to nearby municipalities. The map also show that the dependency rate overall is lower in coastal areas than in the inland of in Hordaland County.

Figure 2.8 *Bergen case, Hordaland county. Sosial sensitivity; population dependency rate. Quintiles*.



Economic sensitivity

Economic sensitivity is measured by dependency on the primary sector and on hotel and service sectors. Dependency is defined as employment in the sectors in absolute terms or relative to total employment.

Figure 2.9 and 2.10 show the economic sensitivity measured by dependency on the primary sector in absolute number and relative dependency respectively. As expected, primary sectors are of relative small importance in Bergen and the municipalities close to Bergen, see figure 2.10.

Figure 2.11and 2.12 show eemployment in service and hotel sectors relative to total employment and indicate that sensitivity is relatively higher in the inland of the County. This could be due to winter sport resorts situated in this part of the region.

Figure 2.9 *Economic sensitivity – dependency on primary sector, Employment in the primary sectors, absolute numbers. Quintiles.*

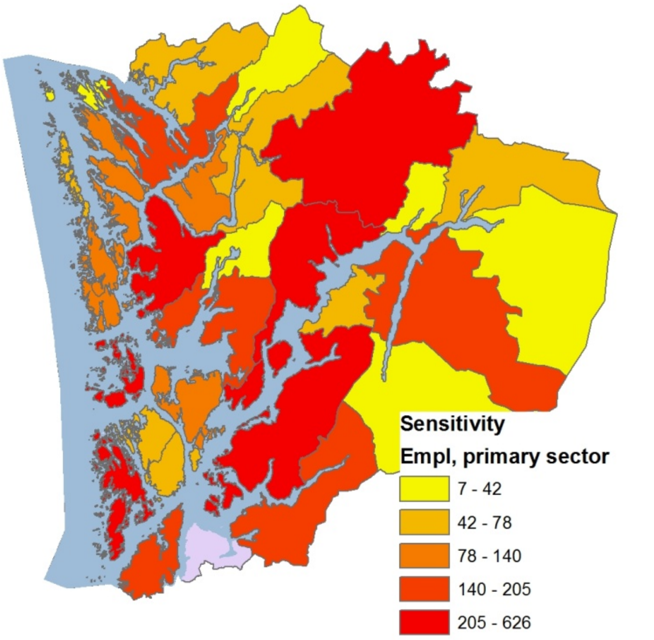


Figure 2.10 *Economic sensitivity – relative dependency on primary sector. Quintiles*.

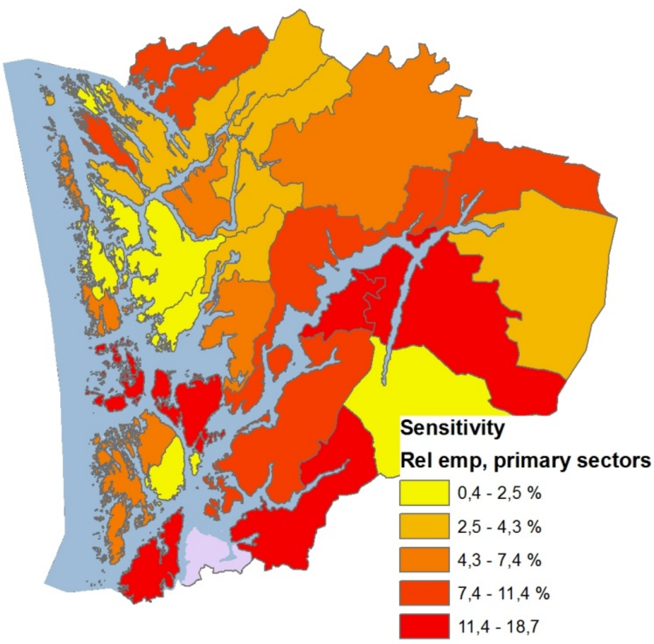


Figure 2.11 *Economic sensitivity: dependency on hotel and service sectors, employment in the sector in absolute numbers. Quintiles.*

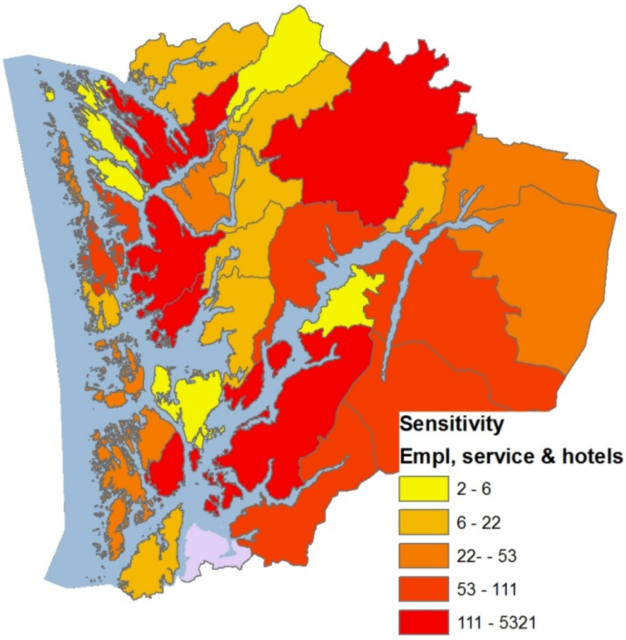
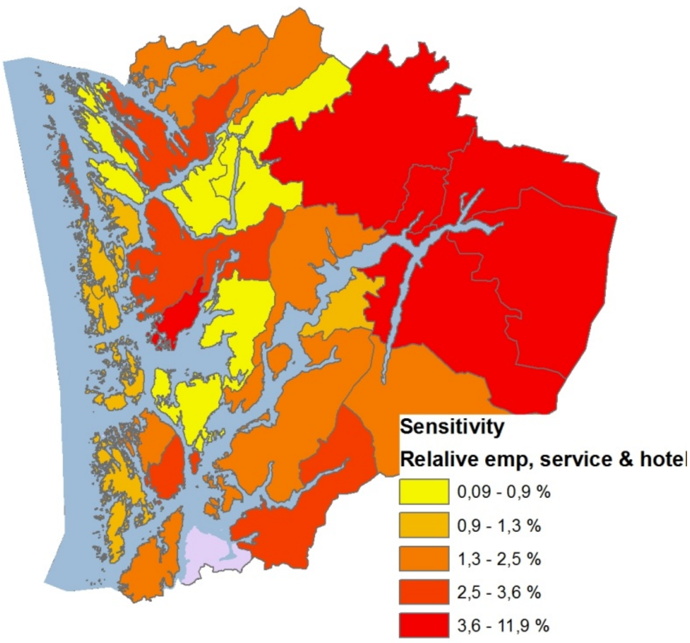


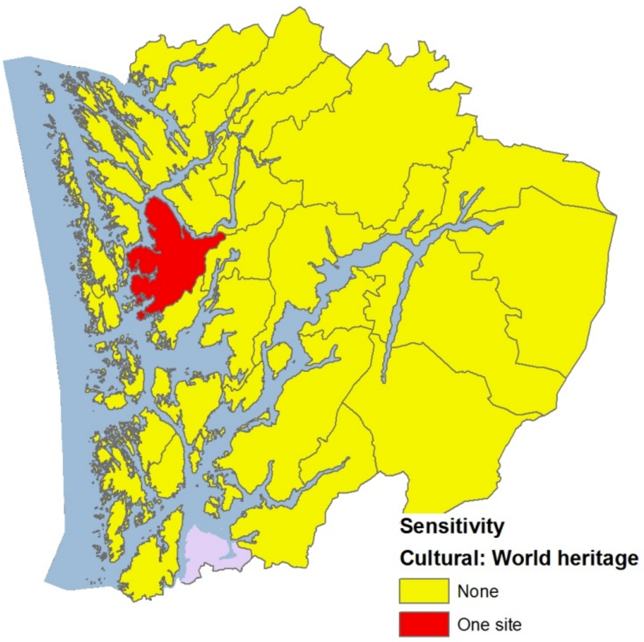
Figure 2.12 *Economic sensitivity: relative dependency on hotel and service sector. Quintiles.*



