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ESPON CLIMATE - Climate Change and Territorial Effects on Regions and Local Economies

Applied Research Project 2013/1/4

Revised Interim Report

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This report presents a more detailed overview of the analytical approach to be applied by the project. This Applied Research Project is conducted within the framework of the ESPON 2013 Programme, partly financed by the European Regional Development Fund.

The partnership behind the ESPON Programme consists of the EU Commission and the Member States of the EU27, plus Iceland, Liechtenstein, Norway and Switzerland. Each partner is represented in the ESPON Monitoring Committee.

This report does not necessarily reflect the opinion of the members of the Monitoring Committee.

Information on the ESPON Programme and projects can be found on www.espon.eu

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This basic report exists only in an electronic version.

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1. Introduction

The study of climate change is highly interdisciplinary. It involves scientific fields like climatology, meteorology, oceanography, solar physics, biology and geology – just for assessing climatic effects. Estimating impacts on societies calls in addition for different disciplines of social sciences. The foci and research methodologies of these fields differ significantly, yielding diverse and sometimes contradictory results. Even within each discipline there are research groups that have developed and employed competing methodologies for ever smaller aspects of the overall phenomenon of climate change. Therefore, specialisation and diversity are hallmarks of the international study on climate change.

This scientific diversity is a challenge but also necessary for advancing knowledge on climate change. Climate change is such a complex phenomenon that it can not be explored by one scientific field alone. However, diversity and specialisation also pose serious problems for understanding climate change and its impacts. Each field and each research group use different concepts, assumptions and methodologies which may not be compatible with each other. This constrains putting all the pieces of scientific evidence together and looking at the overall results and trends of climate change - which is a serious handicap especially vis-a-vis politicians and the general public. It is partly because of the sectoral specialisation that it took so long to establish an institution like the International Panel on Climate Change as an international and interdisciplinary body of scientists dealing with climate change.

Studies on the impacts of climate change have been equally specialised. Some studies deal with impacts on different types of regions, e.g. costal areas, islands, river basins or cities. Actually, it is more common to find studies focusing on impacts on particular countries, regions or cities which are, however internally still sectoral oriented which means that they aim to measure the effects of climate change on different economic sectors, e.g. agriculture, forestry or different types of tourism for a certain area. For this the studies needed to develop tailor-made methodologies that would allow them to capture and analyse the respective sectoral or region-specific effects: For example, the methodology of a study on the impacts of climate change on arctic regions in northern Finland needs to address different issues and mechanisms compared to a study on the Algarve in southern Portugal. Specialised research is sensible and necessary but the findings of specialised studies are not easily transferable between regions or sectors. Findings may not even be comparable due to methodological differences.

This is particularly troublesome in an international policy context like the European Union, when it needs to be determined, for example, how much support Northern Finland vis-a-vis the Algarve may require to cope with or prepare for climate change impacts. Thus one must go beyond mere local, regional, national and sectoral analyses and adopt a territorially comprehensive and thematically integrated approach – not as a substitute, but as a complement to specialised studies which are somehow still part of the ESPON climate project since it aims to assess the sensitivity of economic sectors as the project is asked to respond to question like "How and to which degree are the different sectors of regional and local economies as well as regional and local infrastructures going to be affected by climate change?"

The comprehensive approach has to be seen as a prerequisite for territorially differentiated response strategies, the Territorial Agenda proclaimed: "Further work is required to develop and intensify territorial cohesion policy, particularly with respect to the consequences of territorially differentiated adaptation strategies" (Priority 5, topic 23).

The dimension oriented understanding of sensitivity addresses social and economic cohesion as well and is line with the broadly accepted understanding of sustainable development which has a social, an economic and an environmental dimension.

Moreover, an integrated mainly territorially oriented sensitivity assessment seems indispensable for answering other main research questions raised by the tender and interpreted as hypothesis for further investigations, such as:

- Different types of European regions are differently vulnerable to climate change
- Different types of European regions need different, tailor-made mitigation and adaptation measures to cope with climate change
- There are potentially new development opportunities for European regions in the wake of climate change
- Different types of European regions are characterised by different territorial potentials for the mitigation of climate change
- There are new types of regions emerging, revealing the same characteristics regarding both, their adaptation and mitigation capacities

For that purpose, a new typology of regions has to be developed, characterised by similarities regarding climatic stimuli and their sensitivity.

When looking at key literature, existing studies have not focused on such a comprehensive methodological approach so far.[1] Furthermore, these other studies lacked of a clear territorial European wide focus which makes this approach sensible and somehow indispensable, too.[2]

However, there are several methodological challenges such as availability of indicators for dimensions like cultural and institutional, but also weighting problems when integrating the different dimensions to an index. As research is not legitimised to put weight to factors which are mainly determined by political values, this weighting will be based on a survey asking a couple of stakeholders among Europe for their opinion (see Chapter 7).

The impacts of climate change will often be specific to individual economic sectors or regions, making some sectors and regions more vulnerable than others. A wide range of economic effects will result from climate change in Europe: They include impact associated with the natural environment (including forest and fisheries), coastal zones, agriculture, tourism, energy, human health and the built environment. However, key economic sectors that will be particularly sensitive to climate change impacts include: energy supply; agriculture, forestry and fisheries; tourism; and transport infrastructure and water supply. The results of this assessment will be displayed in

[1] See e.g. the German or Finnish climate change vulnerability/adaptation assessments (but also other national studies) which focus on certain sectors without taking an integrative perspective (Zebisch et al. 2005; Carter 2007). Further, the EEA report on an indicator-based assessment looks at sectors and thus cannot provide an integrated (regional) view (EEA 2008). Other studies like the Stern Review focus only on a limited group of sectors (Stern 2006).

[2] See e.g. the adaptation strategy for North Rhine Westphalia (Kropp et al. 2009) which provides – apart from the sectoral analysis – an integrated (sub-regional) view. So do other climate change impact and adaptation studies; however, they cover a regional perspective and are not able to give an overall European perspective. Due to different methodological approaches in the regional studies these cannot be compiled to an EU-wide assessment; thus, a new European-wide integrated approach is needed.

sectoral economic sensitivity maps, which are important outputs in their own right. In the end, however, the detailed results of actions 2.2 and 2.3 will be aggregated and provide high-level indicators for the overall economic sensitivity being part of comprehensive sensitivity assessment of action 2.1

The conceptual core of the ESPON Climate Change project is depicted in Figure 1:

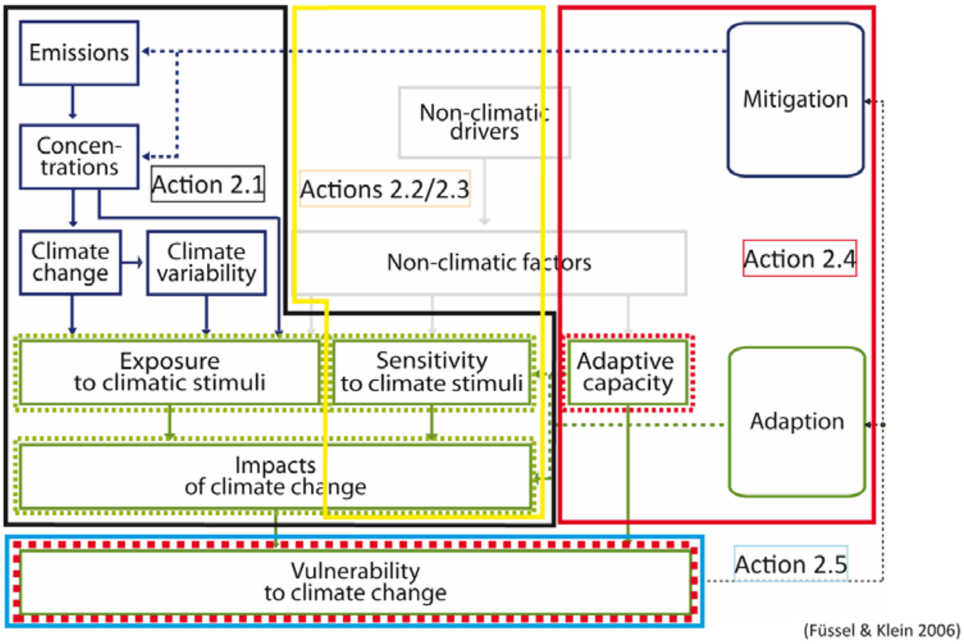

Figure 1: ESPON Climate Change research framework

(adapted from Füssel & Klein, 2002, p. 54)

The following Figure 2 describes the work on the application of this methodological core more in detail. It indicates which steps will be finalised for the interim report.

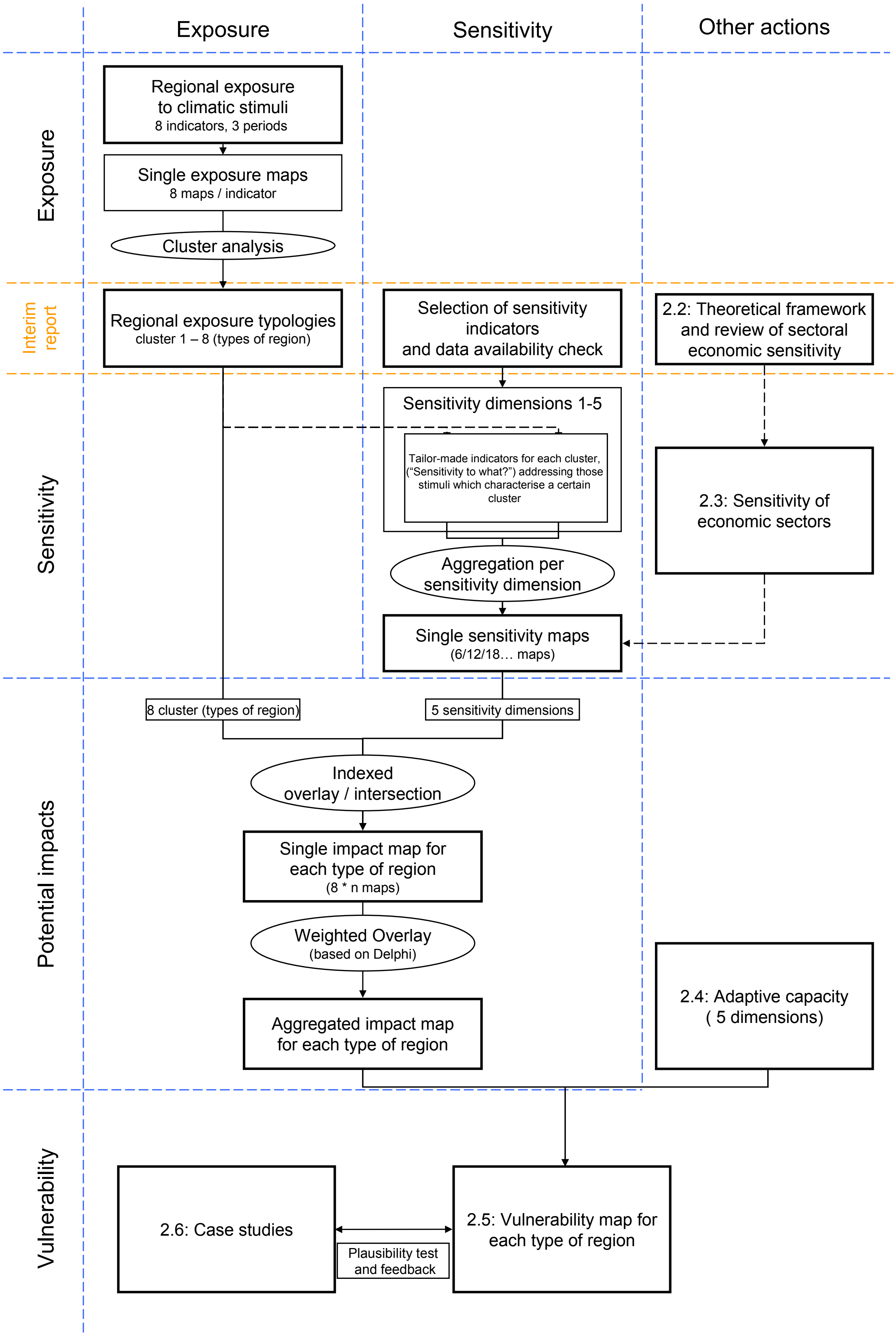

Figure 2: Methodology step-by-step

In the following the various parts and analytical steps that are based on the methodology shall be explained more in detail.

The analysis of exposure to climate stimuli (see for a more detailed discussion chapter 2) made use of existing projections on climate change and climate variability from the CCLM model. These climate data (which come in a spatial resolution of 20x20 km) have then be recalculated and transposed to relate to the NUTS 3 regions of the 27 EU Member States as well as Liechtenstein, Norway and Switzerland, Turkey, Western Balkans and finally Russia and Ukraine. These regionalised climate data haven then been categorised according to their magnitude of change for the respective region. This finally yielded the regional exposure to climatic stimuli. This regional exposure is depicted in various maps, addressing each stimulus separately.

A cluster analysis was performed in order to identify climate change exposure regions, i.e. regions that are affected in a similar way to climate change. Thus each of these types of regions has a distinct profile of relevant climate stimuli changes. This typology becomes the foundation for the subsequent analytical procedures. Thus, a unique approach is chosen for the ESPON Climate project that differs from the existing approaches.

However, the present results coming out of the cluster analysis only offer a typology of climatic changes and are not linked to given territorial characteristics. Therefore, an additional cluster analysis will be undertaken for the reference period (1960-1991), addressing the characteristics of the recent climate. The results will be overlaid with the typology of climatic changes (done for the period 2071-2100). In doing so, shifts of climatic zones can be identified.

In addition to the region's exposure to climate stimuli, their sensitivity to climate stimuli are determined, based on selected sensitivity indicators (see chapter 3). While not discounting the merits of such an approach (which is the foundation for all subsequent research), the ESPON Climate project is not operating primarily at the level of individual indicators, but at a more aggregated level of sensitivity dimensions, which will then allow further aggregation and an integrated comparison of all ESPON regions. Therefore, the sensitivity indicators will be aggregated at the level of the five sensitivity dimensions (physical, social, economic, environmental, cultural) for each exposure cluster, thus taking into account that for some exposure clusters certain sensitivity indicators may not be applicable.

Special attention is paid to the sensitivity of the different economic sectors, directly or indirectly affected by climate change (see chapter 4) and relevant methodological concepts for assessing costs and benefits which are related with climate change impacts and possible adaptation strategies (see chapter 5).

In a next step the five sensitivity dimensions are overlaid to yield one overall sensitivity variable. The necessary weighting of the sensitivity dimensions will be performed by use of the Delphi method (see chapter 7). This method pools the assessments/opinions of a group of persons, e.g. experts, in a serious of questionnaire surveys with feedback loops (see main part of the Interim Report for details).

On this basis exposure and sensitivity are finally combined to explore the impacts of climate change. For this the sensitivity dimensions have already been aggregated as described above. The necessary 'weighting' of the various exposure variables will differ according to the exposure clusters, i.e. the different weights that were identified for each exposure variable by the cluster analysis will also be used as the weights for the exposure aggregation and eventual intersection with climate change sensitivity.

Eventually the exposure and sensitivity scores will be juxtaposed in a matrix that will yield various impact categories. Accordingly, a high impact can be the result of either a high exposure or a high sensitivity to a particular climatic stimulus.

A third major component of the project's research design is the adaptive capacity in regard to climate change, i.e. the economic, socio-cultural, institutional and technological ability of a region to adapt to the impacts of a changing regional climate (see chapter 6). High adaptive capacity counterbalances sensitivity, thus reducing vulnerability. Indicators for the various aspects of adaptive capacity will be assessed and combined in a similar procedure as for climate change sensitivity. A combined adaptive capacity measure is developed, as a generic determinant for each region. Since the capacity for policy development and implementation are crucial determinants of adaptive capacity, a policy review feeds into the development of adaptive capacity indicators.

Mitigation is also highly relevant for territorial development and cohesion since climate policy implementation and the transition to a low-carbon society will have differential effects on sectors and regions. However, mitigation mainly has effects on greenhouse gas emissions and concentrations and thus contributes to a reduction of climate change. Mitigation policies are fed by research on climate change as well as anticipated and observed vulnerability to climate change. Mitigation and adaptation are two options a society can choose in order to deal with the challenge of climate change. However, only adaptation has direct regional effects, while mitigation measures – even implemented at the regional level - will not have significant effects on regional climate but only contribute to an overall reduction of global climate change. Since the ESPON Climate Change project is about differentiating territorial effects, the focus of the project will therefore be primarily on adaptation while mitigation is not integrated into the vulnerability assessment. The results of the mitigation policy analysis will later be juxtaposed with the results of the vulnerability assessment and lead to differentiated policy recommendations.

Finally, climate change impacts and adaptive capacity can be combined to determine the overall vulnerability to climate change. Hence a region with a high climate change impact may still be moderately vulnerable if it is well adapted to the anticipated climate changes. On the other hand, anticipated high impacts would result in high vulnerability to climate change if combined with low regional adaptive capacities. For integrating climate change impacts and adaptive capacity the Delphi method will be employed again.

The climate change vulnerability typology map will be overlaid with regional typologies of other ESPON projects (e.g. urban/rural, FUAs, MEGAs etc.) A factor analysis is foreseen for integrating indicators of these ESPON projects to identify new types of climate change regions with similar characteristics. This will be linked back to the NUTS 3 level to identify which regions correspond to which type of region. Finally the spatial and political distribution of these various regional classes will be explored and mapped.

Finally, a number of case studies are being conducted within the ESPON Climate project. Their aims are to shed light on local or regional specificities in regard to climate change but also to provide a cross-case analysis that will produce valuable input for the analysis at the European level. The case studies will, thus, allow for assessing the general appropriateness and feasibility of the selected pan-European indicators and lead to a better understanding of different impacts on regions against the background of European diversity (culture, systems etc.). Particular emphasis is being placed on institutional aspects of current and future climate change responses, which can best be captured by the case study approach.

In order to ensure compatibility with the pan-European analyses of the other research actions of the project and to enable comparisons across the case studies, a common methodological framework has been agreed that is being followed throughout the case studies. In addition to this common framework each case study will explore in greater detail certain dimensions of exposure, sensitivity and adaptation to climate change that are of particular relevance for the respective case study area.

2. Exposure to climate change stimuli

Exposure to climatic stimuli represents the nature and degree to which a system is exposed to climatic variations. The exposure of a system to climatic stimuli depends on the level of global climate change and, due to spatial heterogeneity of anthropogenic climate change, on the system's location (cp. Füssel and Klein 2006, p. 313). Thus, exposure to climatic stimuli is directly influenced by general trends in climate change as well as climate variability (variations on various spatiotemporal scales) and also concentrations of greenhouse gases. Non-climatic factors also influence exposure as well. In other words, exposure refers to the geographical representation of the effects of climate change, climate variability and greenhouse gas concentrations and non-climatic factors. Taken together with sensitivity3 to climate change as well as adaptive capacity, exposure becomes a component of impacts of climate change (potential as well as residual).

Within the current research framework climatic stimuli and the resulting exposure to climatic stimuli are understood to result from climate change and climate variability as well as from direct impacts of concentrations of greenhouse gases. Thus it is necessary to gain evidence on the spatiotemporal distribution and variability of projected developments. For the ESPON climate project these projections are based on the Intergovernmental Panel on Climate Change (IPCC) scenarios published in 2000 (IPCC 2000) and employed within the fourth IPCC assessment report in 2007. Based on these scenarios the CCLM model has been run simulating future climate change for almost the whole European territory. Besides CCLM also other model projections have been published within the past years. Thus in the subsequent chapters, the IPCC scenarios and the CCLM projections as well as other model projections will be elaborated with the overall aim to provide an overview on the issue of exposure to climate stimuli which is of central importance within the research framework of the ESPON Climate project. Subsequently, the results from the analysis of different climatic parameters derived from CCLM data will be presented followed by an analysis on the regional distribution for the European territory.

2.1 Future Climate projections: The CCLM model

The impacts of climate change will be analysed based on the latest outputs of the COSMO-CLM (or CCLM) model, a non-hydrostatic unified weather forecast and regional climate model developed by the COnsortium for SMall scale MOdelling (COSMO) and the Climate Limited-area Modelling Community (CLM). The model CCLM was selected due to its fine spatial resolution (~20km), an extended and transient simulations period until 2100, spatial coverage of Europe, and its state-of the art climate module, its availability and large output of climate variables. In contrast to the ENSEMBLES[4] database of regional models, CCLM provides aggregated information on variables representing extremes events such as days with heavy rainfall, frost days, summer days and days with snow cover, which are of particular importance within the case studies of this project (see Table 1). Moreover, at the starting time of this project, the simulation runs of CCLM were the most up to date (December 2008), whereas the in the ENSEMBLES database of regional models older versions of climate models are available.

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[3] „The distinction between changes in sensitivity and changes in exposure is not always straightforward for processes that affect the extent or spatial structure of the exposure unit. Consider the vulnerability to flooding of a country that experiences significant internal migration from the highlands into the flood plains. This migration changes the exposure of certain population groups to flooding events. Aggregated to the country level, however, the effects of migration represent changes in the sensitivity of the population to flooding events" (Füssel and Klein 2006, p. 317).
[4] van der Linden P., and J.F.B. Mitchell (eds.) 2009: ENSEMBLES: Climate Change and its Impacts: Summary of research and results from the ENSEMBLES project. Met Office Hadley Centre, 160pp.)

We are aware of the shortcomings associated with the use of a single climate model, which will be communicated together with the results. However, projections of the CCLM model will be compared to other models within the case-studies. Further projects should aim at comparing the European wide results of this project applying a larger range of global and regional climate models and scenarios.

To produce future climate projections this model leans on the emission scenarios as defined by the Intergovernmental Panel on Climate Change (IPCC) in its 2000 report on emissions scenarios (IPCC 2000). Here, IPCC has presented six scenarios on the development of greenhouse gas emissions (GHG) from 2000 to 2100 (SRES scenarios). These scenarios presume the absence of additional climate policies which may affect GHG emissions. These scenarios cover a wide range of GHG emission drivers in the fields of demography, economy and technology. Divided into four scenario families (A1, A2, B1, B2) they explore alternative development pathways with respect to the evolution of future GHG emissions[5] (see Figure 3).

The A1 scenario presumes "business as usual", i.e. a continuous increase of human CO_2 emissions. It based on

- a global population that reaches 9 billion in 2050 and then gradually declines, the quick spread of new and efficient technologies.
- a convergent world - income and way of life converge between regions.
- extensive social and cultural interactions worldwide.

There are subsets to the A1 scenario family based on their technological emphasis: The chosen A1B subset bases on a balanced use of all energy sources.

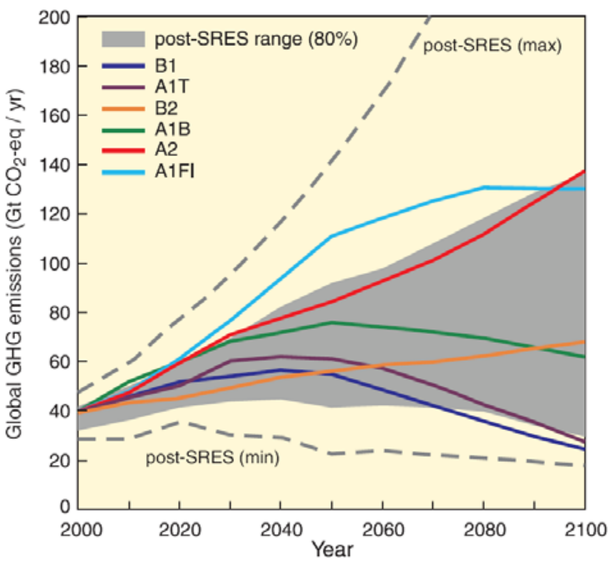

Figure 3: IPCC scenarios of global greenhouse-gas (GHG) emissions until 2100 (source: IPCC 2007, p. 44)

[5] "The A1 storyline assumes a world of very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies. A1 is divided into three groups that describe alternative directions of technological change: fossil intensive (A1FI), non-fossil energy resources (A1T) and a balance across all sources (A1B). B1 describes a convergent world, with the same global population as A1, but with more rapid changes in economic structures toward a service and information economy. B2 describes a world with intermediate population and economic growth, emphasising local solutions to economic, social, and environmental sustainability. A2 describes a very heterogeneous world with high population growth, slow economic development and slow technological change" (IPCC 2007, p. 44).

Since their release these scenarios have been the basis for different studies on climate change and climate change projections. In 2007 the IPCC scenarios have been adopted for running the CCLM climate model. Based on the scenarios A1B and B1 several model runs for the past decades as well as for the coming years until 2100 have been conducted. Exposure to climate stimuli will be analysed based on the latest outputs of the CCLM model.

2.2 Indicators on exposure to climate stimuli

The CCLM model has been adopted for climate change runs with three realisations for the time period 1961-1990 and two realisations for each scenario for the time frame 2001 – 2100 based on two of the IPCC climate scenarios (A1B and B1). Generally, regional models can be assumed to be more accurate with respect to the spatial reference of model projections not least since they usually offer higher spatial resolution outputs. In order for regional models to operate they are normally 'driven' by global models. The results presented here have been conducted in conjunction with the globally coupled atmosphere ocean model ECHAM5/MPI-OM. For European-wide data the spatial resolution available is approximately 18 km. Based on these model projections different climate-change indicators have been calculated constituting the basis for the current analysis of exposure to climate stimuli.[6, 7]

In principle, the CCLM model delivers a wide range of climate-related output parameters (cp. Wunram 2007). These parameters relate to many different fields relevant within meteorology and climate research. For almost all output parameters, data is provided on an hourly to daily basis. Thus, for the purpose of this research, selected parameters have originally been aggregated by PIK for the time frames 1961-1990, 2011-2040, 2041-2070, 2071-2100 for both scenarios (A1B and B1) in order to attain mean values exhibiting projected mean changes for the European territory (see Figure 3 as an example).

Scenario B 1 is not realistic anymore as annual growth rate of global emissions after 2000 has been about 3%, while growth rates under the emissions scenarios is between 1.4% and 3.4% (see e.g. the Global Carbon Project's latest results in Quere et al. 2009). Consequently, the subsequent work will be based on scenario A1B only.

The focus on central climate parameters is crucial since the CCLM model delivers a broad range of parameters (also varying by datastream) which is hardly useful for applied research outside the meteorological domain. A larger range of output data is available for datastream 3 of the model, compared to datastream 2. This includes aggregated data on "extreme" events, such as days with heavy rainfall, summer days or frost days. To represent these events within the study, climate information from datastream 3 was used covering a large area of Europe, but excluding counties like Iceland (see Figure 3) which are part of the ESPON space.

[6] Besides the CCLM model outputs a range of other projections exists for the area of Europe which originate from both global climate models as well as regional climate models. For a more detailed elaboration see Annex 2.

[7] The relevant climate parameters frequently discussed in reports with respect to future climate change impacts relate to temperature and precipitation as well as wind speed (cp. IPCC 2007, pp. 872-879). Analyses focus mostly on changes in mean values as well as in extremes which has been the base for the choice of CCLM parameters as utilized within the exposure to climatic stimuli analysis to be carried out within the present research. Likewise these fields are focussed on in current report of the European Environmental Agency (EEA) (cp. EEA 2008, pp. 39-59). Here, indicators are based on IPCC scenarios A1B and A2 and B2. Indicators in the field of atmosphere and climate include global and European temperature, European precipitation, temperature extremes in Europe and Precipitation extremes in Europe as well as storms and storm surges and air pollution by ozone.

The derived exposure indicators will be discussed in more detail within the subsequent paragraphs. Generally, the change indicators always relate the reference time frame (1961-1990) to the climate conditions within the projected periods as calculated by the CCLM model (e.g. 2071-2100). The absolute or relative difference between these two periods constitutes the projected change for each climate parameter.

The selected climatic variables (see list below) represent a wide range of climatic conditions, from temperature to hydrologic variables. To the previous selected indicators, the variable runoff, evaporation and snow cover have been added to enable a clearer climatic representation of the regions.

Variables of pressure and heat fluxes have been disregarded due to lacking direct relations with the preliminary sensitivity indicators. Data on storm events area subjected to large uncertainties on the European level. Mean wind speeds exhibits regional and large scale biases especially in Eastern Europe, at the west coast of Scandinavia, in France, parts of the Iberian Peninsula and parts of North Africa.[8]

For hydrologic variables, relative changes have been considered to best account for the regional varying climatic conditions. This accounts for the fact that small changes in summer precipitation can have much larger impacts in the Mediterranean area (with little absolute precipitation in summer), than a reduction of the same amount in Scandinavia, with considerably higher precipitation levels.

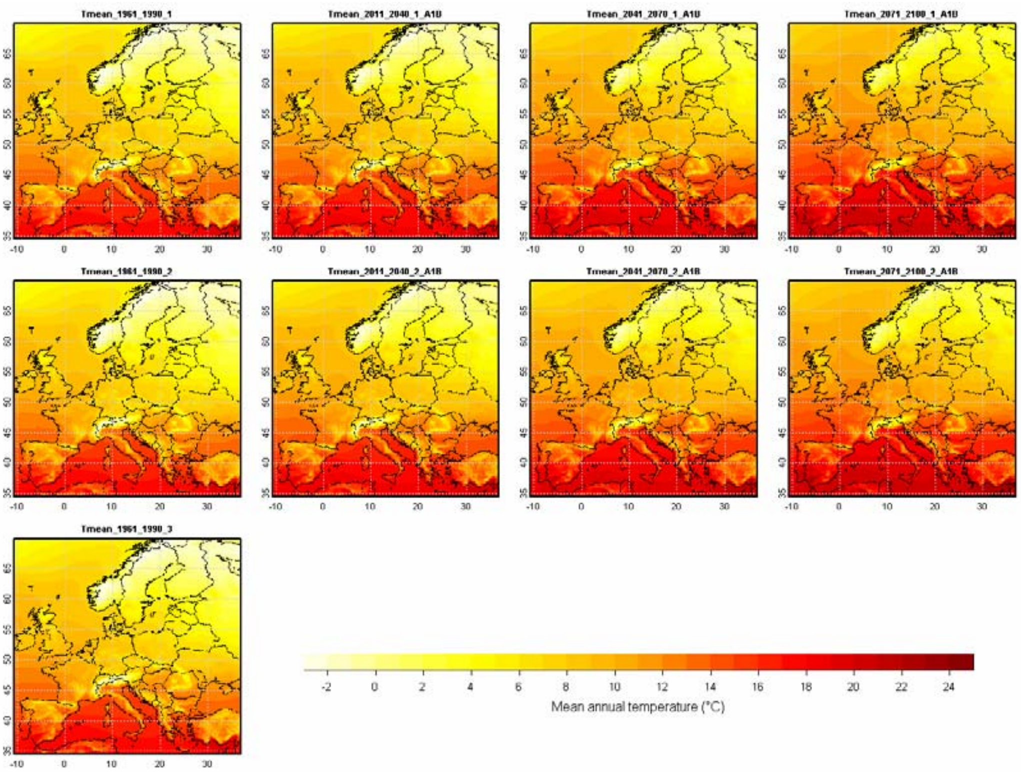

Figure 4: CCLM output on mean annual temperature (T_2M_AV), averaged for different timeframes (1961-1990, 2011-2040, 2041-2070, 2071-2100), for different model runs and scenario A1B. (source: Lautenschlager et al. 2009, preparation by PIK)

[8] Heinz-Dieter Hollweg, Uwe Böhm, Irina Fast, Barbara Hennemuth, Klaus Keuler,Elke Keup-Thiel, Michael Lautenschlager, Stephanie Legutke, Kai Radtke, Burkhardt Rockel, Martina Schubert, Andreas Will, Michael Woldt, Claudia Wunram (2008): Ensemble Simulations over Europe with the Regional Climate Model CLM forced with IPCC AR4 Global Scenarios, M&D Technical Report No.3, Hamburg.

EXP_TMEAN: Change in annual mean temperature

Based on the CCLM parameter ‘air temperature in 2 metres above surface’ (T_2M_AV, yearly) average annual temperatures in degrees Celsius for the selected time frames have been calculated. This indicator serves to indicate regional variation of changes in temperature, as the main indicator for climate change.

EXP_FD: Change in annual mean number of frost days

Based on the CCLM parameter ‘frost days’ (FD, yearly) average annual number of frost days (days with minimum temperatures below *0°C*) for the selected time frames have been calculated. This indicator serves to indicate changes in regional climate extremes with respect to cold temperatures, which is from a territorial perspective especially relevant for natural and agricultural systems.

EXP_SD: Change in annual mean number of summer days

Based on the CCLM parameter ‘summer days’ (SU, yearly) average annual number of summer days (days with maximum temperatures above *25°C*) for the selected time frames have been calculated. This indicator serves to indicate changes in regional climate extremes with respect to summer temperatures. This has from a territorial perspective relevance for the tourism sector as well as human wellbeing.

EXP_PW: Relative change in annual mean precipitation in winter months

Based on the CCLM parameter ‘total precipitation’ (PRECIP_TOT, monthly) average precipitation in kg/sqm for the selected time frames has been summed up for the meteorological winter months (December, January and February). This indicator accounts for changes in winter precipitation. Seasonal averages have been calculated to account for the strong intranannual variation of this variable. Together with precipitation in summer months, conclusions about water availability can be drawn.

EXP_PS: Relative change in annual mean precipitation in summer months

Based on the CCLM parameter ‘total precipitation’ (PRECIP_TOT, monthly) average precipitation in kg/sqm for the selected time frames has been summed up for the meteorological summer months (June, July and August). This indicator represents regional exposure to changes in summer precipitation. Seasonal averages have been calculated to account for the strong intranannual variation of this variable. From a territorial perspective changes in summer precipitation are especially relevant for vegetation.

EXP_HR: Change in annual mean number of days with heavy rainfall

Based on the CCLM parameter ‘rainfall’ (RAIN_TOT, yearly) average annual number of days with heavy rainfall (above 20kg/sqm) for the selected time frames has been calculated. This indicator will illustrate regional exposure to changes in heavy rainfall events and thus indicate hydrologic extremes. This variable has strong relevance for local heavy rainfall event, especially when occurring over highly sealed surface area

EXP_EVAP: Relative change in annual mean evaporation

Based on the CCLM parameter ‘surface evaporation’ (AEVAP_S, yearly) the average annual amount of water evaporating in a distinct area has been calculated. This indicator represents the changes in evaporation, and is from a territorial perspective thus of relevance especially for the natural systems, combining information on temperature and hydrologic conditions.

EXP_SNC: Change in annual mean number of days with snow cover

Based on the CCLM parameter ‘snow cover’ (SNOW_COV) the average annual number of days with snow covering the surface of the reference area has been calculated. This indicator serves to indicate the change in the number of days with snow cover and indicates changes in the snow condition, from a territorial perspective for example for the winter tourism sector.

This choice of climate stimuli is additionally justified by the needs of the different case studies which are characterised by specific climatic conditions, as shown in Table 1:

Table 1: Climate stimuli considered on case study level

	Mean tempera-ture	Frost days	Summer days	Winter precipi-tation	Summer precipi-tation	Heavy rainfall days	Evapo-ration	Snow cover days
Groundwater	x	x		x	x		x	
NRW	x	x	x	x	x	x	x	x
Bergen	x			x	x	x		
Tisza	x			x	x			
Mediterranean	x	x	x	x	x	x	x	
Netherlands	x			x		x		
Alpine space	x	x	x	x	x	x		x

2.3 Mapping climate change indicators

The exposure indicators listed in the preceding chapter have all been calculated based on the outputs of the respective parameters from the CCLM model runs.

The averaged CCLM projections for the four time-slices 1961-1990, 2011-2040, 2041-270, 2071-2100 have been calculated based on the model outputs for the respective parameters. For each of the future projections two climate model runs are available, for the reference period (1961-1990) three respectively. In order to consider all available runs the results from different runs have been averaged prior to further calculations of change indicators for each period of 30 years. The baseline change indicators presented in this chapter compare the future period 2071-2100 to the reference period 1961-1990 for the scenario A1B. The changes are calculated either as absolute changes subtracting the averaged present value from the respective value for the simulated future period or as relative changes in percent relating the absolute change value to the value for the reference period.

In order to approximate the climate data to the European regions the individual cell values have to be aggregated to the NUTS3 level. To accomplish this task, different approaches may be taken. In order to ensure consistency throughout the whole ESPON space with its strong heterogeneity concerning the area of the NUTS3 regions the approach chosen by the project is based on an intersection of the administrative units with the CCLM cells. This approach enables to determine the regional values by considering the single cell values by their aerial shares for each NUTS3 region when calculating the aggregate regional value. All of the results presented in the following maps have been subject to the methodological procedures described above.

Change in annual mean temperature

The projected changes in annual mean temperatures indicate increasing temperatures between 2 and over 4.5 degrees for the ESPON territory (see Figure 4). The UK, Ireland, Denmark, parts of The Netherlands and Northern parts of Germany exhibit the comparatively lowest temperature changes up to 3 degrees Celsius. Western and Northern parts of France, Belgium, most parts of Germany, Poland, Czech Republic and Slovakia as well as Southern parts of Sweden and Norway and the Baltic states will be subject to temperature increases between 3 and 3.5 degrees Celsius. Southern and South-Eastern Europe (except for some parts of Greece, Bulgaria and Romania) as well as Northern Scandinavia and Finland are projected to experience the comparatively highest temperature changes with absolute changes of more than 3.5 degrees Celsius. Spain, parts of Portugal but also parts of the Alpine Space will even experience temperature changes of more than 4 degrees Celsius according to the CCLM projections.

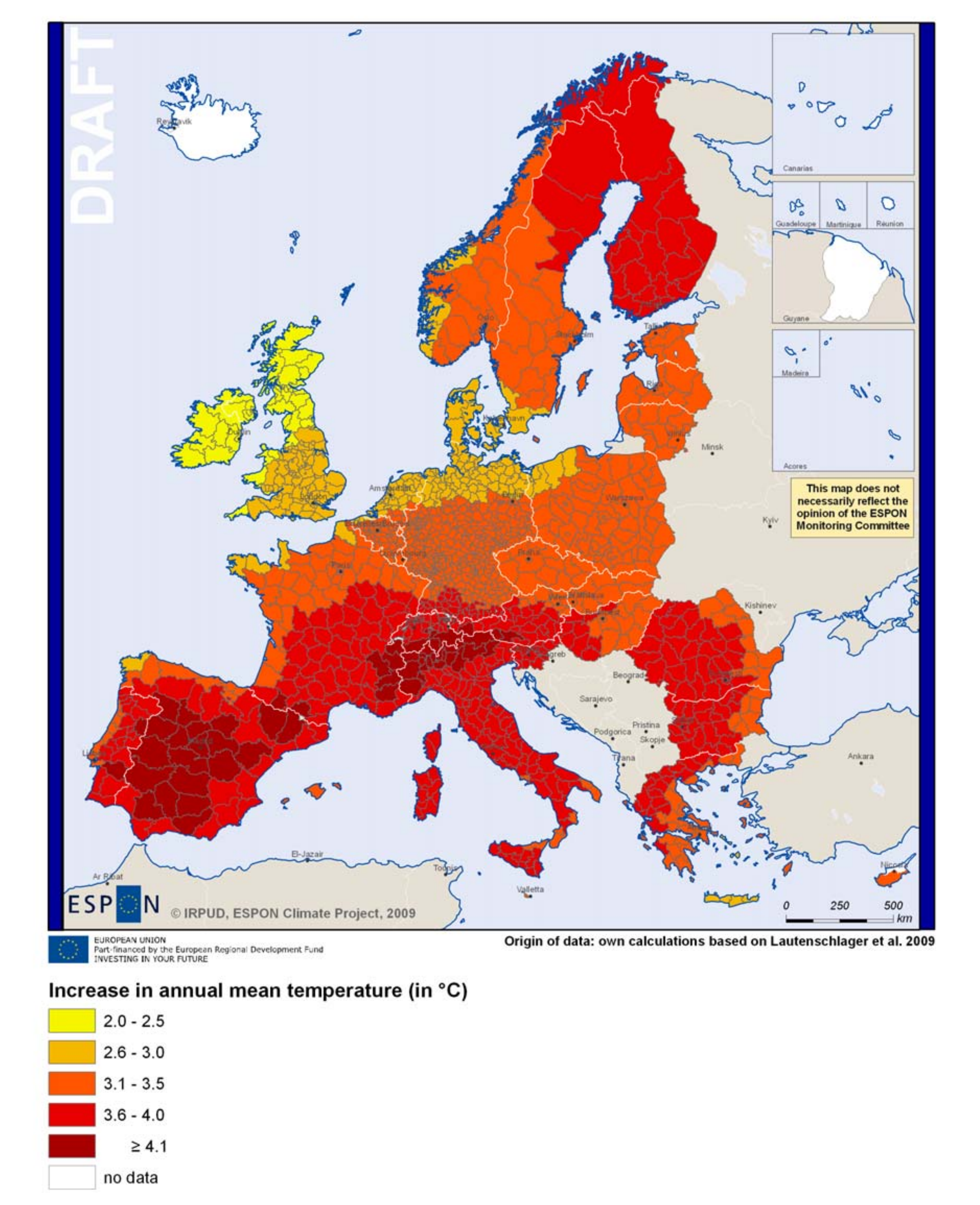

Figure 5: Change in annual mean temperature (EXP_TMEAN)

Change in annual mean number of frost days

The averaged model outputs on number of frost days indicate roughly a South-West to North-East stretched pattern considering the whole of Europe (see Figure 5). While Spain, most parts of France and Italy and also Ireland exhibit comparatively slight decrease in number of frost days particularly the alpine space, most parts of Germany, Eastern Europe as well as the Baltic states, Scandinavia and Finland are projected to experience more severe decrease in the number of frost days with regional peaks of 60 days and more.

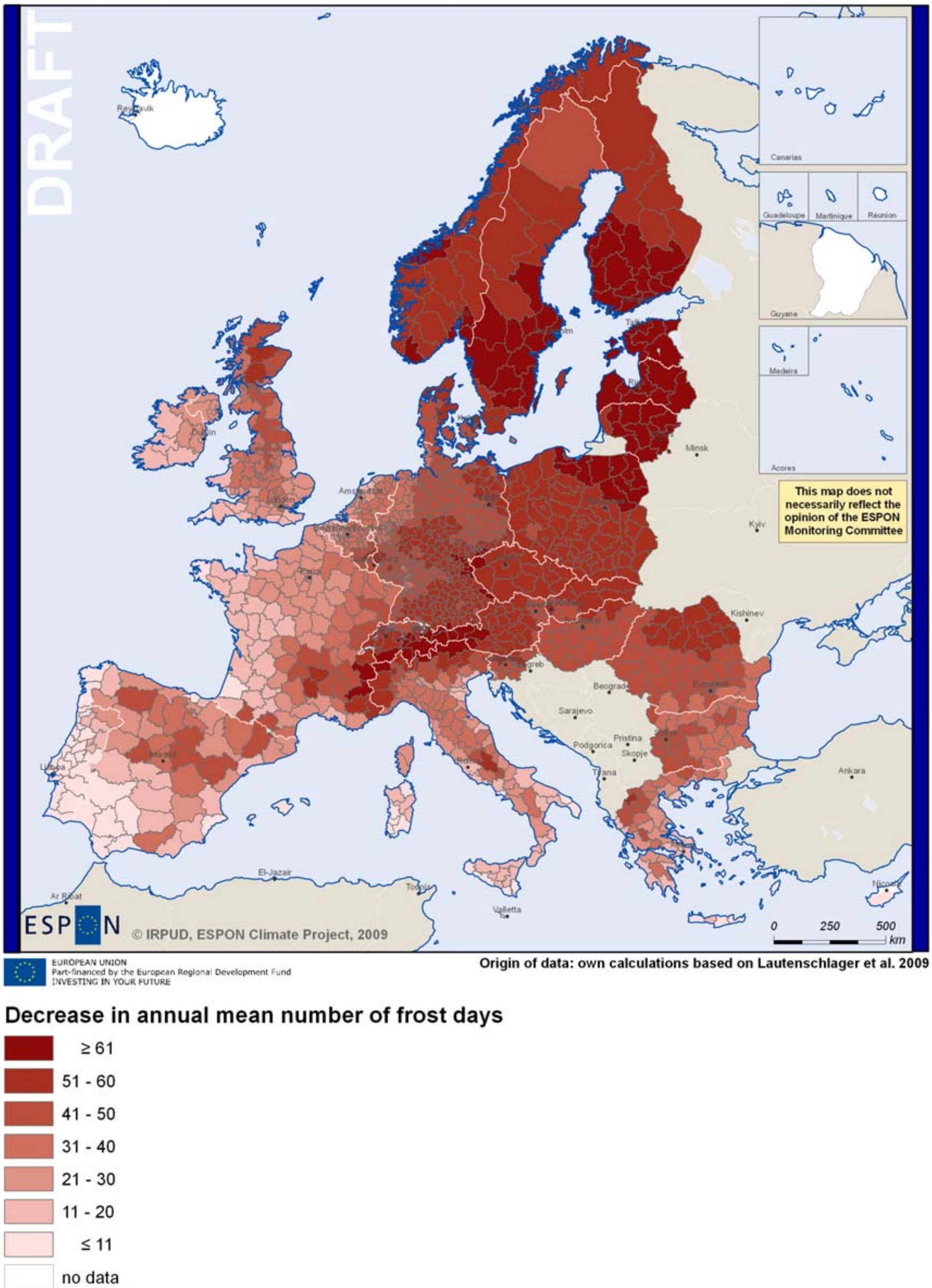

Figure 6: Change in annual mean number of frost days (EXP_FD)

Change in annual mean number of summer days

The patterns on the projected changes of the annual mean number of summer days show almost the inverse picture compared to the change in annual mean number of frost days (see Figure 6). Here, increases between less than 10 and more than 50 days per year in average have been calculated by the model. The comparatively slightest increases are predicted for the North of Europe including Scandinavia, Finland, the Baltic States as well as parts of Denmark, UK and Ireland while predominantly France, Spain and Portugal exhibit increases of more and 40 days per year on average.

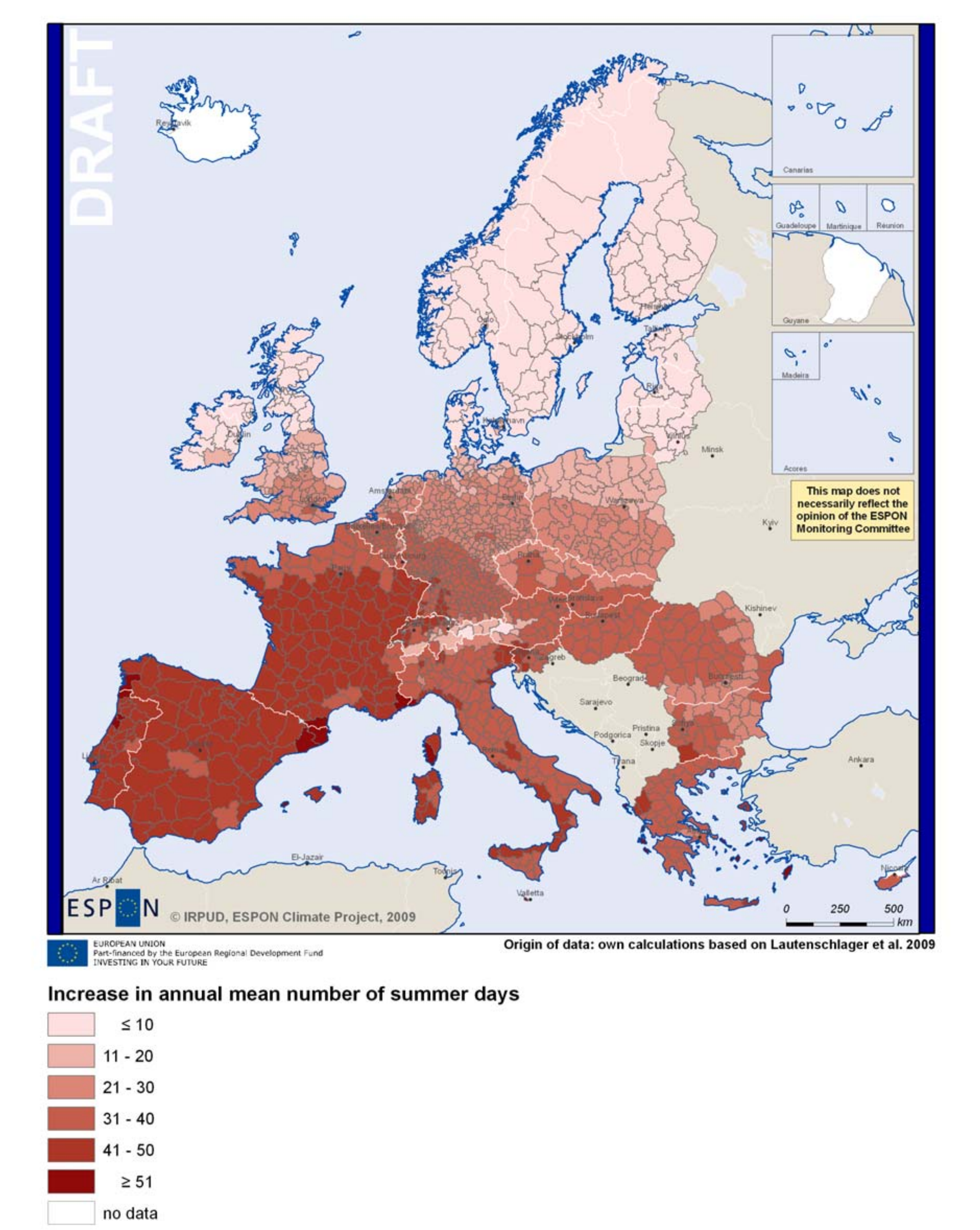

Figure 7: Change in annual mean number of summer days (EXP_SD)

Relative change in annual mean precipitation in winter months

For the European patterns of change in winter precipitation exhibit the CCLM model projects twofold developments (see Figure 7). While in most parts of Northern and Central Europe winter precipitation is projected to increase Southern Europe and particularly most parts of the Mediterranean area will experience decreases in winter precipitation of 10% and more. Regions in Greece and Bulgaria as well as Cyprus show the highest relative decreases.