Cultural sensitivity

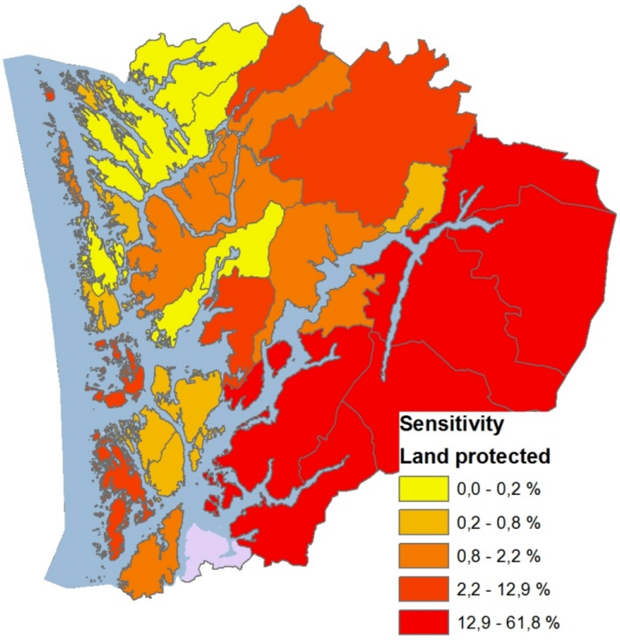
Cultural sensitivity is measured by the occurrence of Wold Heritage Sites, cultural monuments and landscapes. Bryggen (the German Wharf) which is made up by several hanseatic commercial buildings lining the eastern side in Bergen, and it have since 1979 been on the UNESCO list for World Cultural Heritage. This is the only world heritage site in the county, see figure 2.13.

Figure 2.13 *Bergen case, Hordaland County. Sensitivity – World heritage sites*



Environmental sensitivity

Figure 2.14 *Environmental sensitivity; percentage area protected area in Hordaland County. Quintiles.*



Environmental sensitivity refers to protected natural areas or areas of high ecological value and so forth. Figure 2.14 show that the municipalities with the largest protected areas are the ones which have a national park on a large part or some of its area. These are situated in the inland south and east in the County, such as Hardanger which is an area well known for a wild nature with mountains, glaciers, waterfalls and fjords. This area has been attractive for tourists and artists since long ago and is a suitable area for several sport activities. Hardanger is also well known for fruit cultivation.

2.4 Potential impacts

The potential impacts are a function of exposure and sensitivity. It varies how sensitive different regions and sectors are to climate change, and they can be both adversely and beneficially affected. For the Bergen region and Western Norway temperature increase, precipitation and sea level rise are the most important exposure indicators. Increased temperature may imply that the agricultural growth season will be significantly extended towards 2100 (1-3 months), and as such be beneficiary for the region. Increased precipitation, more heavy rainfall and sea level rise increase the risk for flooding and landslide and will affect the region negatively, and particularly endanger settlements, infrastructure and cultural heritages.

Flooding and sea level rise is most harmful

In coastal areas as in the Bergen region settlements and infra structure are often located close to the sea. Big parts of the larger region are un-built areas, cf. figure 2.8 whereas in the central city the built area is concentrated at the sea front, cf. figure

2.9. If the estimated sea level rise of 75 cm in 2100 and the expected storm surge rise up to 2,37 meters it will overflow buildings related to settlements and industries, historical sites, quays and port facilities, fish farming, roads and transport systems, sewage systems and wetlands. Most port facilities in the region will be flooded and useless at a sea level as with the expected the storm surge. But also a sea level rise of 75 cm will make most of the quays unfit for mooring many vessels.

The effects of sea level rise will be most harmful in the central city area, cf. figure 2.10. Large part of the business area is located at the waterfront where also new settlements are developed. A sea level rising up to 2.37 meter will cause power outage, damaging of waste water system and roads, tunnels will be filled with water and the railway station will be flooded.

The harbour plays a particularly important role in the city. A lot of ships call at Bergen port every year, both cargo ships and cruise ship. In 2007 nearly 19 000 ships came to Bergen, out of this 231 cruise ships carrying app. 200 000 passengers (Regional Havstigning 2009). Tourism may be adversely affected by flooding and sea level rise because the arrival by ships will be strongly restricted and the most popular harbour areas (Bryggen and Vågen) will be flooded. The World Heritage Site of Bryggen is a living illustration of the city’s history, with 61 protected buildings covering about 13,000 m2 (www.stiftelsenbryggen.no/). Even today the site is harmed by storm surges and flooding. In combination with sinking ground water this causes irreparable damages on the historical buildings.

Figure 2.15 *Fjords and sea level rise sensitive areas in the Bergen region*

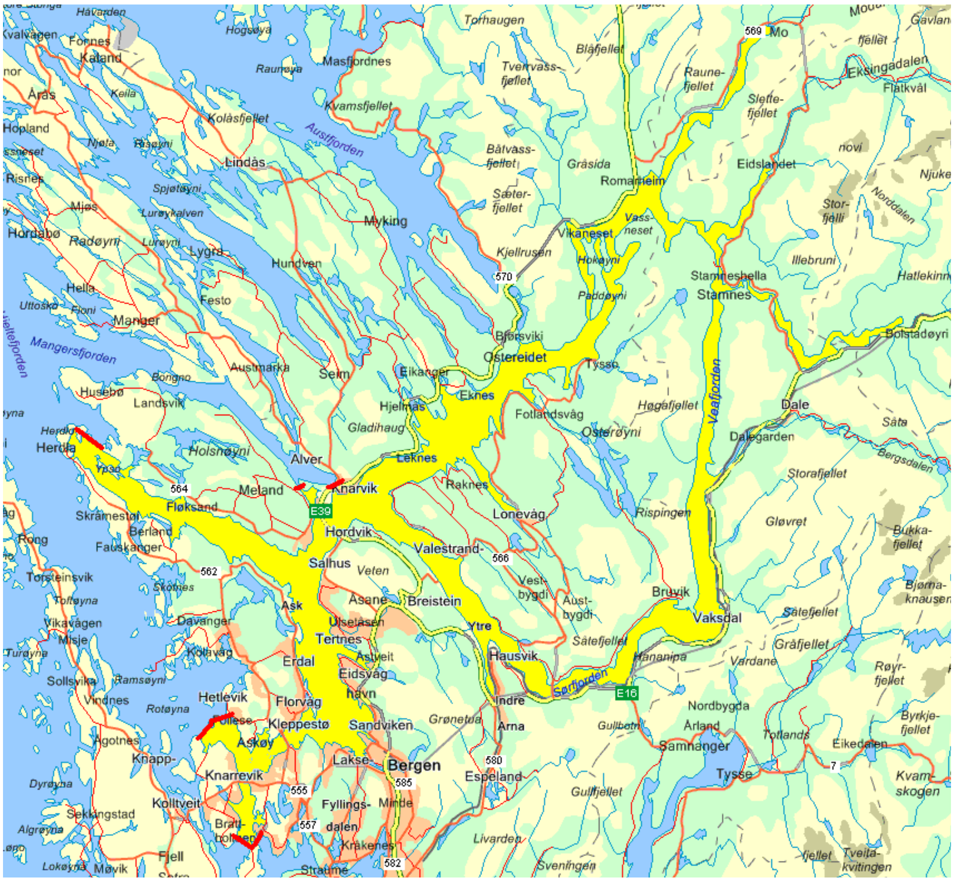


Figure 2.16 *The building zone in Bergen (sum of regulated and unregulated building areas and new building areas).*