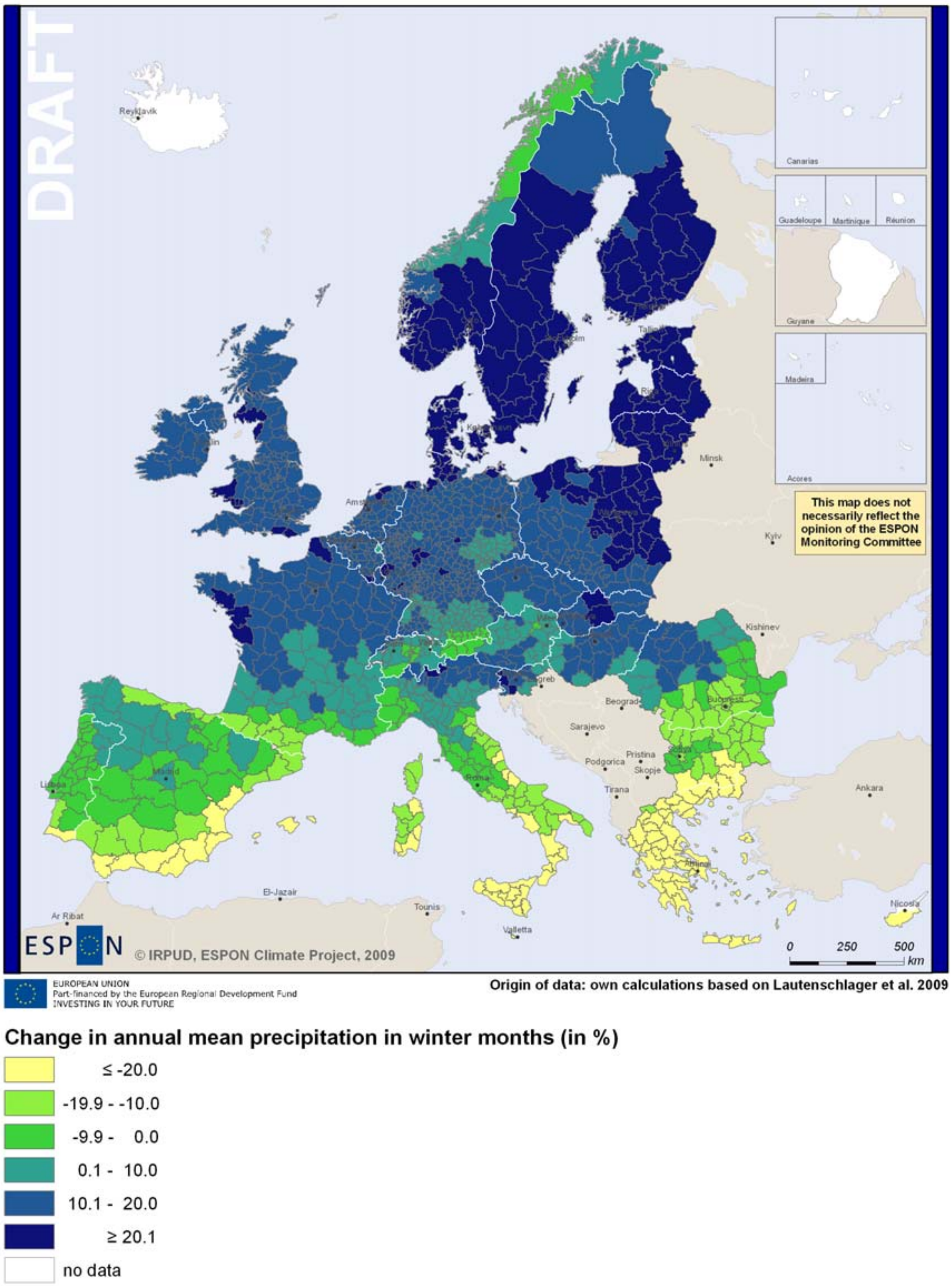

Figure 8: Relative change in annual mean precipitation in winter months (EXP_PW)

Relative *change in annual mean precipitation in summer months*

The CCLM outputs on precipitation in summer month again are twofold considering the changes within the European territory (see Figure 8). While parts of Scandinavia and Finland as well as Northern UK will experience increases up to 40 % most of the ESPON space will experience decrease in summer precipitation up to 40 % and more. For parts of Scandinavia, the Baltic states, Poland, parts of the Czech Republic, Denmark, Ireland and parts of the UK those decreases are projected to range up to 20 % while the rest of Europe and here particularly France, Portugal Spain Italy, Greece are projected to experience the strongest relative decreases in annual summer precipitation considering the overall patterns for the European territory.

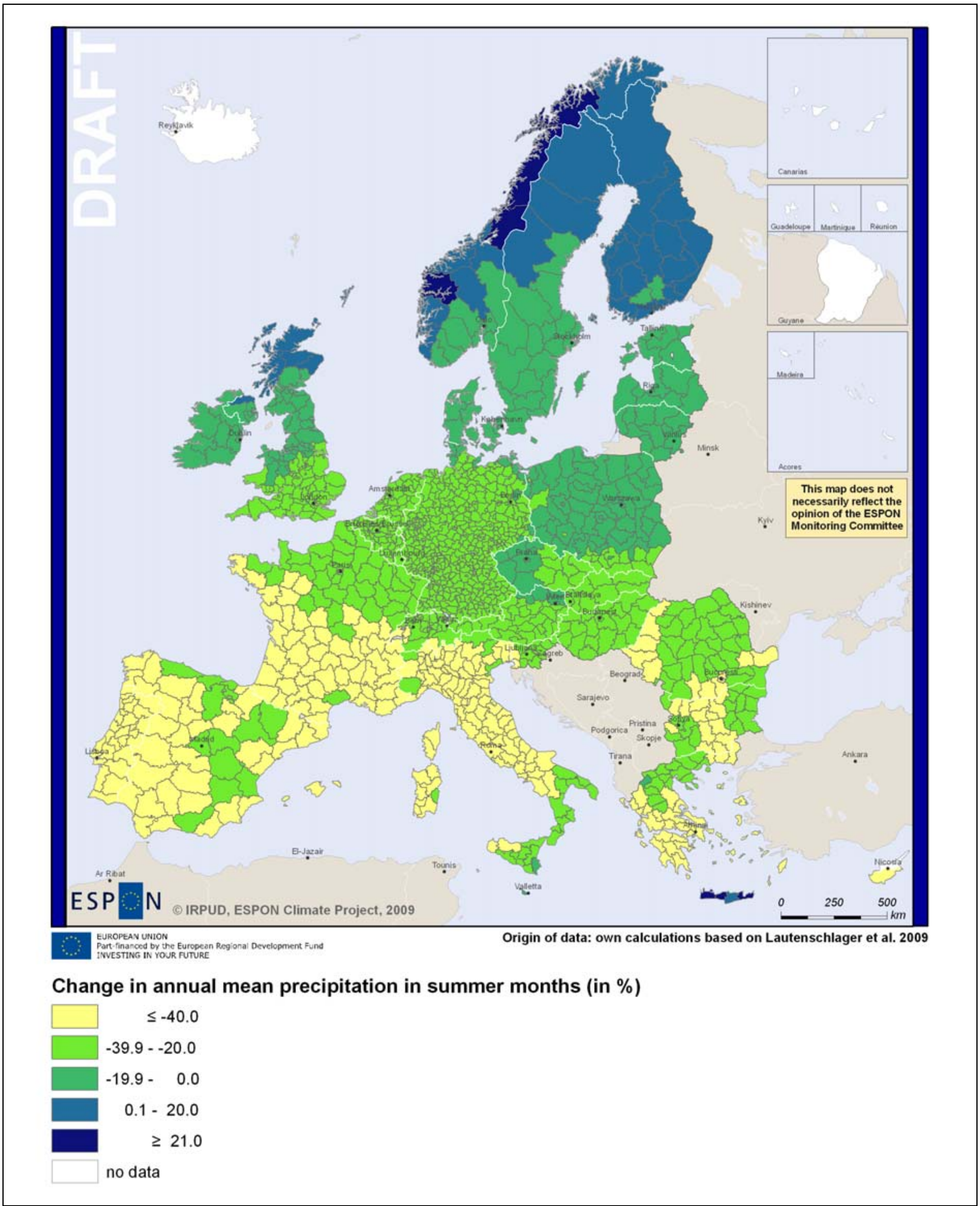

Figure 9: Relative change in annual mean precipitation in summer months (EXP_PS)

Change in annual mean number of days with heavy rainfall

As the previous precipitation-related indicators also the change in annual number of days with heavy rainfall reveals a twofold pattern over the whole of Europe. Roughly a North-South divide with a division at alpine latitudes becomes evident (see Figure 9). Most of the territory at lower latitudes is projected to experience average decreases in annual heavy rainfall of up to 5 days and more whereas for the territory north of this division line is projected to gain in average number of days with heavy rainfall. For most of these regions increases will amount up to 3 % but along the coastline of Norway as well as Western UK and Ireland and some parts of the Atlantic coast of France increases between 4 and 13 days have been calculated by the CCLM model.

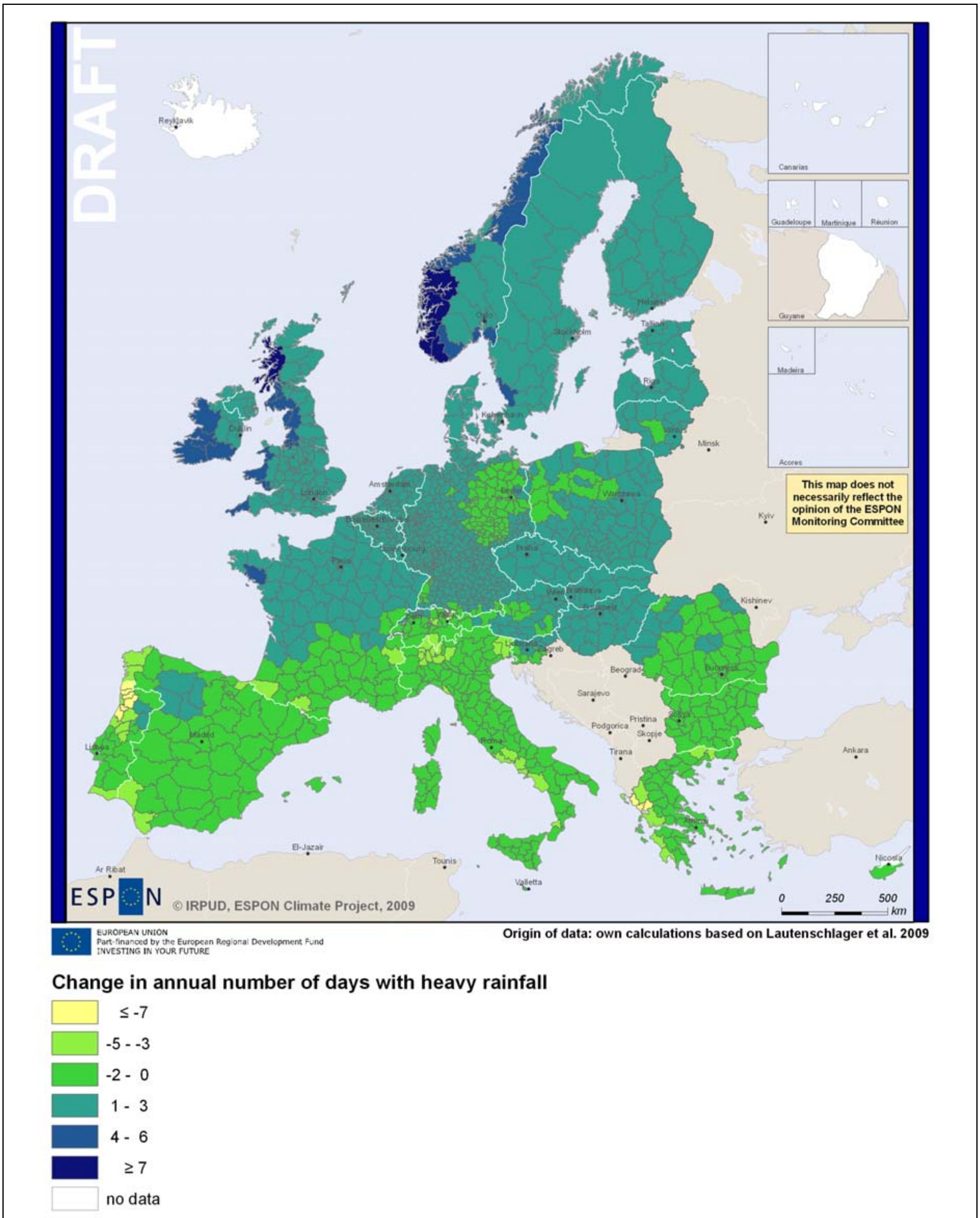

Figure 10: Change in annual mean number of days with heavy rainfall (EXP_HR)

Relative *change in annual mean evaporation*

European patterns on change in annual mean evaporation range from decrease of more than 15 % to increases up to 22 % (see Figure 10). Most of the higher decreases are found in Southern Europe, particularly in the Mediterranean as well as Greece and Romania. Strong increases on the other hand are predominant projected for Scandinavia, Finland and the Baltic States as well as parts of Poland but also the Alpine space and parts of Czech Republic.

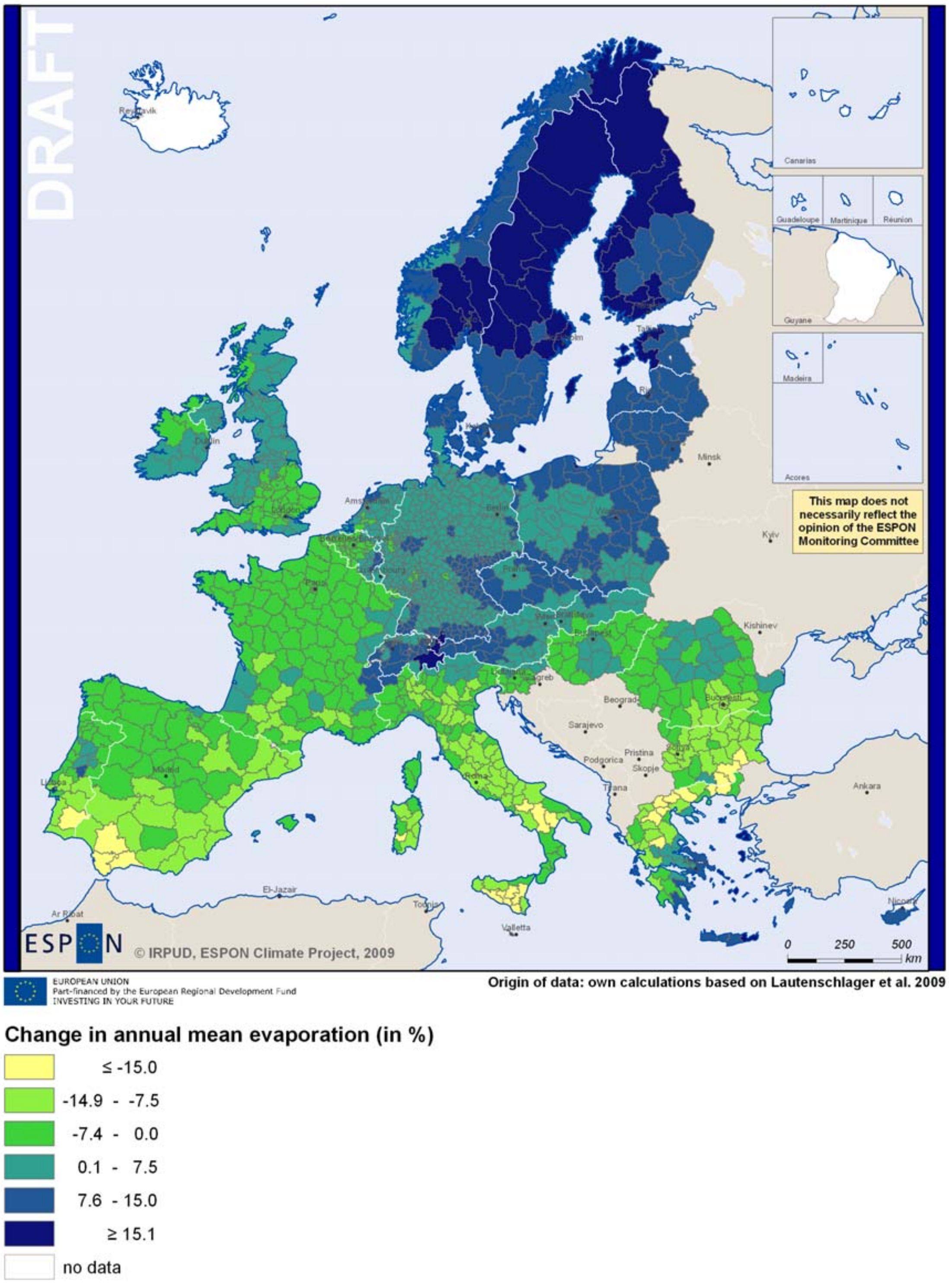

Figure 11: Relative change in annual mean evaporation (EXP_EVAP)

Change in annual mean number of days with snow cover

Snow cover is projected to decrease most significantly in Scandinavia, Finland, the Baltic States and the Alpine Space (see Figure 11). Furthermore, some of the parts of Eastern Europe are also projected to experience a comparatively strong decrease in the number of days with snow cover. The rest of the European territory will mostly experience decreases of up to 15 days.

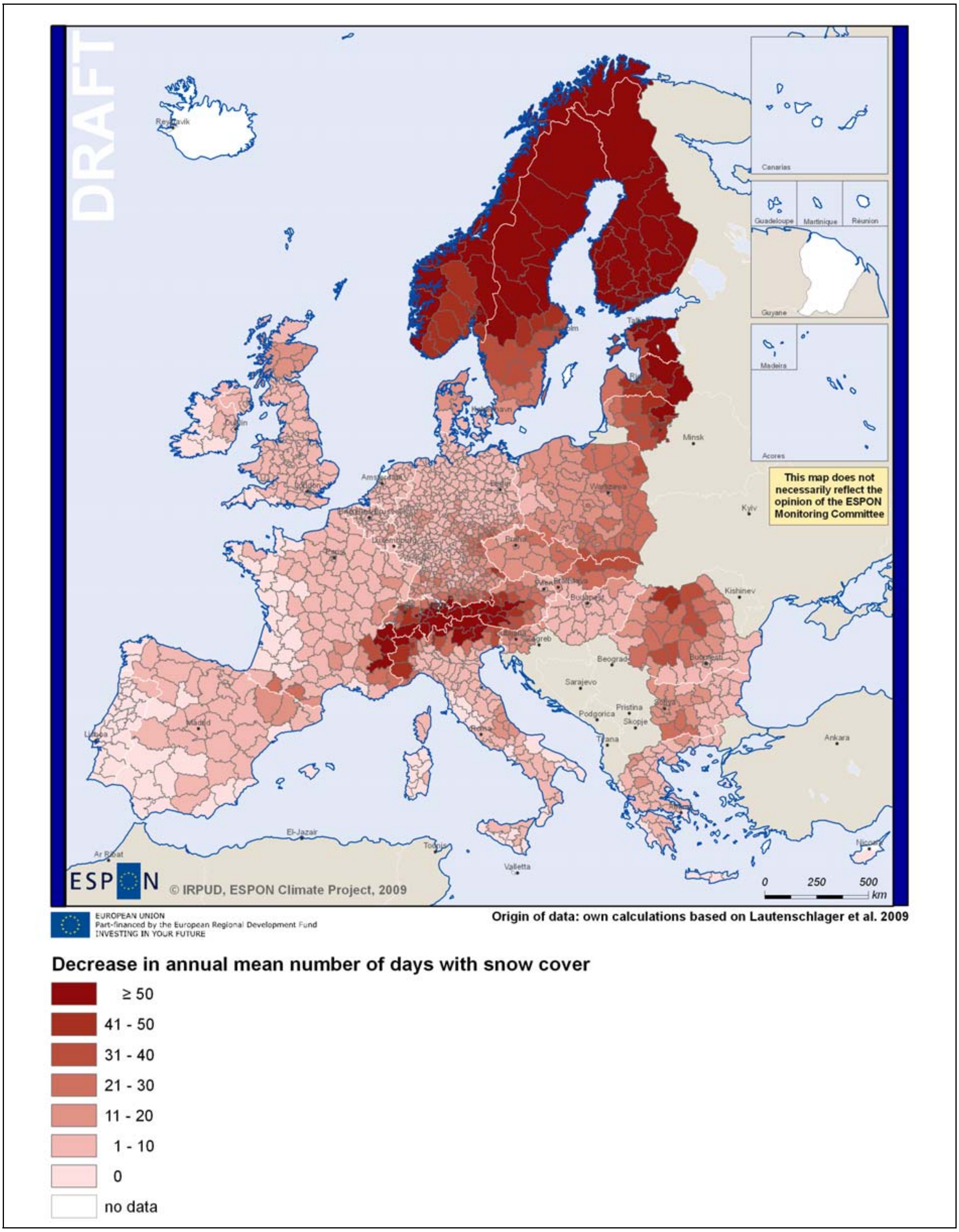

Figure 12: Change in annual mean number of days with snow cover (EXP_SNC)

Open questions related to the coverage of sea level rise and river flooding

Sea level rise is no climate change exposure indicator in the CCLM model, because it is rather a first level effect triggered by changes in global temperatures and regionally also by land up- and downlift. However, a number of large area sea-level rise vulnerability assessments have focused mainly on identifying land located below elevations that would be affected by a given sea-level rise scenario (Schneider and Chen, 1980; Rowley et al., 2007). These analyses require use of elevation data from digital elevation models (DEMs) to identify low-lying land in coastal regions. Accurate mapping of the zones of potential inundation is critical for meeting the challenge of determining potential socioeconomic and environmental impacts of predicted sea-level rise (FitzGerald et al., 2008). However, currently best available elevation data for Europe do not support an assessment using a sea-level rise increment of 1 meter or less. This is particularly important because the 1-meter scenario is slightly above the range of current sea-level rise estimates for the remainder of this century and slightly above the highest scenario used in this product (Titus et al, 2009). Consequently, further investigations are needed if seal level rise can be integrated into the pan-European impact assessment. In any case, it will be addressed by some case studies (The Netherlands, Coastal aquifers, City of Bergen).

Aside sea level rise, some extreme whether events may be triggered by some climate stimuli related with precipitation, such as river flooding and mass movements (IPCC 2007, Prudhomme, C., Reynard, N. 2009). The impact of climate change on flooding is covered by JRC's LISFLOOD model. LISFLOOD is a GIS-based hydrological rainfall-runoff-routing model that is capable of simulating the hydrological processes that occur in a catchment, (Van Der Knijff, J. M., Younis, J. and De Roo, A. P. J. 2008). However, only the A2 and B2 scenarios are considered by the LISFLOOD model. Consequently, further investigations are needed if river flooding can be integrated into the pan-European impact assessment which bases on scenario A1B. A further methodological problem is caused by the fact that river flooding is a catchment-based phenomenon which cannot be analysed offhand in conjunction with the cell raster of the indicators on climate stimuli, the ESPON climate projects makes use of for its exposure assessment. Therefore, integration into the cluster analysis is largely impossible. However, river flooding will be addressed by some case studies (The Netherlands, North Rhine-Westphalia, Tisza River Valley).

2.4 Typology of climate change regions

The typology of climate change regions has been revised since the first version of the interim report. The scope of the underlying analysis has been extended spatially to Eastern Europe and Ukraine. Furthermore, only 8 variables have been considered since the previously selected variable on 'Surface-runoff' has not proven to be useful for this analysis since its lack of relevance in case studies and the technical problem of water and water-near cells which cause "blank spots" on the maps.

Thus, the results differ from the typology presented previously. The subsequent paragraphs reflect on the procedure and methodology used to derive the typology.

Typologies of climate change regions are developed by means of cluster analysis, based on the projected changes in the eight climate variables from the CCLM model between the time periods 1961-1990 to 2071-2100 under the A1B scenario (averaged model runs). It has been carried out for those cells, which contain values for all indicators (i.e. land cells, 2271 cells in total). The African part was excluded from the analysis as it is characterised by large model uncertainties and is not in focus of this project. The spatial distribution of the projected changes in climate variables within the raster cells is summarised in Figure 12.

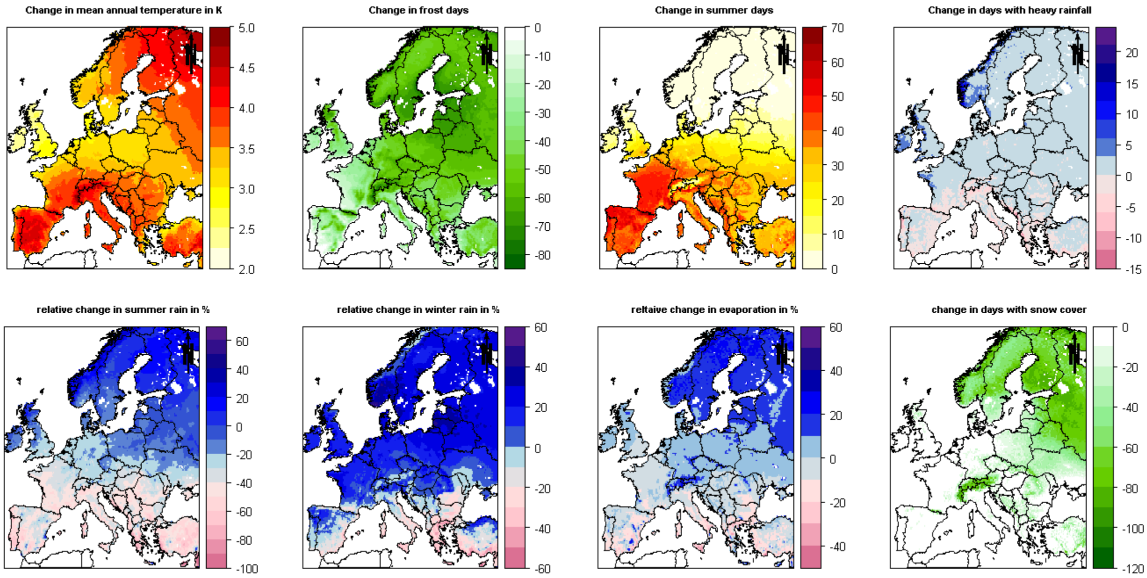

Figure 12: Changes of the eight considered climate variables of the model CCLM between the time periods 1961-1990 to 2071-2100 (Africa is marked with white cells).

Figure 13 gives an overview on the frequency distribution of the values of the climate variables for the considered cells. The variables “change in frost days” and “change in days with snow cover” show negative values (thus decreasing number of days) for all cells, whereas the variables “temperature change” and “relative change in summer days” show positive values (and thus increasing temperature or days). For the other variables, both increases and decreases are projected for Europe.