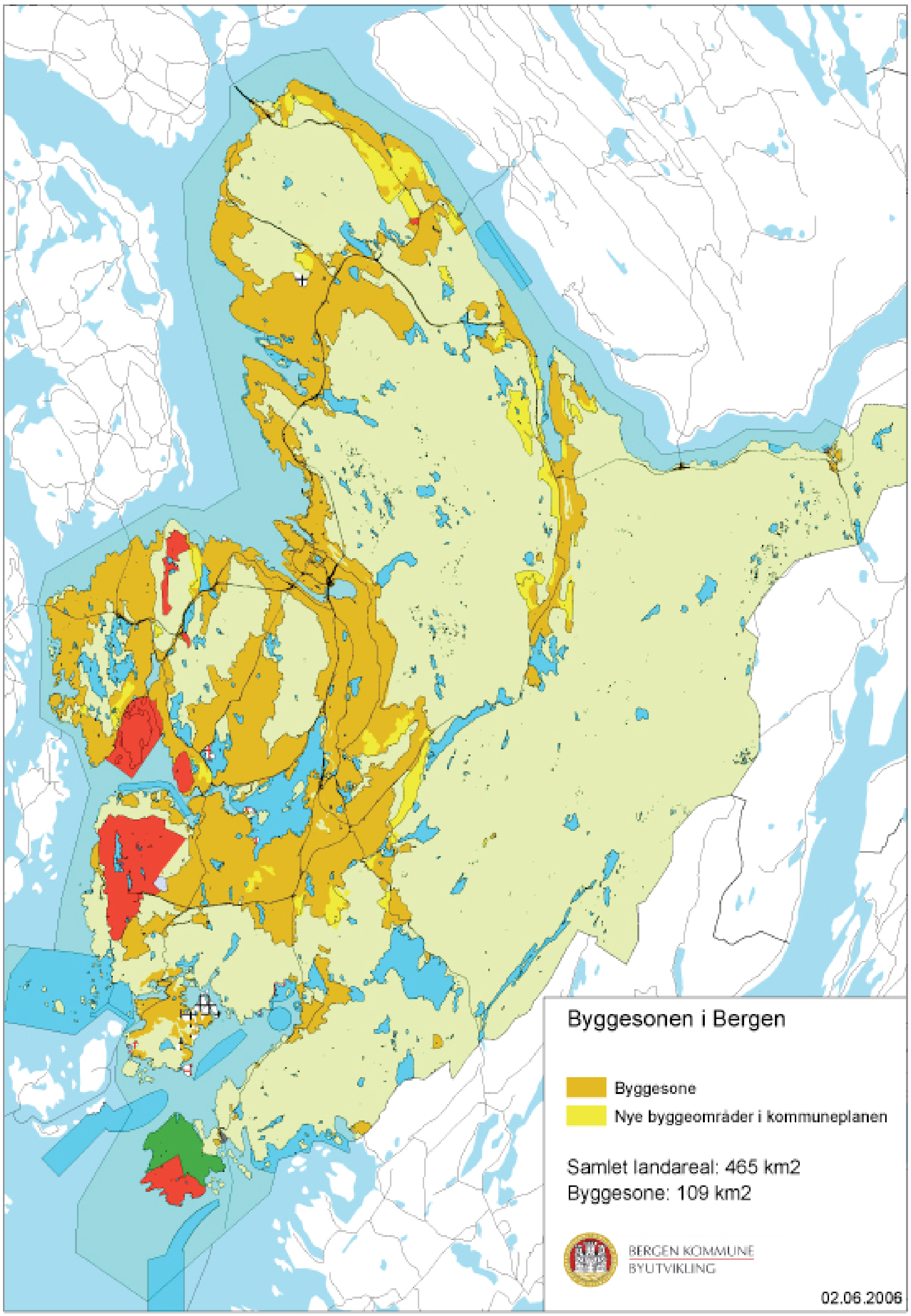
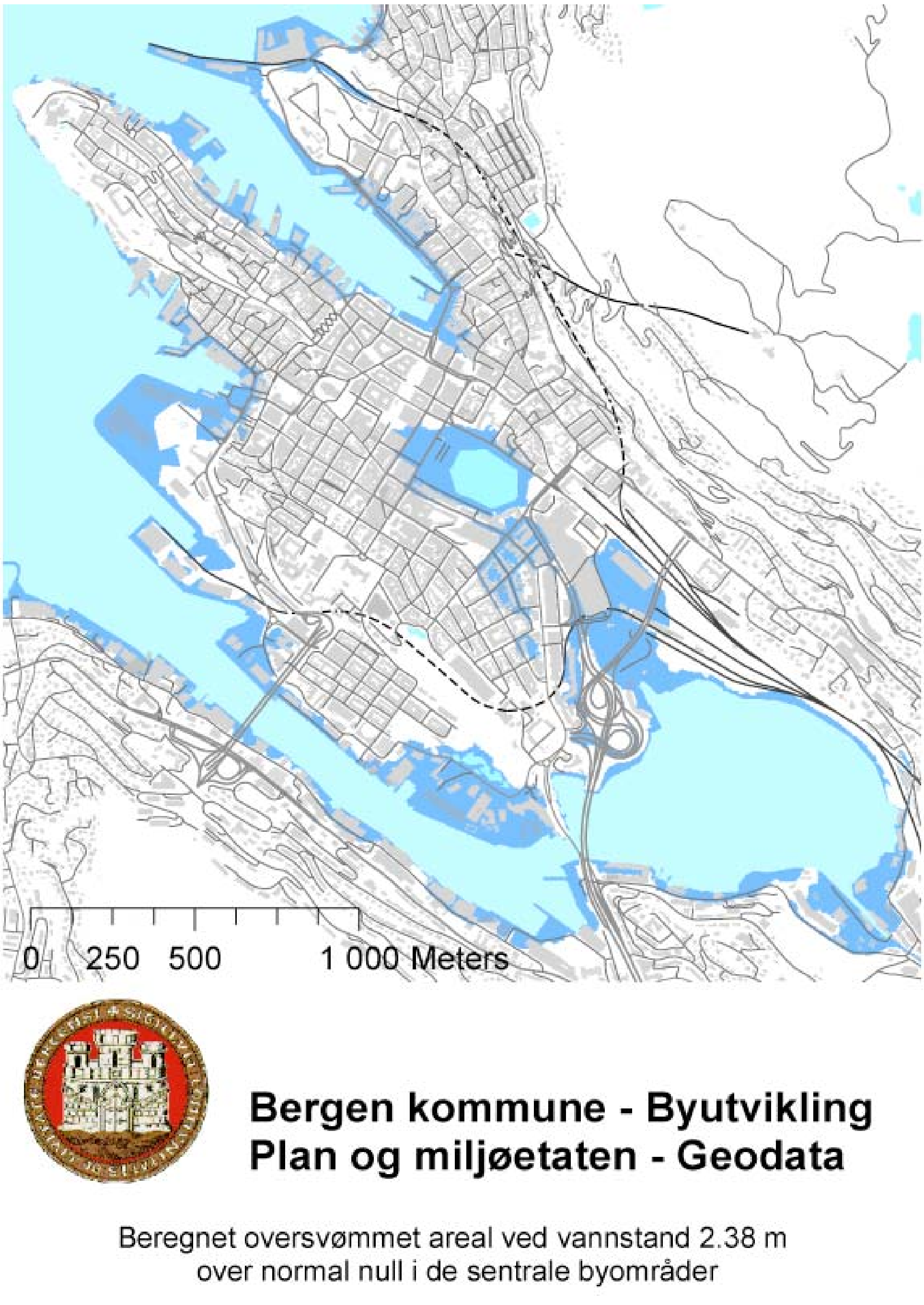


Figure 2.17 *Estimated flooded areas in the central city by storm surge (2.38 m) over normal (0)*

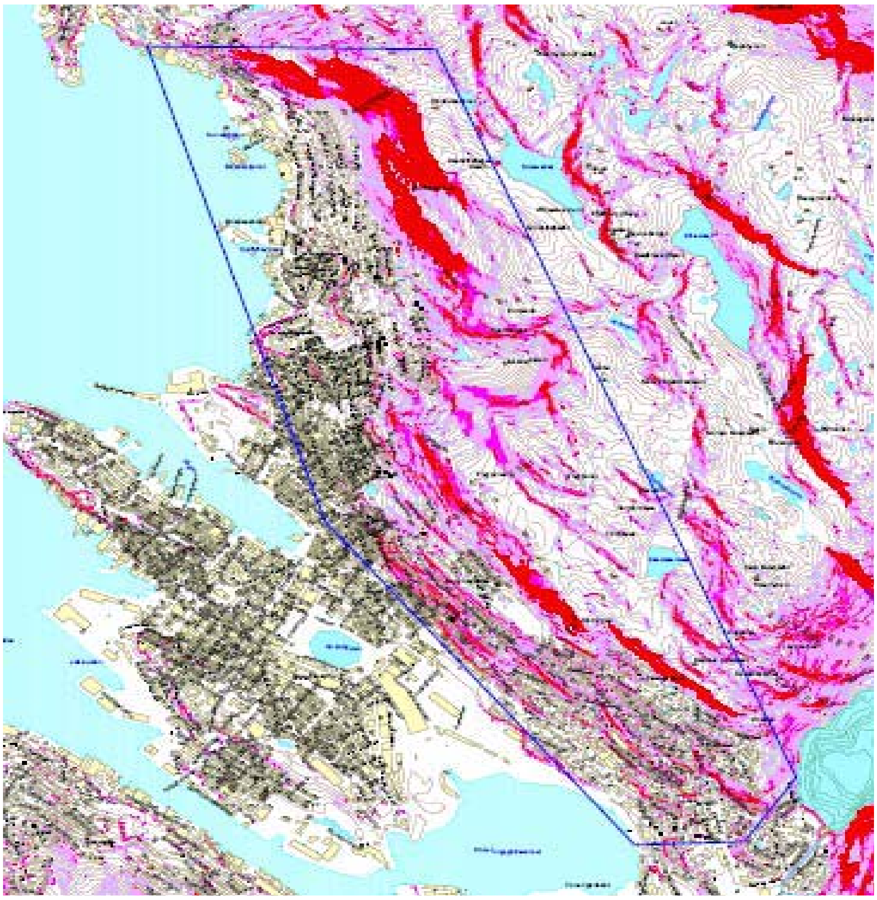


Increased danger for landslide

Bergen is situated amongst several mountains with rather steep hills and as such exposed to landslide. Landslide may occur when the slope of the hill is over 30 degree, and in Bergen large parts of the hillsides are more than 40 degree. Increased precipitation, and particularly heavy rainfall, accumulation of water, processes of freezing and defrosting and human activities related to digging and fill in the mountainside, are the most important releasing causes for landslides.

A lot of settlements, houses and institutions, are situated in the hillsides of Bergen. In the urban area Fjellsiden (the mountain side) approximately 100 houses are estimated to be exposed for landslide. In addition, schools and different public institutions such as nursing homes, kindergarten and sport grounds are exposed in the same area. Figure 2.11 shows the risk zones for landslide in this part of the central Bergen.

Figure 2.18 *Landslide risk zones in central Bergen (the mountain side)*



Slope classification

- Helning > 45 grader
- Helning > 38 grader
- Helning > 30 grader
- Helning > 27 grader

Two accidents have hit the city in past years. First the landslide in a part of the city called Fana (Hatlestad). In September 2005 a landslide of mud and rocks hit several houses and caused the death of three persons, seven were injured and many were forced to move. The landslide was a result of heavy precipitation within a short period of time. It rained approximately 5 percent (110, 5 mm) of the average yearly mean precipitation within twelve hours. Two months later, in November 2005, another landslide occurred in a part of the city called Åsane (Hatlebekk). One person was killed in this accident.

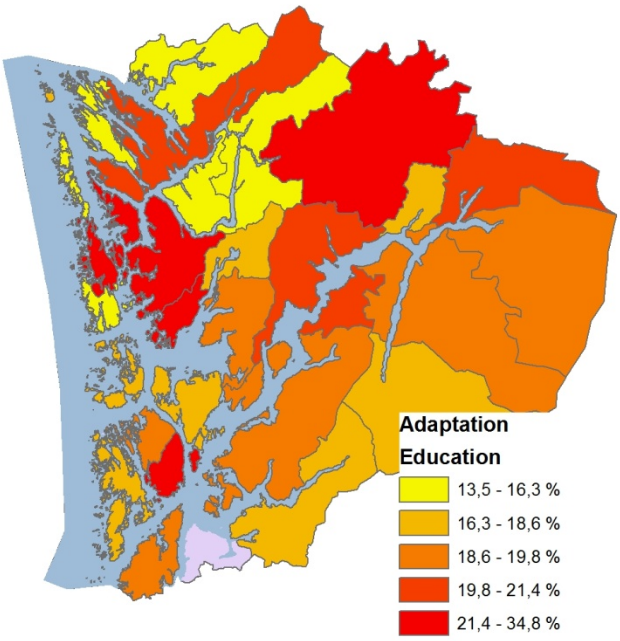
2.5 Adaptive capacity

The IPCC definition of adaptive capacity is made up by five main dimensions - knowledge and awareness; technology; infrastructure; institutions and economic resources. This chapter gives an overview of adaptive capacity in the Bergen region by focusing on these dimensions.

Knowledge and awareness

Knowledge and awareness cover educational commitment, computer literacy and attitudes on climate change. As the second largest University City Bergen has a fairly high score on higher education. Approximately 35 % of persons above 16 years have a university or college education whereas the figure for Hordaland County is 28%, and for Norway it is 27 % (Statistics Norway 2010). Figure 2.19 shows the percentage of inhabitants with higher education in relation to inhabitants 16 years and over for all municipalities in Hordaland County. Bergen has together with a couple of surrounding municipalities and Voss the highest score on this variable.

Figure 2.19 *Adaptation – percentage with higher education in Hordaland County. Quintiles*.



In 2009 88 % of Norwegian households had PC and 86 % had access to the Internet in Norway. This means that almost everybody has computer skills, and there is little geographical variation but the skills vary by age and education.

Attitudes to climate change: Bergen has a very active policy towards climate change and adaptation. The city participate in several climate projects and has many forums for discussion of climate change (regional climate panel and forum), it has carried out many risk and vulnerability analyses, worked out specific plan for climate and energy, cooperate with kindergartens and schools in order to increase the awareness of climate change. This should indicate knowledge and awareness of climate change is fairly well developed among the inhabitants in Bergen. However, there is no data to substantiate this assumption.

Technology

Technology covers resources for technology, capacity for research and patents. Share of GDP in R&D investments is suggested as one indicator. Norway has a rather low share of GDP in R&D investment (1.62 %) but the main bulk of such investments are concentrated in the larger cities such as Bergen. There are no data of human resources in science and technology (HRST) and patents on lower level than NUTS 2 which covers the whole western part of Norway and therefore is of little use to indicate the technology dimension of adaptive capacity for Bergen.