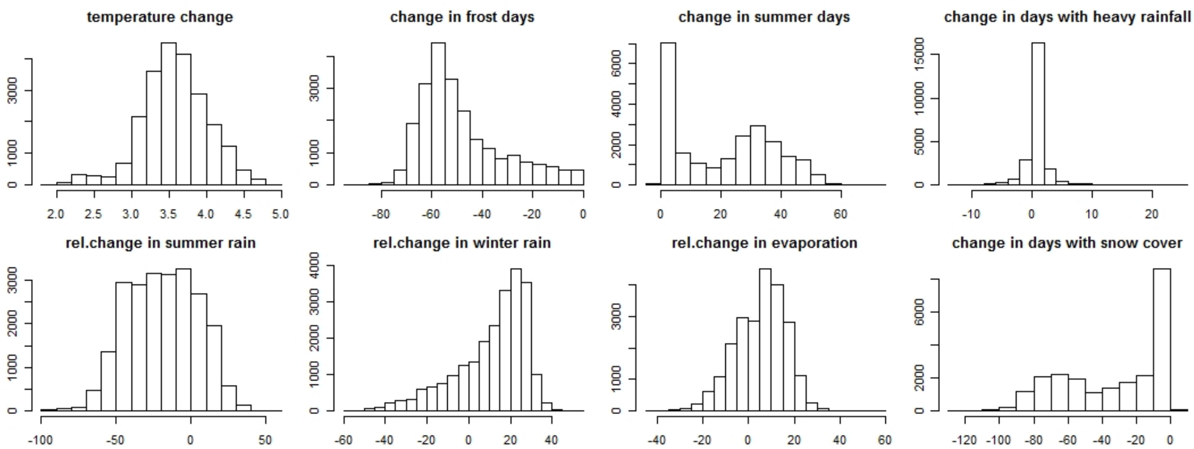

Figure 13: Frequency distribution of the climate variables for the considered cells (n=22771)

The variable „change in days with heavy rainfall“ was treated in a particular way due to the fact that for most of the cells only slight changes are projected and strong changes are projected for only a small number of cells. These extreme values narrow the main part of the data set, so cluster centres would be restricted to a small value range. Thus, the values of this indicator were “trimmed” at the lower and upper end. In effect, this means that all pixels with a projected increase in days with heavy rainfall of more than seven days were set to the value seven, while those with decreases of more than five days were set to the value of five. The standardised distributions for the original as well as the trimmed variable are shown in Figure 14.

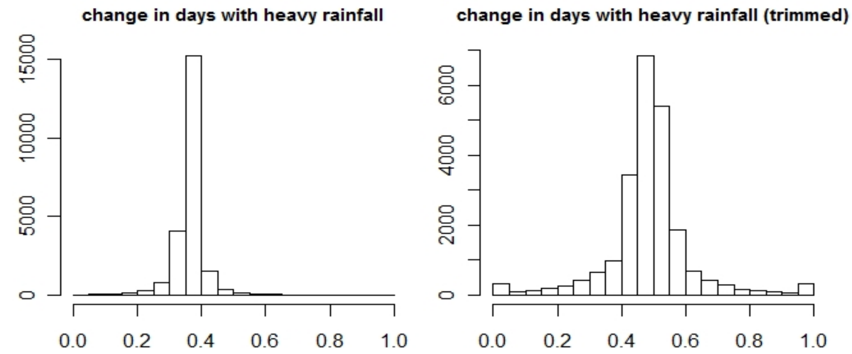

Figure 14: Standardised distributions of the changes in days with heavy rainfall without trimming (left) and with trimming (right).

Furthermore, the whole data set was standardised by its range to values between 0 and 1 (Milligan&Cooper, 1988). The standardised distributions of all remaining variables are shown in Figure 15.

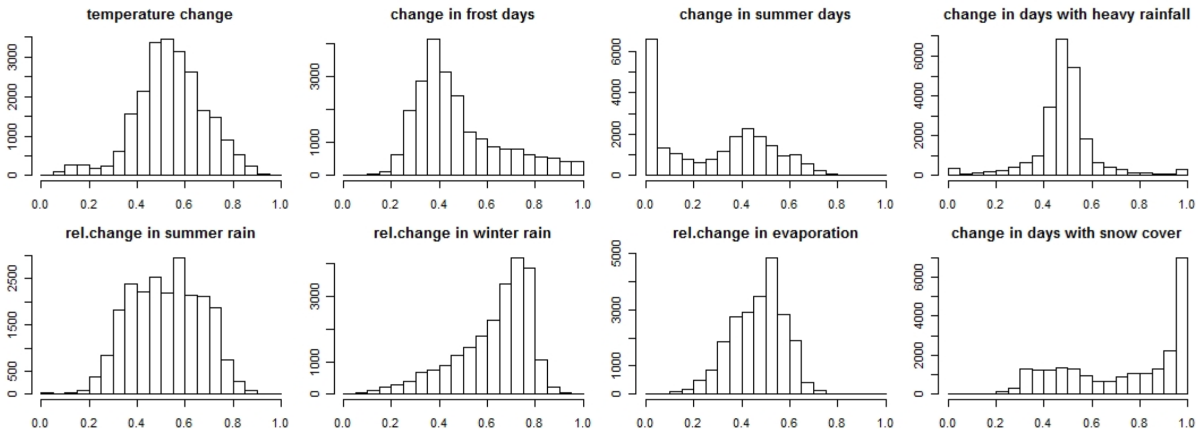

Figure 15: Standardised distributions of the climate variables for the considered cells (n=2277), trimmed values of changes in days with heavy rainfall

Technique of cluster analysis

A cluster analysis reduces the dimensions of a data set by allocating the objects into groups in such a way, that the objects within these groups are more similar to each other than to objects in different groups. The cluster mechanisms can be distinguished in hierarchical, partitioning and density-based methods (Handl et al., 2005). In our analysis the first two methods are being combined.

In a hierarchical clustering the data set is transformed into a distance matrix containing all pair wise distances between the objects in the data set. Using specific amalgamation rules, at first the objects and further the accumulated groups were merged. The “ward”-method has been applied which merges that pair of groups that contributes least to the within-cluster-variance of the whole partition (Ward, 1963).

Hierarchical clustering is used to cluster a small subset of objects to create a starting partition for the subsequent partitioning method. For discovering the structure in the data set the widely known partitioning method of K-means has been applied (MacQueens, 1967). This algorithm minimizes the total within-cluster sum-of-squares (TSS) criterion. If the data set consists of P variables and the number of groups was chosen to K, the criterion is defined by (Steinley, 2006):

$$TSS = \sum_{j=1}^{P} \sum_{k=1}^{K} \sum_{i \in C_k} (x_{ij} - \overline{x}_j^{(k)})^2$$

The objects are assigned to the k given initial cluster centres. Than the new centre is calculated as the average off all objects within the cluster and again all objects are assigned to their nearest cluster centre. This procedure is repeated until a break criterion is reached (e.g. points no longer change position or maximum number of loops). The largest advantages of K-means are the calculation speed and the applicability for very large datasets. On the other hand there is a risk of local minima in the optimization process and the user has to choose in advance the number of cluster which is expecting.

Determination of the number of clusters

For identifying the most robust and therefore most representative number of clusters a consistency measure is used, which belongs to the groups of stability based methods (see also Ben-Hur et al. (2002), Roth et al. (2002)). It is based on the idea that if the pre-given number of clusters does not fit the underlying structure of the data, a stochastically initialised cluster algorithm will generate indefinite and different results.

The procedure of the chosen method is to generate pairs of maps, i.e. run K-means twice, for a pre-given cluster number k. Out of these pairs of maps the size of their overlap e is assigned as a measure for the consistency, showing how much the two cluster results vary (see Figure 16). A lower variety and a higher value for the consistency measure imply a higher similarity between the pre-given number of clusters and the underlying structure in the analysed data. This pair wise matching will be repeated several times (~200) to achieve a certain mean value for the consistency measure. The overall procedure will be repeated for different cluster numbers k whereby we can identify the k which maximises the consistency measure.

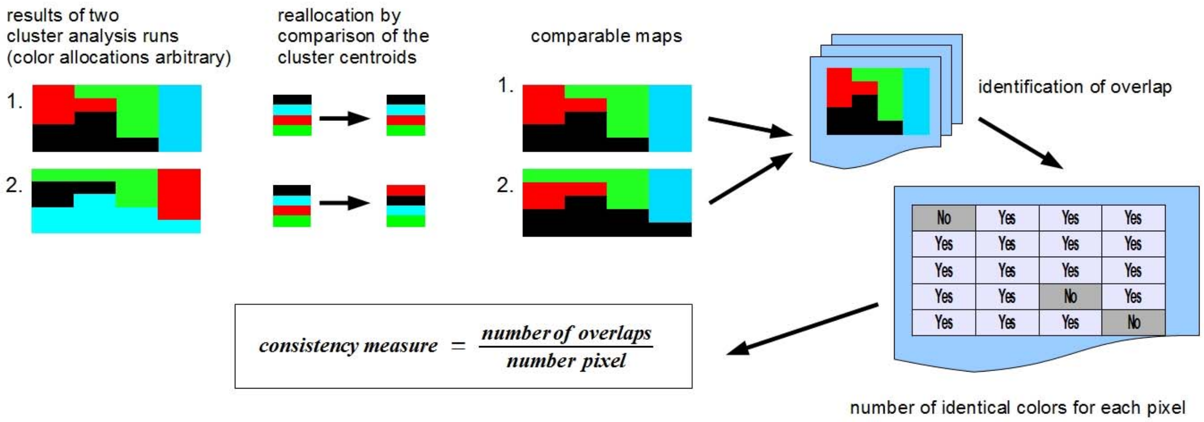

Figure 16: Determination of the number of cluster by means of measuring their consistency (Sietz, in review)

This method provides clearer results than the traditional approach of elbow criterion, as can be seen in Figure 17. In the elbow-criterion, a similarity measure (like the inner-cluster-variance) is applied and the optimal number of clusters can be discerned by a clear "elbow" of the curve. Yet, with an increasing number of clusters, the clusters fit the data-set increasingly better and the detection of "elbows" becomes difficult.

The developed consistency measure gives a clearer picture: The cluster numbers 2, 3 and 5 have the highest consistency values for this data set. Lower numbers of clusters tend to have higher values of consistency but a separation of the data into two and three clusters would not provide a sufficient representation of typologies. Thus, the 5 cluster solution has been selected.

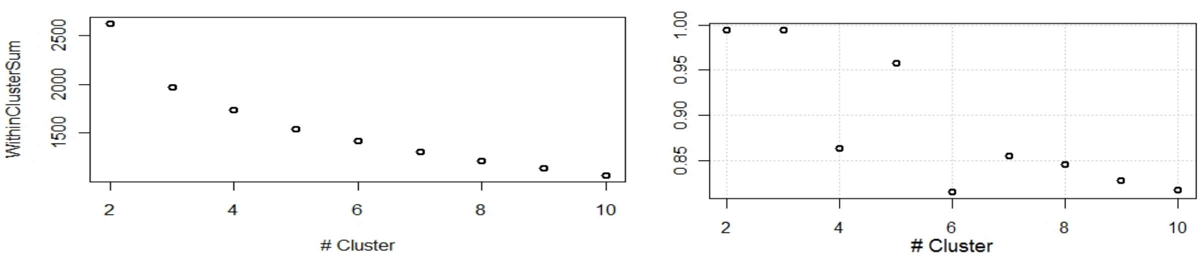

Figure 17: Comparison of the traditional elbow-criterion (left) and the consistency measure (right)

The characteristics of each cluster concerning the mean value of the eight climatic variables can be seen in Figure 18. Some variables show large variations over the cluster, e.g. change in summer days, whereas others are characterised by relatively small variations, e.g. change in evaporation.

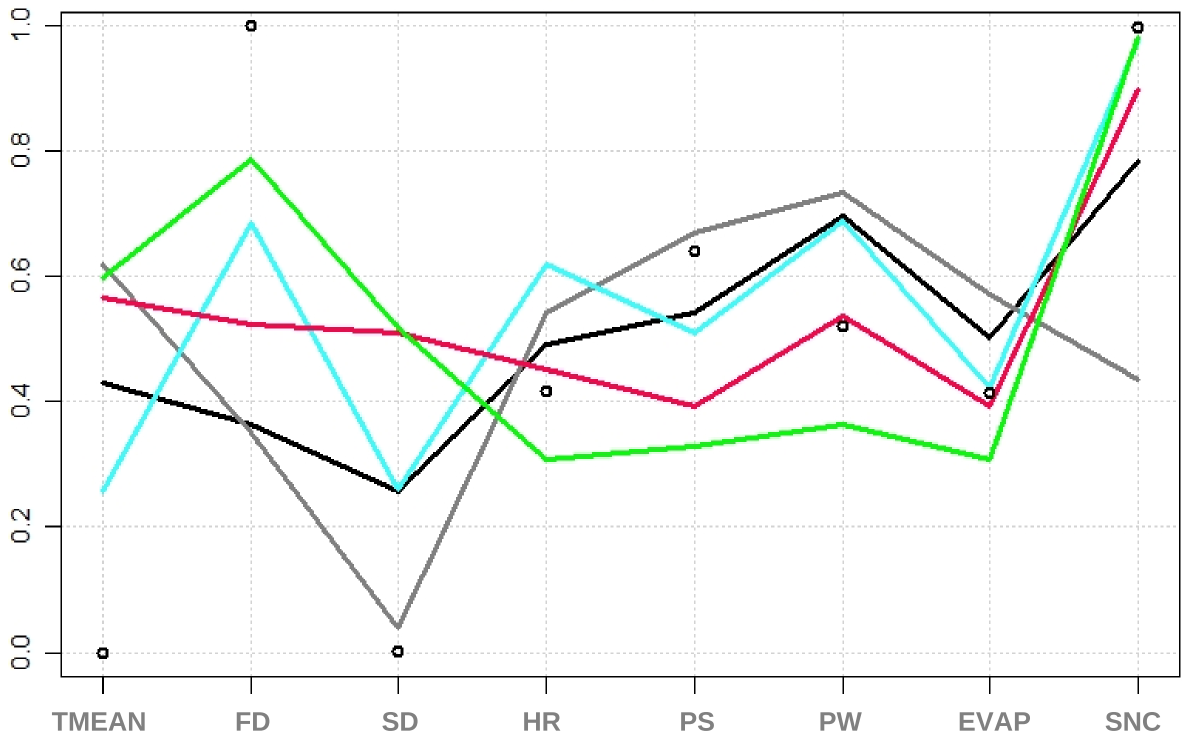

Figure 18: Cluster feature graph for detailed information about the cluster characteristics for the eight climate variables (mean values). Additionally the black circles show the location of the value of zero.

The quality of the cluster representation of each cell (expressed by the distance between the datapoint and the cluster center) is shown in Figure 19. The red pixels are well represented by their cluster centre, in contrast to the violet pixels: the alpine region, the Norwegian coast, the Atlantic coast are not well represented. A good representation by the cluster can be seen for Eastern Europe.

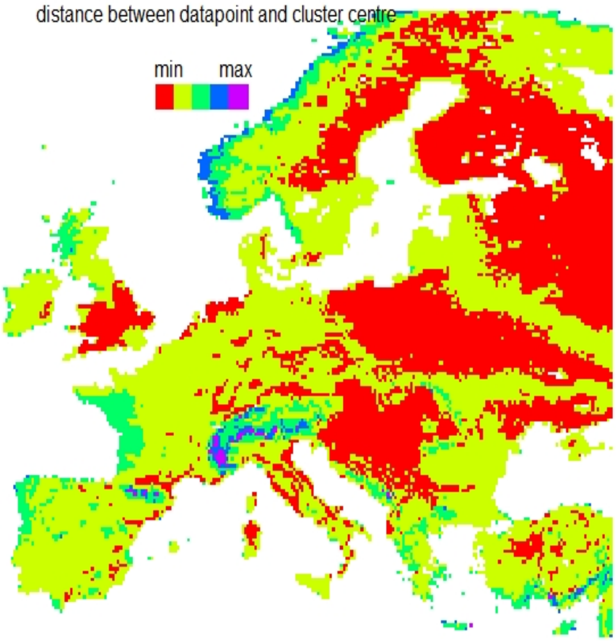

Figure 19: Spatial distribution of the distance of the properties of each data point to the corresponding cluster centre for 5 clusters.

Typologies of climate change regions

The analysis of European patterns of climate change has led to a typology of climate change regions derived from a cluster analysis.9 Based on the exposure indicators 5 different types of regions according to their climate change profile have been identified. The most prominent climate change characteristics in each of these regions are summarised in Table 2. This table shows on the one hand that every chosen stimulus is important for describing the main characteristics of a least one type of region.

Table 2: Different types of regions characterised by climate change based on cluster analysis

Cluster/Stimuli	Northern-central Europe	Northern-western Europe	Northern Europe	Southern-central Europe	Mediter-ranean region
Change in annual mean temperature	+	+	++	++	++
Decrease in number of frost days	--	-	--	--	-
Change in annual mean number of summer days	+	+	o	++	++
Relative change in annual mean precipitation in winter months	+	+	++	o	-
Relative change in annual mean precipitation in summer months	-	-	o	--	--
Change in annual mean number of days with heavy rainfall	o	+	+	o	-
Relative change in annual mean evaporation	+	o	+	o	-
Change in annual mean number of days with snow cover CDSC	-	o	--	o	o

Key:
++ Strong increase
+ Increase
o insignificant stimulus for the characterisation of the cluster
- Decrease
-- Strong decrease

A strong increase in annual mean temperature is observable for three clusters, namely ‘Northern Europe’, ‘Southern central Europe and ‘Mediterranean region’. Strong decreases in number of frost

[9] Originally it was planned to carry out a factor analysis prior to derive this typology. However, due to partly implausible and rarely useful results it was decided to made use of a cluster analysis. See annex 2 for a more detailed discussion.

days predominantly characterise the clusters of ‘Northern central Europe, ‘Northern Europe’ and ‘Southern central Europe’ whereas strong increases in annual mean number of summer days is projected for the clusters of ‘Southern central Europe’ and ‘Mediterranean region’. Concerning change in precipitation in winter months the ‘Northern Europe’ cluster shows particularly strong increases while for summer months most significant changes in terms of strong decrease can be observed in ‘Southern central Europe’ and ‘Mediterranean region’ clusters. The variables heavy rainfall and evaporation do not show very strong changes for any of the clusters while days snow cover are projected to decrease strongly in the ‘Northern central Europe’ cluster.

The resulting spatial patterns (see Figure 20) divide the ESPON territory into 5 regions. The results seem plausible as main topographic characteristics are well covered (such als Alps, Carpathians, Balkan, Pyrenees, Apennines) and underline the validity of the derived typology at least from a pan-European perspective. On the regional level the case studies conducted within this research project will contribute further to local variations of climate change providing more insights to the validity of the developed typology.

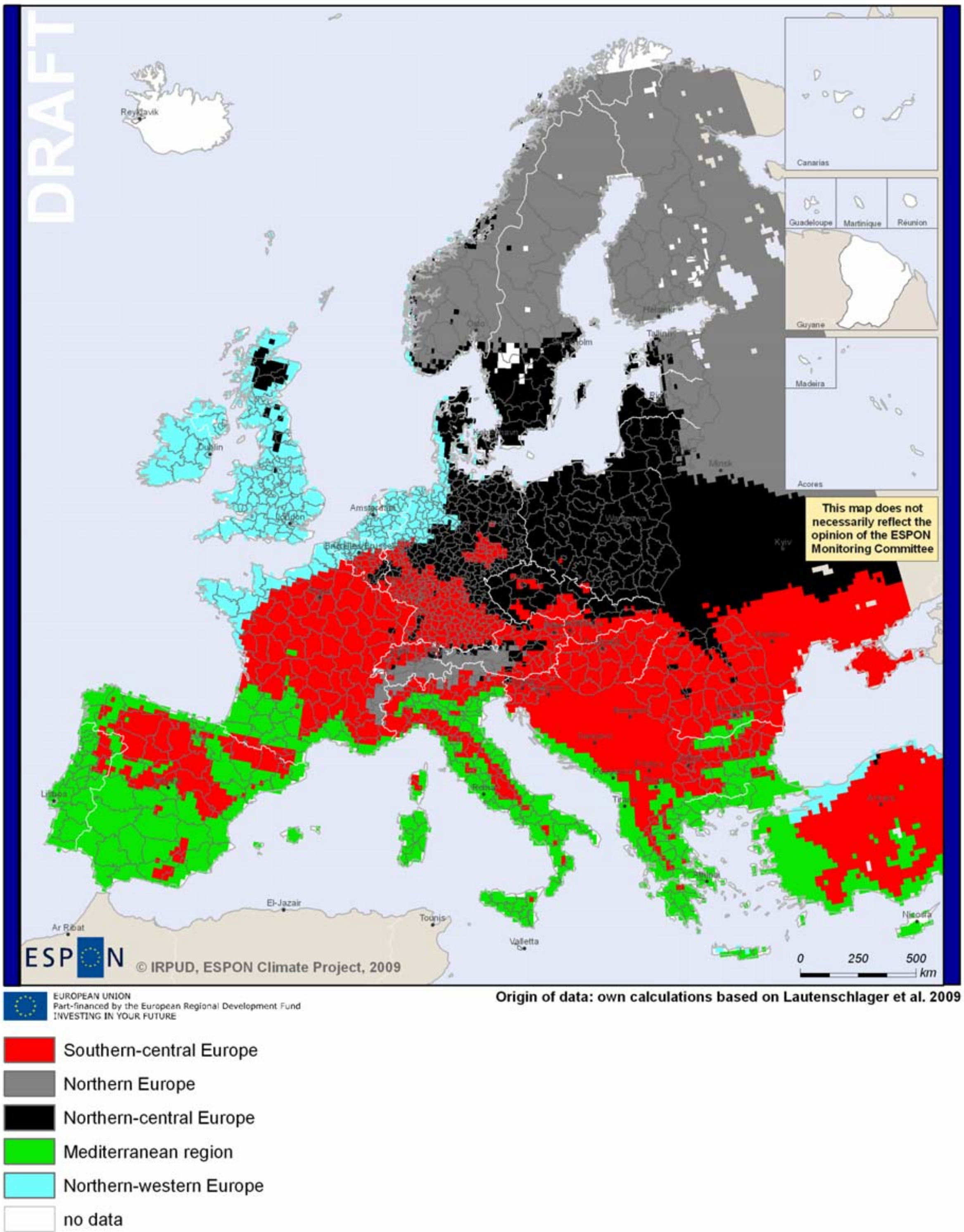

Figure 20: Map of the climate change typology [10]

[10] Note: blank spots result from cells not being considered by the underlying CCLM model datastream 3 (which does not cover Iceland and oversea territories at all) as land cells and, thus, had to be excluded from the analysis. This is for instance the case for the big lakes in Scandinavia and Russia. For the next analysis step aggregating the raster-based typology to NUTS3 boundaries these blank spots will vanish. The issue of land-cells unfortunately also applies for Malta. The research team will, nevertheless, elaborate on options to include Malta in this typology.

3. Sensitivity to climate change

The exposure analysis presented above provides the basis for the sensitivity assessment: Knowing which are the main climatic variables affected by climate change and how the different types of European regions are exposed to them enables a subsequent analysis of how sensitive these types of regions are to the anticipated climatic changes.

The given relation between exposure indicators and the five sensitivity dimensions is considered by the methodological approach as the different sensitivity indicators are tailor-made for each type of region in order to address those stimuli which are characteristic for the respective cluster and being able to capture cause-effect-chains between exposure and related sensitivities ("sensitive to what"?). And within these systems only certain elements are particularly sensitive to climatic changes – and sensitive in different ways and to different degrees and possibly at different times. Therefore, each sensitivity indicator will need to include positive and negative sensitivity values.

According to the IPCC (2007), "sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise)." Consequently, sensitivity expresses the current status of a system. And within these systems only certain elements are particularly sensitive to climatic changes – and sensitive in different ways and to different degrees and possibly at different times. Therefore, each sensitivity indicator will need to include positive and negative sensitivity values.

On the contrary, adaptive capacity is "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC 2007) meaning an active response strategy with regard to recognised impacts. Based on this understanding, each sensitivity indicator has to be able to express direct or indirect effects of climate stimuli on the system. Referring to the example given by the IPCC, is the percentage of settlements prone to sea level rise an suitable sensitivity indicator while coastal defence systems are part of (technical) adaptive capacities.

Nonetheless, a clear demarcation line between sensitivity and adaptive capacity is not always possible. A system which is characterised as particular sensitive (i.e. expressed by the share of population over 65 years which are sensitive to a couple of effects such as heat waves) is at the same time less able to adapt (as elderly people are generally speaking less able to cope with changes and able to adjust their daily live to a changing environment). Therefore, might the same indicator in single cases of relevance for both, assessing sensitivity as well as adaptive capacity.

The project team has not yet conclusively decided on a final list of sensitivity indicators to be used for the subsequent analytical steps (see also work plan). Thus it is possible or even likely that some of the indicators presented below will finally be discarded and/or other indicators be added in order to fulfil the data requirements of the now more detailed exposure (and vulnerability) analysis.

One should note also that sensitivity is understood here as a degree of potential affectedness by climate change without further adaptation measures. Such reactive or proactive behaviour and corresponding technologies are considered in detail in the chapter on adaptive capacity. In the end, only the combination of exposure to climate change, sensitivity to climate change and adaptive capacity will indicate the overall vulnerability of regions to climate change.

3.1 Dimensions of climate change sensitivity

As already outlined in the project's proposal and further elaborated in the inception report, the project's analytical approach to the sensitivity assessment differentiated several dimensions of climate change sensitivity. This approach can be justified from a systems theory perspective, but also from an EU policy perspective. For the latter it may suffice to note that the EU – in their Territorial Agenda and related concepts – like territorial cohesion – likewise uses an integrated, dimension-based approach. Thus it will be easy to later on relate the findings of the ESPON Climate project to the EU's integrated, but also its sectoral policies.