Infrastructure

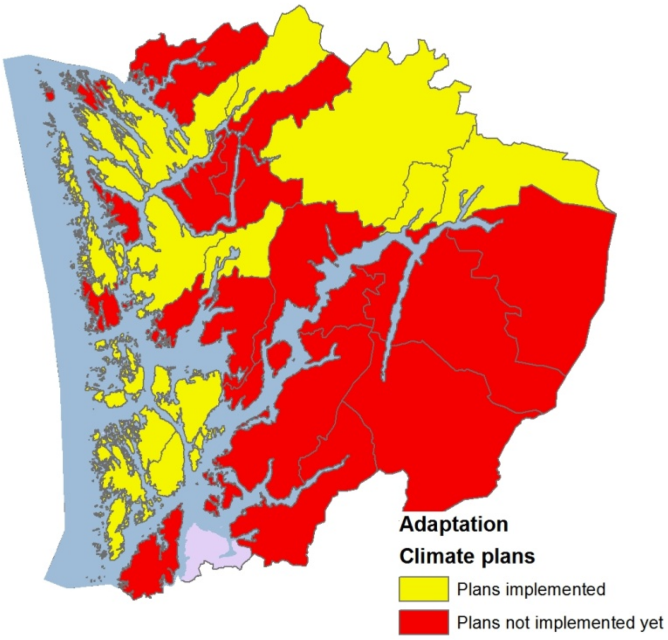
A well-developed infrastructure may enhance the adaptive capacity of a city or region. Transport for instance measured by how easily the population in a region can be reached by emergency services, or leaves the emergency area of their own. The Bergen region has a difficult topography, a scattered settlement with many people living on islands and along fjords. Most islands are now connected with mainland with bridges which constitute a vital but exposed part of the infrastructure in extreme weather events. The smallest municipality in the Bergen region, Fedje, can only be reached by ferry and it takes about 1, 5-2 hours to get to Bergen city. Water supply is also regarded as important for adaptive capacity. Bergen city has a well-developed water infrastructure for supply of fresh water and waste water treatment but some of the smaller municipalities in the region have sometimes problems with water supply in dry periods due to low storage capacity and small ground water reservoirs.

Institutions

Well-functioning institutions are regarded as important for a regions adaptive capacity both for solving emergency situations and to plan for future climate changes. The government effectiveness is regarded as generally high in Norway both on local, regional and national level, and the governance structure is fairly transparent. However, the access of institutional resources varies of course a lot between the municipalities in the region. Bergen city has a parliamentary model of government with its own climate department which coordinate a great number of climate change adaptation measures and projects, whereas the smaller municipality in the region hardly have anyone who can take care of climate issues. Bergen is also strongly involved a several co-operation projects in the region, among others the city plays an active role in a regional climate panel and a climate forum which have representatives from both the public and the private sector.

Whether a country has national adaptation strategies is also assumed to affect adaptive capacity of a region. In Norway, the government has initiated several studies the past year and it recently presented a Green Paper on Climate Change Adaptation (NOU 2010). In this paper the role of the local level (municipalities) in climate change adaptation is emphasized but it is also underlined that both competence and capacity vary a lot between municipalities (Aaheim et al 2009, Harvold et al 2010). Bergen is in the forefront in climate change adaptation both on the local and at the regional level whereas some of the smaller municipalities in the region probably have a rather low adaptive capacity. This is clearly indicated in a recent study which show that climate plans are far more common in larger than in smaller Norwegian municipalities (Harvold and Risan 2010). All municipalities in Hordaland County have decided to work out a climate plan but only some have done it and have implemented it, see figure 2.20. Bergen has been pioneer in this work (www.enova.no).

Figure 2.20 *Adaptation – strategic plans implemented. Hordaland County*.

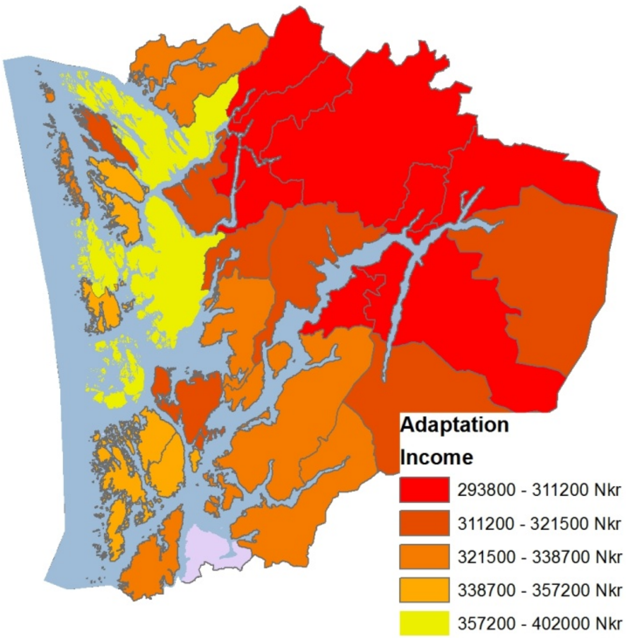


Economic resources

Economic assets are also regarded as important for adaptive capacity, and this could be measured by income per capita, state expenditure at regional level and by the age dependency ratio. Regional Account for 2007 shows that the counties with the larger cities have the highest GDP both per capita and per employed. Hordaland County in which Bergen is situated has index values above the national average. The household's disposable income per inhabitant is also above average in this county (Statistics Norway). Figure 2.21 which shows the average personal income also reveals that Bergen and a few surrounding municipalities are better off than the more remote areas in the county. This should strengthen the adaptive capacity of Bergen.

However, in Norway there is also a long tradition for state subsidies to regional development and innovation. For 2008, figures show that the main part of the subsidies is going to the Northern part which is the most peripheral part of the country. The average subsidy is 266 NOK per inhabitant but Finnmark, which is the most remote county, is receiving 1590 NOK (Johansen 2008). This is over 100 times more than Oslo receive (15 NOK), which the capital and also the richest county. This should imply a strengthening of capacity also in small and remote areas.

Figure 2.21 *Adaptation – average personal income in Hordaland County. Quintiles*.



A rising dependency ratio is also of great concern for many countries, and may affect the adaptive capacity of both countries and regions. The dependency ratio is defined as the number of persons under age 15 plus the number of persons aged 65 or older divided by the active population 15 to 64. The population is relatively young in and around the regional centres and along the coast of Southern and Western Norway, such as Bergen. The dependency rate for the County of Hordaland is 0, 34 but it varies from 0, 32 in Bergen city to 0, 42 on the smallest municipality, Fedje.

The age dependency rate (number of person over 65 divided by active population 15-64) varies more than the total dependency rate. For Bergen it is same as the average for the County 0, 14, but it differs from 0, 10 to 0, 23 between the municipalities in the region (Statistics Norway, population statistics, own calculations). Particularly some of the smallest and most remote municipalities have a high age dependency rate. From figure 2.22 we see that the social dependency rate (age) for Hordaland County is lowest in the coastal areas.

Unemployment may also have impact on adaptive capacity and figure 2.23 shows the average registered unemployed as percentage of the population 16-66 year. This figure includes more than the labour force but figures for the labour force this is not available at municipal level. The same is the case for long term unemployment which also would have been a relevant indicator.