At the outset of the project, six dimensions of sensitivity were identified. However, upon closer analysis the sixth dimension (institutional sensitivity) was found to better fit into the adaptive capacity concept: Institutions are not so much sensitive themselves to climate change, but they influence the climate change sensitivity of a region indirectly. For example, future-oriented and efficient institutions may increase or reduce the capacity of a region to cope with an extreme weather event triggered by climate change. Therefore most aspects of what was formerly referred to as 'institutional sensitivity' could be shifted to the adaptive capacity section of the vulnerability assessment. Hence the following sensitivity dimensions remained:

Physical sensitivity relates to all human artefacts that are important for territorial development, such as settlements or infrastructure, and are affected by climate change.

Environmental sensitivity in contrast involves natural ecosystems that are under the duress of changing climate conditions – or may benefit from them.

Economic sensitivity relates to all economic activities that are sensitive to long-term or rapid climate changes. Some economic sectors may benefit, others are likely to suffer from these changes, as is analysed in detail in Actions 2.2 and 2.3 of the project (represented in Chapter 4 and hence not dealt with in the following indicator description).

Cultural sensitivity encompasses natural and urban landscapes and monuments with special cultural attributes that render them important parts of the cultural heritage of local communities, regions, nations or even the global community and that in addition are influenced by climatic changes.

Social sensitivity denotes the sensitivity of population in general, but also different social groups to climate change effects, e.g. old people's health-related sensitivity to increasing temperatures.

3.2 Towards a comprehensive set of climate change sensitivity indicators

According to the project's workplan the identification and assessment of sensitivity indicators began in November 2009 and run till. Therefore the following section presents a first list of sensitivity indicators and how they relate to the identified exposure indicators. The list is very much work in progress and should be expected to undergo significant changes and additions in the following months. Note that indicators for economic sensitivity are covered in separate sections of this report.

3.2.1 Physical sensitivity indicators

Settlements prone to heavy rainfall

Heavy rainfall may result in flash floods which can severely damage or destroy settlements. In fact, flash floods are highly visible and politically prominent hazards that potentially increase due to climate change.

Using the CORINE database in conjunction with appropriate digital elevation models it should in principle be possible to measure the % of settlement area of each NUTS 3 area located in sinkholes. Furthermore steepness of slopes could be added as a factor aggravating the flash flood and thus also mass movements issues triggered by heavy rainfall.

Settlements prone to sea level rise

Maps that depict coastal areas at risk of potential inundation or other adverse effects of sea-level rise are appealing to planners that are charged with communicating, adapting to, and reducing the risks (Coastal States Organization, 2007). Likewise, map-based analyses of sea-level rise vulnerability often include statistical summaries of population, infrastructure, and economic activity in the mapped impact zone, as this information is critical for risk management and mitigation efforts. Many studies have relied on elevation data to delineate potential impact zones and quantify effects. However, in general, many vulnerability maps (and corresponding statistical summaries) imply that a simple inundation scenario is an adequate representation of the impacts of rising seas (Schneider and Chen, 1980; Rowley et al., 2007; Demirkesen et al., 2008).

It is unclear whether simply modeling the inundation of the land surface provides a useful approximation of potential land areas at risk from sea-level rise. Some studies do mention the various types of coastal impacts (erosion, saltwater intrusion, more extreme storm surge flooding) (Najjar et al., 2000; Gornitz et al., 2002), and some studies that focus on wetland impacts do consider more than just inundation (Larsen et al., 2004). However, new assessments must include recognition that inundation, defined as submergence of the uplands, is the primary response to rising seas in only some areas. In other areas, the response may be dominated by more complex responses such as those involving shoreline erosion, wetland accretion, or barrier island migration.

Infrastructure prone to sea level rise

The same reasoning as above applies to infrastructure like streets, railway networks and power plants. For data availability and methodological challenges to calculate this indicator see 'Settlements prone to sea level rise'. Projections into the future are not easy (could only be assumed to run parallel to population and GDP growth).

Infrastructure prone to heavy rainfall

The same reasoning as regards settlements can be applied to infrastructure like streets, railway networks and power plants. The % of these infrastructures per NUTS 3 region lying within certain categories of sinkholes can be used as an indicator.

Data availability, quality and suitability for forecasting as discussed above.

3.2.2 Environmental sensitivity indicators

Forests

Increasing mean annual temperatures, more days above 25 °C and decreasing summer precipitation in a region will likely cause forests to be drier and more prone to forest fires. For this sensitivity one can use the share of forest area in relation to the total area of a NUTS 3 region. However, sensitivities differ for different types of forest, which has to be taken into account for this indicator. It also has to be considered that most forest fires are actually caused by humans, but drier vegetation increases the likelihood that fires will spread quickly. Therefore data related to the actual occurrence of forest fires cannot be interpreted in a clear way in regard to sensitivity.

Reliable and detailed data on forest coverage by forest types across Europe is available in the CORINE database. Data on actual occurrence of forest fires is also available from ATSR World Fire Atlas for the time period 1997 – 2008, but is analytically problematic as explained above. Forecast of forest coverage is not so easy and is itself also dependent on other climate variables.

Especially sensitive/protected natural areas

For areas that are of special natural value and therefore legally protected any extraordinary changes of climate parameters can have serious environmental effects. Any changes also means it does not matter in which direction these climate parameters change, since natural habitats (especially very sensitive ones) are ideally adapted to the specific environment to be found in a certain location. Thus whether e.g. annual precipitation increases or decreases significantly might cause such a habitat to be altered irrevocably. However, different ecosystems have different sensitivities to climatic changes. Therefore, while the share of Natura 2000 areas in relation to the total NUTS 3 area or a region can be used as a general indicator, but also has to consider the specific sensitivities of different types of Natura 2000 areas.

The Natura 2000 register includes data on these protected areas (which include Special Areas of Conservation and Special Protection Areas for birds). Detailed data exist on each Natura 2000 area, which have been used before for estimating their climate change sensitivity.

Ecoregions especially sensitive to climate change

Apart from protected habitats there are other habitats whose fauna and flora is especially sensitive to climatic changes. For some types of these ecoregions, a decrease of temperature and precipitation is problematic, for others it is a rise of temperatures and precipitation. Thus different types of ecoregions have to be selected and analysed separately. The respective indicator is the share of area of such ecoregions in relation to the total area of a NUTS 3 area.

Data quality and availability for this indicator is very good as the European Environmental Agency (in collaboration with other institutions) has up-to-date and detailed digital maps of many types of ecoregions in Europe, which need to be combined with studies on the climatic sensitivity of each ecoregion type.

Areas of high ecological value

Climate change and related habitat changes (and potential negative ecological consequences) are especially important for areas with a high ecological value (based on their rare and/or untouched vegetation and fauna). Any climate changes that may result in a decreasing size or reduction of biodiversity in these areas would be of special importance. Thus an indicator measuring the share of such area in relation to the total area of a NUTS 3 area is proposed.

Data quality and availability for this indicator is very good as the European Environmental Agency (in collaboration with other institutions) has up-to-date and detailed digital maps of different vegetation type regions in Europe. An identification and reclassification of the most valuable vegetation types will enable to calculate the relative share of such regions in relation to NUTS 3 areas, as has been implemented in other research projects.

Fragmented natural areas

Small, fragmented natural areas are generally more sensitive to changes in temperature and moisture conditions, because they are destroyed faster than larger natural areas which have a higher capacity to – after an initial, climate induced reduction – to recover. Thus out of the ecoregions identified in the previous indicator it is possible to calculate the share of small, fragmented natural areas to all natural areas.

Data quality and availability conditions are the same as above. This indicator has also already been used by the ESPON Hazards project with good results.

Further issues

Further relevant environmental drivers of territorial and socio-economic sensitivity such as climate change impacts on soils (carbon, water retention, soil sealing), on ecosystems and biodiversity (phenology, localisation, disruptions, invasive species, etc.) will be added to the final list of indicators.

3.2.3 Cultural sensitivity indicators

Cultural monuments especially sensitive to climate change

Changing temperature and moisture conditions (annual mean temperatures, precipitation, frost and snow days) can have a detrimental effect on monuments, many of which are very old buildings. Generally higher moisture is more detrimental to the physical, structural condition of such buildings. Some may also be located in areas that are potentially affected by river flooding and coastal storm surges. Therefore the density of monuments per NUTS 3 region and the density in regions with a high share of land below 5 metres above mean sea level and affected by river floods will be suitable indicators. Different types of cultural monuments (with different sensitivities) may have to be differentiated.

Within ESPON 2007 a composite indicator of monuments registered locally and regionally has been compiled which can be used within ESPON Climate as well. For data availability and methodological challenges related to sea level rise and heavy rainfall see the comments for ‘settlements prone to sea level rise’ and ‘settlements prone to heavy rainfall’.

UNESCO World Heritage Sites especially sensitive to climate change

A special case are historical sites (buildings, monuments, cities) protected by the UNESCO as world heritage sites. These are monuments of global importance and hence have the highest protection status. As argued above, these sites are sensitive especially to changing moisture conditions, but also to river floods (caused by prolonged high precipitation in winter months and high surface water runoff) and coastal storm surges due to rising sea levels. The indicator to be used would therefore be density of UNESCO World Heritage Sites per NUTS 3 region, which can then also be related to NUTS 3 regions with a high share of area affected by heavy rainfall and costal storm surges respectively.

Data quality and availability for World Heritage Sites is especially good, as the UNESCO maintains a database with exact geographic references for each site. Different types of historical sites with possibly different sensitivities may have to be differentiated. As regards future changes, as argued above, the number of World Heritage Sites can be considered to remain more or less stable, especially considering the high protection status of these sites. For data availability and methodological challenges related to coastal storm surges and river flooding see the comments for 'settlements prone to sea level rise' and 'settlements prone to heavy rainfall'.

Cultural landscapes especially sensitive to climate change

A special case of heritage sites registered by UNESCO are cultural landscapes "representing the combined work of nature and man" (UNESCO definition). These may be landscapes designed and created by humans intentionally, or shaped by humans over longer time periods and now valued for religious, artistic or cultural reasons. Their protection status is the same as other World Heritage Sites, but in terms of climate change sensitivity they differ because they are not buildings or historical monuments. Thus in terms of sensitivity this indicator has to be treated more like indicators in the environmental sensitivity dimension. However, their sensitivity is generally lower than e.g. protected natural habitats, because they have by definition been shaped and influenced by human intervention, usually over centuries.

Data quality and availability is the same as for other UNESCO World Heritage Sites. However, the cultural landscapes are larger areas (as opposed to a e.g. a historic building) thus the indicator would be share of area covered by a cultural landscape in relation to total NUTS 3 area. As argued above, different types of cultural landscapes with potentially different degrees of sensitivities may have to be differentiated. As far as suitability for future oriented analyses is concerned, the number and size of these cultural landscapes can be considered more or less stable given the high protective status of these sites.

Museums, galleries, theatres and public libraries especially sensitive to climate change

Public and private cultural institutions are potentially endangered by flash floods and seal level rise. Therefore a suitable sensitivity indicator is the density of such institutions in NUTS 3 regions projected to be affected by increased river floods or being below 5 metres above current mean sea levels. For data availability and methodological challenges to calculate this indicator see 'Settlements prone to sea level rise' and 'Settlements prone to heavy rainfall'.

Separate indicators for museums, galleries, theatres and libraries have been used in ESPON 2007 projects but can be combined here to a composite indicator. However, given the trend of closing cultural institutions due to public budget constraints it is a little doubtful if the same number of institutions can be assumed to exist in the forecasting period of special interest to ESPON Climate (2070-2100). It might be possible to relate the number of cultural institutions to projected population and especially GDP changes and adjust the numbers accordingly.

3.2.4 Social sensitivity indicators

Total population

A major indicator for measuring the social sensitivity of regions is the number of inhabitants of a region. Some might argue that only special population groups, such as senior citizens, should be the focus of a climate change sensitivity analysis. Such special groups are indeed the most likely and most severely groups to be affected by climate change. However, even if all other persons are only marginally affected, it makes a difference if they amount to several million persons (in the case of major agglomerations) or only to a few thousands as in rural areas. This difference in scale can therefore be captured with this indicator.

Data for total population of regions in the ESPON space are readily available. Projections into the future are currently being developed by the ESPON project DEMIFER, which will be ready for use within the next months.

Coastal population

General increases of annual mean temperatures are projected to lead to a rise of sea levels. This sea level rise will not be enough to flood coastal areas right away because of existing coastal protection (e.g. dikes). However, these coastal protection facilities will be under greater stress and may not suffice if mean sea levels are already higher than they are now. Thus a useful indicator is the share of population living in areas prone to sea level rise in relation to total population in a NUTS 3 area.

For data availability and methodological challenges to calculate this indicator see 'Settlements prone to sea level rise'. As far as future projections are concerned, relief data will not change significantly. Demographic forecasts are the subject of another ESPON project (DEMIFER) which promised to calculate projections up to 2100. These projections for NUTS 3 will then have to be related to existing population distributions within NUTS 3 areas in order to estimate future population figures.

Population endangered by heavy rainfall

Rising or decreasing risks of heavy rainfall which triggers flash floods and mass movements has detrimental or beneficial impacts on all inhabitants of prone areas. Thus a suitable indicator is the total population in areas prone to heavy rainfall of NUTS 3 regions.

For data availability and methodological challenges to calculate this indicator see 'Settlements prone to heavy rainfall'. Population projections until 2100 will be provided by ESPON's DEMIFER project.

Urban population

Increasing number of days with maximum temperatures above 25 °C are generally a possible health risk for humans. In rural areas hot temperatures are usually mediated by wind and vegetation, but in urban areas temperatures can even be higher due to the high proportion of sealed surface. The problem can be especially severe when so called heat islands develop in densely built-up areas. These heat related phenomena affect the urban population in general and certain population groups in particular (see senior citizen below) but also have economic effects, e.g. costs for in-house cooling systems. The indicators to be used for this sensitivity are share of urban population of a NUTS 3 area population and share of high density urban areas in relation to total NUTS 3 area (for heat islands).

Data on urban populations are available for NUTS 3 areas across Europe. Population projections and possibly also trends for urban populations are expected from the DEMIFER project. Data availability and comparability of data across Europe on the density of housing units, industrial and commercial establishments could not be ascertained yet. Future changes of such densely built-up areas would have to be modelled using general population and GDP projections, which also has an impact on energy demand.

Senior citizens

Human sensitivity to climate changes is age dependent. Older persons are in general more sensitive to environmental changes than other age groups. Senior citizen may be affected by climate change in terms of health (more moderate temperatures are beneficial, more heat days and frost days are detrimental) and mobility (number of snow days and days with heavy rainfall). As an appropriate indicator it is suggested to use share of population above 65 years in relation to total population of a NUTS 3 region. This should be combined with indicators on urban population densities, because temperatures are generally higher in urban areas (potentially leading to urban heat islands) and thus create conditions that more harmful for senior citizen's health.

Reliable population data for different age groups are available across Europe. Projections up to 2100 for the age group 65 years and older are usually only computed for national populations. Based on known age distributions in each NUTS 3 area these national data can be used (with a few assumptions e.g. regarding migration of senior citizen) for calculating regional trends for this age group.

This list of indicators represents the current status quo of the sensitivity assessment. As already indicated above it constitutes 'work in progress'. The following issues and analytical steps are still to be dealt with:

- *Data projections/scenarios:* Some indicators presented above are rather static (e.g. number of monuments). However, many other indicators are (also) influenced by other drivers of change and are possibly very dynamic (e.g. economic development). In these cases some kind of 'extending' the data towards the second half of the 21^{st} century is called for, because it would be misleading to use sensitivity data of e.g. 2005 and relate them to exposure values for the last decades of the 21^{st} century. However, for very few indicators do such long-term forecasts exist (e.g. population changes) and even these are not very robust. Therefore the project will probably have to resort to some plausible scenarios or make some rough qualitative assumptions regarding the future direction of certain indicators.
- *Data availability:* Even though a first data availability check has been carried out for the presented indicators (for many also in Balkan countries and Turkey), the real quality and complete availability of the respective data across the ESPON space can only be ascertained when the data are being processed. Therefore the data identification has so far also focused on relatively standard and widely available statistical data.
- *Data aggregation:* For the purpose of subsequently calculating the climate change impact and vulnerability of each region, the sensitivity data related to one particular exposure

variable need to be aggregated. Since this entails substantive and normative judgements regarding the importance of various indicators, it is planned to involve experts from across Europe in a tailor-made Delphi Survey (see Chapter 7). For aggregating indicators towards a composite indicator for each sensitivity dimension, these judgements will be made by the project team (since the results will not be used for subsequent calculations).

- *Validation*: The suspected relation of sensitivity indicators to exposure variables and the projection methods need to be validated by scientific studies in the respective fields of the indicators.

4. Sectoral economic sensitivity to climate change

4.1 Introduction

One of the five dimensions of sensitivity to climate change is economic sensitivity. This is the focus of Actions 2.2 and 2.3. The overall objective is to map the economic sensitivity of European NUTS 3 regions to climate change by looking at the economic future of various economic sectors. The following section of the report present the result of a literature review and the development of an analytical framework (jointly undertaken under Action 2.2 and 2.3) as well as preliminary results of identifying economic sensitivity indicators and data availability.

4.2 Methodology

The methodology consists of the following key steps. Steps 1-4 are presented in this interim report. Steps 5-11 will be presented in the draft final report:

1. Identifying key sectors of the economy that are directly affected by the climate change exposure using knowledge gained from the literature review
2. Identifying sectors of the economy that are indirectly affected through downstream effects on production/consumption using knowledge gained from the literature review
3. Identifying and describing other economic aspects including a discussion of urban agglomeration and climate change
4. Identifying the key indicators (or proxy indicators) for assessing the dependency of each European region on each of the economic sectors that have been identified in step 1 above
5. For each type of climatic region identified by the cluster analysis assessing sensitivity and finally impact (in terms of positive, negative, and negligible) on each economic sector that has been identified in step 1. The assessment will be based on knowledge gained from the literature review.
6. Assessing the level of regional dependency on the economic sectors that have been identified in step 1 in terms of high, medium and low impact. The assessment will be based on the indicators identified in step 4.
7. Map economic dependency for each sector
8. Undertake cluster analysis to produce typologies of regions with similar patterns of dependency (e.g. regions with high dependency on agriculture and low dependency on tourism)
9. Map typology of the regions based on the cluster analysis in step 8
10. Undertake cluster analysis to produce typologies of regions with similar patterns of economic sector sensitivity for climate change.
11. Map the typologies of regions with similar patterns of economic sector sensitivity for climate change on the basis of analysis in step 10 above.

4.3 Direct impacts of climate change on economic sectors

Climate change can potentially impact a wide range of economic activities and sectors. Some of these sectors are directly affected by the changes in climatic variables such as long term changes in the level of precipitation and temperature. Others will be affected indirectly through the supply and demand chains. A third category can be affected as a result of extreme weather events such as flooding.

Based on a comprehensive review of scientific literature, the key sectors of the economy which are likely to be directly affected by climate change are: the primary sectors (agriculture, forestry, fishery and aquaculture), the tourist sector, the energy sector and infrastructure. Linked to these sectors are those sectors of the economy that will be affected indirectly, notably the food processing industry and pulp and paper industry (related to primary sectors), supply services for tourist industry and the insurance industry.

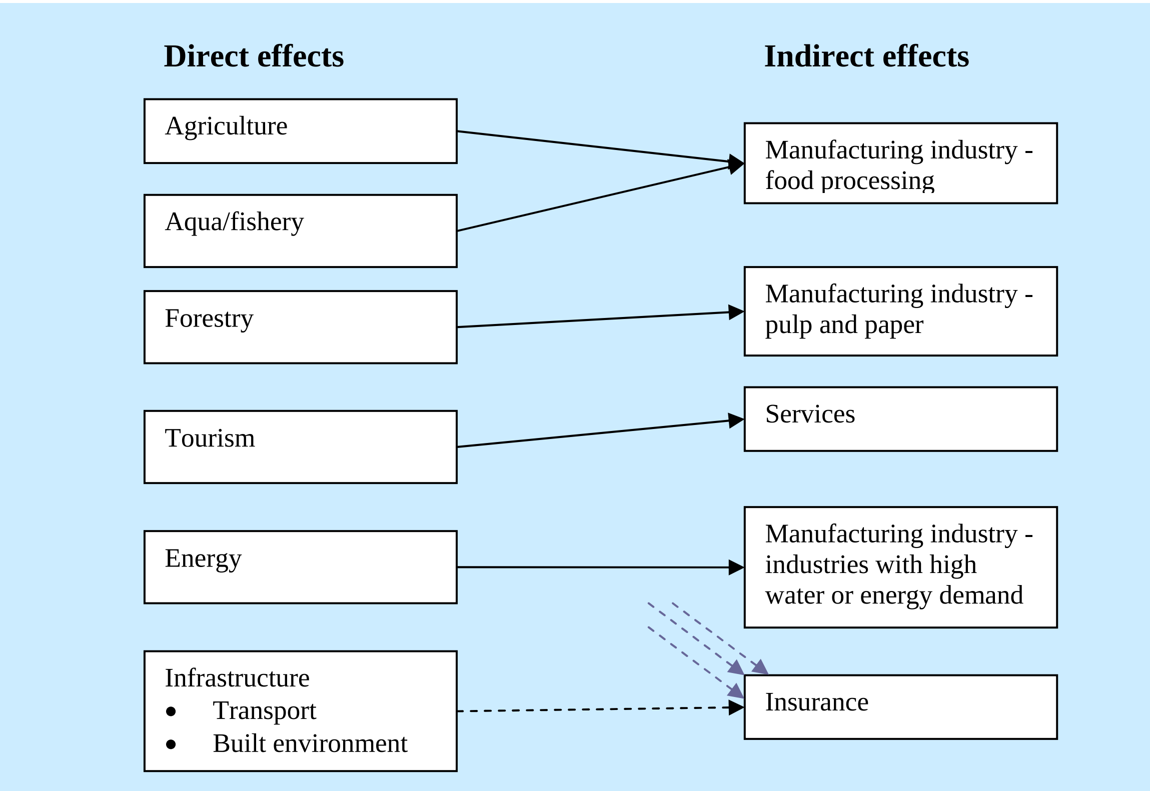

Figure 21: Direct and indirect effects on economic sectors

Different economic sectors are sensitive to different climate exposure indicators. For agriculture the length of growing season and the level of water availability are crucial. For winter tourism, the level of snow fall is significant while for summer tourism the change in temperature below or above the Tourism Comfort Index is important. For energy and / or water intensive industries, the scarcity and cost of energy and water can have major impacts. Infrastructure can be affected through extreme events.

The following section summarises the results of the literature review on the likely impacts of climate change on the economic sectors that are identified above.

Agriculture

Rising mean temperatures and increased atmospheric CO2 are in general conducive to plant growth. However, in the case of Europe the estimated climate changes are expected to only lead to small increases in crop productivity (Alcamo et al., 2007). These small effects will most likely be far out-weighted by technological development in the agricultural sector, e.g. new crop varieties and better cropping practices (Evert et al., 2005).

Agriculture is directly affected by climate change through changing production possibilities. With a fraction of only approximately 2 % of total gross domestic production (GDP) and 4 % of total employment, agriculture accounts for a small fraction of the European economy. But between countries the agriculture fraction of total domestic production differs considerably.

Agriculture accounts for a larger part of GDP in the south and east of Europe. The sector accounted in 2008 for 3,4 % in Spain, 3,7 % in Greece and 4,5 % in Poland, but only 0,9 % in Germany and 1,3 % in UK. Unfortunately, the southern and eastern parts of Europe are – according to most climate scenarios - precisely the ones to be most affected by climate change.

A recent research project (PESETA) estimated the economic impacts of climate change on different sectors of the European economy (see Ciscar, 2009). Their projections on agricultural impacts conclude that for the 2071-2100 time period, southern Europe would experience large decreases in yields, while in Nordic countries increasing yields are expected due to a longer growing season and higher minimum temperatures in winter. In southern Europe agriculture will also have to cope with increasing water demand for irrigation, and with additional restrictions due to increases in crop-related nitrate leaching (see also Alcamo et al 2007). This will even worsen the projections for the south, and this is not fully built into the PESETA model.

Easterling et al (2007) summarises the projected effects of climate change on agriculture crop productivity to increase slightly at mid- to high latitudes for local mean temperature increases of up to 1 to 3°C depending on the crop, and then decrease beyond those temperature in some regions. At lower latitudes, especially in seasonally dry regions, crop productivity is projected to decrease for even small local temperature increases (1 to 2°C). Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1 to 3°C, but with temperatures above this, it is projected to decrease.

Therefore, the negative effects of climate change on the agriculture sector in the south, combined with the relative greater importance of the sector, will probably impose larger income losses in these regions than in the rest of Europe. In contrast, the agricultural systems in the north and west of Europe are considered to have lower sensitivity to climate change, and modelling predictions show likely opportunities in terms of yield increases and wider agricultural crops for northern Europe (EEA, 2008).

Main climate stimuli / drivers for the agriculture sector (selected from the list in table 1 section 2.3):

- Change in annual mean temperature
- Change in annual mean precipitation in summer months
- Change in annual mean number of days with heavy rainfall

Forestry

Forestry in Europe is also a small sector in terms of its GDP share, and in 2003 1.4 mill workers was employed in the sector (measured in full-time equivalents, see Blombäck et al 2003), but the importance of the sector vary substantially between European regions.

Forest ecosystems in Europe are very likely to be strongly affected by climate change (Alcamo et al, 2007). Forests might be particularly sensitive to climate change because of the long growth time of trees. Trees planted today will grow under future climate conditions for several decades. High temperatures and drought will increase forest fire risk, which might lead to drastic damages in Mediterranean forests. Increased frequency and intensity of storm might also damage the forest sector.

Forest area is expected to expand in the north, and contract in the south. Climate change is also likely to affect forestry by changes in composition of species, changing forest yields, and increased costs of extreme weather damage and drought/forest fires (Alcamo et al 2007, EEA 2008).

Main climate stimuli / drivers for the forestry sector (selected from the list in table 1 section 2.3):

- Change in annual mean temperature
- Change in annual number of frost days
- Change in annual mean precipitation in summer months

Fisheries and aquaculture

As share of GDP the fishing sector in European countries are generally less than 1%. But it's economic impact is highly significant as a source of employment in some rural areas where there are few alternatives for employment.

Increasing sea temperature will change maritime species distribution, increase production in the northern parts of the North Sea and decrease production in the southern parts of current ranges. An assessment of the vulnerability of the north-east Atlantic marine eco-region concluded that climate change is very likely to produce significant impacts on selected marine fish and shellfish (Baker, 2005, Alcamo et al 2007). High fishing pressure is likely to exacerbate the threat to fisheries, e.g., for Northern cod (Alcamo et al 2007). Historical sea-surface temperature changes - as low as 0.9°C over the 45 years to 2002 - have led to mismatches between species.

Long-term climate variability is an important determinant of fisheries production at the regional scale, with multiple negative and positive effects on ecosystems and livelihoods. The interactions and impacts of multiple stressors on the marine – like sea-level rise, increased storms and other stressors such as pollutants - are likely, but little known.

Warmer sea temperatures have increased growing seasons, growth rates, feed conversion and primary productivity in the marine and freshwater fish and shellfish aquaculture, all of which will benefit shellfish production (Alcamo et al 2007). Opportunities for new species will arise from expanded geographic distribution and range, but increased temperatures will also increase stress. Ecosystem changes with new invasive or non-native species will increase operation costs. Increased storm-induced damage to equipment and facilities will increase capital costs. Increased water temperature in the sea may also increase the problems with salmon louse and thereby represent a danger to salmon fish farming in several European countries.

Main climate stimuli / drivers for the fishery sector (selected from the list in table 1 section 2.3):

- Change in annual mean temperature

- Change in annual mean number of days with heavy rainfall (comment: if this can be used as a proxy on storms)

Economic dependency assessment

Comparable data on the primary sector at NUTS3 level is only available in aggregated form. Disaggregated data for agriculture, forestry and fisheries is not available for NUTS3 regions. For the final draft report, we will also look at ESPON Edora project to find out what are possible indicators are available.

If disaggregated data is not available, the dependency assessment will be undertaken for the primary sector as whole using the following indicators:

- Share of Gross Value Added (GVA) in primary sector to total regional GVA and / or
- Share of jobs in primary sector to total regional employment

Tourism

Tourism sector is closely linked to climate, in terms of the climate of the source and destination countries of tourists and climate seasonality, i.e., the seasonal contrast that drives demand for summer vacations in Europe (Alcamo et al 2007). A climate change scenario of 1°C increase in mean temperature would lead to a gradual shift of tourist destinations further north and up the mountains, affecting preferences of sun and beach lovers from western and northern Europe. Mountainous parts of France, Italy and Spain could also become more popular because of their relative coolness. Thus some studies forecast a potential shift towards a greater level of domestic tourism.

Higher summer temperatures may also lead to a gradual decrease in summer tourism in the Mediterranean but an increase in spring and perhaps autumn (Ciscar 2009). Occupancy rates associated with a longer tourism season in the Mediterranean will spread demand evenly and thus alleviate the pressure on summer water supply and energy demand (Alcamo et al 2007). Thus climate change may even be beneficial for the Mediterranean tourist industry if it levels-out demand and reduces the summer peak, while increasing occupancy in the shoulder seasons (EEA, 2008). However, in the absence of such adjustments the Mediterranean tourist industry will be among the main losers.

Winter tourism will also be affected by climate change. The ski industry in central Europe is likely to be disrupted by significant reductions in natural snow cover. Especially at the beginning and the end of the ski season this will be a problem. An estimate of the effect at the most sensitive elevation in the Austrian Alps is a 1°C rise leads to four fewer weeks of skiing days in winter and six fewer weeks in spring (Alcamo et al 2007). Another estimate was that a 2°C warming with no precipitation change, would reduce the seasonal snow cover at a Swiss Alpine site by 50 days/yr (Alcamo et al 2007).

However, the economic effects of climate change on tourism depend very much on the question whether holiday seasons remain fixed or if shifts in the holiday season will occur. For example a more flexible timing of holidays among a large proportion of the population would alter projected impacts significantly. These effects may be offset.

Main climate stimuli / drivers for summer tourism sector (selected from the list in table 1 section 2.3):

- Change in annual mean temperature
- Change in annual mean number of summer days
- Change in annual mean precipitation in summer months

Main climate stimuli / drivers for winter tourism sector (selected from the list in table 1 section 2.3):

- Change in annual mean temperature
- Change in annual mean number of days with snow cover
- Change in annual mean precipitation in summer and winter months

Economic dependency assessment

For tourism, comparable data on GVA and employment are aggregated with a long list of other sub-sectors such as retail, restaurants, etc and they not available at NUTS 3 level. However, data is available on number of beds in hotel and similar accommodations at NUTS 3 level. We will use this proxy indicator for estimating the significance of this sector in the regional economy.

- Number of beds per 1000 inhabitants

Energy

Energy demand is dependent on climatic conditions (e.g. outside temperature), particularly in the domestic sector, but also in the service and industry sectors. Climate change, and in particular changes in temperature, is likely to lead to a decrease in demand for winter heating and an increase in summer cooling (Alcamo et al 2007, EEA (2008)).

Projections for Europe suggest reductions in days with heating, and increases in days with cooling, due to mean average temperature increases. The overall changes in energy and economic costs are predicted to be modest in the short-medium term, due to the aggregated effects of decreased winter heating demand vs. increased summer cooling demand (EEA, 2008).

But when looking at regional patterns across Europe it becomes apparent that there will be increasing electricity demand due to cooling in the summer in southern Europe and reduced heating energy demand due to more moderate winters in nothern Europe (EEA 2008). This translates into a likely net benefit to northern Europe and net losses for southern Europe. Around the Mediterranean, two to three fewer weeks in a year will require heating, but an additional two to five weeks will need cooling by 2050 (Alcamo et al 2007). Peak electricity demand is likely to shift in some locations from winter to summer.

The economic costs of the changes in demand are more complex to estimate. The reason is the interactions between energy sources, technology, socio-economic trends and future mitigation scenarios (EEA, 2008). Winter heating demand is primarily from fossil-fuel use, and summer cooling from electricity, and there may be additional issues of peak demand levels in southern Europe in the summer.

On the energy production side hydropower is the main renewable energy source today, and it is highly dependent on water. Its importance is expected to decline somewhat in the future, with a large decrease around the Mediterranean, a stable hydropower pattern for western and central Europe, and a modest increase in northern and Eastern Europe (Alcamo et al 2007).

The generation of electric power in thermal power stations (in particular coal-fired and nuclear facilities) relies on large volumes of water for cooling (EEA 2008). The use of cooling water may be restricted if limit values for temperature are exceeded during heat waves or drought periods, and this may force plant operators to reduce capacity - or even temporarily close down plants.

Main climate stimuli / drivers for energy (selected from the list in table 1 section 2.3):

- Change in annual mean temperature
- Change annual in mean precipitation in winter months
- Change annual in mean precipitation in summer months

Economic dependency assessment

For energy we plan to take advantage of data from another ESPON 2013 project – ReRisk (Regions at risk of Energy Poverty). The updated list of indicators in their Annex to the Inception Report – 21 Nov. 2008, indicates that most data are availability on NUTS 2, and some at NUTS 3 level for Central European and candidate countries (according to ESPON Data Navigator). The most promising indicators for our purpose are

- Electricity consumption by sector (in gigawatt hours)
- Electricity consumption/GDP
- Electricity production capacity (in megawatt)
- Proportion of electricity generated by fossil fuels, solid fuels and natural gas respectively

Infrastructure

A significant direct impact of climate change, and particularly extreme climate events (such as drought, heat waves, heavy precipitations), is the damage to buildings, infrastructure and other assets. In addition to direct costs to infrastructure, there are indirect costs to industry and businesses which are due increased delays and cancellation in transportation of people and goods, problems with communication and power infrastructure (such as decreasing input reliability). In 2003 the heat wave and draught in Europe resulted in record low river levels which adversely affected the transportation of goods along inland waterways (Bates et al, 2008:75). Disruption in transportation infrastructure (such as ports, airports, railways and highways) has not only a direct impact on trades and businesses transactions, but also an indirect impact through the rise in transportation costs (extra repairs and maintenance).

Climate mitigation policies, such as the introduction of a carbon tax, could also increase the cost of transporting goods and industrial processes. Utilities, such as electricity, gas, water and sewage systems are also vulnerable to climate change and particularly extreme climate events. Disruptions in infrastructures such as such as refineries, power plants, electricity sub-stations, water treatment plants, waste management facilities) can cause major disruptions to businesses and economic activities.

The impact of climate change on settlement sand infrastructure is further elaborated in the physical sensitivity analysis.

4.4 Indirect impacts of climate change on economic sectors

As mentioned above, in addition to those sectors of the economy that are directly affected by climate change, there are sectors of the economy that are indirectly affected through a supply and demand chain. The most sensitive sectors are natural recourse intensive industries like food processing industry and pulp and paper industry, the energy-intensive industries (see energy under 4.3), and supply services for tourist industry. The insurance industry is also indirectly affected, as a result of the effects on infrastructure and production (production loss) of extreme weather events.

Given that data for GVA and employment (or any other suitable proxy) on these sectors are not available at NUTS3 level, we are not able to do dependency assessment for these sectors. However, the following section provides a qualitative review of how these sectors may be affected by the changing climate.

Food processing

Activities which involve the primary processing stages of agricultural or fishing products are concentrated in areas close to the source of the raw material. Regions most specialised in food and beverages manufacturing are located in rural areas in or close to agricultural production centres; Bretagne in France was the NUTS 2 region in the EU27+Norway area that was most specialized in 2006, with 11 % share of non-financial business economy employment in this sector (Eurostat regional yearbook 2009). Average share, for all regions, was for comparison about 4 percent.

Agriculture, fishing and aquaculture sectors are highly climate sensitive sectors. The literature on (indirect) climate change effects on the food processing industry is limited, and existing studies do not provide estimates of these indirect economic impacts.

Wood industry/Pulp and paper

Employment in the wood industry and pulp and paper industry are almost twice as large as the forestry sector. European Wood and Pulp and paper industries were employing about 2,5 mill employees (full-time equivalents) (Blombäck et al, 2003). The relative importance of the Pulp and paper industry varies throughout Europe. The importance is highest in traditional wood fibre-rich countries like Sweden and Finland (between 6 and 9 % of manufacturing employment). In other European countries its share of manufacturing employment is less (1-3 %).

The literature on (indirect) climate change effects on the wood industry and pulp and paper industry is limited, and the existing studies do not provide estimates of these indirect economic impacts. But as these sectors depend on inputs (raw material) from forestry, the expectation is that these industries will be affected indirectly by climate changes in the long run. The indirect effect of these sectors will probably increase the overall economic sensitivity of the forest dependent regions, as the industry typically is situated in fibre-rich regions.

Supply services for tourist industry

The impact of climate change on the tourist industry propagates into the economy and leads to indirect impacts on supply services such as travel agencies, tour operators, local restaurants, leisure and recreational facilities. The number of tourist accommodations had risen to over 27 million by 2006 in EU27. These plus restaurants provide jobs for 4.2% of the total persons employed. In addition, there were about 75,000 travel agencies and tour operators who are dependent on the viability of the tourist industry. An indication of the significance of tourism for supply services is the level of tourist expenditure which in 2006 had risen to about 244 million Euros. Regions traditionally associated with tourism, in particular in Spain, Greece and Portugal, were also the most specialised in hotels and restaurants (Eurostat regional yearbook, 2009).

Climate-related changes in the number of visitors will not only affect the tourist industry directly but also businesses whose revenue is partly dependent on the number of visitors such as galleries, theatres, museums, theme parks, site seeing companies, and other tourist attractions. The existing studies do not provide any estimates of these indirect economic impacts. Another potential impact is the change in the pattern of air and rail travel in Europe with economic implications for airlines or rail operators.

Insurance sector

Insurance coverage varies in different parts of Europe but there tends to be a correlation between economic growth and insurance coverage (Petterson et al, 2006). Lack of insurance cover will increase the vulnerability of infrastructure and buildings to climate change. It is estimated that in countries with median per capita incomes of above 9000 US dollars, 29 percent of total property losses are covered by insurance (Freeman and Warner, 2001). This figure is reduced to 1 percent in the lower income countries. With a few exceptions (e.g. Macedonia FYR, Turkey, Bosnia and Herzegovina and Ukraine) per capita income in all European countries is above 9000 US$. However, firstly, private insurers are increasingly reluctant to provide insurance for areas which in the past have suffered from major damages as a result of extreme weather events such as flooding. Secondly, the cost of private insurance is likely to increase in such areas.

Insured damages in Europe are estimated to increase by 5% due to extreme storms with the costs of a 100-year storm doubling from US$25 billion to US$50 billion by the 2080s (Hunt and Watkiss, 2007:21). Large cities with concentration of buildings, economic activities and infrastructure are particularly vulnerable. In countries where government provides funding for reconstruction, given the frequency and intensity of events, such funding sources are also under major pressure.

As the vulnerability of properties in high risk areas increases, so is the vulnerability of the insurance sector. Climate related extreme events have increased the risk of insolvency for insurance sector. For example, damages resulting from Hurricane Katrina in New Orleans almost bankrupted the National Flood Insurance Programme (Wilbanks et al, 2007:369). In places such as Norway, damages to buildings and infrastructure are expected to increase from changes in precipitation patterns (O'Brian et al, 2004). Insurance costs along the Lena river in Russia have increased as a result of more frequent and severe flooding (Perelet et al, 2007). The Association of British Insurers have estimated that claims for storm and flood damages in the UK doubled to over 6 billion pounds over the period 1998-2003, with the prospect of a further tripling by 2050.

4.5 Urban agglomeration and climate change

Cities have a key role to play in the global agenda for addressing the challenge of climate change. Today, approximately half of the world's population lives in cities; by 2050, that proportion will probably have increased to two-thirds. In Europe over 78 percent of population lives in urban areas. This proportion is estimated to reach over 91 percent by 2030 (UN, 2001). As key engines of the global economy, cities are responsible for the bulk of national output, innovation and employment, and they constitute the key gateways of transnational capital flows and global supply chains (OECD, 2006). Europe's urban system is very diverse and includes: global cities, such as London and Paris, large metropolitan areas, such as Madrid and Munich, and numerous small and medium sized towns. ESPON2006, 1.1.1 Project has identified 1595 functional urban areas (FUA) in 29 countries. Out of these FUAs, 76 Metropolitan European Growth Areas (MEGAs) have been identified which present: a large population, a highly competitive economy, a strong knowledge base, good accessibility, and access to decision making (i.e. headquarters of the top 1500 European firms). Cities also use between 60 to 80% of energy production worldwide and account for a roughly equal share of global greenhouse emissions. In Europe, per capita greenhouse gas emission in 2002 was 10.4 tonnes CO2 equivalent. Concentration of population and economic activities in large metropolitan areas put pressures on environmental assets and increase risk of pollution, congestion, loss of habitat and a larger share of emissions.

Some European urban agglomerations are home to the highest combination of high risk natural and technological hazard (ESPON 2006:44). The location of major cities in coastal areas, for instance increases their vulnerability to water-related calamities, increasing the risk to property, livelihoods and urban infrastructure. How cities develop is part of the climate problem, but it can also be part of the solution. The future urban economy that will be impacted by climate change will differ from today's economy, and even small changes in economic development can make a difference in climate change impacts.

Cities function as integrated systems, consisting of many closely interlinked sectors of economic activity and types of infrastructure. Major urban agglomerations are totally dependent on public transportation and the economic activity in cities like London and Paris would be threatened by a long interruption of their subway service. In the same way, damages to the sewage and water drainage infrastructure may lead to serious health issues, with indirect consequences on all activities. Direct impacts of climate change can be estimated with some level of confidence but indirect effects of this impact on the entire urban economy are far more complex to assess. Direct impacts will often make up only a fraction of total economic impacts whereas indirect or systemic impacts on the city as a whole may be much more severe (Hallegate, S.F and J. Corfee-Morlot 2008).

Since cities concentrate so much activity in limited areas and consist of many sectors and infrastructures closely interlinked, assessment of indirect impacts is particularly important in urban areas. Assessing climate change impacts in urban agglomeration, therefore, cannot be based on a quantitative single sector approach (Mendelsohn et al., 2000; Nordhaus and Boyer, 2000; Tol, 2002a, b). It requires a systemic view, taking into account all components of the socio-economic activity and the network of relationships making up the system.

Cities and economic concentration

Urban areas are characterised by a concentration of diverse economic activities and high productivity. A pooled labour market increases the possibility of skills-matching between workers and firms, and firms agglomerate seeking to reduce risks of contract defaulting, as they have access to a wider set of skills and can establish linkages with suppliers and buyers. Knowledge spill-over in urban areas benefit not only the city but also the wider regional area. In approximately half of OECD countries, more than 40% of the national GDP is produced in less than 10% of all regions, which account for a small share of the country's total surface and a high share of the country's population (OECD, 2009c). In Europe, 46 % of the GDP is produced in Pentagon[11] which covers only 14% of the EU25 territory and hosting 32% of its population.

Urbanisation is generally associated with higher income and productivity levels. This is particularly so in metropolitan areas. In many OECD countries, one single metropolitan area produces one-third to one-half of the national GDP (e.g. Oslo, Auckland, Prague, Tokyo, Stockholm, London, and Paris). Most OECD metropolitan regions with more than 1.5 million inhabitants feature a higher GDP per capita, a higher labour productivity and higher employment levels than their national average.

Cities and energy use

Cities account for an increasingly large proportion of global energy and CO2 emissions. It is estimated that 60-80% of world energy use currently emanates from cities (IEA, 2008a). Cities (including towns) currently use over two-thirds of the world's energy even though they only account for approximately 50% of the world's population. By 2030, cities are expected to account for more than 60% of the world's population and 73% of the world's energy use (IEA, 2008a). Of the global energy use projected by 2030, 81% is expected to come from non-OECD countries. Urban areas in the European Union will likely account for 75% of EU energy consumption, up from 69% in 2006. Cities contribute to climate change in three main ways: through direct emissions of GHGs that occur within city boundaries; through the GHG emissions that originate outside of city boundaries but are embodied in civil infrastructure and urban energy consumption; and through city-induced changes to the earth's atmospheric chemistry and surface albedo.

Climate change impacts specific to urban regions

Cities and metropolitan regions contribute to climate change in specific ways, and they are also vulnerable to potential climate change impacts in specific ways. Climate impacts will result from worldwide climate change trends, but will affect individual metropolitan regions differently. Some effects of climate change are reasonably predictable (e.g., melting of glaciers, changes in global temperature regimes), while others are not (e.g., frequency and magnitude of extreme weather events). In addition, many impacts, including sea level rise, heat waves, droughts, spread of alien species and disease, vary in their local impact. In general, those that show high regional variation are particularly difficult to predict. Cities are vulnerable because of the complex and fixed nature of urban infrastructure, the density of economic activities and the potential for higher concentrations of poor residents. Functioning urban infrastructure and a healthy environment not only provide the urban population with the necessary structure for carrying out economic and social activities, but are also prerequisites for ensuring the competitiveness of a city.

Coastal flooding risk

Cities are highly concentrated in coastal zones, which put a large portion of the urban population at risk from rising sea levels and intensifying storm surges. Mean sea level has risen 10-20 centimetres in the 20th century, and the IPCC expects sea levels to rise 30-50 centimetres by 2100 (Watson et al, 2001). Peak sea levels, which are most relevant for coastal planning as they characterise storm surges, may be rising even faster. Regional climate modelling for Norway show that sea level rise at the West coast will be about 75 centimetres in 2100 and the storm surge may increase up to 221 to 276 centimetres (Hansen-Bauer et al 2009). Rising sea levels, therefore, are

[11] Area covering metropolitan areas of London, Paris, Milan, Munich and Hamburg

a critical issue for major cities, particularly in developing countries. But even in Europe, 70% of the largest cities have areas that are less than 10 metres above sea level (McGranahan et al., 2007). Projected sea level rise is also associated with significant loss of land in coastal regions.

Precipitation and storm impacts

More frequent storm events caused by climate change can result in hydrological changes that stress the capacity of drainage infrastructures, sewage systems and water treatment facilities in cities (Ruth & Gasper in OECD 2008a). Heavy precipitation events wash urban pollutants into rivers and lakes, and can reduce water quality in reservoirs by increasing turbidity. Urban runoff and failures of combined sewer overflows and municipal sewer plants can all introduce pathogens into water systems that pose a variety of health risks. Floods are one of the most costly and damaging disasters, and will pose a critical problem to city planners as they increase in frequency and severity.

Heat impacts and heat-island effects

Cities also face significant increases in temperatures and in the frequency of heat waves. According to the IPCC A2 scenario, average annual temperatures projected for the period 2070-2100 indicate that urban population in European cities will feel as if the weather of the city had moved southwards. London will feel more like Bordeaux, Paris much more like Marseilles and Madrid and Rome will be as hot as North African cities. Heat waves are likely to increase in severity and duration in the future, and these increases will likely be more strongly felt in urban areas, as cities tend to have higher air and surface temperatures compared to rural areas. This is known as the urban heat island (UHI) effect. The built environment, including buildings and roadways that absorb sunlight and re-radiate heat, combined with less vegetative cover to provide shade and cooling moisture, all contribute to cities being warmer and susceptible to dangerous heat events (OECD, 2009b).

Effects of increased drought and water scarcity

Climate change may intensify competition for water. Cities generally rely on their immediate surroundings for water. Areas most likely to be affected include those that rely on snow melt for water over the course of the summer, since winter snow packs in most places will decline (McCarthy et al, 2001). This will exacerbate the pressure on water resources caused by rising population and affluence (AAAS, 2006) and require revision of urban water supply strategies.

More acute impacts on health and the poor

Urban centres may be particularly vulnerable to some of the distributive impacts of climate change. Poor populations in both rich and poor nations are expected to be the most vulnerable to climate change in part due to the lack of resources and capacity to respond in a timely manner or to adapt or to move to less vulnerable areas. Climate change can also impact cities by increasing rural-urban migration. According to the International Federation of the Red Cross, climate change disasters are now a bigger cause of population displacement than war and persecution. Rapid and unmanaged growth in urban populations can strain the availability of housing and basic infrastructures (particularly water and sanitation), increasing the potential for negative health impacts and vulnerability to natural disasters (Hallegatte et al., 2008).

5. Cost-benefit analysis for climate change assessment

First, a short general discussion of cost-benefit analysis will be given. Then, issues more particularly addressed to climate change will be considered.

5.1 Cost-benefit analysis – a general introduction[12]

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 carried out. 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).

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 (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.

When there are conflicts of interest (losers and winners): there is no such thing as a neutral social benefit measure. CBA measures costs and benefits in money; but *money* does not mean the same to all in terms of *utility*. When politicians sometimes regard CBA as non-neutral it might be fully rational and reasonable.

[12] This part is to a large extent based on Nyborg (2005) and NOU 1997:27. Both publications are written in Norwegian.

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.

5.2 Cost-benefit analysis and climate change[13]

There are to main types of responses to climate change where CBA can be used; adaptation and mitigation. In the following, we only consider adaptation. Unlike mitigation which has to be coordinated internationally, adaptation decisions are largely decentralized. Even the most stringent mitigation efforts cannot avoid further impacts of climate change in the next few decades, which makes adaptation essential, particularly in addressing near term impacts. Some adaptations will have a public character and as such may be provided by the state (local authorities or national governments). Other, perhaps most, adaptation decisions will be taken by private agents, such as individuals and firms.

Let us consider sea level rise as an example. Sea level rise is relevant in costal zones. 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 in the coastal zone case can be:

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

[13] This part is to a large extent based on Agrawala and Faukhauser (2008).

Guidelines for CBA

A cost-benefit analysis of adaptation has to be done in several steps:

- Step 1: Identify 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 are not really a part of the CBA but steps used as inputs, such as climate data provided by natural scientists. The kind of action one should take is chosen on basis of hazard assessment and vulnerability assessment. Cost estimates in a CBA are based in models that seek to minimise the total costs of climate change, i.e. the costs of protection and the residual (unprotected) damages that will be incurred through loss of valuable endowments, such as land and natural habitats. Benefits in the protection case will be the avoided damages as a result of protection. While not always reported explicitly, they are nevertheless a key component to computing optimal levels of protection. The damages of e.g. sea level rise can be of the following types:

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

Empirical studies face some limitations caused by narrow scope, uncertainties due to endowment values - endowment values are often assumed to be static - and the studies are often micro-based, which lead to partial analyses. Climate issue is global, but assessments are carried out in restricted geographical areas.

The long-term nature of climate change makes timing an important part of adaptation decisions. Like decisions about the level of adaptation, timing decisions will be based on the relative costs and benefits of taking action at different points in time. The timing decision thus depends of three factors:

- The difference in adaptation costs over time
- The short-term benefits of adaptation
- The long-term effects of early adaptations

Uncertainty about the exact nature of climate change impacts at the local and regional level makes it difficult to fine-tune adaptation measures.

5.3 Monetary valuation in practice[14]

Environmental goods (E) can in CBA be valued by the individuals in three ways:

- User value: Willingness to pay to go fishing, hiking etc.
- Option value: Willingness to pay for the option to use the good later (or having the option than others can use it later)
- Existence value: Willingness to pay for knowing that the environmental good exists, even if one never plans to use it

[14] This part is based on Nyborg (2005) and a workshop in Potsdam in the Baltcica project.