Figure 2.22 *Adaptation – social dependency rate in Hordaland County. Quintiles*

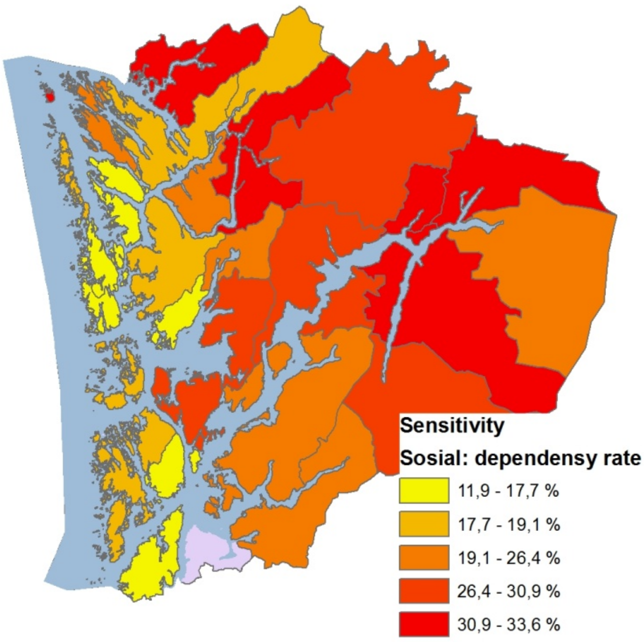
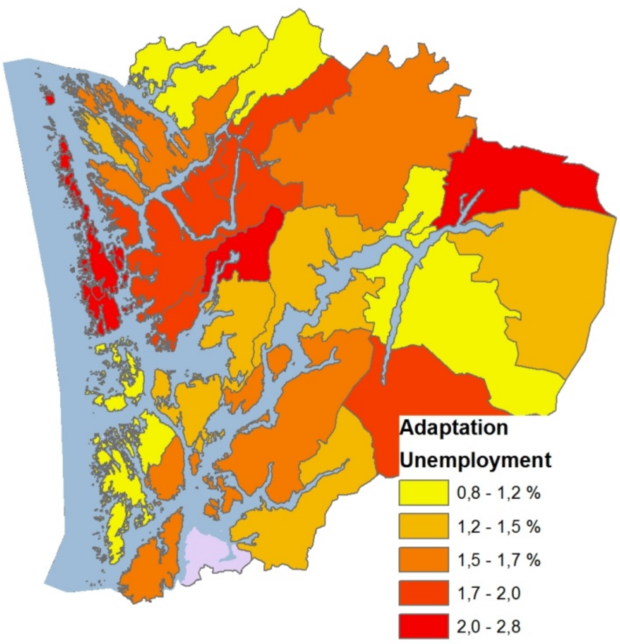


Figure 2.23 *Adaptation – registered unemployment related to inhabitants 16-66 years in Hordaland County. Quintiles.*



2.6 Vulnerability analysis

The vulnerability of a region is dependent of how exposed it is for climate change, how sensitive it is and of its adaptive capacity. High potential impacts (determined by exposure and sensitivity) increase vulnerability whereas high adaptive capacity may reduce impacts and thus the level of vulnerability.

As explained in section 2.4 the expected potential negative impacts for the Bergen region are related to flooding, sea level rise and increased precipitation which may endanger business activities, settlements, infrastructure and cultural heritages in areas prone to flooding and landslides. Projected sea level rise for instance indicate that measures had to be taken in the next decades in order to avoid severe negative impacts (see next section on a modified CBA for sea level rise in Bergen). The ability to do so, i.e. the adaptive capacity, cf. Section 2.5, indicates that Bergen has a relatively good basis for taking the necessary steps. The region has a well-educated population and good access to electronic media which should imply effective dissemination of knowledge on climate change, and thus high awareness. A city government with an active climate policy should also pull in the same direction.

2.7 A modified CBA for sea level rise in Bergen[1]

CBA – A general introduction

The purpose of Cost-benefit analysis (CBA) is to find the economically most efficient allocation of society's resources. All considerations are measured in monetary terms.

CBA can be used in project evaluation to find out whether the benefits of a project is larger than its costs, if this is the case, the project should be started. CBA can also be used to choose between projects, e.g. to find whether the net benefits of project z is larger than the net benefits of project y. If this is the case project z should be chosen.

Let us introduce some notations:

WTP = willingness to pay
C = costs
NWTP = net willingness to pay

A project is socially efficient if $\Sigma_j WTP_i – \Sigma_j C_i > 0$, aggregate willingness to pay for the project is larger than its total costs or equivalently: if $\Sigma_j (WTP_i – C_i) = \Sigma_j NWTP_i > 0$, the net benefits of the project is larger than zero.

CBA and decision-making

With respect to decision-making CBA can be used for two purposes. The first purpose is to make final ranking of projects. Then one must choose normative premises (choose Social Welfare Function) and all relevant concerns must be valued in monetary terms (to be counted).

[1] In chapter x a general introduction to be CBA is given.

The second purpose is less clear, but also more widespread. In this case CBA is used to provide factual input to a (democratic) debate between decision-makers with different normative views (in economics we would say different Social Welfare Functions). This looser way of using CBA requires that information improves decision-makers' (intuitive) understanding of effects. Valuation is in this way of use required only if it improves the understanding. As a rule of thumb one can say that the harder it is to value something in money, the harder it is to understand, intuitively, what that money value means.

CBA measures social welfare effects if either compensations are paid (then there will be no losers) and counting in money is straightforward, or the initial income distribution is optimal (according to some normative view,) then money is, from a social point of view, equally important for everyone. If neither holds: Aggregate willingness to pay does not measure welfare.

CBA measures costs and benefits in money; but *money* does not mean the same to all in terms of *utility*.

There are two main types of responses to climate change; adaptation and mitigation. In the following, we only consider adaptation. Sea level rise is relevant in the Bergen case. There are three main adaptation strategies in the coastal zone case:

Protect: aims to protect the land from sea so that existing land uses can continue, by constructing hard structures (e.g. seawalls) as well as using soft measures (e.g. beach nourishment) .
Accommodate: increases the ability to cope with the effects of the event. This strategy implies that people continue to occupy the land but make some adjustments (e.g. elevating buildings on piles, growing flood – or salt tolerant crops)
Retreat: reduces the risk of the event by limiting its potential effects. This strategy involves no attempt to protect the land from the sea. In an extreme case, the coastal area is abandoned.

Physical impacts in the coastal zone case are typically:

- Inundation, flood and storm damage
- Wetland loss (and change)
- Erosion (direct and indirect change)
- Saltwater intrusion
- Raising water tables and impeded drainage

Examples of the three adaptation strategies can be:

Protect: Dikes/surge barriers
Accommodate: Building codes / flood wise buildings
Retreat: Building setbacks

A CBA of adaptation has to be done in several steps:

Step 1: Indentify the problem (flooding, sea level rise)
Step 2: Vulnerability assessment

Step 3: Select adaptation measure/action
Step 4: Monetary valuation of all impacts (positive/negative)

The first two steps as we see no part of the CBA, the steps are used as inputs. E.g., the problem is sea level rise. In step 2 we need vulnerability assessments done by natural scientists. In step 3 we select an adaptation measure, like building outer barriers. In the next section, we consider step 4, monetary valuation.

CBA and monetary valuation
Monetary valuation can be done by direct methods like surveys and by indirect methods, as we will return to later. Valuation of benefits are often more difficult to measure than valuation of costs. This can lead to underestimation of net benefits. Benefits of environmental goods are often especially difficult to measure. We also can have an intergenerational conflict. If we want to compare benefits and costs occurring at different time scales *discounting* is needed to express future costs or benefits at today's equivalent value.

Each cash inflow/outflow is discounted back to its present value (PV). Then they are summed. Therefore NPV (Net Present Value) is the sum of all terms,

$$\frac{R_t}{(1+i)^t}$$

Where:

t - the time of the cash flow
i - the discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.)
R_t - the net cash flow (the amount of cash, inflow minus outflow) at time *t.* For educational purposes, R_0 is commonly placed to the left of the sum to emphasize its role as (minus) the investment.

If we use an infinite time horizon, net present value is given by the following equation.

$$NPV = -R_0 + (R_t / i)$$

The valuations can be done by:

Direct methods: Surveys, voting
Indirect methods: Use of market prices/revealed preferences

The Bergen Case - Background
The municipality of Bergen has already analysed some possible adaptation measures. The adaptation measures range from drastic protection of the whole metropolitan area by building outer barriers to a simple sheltering of limited areas.

The costs of the adaptation measures have also been estimated, but the estimates contain only investment costs, not maintenance costs. The cost of building outer barriers are estimated 30 billion Norwegian Crones. The costs of building three inner barriers are estimated to be slightly more than 1 billion Norwegian crones. The spunt solution for the flood prone area of Bryggen is estimated to cost less than 50 million Norwegian Crones. The cost estimates are based upon the assumption that the adaptation measures will be carried out today.