The valuations can be done by:

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

Direct methods

Direct methods can be laboratory experiments. Then the participants are given choices in the lab: E.g. give the participants a sum of money and auction an environmental good between subjects. Does the willingness to pay vary with information on the environmental good?

Or you can use the method of contingent valuation by interview surveys. E.g. one can ask the respondents: «How much would you be willing to pay to improve air quality in Oslo by 10 %? ». There is some kind of problems by the use of contingent valuation. The main problems are:

- Strategic reporting (free riding, support)
- Misperceptions (what does it mean to «improve environmental quality by 10 %»?)
- Inexperience: Anchoring effects[15], framing effects [16]
- Contingent valuation can be costly

But, the method of contingent valuation has also some advantages:

- Only way to measure existence values
- Great flexibility: can ask almost anything

Indirect methods

Even if there are no markets for environmental goods there might be market goods which are closely tied to the use of environmental goods.
Some goods are *complementary* to an environmental good:

- Fishing rod to clean water
- Bus tickets to a national park

Some goods are *substitutes* to an environmental good:

- Bottled drinking water to clean tap water
- Noise isolating window glass to quiet outdoors environment

By making appropriate assumptions about the relationship between the market good and the environmental good, use value of environmental good can be estimated.
The most used indirect methods are:

- The travel cost method
- The hedonic price method

Travel cost method

The travel cost method estimate the willingness to pay for environmental goods one must travel to like national parks and skiing amenities etc. The «price» to visit the amenity expresses the lower limit of the willingness to pay to visit.

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[15] **Anchoring** is a cognitive bias that describes the common human tendency to rely too heavily, or "anchor," on one trait or piece of information when making decisions.

[16] The **framing effect** is a cognitive bias that describes that presenting the same option in different formats can alter people's decisions. Specifically, individuals have a tendency to select inconsistent choices, depending on whether the question is framed to concentrate on losses or gains

Travel costs might be:

- Train/bus tickets.
- Gas/car expenses.
- Entrance fees, fishing permits etc.
- Time costs: Alternative use of time (e.g. working, earning money)

Advantages of the Travel Cost Method are:

- The travel cost method closely mimics the more conventional empirical techniques used by economists to estimate economic values based on market prices.
- The method is based on what people actually do rather than what people say they would do in a hypothetical situation.
- The method is relatively inexpensive to apply.
- On-site surveys provide opportunities for large sample sizes, as visitors tend to be interested in participating.
- The results are relatively easy to interpret and explain.

There are also some limitations of the Travel Cost Method, such as:

- The travel cost method assumes that people perceive and respond to changes in travel costs the same way that they would respond to changes in admission price.
- The simplest models assume that individuals take a trip for a single purpose – to visit a specific recreational site. Thus, if a trip has more than one purpose, the value of the site may be overestimated.
- Defining and measuring the opportunity cost of time, or the value of time spent traveling, can be problematic. Because the time spent travelling could have been used in other ways, it has an "opportunity cost." This should be added to the travel cost, or the value of the site will be underestimated.
- The availability of substitute sites will affect values.
- Those who value certain sites may choose to live nearby. If this is the case, they will have low travel costs, but high values for the site that are not captured by the method.
- Interviewing visitors on site can introduce sampling biases to the analysis.
- Measuring recreational quality and relating recreational quality to environmental quality can be difficult.
- Standard travel cost approaches provides information about current conditions, but not about gains or losses from anticipated changes in resource conditions.
- In order to estimate the demand function, there needs to be enough difference between distances travelled to affect travel costs and for differences in travel costs to affect the number of trips made. Thus, it is not well suited for sites near major population centres where many visitations may be from "origin zones" that are quite close to one another.
- The travel cost method is limited in its scope of application because it requires user participation. Most importantly, it cannot be used to measure non-use values. Thus, sites that have unique qualities that are valued by non-users will be undervalued.
- As in all statistical methods, certain statistical problems can affect the results.

Hedonic price method

The hedonic price method is used to estimate economic values for environmental services that directly affect market prices. Some goods are heterogonous; different units have different characteristics. The most usual example is houses: they have different number of rooms, different location; the exposure to noise can be different. But, you can also use the hedonic price method with respect to jobs with different exposure to hazardous substances.

Hedonic pricing is done by:

- Estimating demand for environmental quality, exploiting such market good heterogeneity:
- Estimating expected price increase if a house becomes marginally less exposed to noise
- Estimating the wage increased demanded by workers to accept marginally higher health risk

The advantages of the Hedonic Price Method are:

- The method's main strength is that it can be used to estimate values based on actual choices.
- Property markets are relatively efficient in responding to information, and can be a good indication of value.
- Property records are typically very reliable.
- Data on property sales and characteristics are readily available through many sources, and can be related to other secondary data sources to obtain descriptive variables for the analysis.
- The method is versatile, and can be adapted to consider several possible interactions between market goods and environmental quality.

The method also has some limitations, such as:

- The scope of environmental benefits that can be measured is limited to things that are related to housing prices.
- The method will only capture people's willingness to pay for perceived differences in environmental attributes, and their direct consequences. Thus, if people aren't aware of the linkages between the environmental attribute and benefits to them or their property, the value will not be reflected in home prices.
- The method assumes that people have the opportunity to select the combination of features they prefer, given their income. However, the housing market may be affected by outside influences, like taxes, interest rates, or other factors.
- The method is relatively complex to implement and interpret, requiring a high degree of statistical expertise.
- The results depend heavily on model specification.
- Large amounts of data must be gathered and manipulated.
- The time and expense to carry out an application depends on the availability and accessibility of data.

5.4 CBA in case studies

CBA is a suited tool to compare costs and benefits of adaptation measures, but the method has its limitations. One serious limitation is that there is no agreement on the correct discount rate. This is especially relevant when long-term issues like climate change are analysed.

We have presented two main types of monetary valuation in practise; direct methods and indirect methods. Two direct methods is presented; laboratory experiments and contingent valuation. In the case studies in this project it would probably be impossible to use laboratory experiments. Contingent valuations will also be difficult because the method is very time-consuming.

Both of the indirect methods we have presented; the travel cost method and the hedonic price method, can be applied in the case studies in this project. The travel cost method are especially well suited related too tourism (both summer and winter tourism). The hedonic price method is especially well suited related to sea level rise and flooding.

Aggregation and discounting problems

To use CBA on a pan-European level is in principle the same as to use it in more disaggregated analysis (a city, local area etc.). However, aggregation will lead to bigger problems considering assessments of costs and benefits. It will also bring about problems because of differences in income between regions. An un-weighted analysis cannot handle such differences, and weighting leads to a new set of problems because there is no neutral procedure of weighting. Since adaptation measures are not implemented on a pan-European level, the problems of aggregation will not be that important here. On the other hand, mitigation has to be done on global level.

The problem of discounting is especially problematic when we considering climate change. The *Social Discount Rate* (SDR) is a measure used to help decision-makers in their choice of allocating funds to different social projects. It is defined as “the appropriate value of r to use in computing present discount value for social investments”. Discounting is mechanically easy, but no agreement exists on what the correct discount rate is. The choice of discount rate can often determine whether the net benefits are found to be positive or negative. Discounting leads to low values of future costs and benefits.

A higher SDR makes it less likely that a social project will be funded, and then implies a greater risk that the benefits of the project will not be reaped. A small increase in the social discount rate can have enormous impacts on benefits far into the future. Therefore, it is very important to be as accurate as possible when choosing which rate to use.

The social discount rate is a reflection of a society’s relative valuation on today’s well-being versus well-being in the future. The appropriate selection of a social discount rate is crucial for cost-benefit analysis, and has important implications for resource allocations. There is wide diversity in social discount rates, with developed nations typically applying a lower rate (3–7%) than developing nations (8–15%).

The social discount rate in a CBA considering climate change varies from zero to over 3 percent. 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 argues for zero discounting of future generations.[17]

[17] The Stern Review considered mitigation.

CBA in case studies in ESPON Climate

It will be difficult to carry out a strict CBA in the case studies in this project. However, the CBA approach can be useful as a guideline of how to identify costs and benefits of climate change in addition to impact assessment. Let us consider sea level rise as an example. Sea level rise can lead to damages e.g. on buildings and cultural heritage in all coastal zones in Europe.

As a guideline, examples of costs due to sea level rise can be listed as following:

- Building structure damage
- Building content costs
- Infrastructure costs
- Crop replacement costs
- Car replacement costs (probably not very important)
- Nourishment costs
- Evacuation costs
- Treatment costs (e.g. due to contaimed water)
- Opportunity costs e.g. costs due to reduced tourism
- Fresh water costs
- Disruption of public/social services
- Costs of changes in ecosystems (probably extremely difficult to value in monetary terms)

CBA puts monetary values on all these of damages. The benefits are the avoided damages. An adaptation measure can be to set up dikes. The costs of building e.g. dikes[18] are then compared with the benefits of avoided damages. Even, in cases where it can be difficult to put monetary values of all costs and benefits, a systematic listing can be useful.

Table 4 gives some examples of problem identification and possible adaptation measures of the case studies of the ESPON project.

Table 3: Examples of problems and adaptation measures of cases in ESPON Climate

Case	**Problem (example)**	**Adaptation measure (example)**
Mediterranean Spain	Flooding, water scarcity	New infrastructure
Alpine Space	Snow melting	Artificial snow
North Rhine-Westphalia	Snow melting	Artificial snow
Netherlands	Sea level rise, flooding	Dikes
Hanko	Salt water intrusion	New infrastructure
Tisza river	Flooding	Dikes/barriers
Bergen	Sea level rise, flooding	Dikes/barriers

All cases contain vulnerability assessments but they also consider several adaptation measures, not one single measure. Therefore, it will be time-consuming to do a proper CBA within the limits of this project. However, the cases are designed in a way that makes it possible to consider one adaptation measure as an illustrative example of CBA. In municipalities, cost assessments of adaptation measures normally exist as a part of budget considerations, at least on the investment side. These data can be used to carry out illustrative examples of CBA.

In general it is more difficult to carry out a CBA in a large geographical area spread by borders between counties and nations than in one jurisdiction. The Bergen case and the Hanko case are probably the easiest cases to do CBA in because they are limited to one jurisdiction or one

[18] The main costs of building dikes are the investment costs, but there is also some maintenance costs.

metropolitan area. Then, on can rely on assessments done by local officials and so on. The Tisza river case is on the other hand geographically divided between five countries and considers several adaptation problems. This will create significant aggregation problems. North Rhine-Westphalia and Mediterranean Spain represent more than a jurisdiction, but less than a nation. The Netherlands is a nation with a long history of flooding protection and there probably exist some examples of CBA which can be used in project.

Impact assessment

Impact assessment (IA) is an alternative method which can be used for comparing costs and benefits of adaptation measures as an alternative to CBA. An *environmental impact assessment (EIA)* is an assessment of the possible impact - positive or negative - that a proposed project may have on the environment, comprising natural, social and economic aspects.

The purpose of the IEA is to ensure that decision makers consider the ensuing environmental impacts when deciding whether to go on with a project or not. The International Association for Impact Assessment (IAIA) defines an environmental impact assessment as "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made." Impact analysis (IA) is somewhat easier to carry out than CBA.

6. Adaptation and mitigation capacity

6.1 Adaptation to climate change

Within the framework of this project *adaptation* is seen as a response strategy to climate change, involving the adjustments to reduce vulnerability of communities, regions, or activities to climate change. Adaptation refers to the processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with the changing climate (Smit, Pilifosova 2001)(IPCC 2007a). Therefore, adaptation is a normative, cross-sectoral issue to be addressed by different policies on European, national and regional level (see EC 2009a). For a detailed review of existing policies see Annex 5.

Adaptation of a society is dependent on the *adaptive capacity* of that particular society, irrespective of whether adaptation is autonomous or planned. Adaptive capacity is defined as the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies (IPCC 2007a). It has been argued that adaptive capacity, first and foremost, is context specific and varies from country to country and region to region and within social groups and individuals. It also varies over time, responding to society’s changing economic, institutional, political and social (Smit, Wandel 2006).

Thus, adaptive capacity is crucial to the process of adaptation. Although it is necessary to note the importance of the role that adaptive capacity plays in the process of adapting to climate change, it has been argued that it is not enough on its own for adaptation to take place (Smith, Vogel & Cromwell III 2009) (Næss et al. 2005). There have been recent efforts to produce a list of general outlines required for planned adaptation (Füssel 2007). Furthermore, it should be noted high capacity at the national level is not necessarily reflected as high capacity at the lower levels of governance (O'Brien et al. 2006).

Climate change related adaptive capacity includes also coping capacity because climate change triggers frequency and magnitude of extreme weather events. Coping capacity refers to a society’s ability to effectively react to sudden weather induced events, e.g. to rescue victims of a river flooding. In spatial terms, adaptive capacity has to be seen as a nested concept: Capacities of regions are tied to the capacity of countries in terms of enabling or constraining environments for adaptation. But the adaptive capacities at the national level may not always correspond to those at the regional level.

6.1.1 Determinants of adaptive capacity

Irrespective of the complex nature of the concept, identifying the determinants of adaptive capacity is of importance to both scientists and policy-makers. Building on the IPCC’s definition of adaptive capacity Smit and Pilifosova have identified six broad areas of determinants:

Table 4: Determinants of adaptive capacity (adapted from Smit, Pilifosova 2001)

Economic resources	Economic assets, capital resources, financial means and wealth
Technology	Technological resources enable adaptation options
Information and skills	Skilled, informed and trained personnel enhances adaptive capacity and access to information is likely to lead to timely and appropriate adaptation
Infrastructure	Greater variety of infrastructure enhances adaptive capacity
Institutions	Existing and well functioning institutions enable adaptation and help to reduce the impacts of climate-related risks
Equity	Equitable distribution of resources contributes to adaptive capacity

Economic resources are considered to be important as it is recognised that societies with greater economic resources are likely to be more able to adapt to climate change, and conversely lack of economic means limits the ability to adapt. Second, it is argued that technological resources enable the design, development and implementation adaptation. Third, a skilled and informed personnel is considered to enhance adaptive. Fourth, a greater variety of infrastructure is believed to lead to more options for pursuing adaptation. Fifth, well-developed and functioning institutions do not only manage current climate risks in a satisfactory way but also enable future-oriented planning. Sixth, it is argued that the availability and access to resources for adaptation in an equitable manner is crucial for adaptive capacity. These determinants are not independent of each other nor are they mutually exclusive. Rather it should be considered that the combination of these determinants varies between regions and countries.

Since the publication of the IPCC's Third Assessment Report in 2001, there have been several further studies that have focused on identifying determinants of adaptive capacity - both at the national level (Adger, Arnell & Tompkins 2005, Haddad 2005, Yohe, Tol 2002, Moss, Brenkert & Malone 2001, Alberini, Chiabai & Muehlenbachs 2005), at the local level (Posey 2009, Engle, Lemos 2010) and across all levels of governance (Westerhoff, Keskitalo & Juhola Submitted). An attempt to operationalise a working definition of adaptive capacity at the national level utilises the IPCC TAR list of determinants, also detailed above in Table 5 (Engle, Lemos 2010).

There have been some local case studies that have analysed the adaptive capacity of a particular region or a community. These studies argue for the need to assess and measure adaptive capacity at the regional or local level because the decisions to adapt are made at that level. Engle and Lemos analysed the adaptive capacity of river basin management in using nine broad categories of determinants (Engle, Lemos 2010):

Table 5: Determinants of adaptive capacity according to Engle and Lemos

Determinant	Encompasses
Wealth and financial capital	Income and wealth distribution, economic marginalization, accessibility and availability of financial instruments (insurance, credit), fiscal incentives for risk management
Information and technology	Communication networks, freedom of expression, technology transfer and data exchange, innovation capacity, early warning systems, technological relevance
Human capital	Knowledge (scientific, 'local', technical, political), education levels, health, individual risk perception, labor
Material resources and infrastructure	Transport, water infrastructure, buildings, sanitation, energy supply and management, environmental quality
Organisation and social capital	State-civil society relations, local coping networks, social mobilization, density of institutional relationships
Political capital	Modes of governance, leadership legitimacy, participation, decentralization, decision and management capacity, sovereignty
Institutions and entitlements	Informal and formal rules for resource conservation, risk management, regional planning, participation, information dissemination, technological innovation, property rights, risk sharing mechanisms

A four-country study of regional and local adaptive capacity in Europe used determinants based on the IPCC definition of capacities (Westerhoff, Keskitalo & Juhola Submitted). The importance of each capacity was discussed by almost one hundred respondents across governance levels, including policy makers, scientists and practitioners. Determinants that were considered important included issues such as human capital, the ability to access regional networks and political support. This and other local case studies also note that adaptive capacity within communities is also extremely heterogeneous by locality but that it is also distinguished by age, gender, health and social status at the individual level.

6.1.2 Towards adaptive capacity indicators

The complexity of the concept of adaptive capacity and its measurement is immense. Therefore only a few studies have been conducted that are truly comprehensive and the IPCC comes to the conclusion that 'the literature lacks consensus on the usefulness of indicators of generic adaptive capacity and the robustness of the results' (IPCC 2007, p. 728), mainly because different capacities are needed in different localities.

A key question is how to identify and agree on the main determinants of adaptive capacity that will form the basis for the indicators to be used in the next stage of the project. There are examples in the literature of where selection is made by the researchers based on a literature review (Haddad 2005) and also examples where more elaborate processes are gone through in order to arrive at a decision (Brooks, Adger & Kelly 2005).

Given the time and resource constraints of this project, it is suggested that a well-accepted IPCC definition is selected as the basis for the determinants of adaptive capacity, as presented in Table 5 and develop these further. Equity is left out of the adaptive capacity determinants because this is already considered in measuring social sensitivity.

In this project, the focus of the determinants and indicators will be on generic determinants of adaptive capacity that can be measured across the regions in Europe. It is accepted that some determinants are generic in that they enable adaptation across the localities and countries, whilst others are more specific to particular climate change impacts (IPCC 2007a). On the one hand, factors such as education, income and health are considered to be contributing towards higher adaptive capacity in general. On the other hand, there are particular climate change impacts, such as droughts or floods, solutions of which require specialised technical knowledge or technological capacity.

Within the scope of this project, the focus is on generic determinants, and this enables the project to relate adaptive capacity data to data on the likely impacts of climate change (already encompassing exposure and sensitivity) in order to arrive at results on the vulnerability of European regions to climate change. In addition to this cross-European assessment it should be noted, however, that the adaptive capacity of a region to specific climate hazards could and will be explored in the case studies within the ESPON Climate project. The following five sections focus on the groups of generic determinants of adaptive capacity. See Table 7 for more details on the preliminary indicators.

Economic resources

It is widely accepted that economic assets, capital resources, financial means and wealth play an important role in adaptive capacity (Smit, Pilifosova 2001). Wealthy nations are more likely to be in a better position to adapt to changes in the climate, by being able to bear the costs of adaptation. However, it should be noted that adaptation is not an exclusive concern for areas with lower economic development, and a high income per capita is neither a necessary nor a sufficient indicator of the capacity to adapt (IPCC 2001). The following indicators can be used to measure the economic capacity to adapt.

Possible indicators include:

- Income per capita
- Insurance penetration
- State expenditure at regional level
- Public deficit

Technology

Technological resources enable adaptation options, and consequently lack of access and development of technology can lead to lower adaptive capacity as many of the strategies identified in response to climate change involve technology (IPCC 2001). Development of technologies can be undertaken both the public and private sector, and innovation is considered an important factor in this. However, it is necessary to keep in mind the distinction between general technological capacity versus a specific technological response that can be developed for a specific climate change impact (IPCC 2007a).

Possible indicators include:

- Resources for technology
- Capacity to undertake research
- Communication uptake
- *Patents*

Infrastructure

Greater variety of infrastructure is considered to enhance adaptive capacity (IPCC 2001). Existence and development of infrastructure can form the basis for the development of adaptation options and measures.

Possible indicators include:

- Transport
- Natural assets
- Land use
- Water infrastructure
- Energy supply and management

Information and skills

Recognition of the necessity to adapt, gathering knowledge of available options, and the ability to asses and implement the adaptation measures are crucial for adaptive capacity (IPCC 2001). Skilled, informed and trained personnel enhances adaptive capacity and access to information is likely to lead to development of adaptation options that are timely and appropriate, whilst lack of trained and unskilled personnel lower a nation's adaptive capacity. Despite this, there are studies that highlight that social capital and networks, values and perceptions can play an important component in compensating for lack of official training and skills (IPCC 2007a).

Possible indicators include:

- Educational commitment
- Education levels
- Health expenditure per capita
- Public health expenditure per capita
- Attitudes towards climate change
- Public information on climate change

Institutions

Institutions, defined as a means of holding society together, are considered to play an important part of adaptive capacity, and it is argued that existing and well-functioning institutions enable adaptation and help to reduce the impacts of climate-related risks (IPCC 2001). Countries that have well developed and functioning institutions are considered to have higher adaptive capacity in relation to developing or transition countries. Well developed institutions and governance structures not only have the capacity to deal with present day challenges but also enable to plan for future.

Possible indicators include:

- Modes of governance
- Government efficiency
- Decentralisation
- Regional co-operation
- Public attitudes towards the political-administrative system
- National adaptation strategies

Table 6: Determinants of adaptive capacity and preliminary indicators

Determinants of Adaptive Capacity	**Proxy**	**NUTS# level**	**Source**
Economic resources	***Economic assets, capital resources, financial means and wealth***		
Income	GDP per capita (€ PPP)	NUTS 3 (2003)	ESPON database (Project 3.2)
Insurance penetration	http://www.cea.eu/index.php?page=statistics		
State expenditure			
Technology	***Technological resources enable adaptation options***		
Resources for technology	R&D investment (% GNP)	NUTS 2	Eurostat
Capacity to undertake research	Scientists and engineers in R&D per million population	NUTS 2	Eurostat
Communication uptake	Telecommunication uptake	NUTS2	ESPON database (Project 1.2.2)
Patents	No of patent applications per million inhabitants	NUTS2	ESPON database (Project 3.1)
Infrastructure	***Greater variety of infrastructure enhances adaptive capacity***		
Transport	Roads (km)	NUTS 3 (1999)	ESPON database (Project 1.2.1)
Natural assets	Percentage of NATURA 2000 area	NUTS3	ESPON database (Project 2.4.1)
Land use			
Water infrastructure			
Energy supply and management			
Information and skills	***Skilled, informed and trained personnel enhances adaptive capacity and access to information is likely to lead to timely and appropriate adaptation***		
Educational commitment	Education expenditure as % of GNP		
Education levels	Share of tertiary educated people in %	NUTS2	ESPON database (2.4.2)

Health	Health expenditure per capita		
Health	Public health expenditure (% of GNP)		
Attitudes towards climate change	Attitudes towards climate change		Eurobarometer 2008 and 2009
Public information on climate change	Public information on climate change	NUTS2	Eurobarometer 2008 and 2009
Institutions	***Existing and well functioning institutions enable adaptation and help to reduce the impacts of climate-related risks***		
Modes of governance	Shift from Government to governance	NUTS0	ESPON database (Project 2.3.2)
Government efficiency	Government effectiveness index	NUTS0	http://econ.worldbank.org/ ESPON Governance
Decentralisation			
Regional co-operation	Number of project co-operations	NUTS2	ESPON database (Project 2.4.2)
Public attitudes towards the political-administrative system	Public attitudes towards the political-administrative system		Eurobarometer
National adaptation strategies	Existence of a national adaptation strategy	NUTS0	PEER/EEA

6.2 Mitigation of climate change

In contrast to adaptation, which stresses the inevitability of climate change, the concept of mitigation is based on the conviction that the underlying causes of climate change can indeed be influenced by human intervention and thus the extent or future development of climate change be altered. Thus climate change mitigation refers in general to all human attempts to mitigate the effects of climate change. In the following discussion both the (already existing) mitigation capacity of a region as well as a region's potential to possibly implement mitigation activities are considered.

6.2.1 Determinants of mitigation capacity

Yohe (2001) has listed factors which influence to a country's mitigation capacity:

- range of viable *technological options* for reducing emissions;
- range of viable *policy instruments* with which the country might effect the adoption of these options;
- structure of critical *institutions* and the derivative allocation of decision-making authority;
- availability and distribution of *resources* required to underwrite their adoption and the associated, broadly defined opportunity cost of devoting those resources to mitigation;
- stock of *human capital*, including education and personal security;
- stock of *social capital*, including the definition of property rights;

- country's *access to risk-spreading processes* (e.g., insurance, options and futures markets, etc.); and
- *ability of decision makers* to manage information, the processes by which these decision makers determine which information is credible, and the credibility of the decision makers themselves.

Yohe's list as such is rather difficult to apply for indicator purposes, this, however, does not decrease the importance of these factors which have been used by IPCC (2001) as well. Winkler et al (2007) have further developed Yohe's list and identified the following factors influencing mitigative capacity: economic factors (ability to pay, abatement cost, opportunity cost), institutional factors (regulatory effectiveness and market rules, education and skills base, public attitudes and awareness) and technological factors.