No benefit assessments have been done in monetary terms. But, some qualitative assessments has been done like “the benefits are estimated to be small” or “the benefits are of great importance”.

The benefits of adaptation measures are the reduced damages caused by the measure.
The aggregated costs of extreme natural events in the area can to some degree be measured by the expenses of the Norwegian Natural Damage Fund. However, the fund does not cover “normal” damages. Benefits can be measured as the reduction of property values caused by flooding or the insurance value of the building, but it is unclear if the risk of storm surges has been taken to account in the sale prices/insurance values of the buildings today. Cultural heritage is an important benefit that is even more difficult to measure in monetary terms. A problem of assessing costs of infrastructure is that some infrastructure will be replaced irrespective of any climate change. Normal maintenance and improvement of infrastructure belongs to this category.

A modified CBA – example sea level rise

The problem in focus here is sea level rise.

The adaptation measures we consider are outer barriers and inner barriers. Our approach can be regarded as a modified CBA.

There is no need for adaptation measures in the nearest future. The vulnerability assessment is based upon hazard rates in different scenarios and carried out by natural scientists. Figure 2.12 show sea level rise by different levels of yearly increase.

Figure 2.24 *Sea level rise by constant yearly increase*

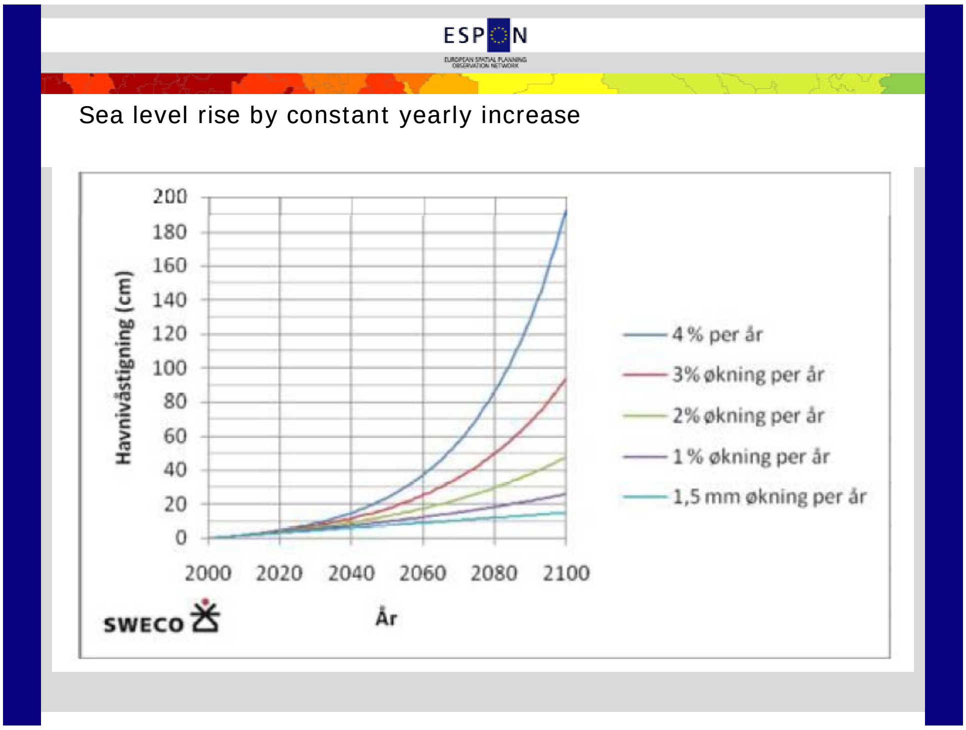


Table 2.5 *Sea level rise and year of measurement*

Sea level rise per year	Year adaptation measures has to be carried out	Sea level rise year 2100
As today		
1 %	**2100**	**15 cm**
2 %	**2075**	**48 cm**
2,70 %	2065	75 cm
3 %	**2060**	**94 cm**
4 %	**2050**	**193 cm**

Table 2.5 shows when it is necessary to carry out adaptation measures according to these estimates by different assumptions of sea level rise.
The investment costs of building outer barriers are estimated 30 billion Norwegian Crones. To do even a modified CBA, one has to make assumptions. Of course, all assumptions we make are very uncertain.

To measure net benefits, we use an indirect method, the costs of avoided damages. We had access to data on the expenses of the Norwegian Natural Damage Fund in the period 1994-2010. The reason for using these data is lack of other data sources.

First, we assume a 2.7 per cent sea level rise per year. It will then be necessary to build outer barriers in 2065. If we assume 2.5 per cent inflation per year, the investment costs will be 117 billion Norwegian Crones in 2065. The yearly expenses of the Norwegian Natural Damage Fund in the municipalities in the Bergen area were 1.2 Million crones in the period 1994-2010. In 2065, this value will be 4.66 Millions. If we assume that these costs will be doubled if the sea level rises by 75 cm, the costs will then be 9.33 million Norwegian Crones per year. However, these costs are just a fraction of the avoided damages caused by the barriers. If we assume that the fraction covered by the Norwegian Natural Damage Fund is 0.5, half of the costs, the costs will be 18.66 Million per year.

We assume an infinite time horizon of the investment for simplicity reasons. There have been a lot of discussions of the social discount rate in CBAs of climate change. The discount rates vary from zero to just above 3 per cent. Some argue that the only reason for discounting future generations is that these generations might cease to exist in the future. The Stern Review on the Economics of Climate Change is one such report that argues for zero discounting of future generations.[2] If we use a discount rate of 2 per cent, the present value of the net benefits will be 933 Million Norwegians Crones per year.[3] This is far below the investment costs and the project should not be carried out. In formula terms:

$$NPV = -117000 millions + (18{,}66 millions / 0{,}02)$$

If we assume a 4 per cent sea level rise per year, the worst case scenario, it will then be necessary to built outer barriers in 2050. If we assume 2.5 per cent inflation per year, the investment costs will be 71 billion Norwegian Crones in 2050. In 2050, the yearly expenses due to natural damages will be 2.84 Millions.[4] If we assume that these costs will be ten times as high, if the sea level rises by 193 cm, the costs will then be 28.4 million Norwegian Crones per year. However, these costs are just a fraction of the avoided damages caused by the barriers. If we, as in the first case, assume that the fraction covered by the Norwegian Natural Damage Fund is 0.5, half of the costs, the costs will be 56.8 Million per year. If we use a discount rate of 2 per cent, the present value of the net benefits will be 2840 Millions Norwegians Crones per year.[5] In formula terms:

$$NPV = -71000 millions + (56{,}8 millions / 0{,}02)$$

This is also far below the investment costs. The conclusion remains, the project of building outer barriers should not be carried out.

The costs of building three inner barriers are estimated to be slightly more than 1 billion Norwegian crones.

If we assume a 2.7 per cent sea level rise per year it will then be necessary to built barriers in 2065. If we assume 2.5 per cent inflation per year, the investment costs will be 3.88 billion Norwegian Crones in 2065. The yearly expenses of the Norwegian Natural Damage Fund in Bergen municipality[6] area was 0.136 Million crones in the period 1994-2010. In 2065, this value will be 0.53 Millions. If we assume that these costs will be doubled if the sea level rises by 75 cm, the costs will then be 1.06 million Norwegian Crones per year. If we assume that the fraction covered by the Norwegian Natural Damage Fund is 0.5, the costs will be 2.12 Million per year. If we

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[2] The Stern Review considered mitigation.

[3] 18, 66 millions divided by 0, 02.

[4] The yearly expenses of the Norwegian Natural Damage Fund in the municipalities in the Bergen area were 1.2 Million crones in the period 1994-2010.

[5] 56, 8 millions divided by 0, 02.

[6] The inner barriers benefits only Bergen, not the whole Bergen area.

assume an infinite time horizon of the investment and use a discount rate of 2 per cent, the present value of the benefits will be 106 Millions Norwegians Crones per year. [7]

$$NPV = -3880 millions + (2{,}12 millions / 0{,}02)$$

This is also far below the Investment costs. The conclusion remains, the project of building inner barriers should not be carried out.

If we assume a 4 per cent sea level rise per year, the worst case scenario, it will then be necessary to built outer barriers in 2050. If we assume 2.5 per cent inflation per year, the investment costs will be 2.37 billion Norwegian Crones in 2050. In 2050, the yearly expenses due to natural damages will be 0.32 Millions.[8] If we assume that these costs will be ten times as high, if the sea level rises by 193 cm, the costs will then be 3.2 million Norwegian Crones per year. If we assume that the fraction covered by the Norwegian Natural Damage Fund is 0.5, the costs will be 6.8 Million per year. If we use a discount rate of 2 per cent, the present value of the benefits will be 340 Millions Norwegians Crones per year.[9]

$$NPV = -2370 millions + (6{,}8 millions / 0{,}02)$$

This is also far below the investment costs. The conclusion remains the same, the project of building inner barriers should not be carried out.

However, as said, our assumptions may underestimate the benefits due to avoided damages.

The spunt solution for the flood prone area of Bryggen is estimated to cost less than 50 million Norwegian Crones, but here we lack any data of the benefits. A CBA is therefore impossible to carry out. The most important damages in the case of Bryggen are due to building structure. We are not sure that all this is captured in the insurance value (and insurance values are not available). The cultural heritage of Bryggen is also of value not only to Bergen, but for the whole country, and the world. In addition to the damage costs of the building structure we might also have some opportunity costs due to reduced tourism if the buildings are damaged.
The most important lesson learned from this exercise, and which all examples clearly illustrate, is that it is very difficult to carry out even a modified CBA in the Bergen case.

3 Strategies and policy development

Bergen is involved in several climate change projects and the city co-operates closely with numerous research institutions and universities. The city has implemented a lot of adaptation measurements, and it is developing new plans for future measurements. This section gives a brief overview of mitigation and adaptation measures taken on local/regional level in order to see what plans have

[7] 2, 12 millions divided by 0, 02.

[8] The yearly expenses of the Norwegian Natural Damage Fund in the Bergen municipality was 0.136 Million crones in the period 1994-2010.

[9] 6, 8 millions divided by 0, 02.

been adapted and what actions have been taken. First it presents some of the main climate related plans, then it gives an overview of risk- and vulnerability analyses, thirdly, participation in network and organisations is described, and finally it outline the city's involvement in different projects.

Climate plans

Bergen was the first municipality in Norway to work out a climate plan in year 2000, and the plan has been furtherer developed several times since then (www.bergen.kommune.no/). In 2008 the city established a climate department which coordinates the work with climate, environment and energy. The City of Bergen was also the first municipality in Norway with a comprehensive watercourse plan. In 2007 environment and energy were implemented in the land use part of the municipality master plan. Reduction in greenhouse gas and use of energy is thereby included in the land use and transport policy of the municipality. Bergen has also been active in working out the new climate plan for Hordaland County (www.hordaland.no) which was decided upon in 2010. This is a regional plan for 2010-2020 and it is founded on the national Planning and Building Act. The plan focuses on emission of greenhouse gases, energy and adaptation to climate change and is accompanied by its own action program.

Risk- and vulnerability analyses

The City of Bergen has conducted risk and vulnerability analyses on several areas. Analyses has been focusing on the risk of floods, powerful winds, high tides, large waves, extreme precipitation and earth and rock slides in Bergen as a result of climate change. This knowledge is employed to reduce the potential consequences of accidents and disasters, and it also plays an important role in urban planning and in the processing of building applications.

Networking

Bergen participates in several national and international networks on climate change adaptation policy. At the local and regional level there is a *Regional Climate Panel* consisting of representatives from the City of Bergen, the regional council and Business Region Bergen. The regional climate panel is the driving force behind the region's climate adaptation work, and address issues such as regional climate work, transport analyses, and climate challenges that represent a potential for new commercial development. Bergen also participates in *The Climate Forum* which is a meeting place for players from the business community, authorities, organisations and research institutions. The aim of the forum is to increase dissemination of knowledge on climate change and adaptation policies in Bergen and Western Norway by building bridges between the research community, the business community and society at large. On the national level Bergen is part of the program *Cities of the Future* (www.regjeringen.no/en/sub/framtidensbyer/cities-of-the-future.html?id=548028) which is a co-operation between 13 Norwegian cities and the Government. The aims of the program are to develop urban areas with lowest possible greenhouse emissions and make the cities better places to live. The program focuses on four areas - land use and transport, consumption and waste, energy and buildings, and climate change adaptation. Bergen also participates in several international climate networks. The city is member of *European Climate Forum* (EFC), it has signed *The Covenant of Mayors*, an initiative of the European Commission for cities to reduce their carbon dioxide emissions, it is member of organisation *United Cities and Local Governments* (UCLG) aiming at reducing greenhouse gas emissions, and part of the *International Council of Local Environmental Initiatives* (ICLEI), which works for a sustainable development and the environment.

Participation in projects

In order to acquire knowledge on climate change and possible adaptation measures, Bergen city participate in numerous national and international research projects and municipality-led projects on climate change adaptation. The city is associated partner in *Espon Climate* and in the Interreg project *BaltCICA* (www.baltcica.org) which focuses on climate change adaptation the Baltcic Sea region. It is also partner in the Interreg project *MARE* (www.mare-project.eu/) which focuses on implementation of local adaptation measures to reduce and adapt to flood risk in the North Sea region. Bergen is also case in the large EU-project Techneau (www.techneau.org) focusing on technology solutions for drinking water supply. At the national level the city participates amongst others in *NORADAPT* (www.cicero.uio.no). This project maps the vulnerability of climate change in 8 Norwegian municipalities and seeks to work out individual adaptation strategies. Bergen also collaborates with Stavanger and Kristiansand on the energy solutions of the future through the *EnergiMiljø i Sørvest* project. These cities wish to take the lead in developing sustainable and environmentally efficient transport solutions and forward-looking use of energy. In addition to the research projects, Bergen carries out several local projects focusing on infrastructure, water supply, wastewater management and natural watercourses. The city also has a particular school projects related to waterway management, and a project focusing on climate change and human rights.

4 Conclusion

This section concludes the case study by looking into future aspects specific for the Bergen case, and by discussing the validity of European-wide analyses from a regional perspective and the possible transferability of results to other regions.

Problems already affecting the city and which are highlighted in adaptation strategies are related to flooding by river and precipitation, and to landslide. Measures have already been taken to prevent future incidents and to adapt to current events. Problems affecting the city in the near future, i.e. in a climate perspective in this century, are related to sea level rise and extreme weather. These problems are strongly focused upon in several projects and networks in which Bergen are partner or responsible for. Adaptation measures related to these problems are in pipeline, for instance development of Risk Management Plans and Standards for building new infrastructure.

With regard to the validity of European-wide analyses from a regional perspective and the possible transferability of results to other regions it is always a question of what is transferable. It could be either knowledge of specific adaptation measures or of adaptation processes. Specific measurements towards sea level rise can for instance be relevant for coastal cities in several regions. Bergen can for instance learn from Hamburg and Amsterdam, and vice versa. However, knowledge of processes and tools used in adaptation policies can also be useful for other regions regardless of what measures that have been taken. Steps taken to ease the adaptation processes, good regional governance and successful ways of involving relevant stakeholders, can also be part of a learning process between regions although the specific adaptation measures may be different.

5 Literature

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