Based on the above, from a regional perspective the factors affecting climate change mitigation capacity could include at least eight factors, which will each be briefly discussed. Note that some are capacity indicators (e.g. existing policies and measures), while others are mitigation potential indicators (e.g. economic resources for mitigation):

1. *Existing direct greenhouse gas emissions*
   Greenhouse gases (GHG) deemed responsible for climate change are identified in the UNFCCC Kyoto Protocol (1997). Since GHG emissions data are generally not available at regional/local level, one possibility is to estimate them by using national GHG data and breaking them down geographically based on the area, population, gross domestic product, total primary energy supply, final energy consumption or electricity consumption of each region.
2. *Existing indirect GHG emissions*
   Of the human activities causing GHG emissions energy production and consumption are the most important drivers. Differentiated energy data are mostly only available at the national level, but can again be estimated using e.g. population and GDP shares of each region.
3. *Types of land use and their shares*
   The most important land use type in this respect is forests, because they are an important carbon sink in the climate system. Possibly the forest area could even be increased to enhance the mitigation effects.
4. *Patterns of land-use*
   A basic assumption will be that climate change is not only a driver of land use change (due to change in climatic zones, adaptation needs), but also vice versa (CO2 emissions caused by non-sustainable patterns of land-use) (see European Commission: Staff working document accompanying the White Paper *Adapting to climate change: Towards a European framework for action: 70*). Effects of local land-use changes on climate change can be perceived at regional or even global scale, making clear i.e. the need for EU action in co-ordinated planning of land use, water and ecosystems.
5. *Non-carbon energy resources available*
   The availability of alternative, non-fossil energy resources is an important part of climate change mitigation capacity. These energy sources include biomass, hydro, geothermal and nuclear power. Data on these energy sources is generally scanty. Furthermore, disaggregating national data using mechanisms outlined above may provide misleading results.

6. *Policies and measures in use for climate change mitigation*
   Climate change related policies (e.g. GHG emission targets, economic instruments, voluntary agreements etc.) can mostly be found at the national level (even though some regions are in the process of setting their own GHG emission targets now).
7. *Technologies available for reducing GHG emissions*
   Some technologies that are important for climate change mitigation exist (e.g. in relation to non-fossil energy sources), but others may become very important in the future, such as carbon capture and storage technologies.
8. *Economic resources available for reducing GHG emissions*
   Because developing and applying new GHG reducing technologies is costly, climate change mitigation also depends on the economic resources available to a region, e.g. measured by the regional gross domestic product per capita.
9. *Willingness to use the physical and economic resources available for reducing GHG emissions.*
   The willingness to become active in climate change mitigation may be measured by the policies and measures already adopted or currently regional decision-making processes.

6.2.2 Towards mitigation capacity and potential indicators

The lists of factors influencing climate change mitigation capacity (e.g. Yohe 2001, Winkler et al 2007, Tompkins/Adger 2005) have not been widely operationalized into the form of a particular mitigation capacity indicator. However, the EU Sustainable Development Indicator set includes a number of indicators that can possibly be utilised (see CEC 2009). On the basis of this and other data sets and the conceptual work presented above, the project intends to identify or generate indicators for the following aspects of climate change mitigation:

1. *Existing amount of greenhouse gas emissions*
   Operationalisation could follow the procedures outlined above.
2. *Renewable energy potential*
   Available resources for renewable energy production in the region, including possible carbon sinks.
3. *Energy saving potential*
   Potentials of a region for improving energy efficiency, avoiding unnecessary energy consumption, changing energy-consumption activities or shifting industrial production to another location.
4. *Policies and measures in use for climate change mitigation*
   Number of policies and measures in use for mitigating climate change. Even if the policies are instituted nationally, their impacts on different regions are different, depending on the special e.g. natural and energy consumption characteristics of each region.
5. *Ability and willingness to act/pay mitigation measures*
   Regional gross domestic product per capita can be used to measure a region’s ability to pay for mitigation oriented measures. To some extent a higher economic ability will also influence regional actors’ willingness to implement such measures.

An obvious difficulty of climate change mitigation capacity from a regional perspective is the difficulty of gathering regional data. Climate change is a global phenomenon and a global problem, and climate policies are usually planned and implemented at national level. To some content mathematical allocation of national data to regions may be reasonable, but obviously gathering original data at the regional level requires access to original data collected for national statistics. This is often not available, which strongly limits the possibilities to provide relevant and reliable information on regional climate change mitigation capabilities. Thus, identifying the problems in a number of case study regions and making related policy recommendations will be important to carry out within the ESPON Climate project.

7. Indicator weighting based on expert opinions

The integration of exposure, sensitivity and adaptive capacity raises particular issues induced by the theoretical framework. At these stages of the analysis process weighting issues occur referring as rather normative questions, as cultural believes and political preferences influence the weighting of factors like social or economic sensitivity on the aggregated level, ESPON Climate deals with (e. g. value of live against economic damages).

The conceptual framework for determining exposure, sensitivity, impacts and vulnerability to climate change suggests to integrate variables/factors of the approach at various levels (see also Figure 14).

1. *Weighting of sensitivity dimensions among each other*
   After three rounds of assigning weights, the individual scores are finally aggregated to achieve collective weights for all sensitivity dimensions. The term 'dimensions' refers to a group of several indicators assigned to a specific topic area (e.g. indicators related to economy).
2. *Integration of exposure and sensitivity*
   There is also a need to agree on the weighting factors for the integration of exposure and sensitivity, both factors that determine the impacts of climate change.
3. *Weighting of adaptation dimensions among each other*
   After three rounds of assigning weights, the individual scores are finally aggregated to achieve collective weights for all adaptive capacity dimensions. Again, the term 'dimensions' refers to a group of several indicators assigned to a specific topic area (e.g. indicators related to economy).
4. *Integration with adaptive capacity*
   Finally, there is a need to agree on the weighting factors for the integration of impacts of climate change and adaptive capacity, both factors that determine the vulnerability to climate change. This step is necessary as the weight of adaptive capacity and its different dimensions depends to a certain extent from the willingness to take action.

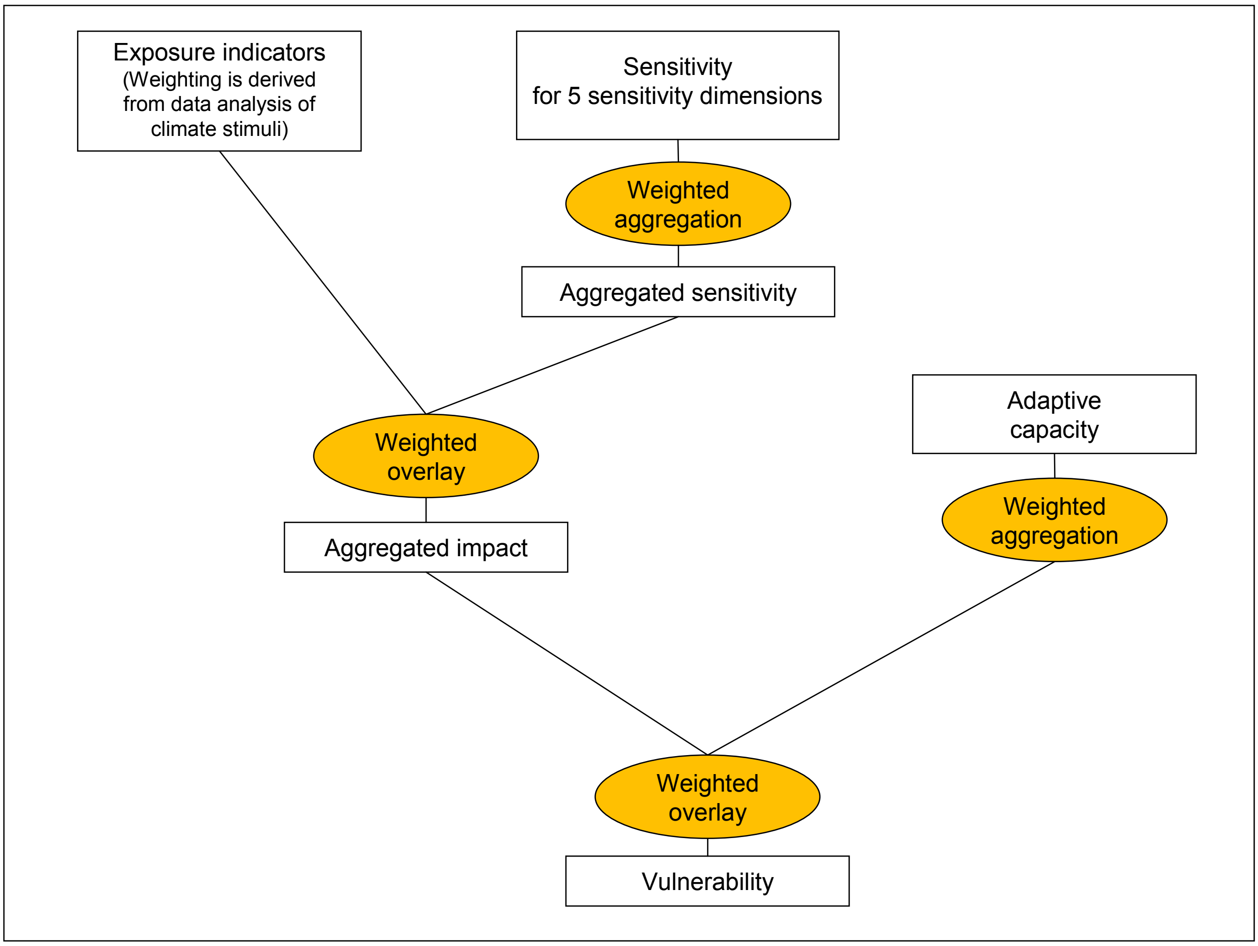

Figure 22: Weighting issues at different stages of the analysis

7.1 A Delphi-based survey

These weighting issues can be tackled by experts using a Delphi-based approach which has already been applied successfully in the ESPON Hazards project as a tool to weight hazards on regional and European levels, as well as to weigh vulnerability components on the regional level (Greiving 2006). The application of the Delphi-based method will be a suitable solution for determining weighting factors for sensitivity dimensions as well as for weighting other factors within the ESPON Climate Change research framework. Using this method, experts will be asked, i.e. which sensitivity dimension or factor has – in their views – a higher relevance or a lower relevance. Based on subjective opinions of people the tool aims at creating a maximum level of agreement between the experts but without disclosing their identities to avoid distortions in the process.

The Delphi Method is based on a structured process for collecting and synthesizing knowledge from a group of experts generating a maximum level of agreement through iterative and anonymous investigation of opinions by means of questionnaires accompanied by controlled opinion feedback (Helmer 1966; Linstone/Turoff 1975; Cooke 1991). As principle advantages this approach:

- avoids key persons taking influence on responses,
- overcomes the geographical constraints and costs of bringing together a group of experts and
- allows Delphi participants to express their personal views freely due to the anonymity of answers.

Furthermore, the Delphi-method due to its design is particularly useful for a subject with strong differences of opinion or high levels of uncertainty like given in the study at hand. Finally, the method was already applied for a definition of successful adaptation to climate change (Doria et al 2009).

The survey will be applied for the whole of Europe (in context of the pan-European vulnerability assessment). As each type of region is differently affected by climate stimuli, a regionalised weighting may in principle be appropriate. However in the context of this ESPON project this approach is not feasible since it will expand the quantitative analysis framework significantly although the weighting itself is, in fact, inter alia aiming at condensing the analysis towards aggregated indicators. In order to capture regional variations from the pan-European perspective, guidance will be offered for tailor-making use of the Delphi method for the case studies.

The survey is conducted in three rounds:

1. In a first round, all project members and external experts will be asked for their initial opinion. They have to allocate on the one hand percentages for each sensitivity dimension as well as for exposure/sensitivity and impacts/adaptive capacity. Each of these three estimations adds up to a sum of 100%.
2. Before the second round all participants will be informed about the average estimation before being asked to again distribute percentage scores. Normally, those participants, whose opinions differed significantly from the average scores of the first round, often allocate more moderate scores in the second round.
3. The same process as before will be repeated once more. Afterwards, a higher level of agreement in weighting the different hazards and vulnerability indicators will have been reached.

Step 1: Setting up the Delphi monitoring team

IRPUD, as the main coordinator of the Delphi implementation is supported by the other partners.

Step 2: Panel of experts/specialists

In the planned Delphi survey the main aim is to reach a certain consensus about weighting factors among participating experts. For this kind of quantitative Delphi surveys literature suggests to select a rather large group of experts in order to minimise selection failures. The minimum size of the group should be not less then 10 experts.

Since the weighting issues to be answered constitute normative questions rather than scientific ones the monitoring group for the ESPON Climate Delphi survey suggests to recruit experts from the members of ESPON Monitoring committee and the ESPON contact points in order to take for a Europe-wide expertise. It has to be ensured that the participating experts will be made familiar with the vulnerability concepts used in this project.

Step 3: Initial survey instrument

The survey instrument will be implemented as a web-based questionnaire. Experts will be notified in each round to participate and given a personalised login to access the survey. The questionnaire can be filled online and the results can subsequently be accessed and analysed by the monitoring team to prepare for the next round.

Step 4: Pre-test the initial survey instrument

The initial survey instrument will run through a pre-test before the first Delphi round will be carried out. The pre-test will be used to tune the survey instrument itself but also to adapt the introductory text in case there are any imprecise explanations. The pre-test will be run among the ESPON Climate study team.

Step 5: Adapt and distribute the initial survey instrument

After having integrated the findings from the pre-test the survey starts by sending a notification email to the participating experts (experts will receive a general notification prior to this from ESPON CU). The anonymous application has to be kept in mind.

Step 6: Analyse initial 'wave' of data

Receive the responses and copy them into the sheet '1st round' of the basic table – find out the average values obtained.

Step 7: Prepare, conduct and analyse a second and third Delphi wave

Step 8: Prepare and distribute report

The results will feed into the mapping process of the project. A report on the Delphi survey will be prepared for the Draft Final Report and will also be circulated among the participating experts.

8. Case studies

The case studies of the ESPON Climate project serve to cross-check and deepen the findings of the pan-European assessment of the other research actions. Therefore seven case studies were identified in the proposal, some of which were later expanded based on early comments (see Inception Report). After completion of the exposure analysis, presented in chapter 2, it can now be seen that these case studies were indeed wisely chosen: the case studies cover all five types of climate change regions identified in the exposure cluster analysis (see Figure 23).

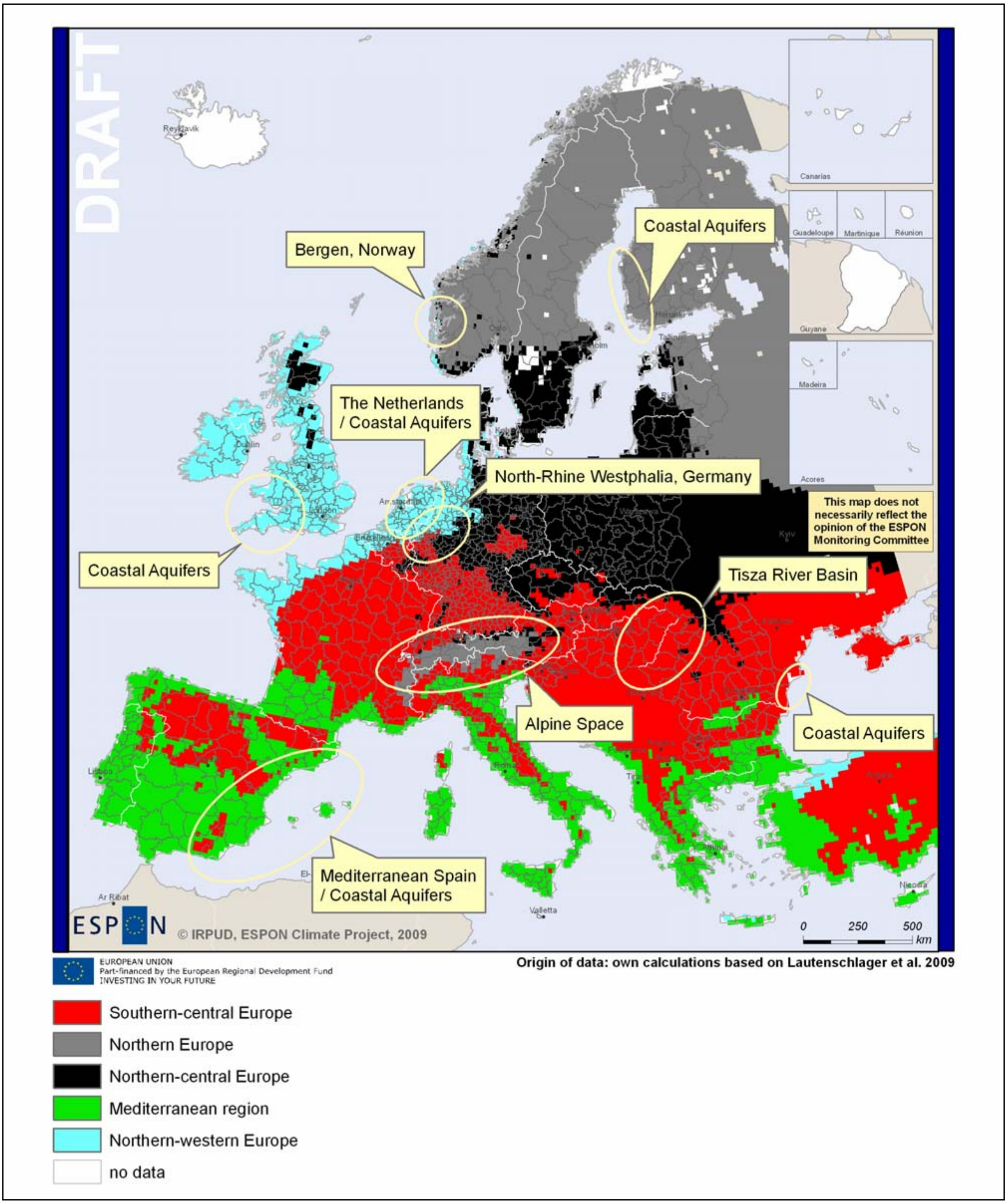

Figure 23 : Case study locations within the major climate change regions

In order to ensure compatibility with the pan-European analyses of the other research actions of the project and to enable comparisons across the case studies, a common methodological framework has been agreed that will be followed throughout the case studies: This framework coves the following general aspects:

1. General characterisation of the region
2. Vulnerability assessment
    a. Main effects of climate change on case study region so far
    b. Exposure to climate change
    c. Sensitivity to climate change
    d. Impacts of climate change
    e. Adaptive capacity in regard to climate change
    f. Vulnerability to climate change
3. Response strategies and policy development in regard to mitigation and adaptation
4. Further aspects specific to the respective case study area
5. Discussion of validity of European-wide analysis from a regional perspective
6. Transferability of results to other regions

Particular emphasis will be placed on institutional aspects of current and future climate change responses, which can best be captured by the case study approach. In addition each case study will explore in greater detail certain dimensions of exposure, sensitivity and adaptation to climate change that are of particular relevance for the respective case study area.

According to the project's overall schedule preparatory work has been conducted for each case study analysis, scoping the climatic, environmental, demographic and socio-economic characteristics of the case study areas and defining the particular focus of the additional analyses. Both are briefly summarized below for each case study area[19].

Bergen, Norway

Bergen is the second largest city in Norway with approximately 250,000 inhabitants. The city region consists of 14 municipalities with about 360,000 inhabitants. 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.

Due to its location Bergen's climate is characterized by cool temperatures and large quantities of precipitation: The annual precipitation reaches up to 5000 mm in some areas of the Bergen city region – and is still expected to increase according to the latest climate change scenarios for the region, especially in autumn and winter. More importantly, number of the days with heavy rainfall is expected to double, thus increasing the likelihood of river flooding and landslides. In addition, due

[19] See Annex 6 for more detailed elaborations on each case study.

to rising temperatures worldwide the sea level in Bergen is estimated to increase by 75 cm by the year 2100, but will even increase up to 221-276 cm during storm surges.

Being close to the mountains the urban population of Bergen is likely to be highly affected by the increases of precipitation and heavy rainfall in particular. The greatest impact of climate change, however, will be caused by the expected sea level rise and subsequent heightened exposure to coastal storm surges. This will put the city's infrastructure, transport system and tunnels, buildings and sewage system under risk.

In addition to the comprehensive climate change assessment conducted in all ESPON Climate case studies, the Bergen case study will contribute a detailed analysis of climate impacts on selected sectors of Bergen's economy, namely marine industries, maritime sector, tourism, energy industries and energy-intensive industries. Another focus will be Bergen's extensive mitigation and adaptation measures already implemented or planned for the future.

Coastal Aquifers

Low-lying coastal areas are a common feature of Europe's geography. For example, such coastal areas can be found in Finland (Baltic Sea), the Netherlands (North Sea), England (Atlantic Ocean), Spain (Mediterranean) and Romania (Black Sea), all of which are included in this trans-national case study. Many of these coastal areas are densely populated and economically highly developed. Both private and corporate water consumption depend to a large degree on coastal aquifers which are the main focus of this case study.

Climate changes in the various coastal areas that make up this case study are of course varied. In regard to coastal aquifers the most important climate change variable are changes of sea water levels, precipitation, temperature and evaporation. A specific risk and threat for seashore acquifers is contamination due to salt water intrusion.

Sensitivity in this case study revolves around the importance of drinking water and irrigation water for coastal populations and economies respectively. The specific importance and sensitivity of groundwater in a particular case study area depend on a number of other variables, such as geological composition or available alternative water resources.

The coastal aquifer case study will apply the project's comprehensive methodology at first to two regions in Finland before extending it to all the coastal regions mentioned above. A special focus will of course be on hydrological and geological conditions and processes affected by climate change, but also on the adaptation and mitigation strategies that local/regional actors can adopt in response to expected climate changes.

Netherlands

The Netherlands is a small but densely populated country. Its territory comprises about 40,000 square kilometres and is inhabited by 16.5 million inhabitants. The Netherlands are a low-lying country and are geographically characterised by a delta formed by three major European rivers (the Rhine, Meuse and Scheldt).

Already today the climate in north-western Europe and the Netherlands in particular has changed significantly and has multiple effects. The expected future climate change, especially the increase of temperature, sea level rise and river discharges, and a higher variability of precipitation, will lead to increasing impacts in the Netherlands. To reduce the negative impacts of climate change the Dutch society will need to adapt to this new conditions. Therefore, the Netherlands, being one of the most densely populated deltas of the world, needs a transnational strategy how to foster climate change mitigation and adaptation.

The Netherlands are very sensitive to climate change impacts. 60-70% of the country's population and economy is concentrated in areas at risk from flooding from the sea or from the rivers. In addition rising global temperatures and resulting sea level rise will affect freshwater availability and agriculture. In regard to response policies the Netherlands have been at the forefront of devising strategies on the long-term protection against river flooding and coastal storm surges, not least because these are natural hazards the country has had to cope with for centuries.

In addition to conducting the project's overall vulnerability assessment this case study will concentrate on specific vulnerabilities and response strategies in regard to sea level rise and river discharges under various climate change scenarios. Among others the vulnerability concept used for European studies on flood risks will be compared with the Dutch studies on flood risks.

North-Rhine Westphalia, Germany

With around 18 million residents North-Rhine Westphalia (NRW) is the most populous state of Germany and includes Europe's largest conurbation (the Ruhr district). The state comprises 396 municipalities ranging from rural to urban characteristics, with different climate conditions.

While in summer it can become very hot in the Rhine-Ruhr Basin, the temperature in the highlands and mountainous regions is more moderate. The latter are recreational regions for the densely populated Rhine-Ruhr area. Climate scenarios imply that temperature increase, seasonality and the amount of precipitation change, as well as a generally decrease of river run-off in summer.

NRW accounts for around one quarter of the German GDP. Functioning of the economy needs a sufficient infrastructure and depends on energy production. While these branches can be affected by decreasing river run-off (river water for cooling), freezing rain or heat waves, other sectors are risk prone to increasing temperatures or storm events, like the forest sector or the skiing areas situated in the low mountain range. Thus, climate change might have strong impacts in different regions of this state.

For this case study, the developed European-wide vulnerability system will be applied and, where possible, adapted to the characteristics of this region. However, links between vulnerability components are likely to be lost, and defining specific thresholds may be difficult. The aggregation of components would also lead to a loss of information and transparency. Therefore a systemic approach (as opposed to the dimensions approach) may better convey the information of this case study area, since this is normally in the operational focus of decision makers. Thus, in addition to the proposed European-wide vulnerability system, a vulnerability analysis of exemplarily systems, where information about process links already exist, will be carried out. Further, it is intended to compare some of the obtained results from the systemic approach with results based on other climate models, e.g. a regional statistical model. In this sense, the case study NRW can help to validate and complement the methodology and results of the European-wide vulnerability analysis.

Alpine Space

The European Alps comprise an area of 190,000 square kilometres in the centre of Europe and are shared by eight countries. The Alps are characterized by mostly rural areas, but many of its 13 million inhabitants live in the densely populated river valleys. These and several Metropolitan

Growth Areas in the surrounding lowlands need a transnational strategy how to foster climate change mitigation and adaptation.

Climate change has already led to a significant retreat of glaciers and the decline of snow cover. Further increases of temperatures and higher variability of precipitation are expected and will result in changes of glaciers and permafrost zones as well as water scarcity in summers and reduced snow reliability in winter months. The occurrence of alpine hazards (e.g. avalanches, land slides) is also forecast to increase significantly.

In terms of sensitivity and adaptation strategies the population concentrations in river valleys, the traditionally strong agricultural sector as well as nature-based tourism are of greatest importance. Additional water use by vacationers and agricultural irrigation will continue to exacerbate water scarcity in summer months. Winter tourism already is and will increasingly be affected. The decline of snow cover over the last centuries has already led to autonomous adaptation strategies in winter tourism (e.g. artificial snow production).

The Alpine Space case study will follow the overall methodological framework of the ESPON Climate project, detailing and cross-checking findings of the pan-European exposure, sensitivity and adaptation analyses. Subsequently the case study will focus especially on the cultural dimension and investigate current and potential proactive and long-term adaptation options within the tourism sector.

Tisza River Basin

The Tisza River Basin is the largest sub-basin of the Danube River Basin. It covers 157,000 km2 and is home to approximately 14 million people. The Tisza River Basin consists of a mountainous upper part (the first 200 km of the Tisza River) and the lowlands (last 760 km of the river). The case study area comprises 85 % of the river basin, made up of 26 NUTS 3 regions in Hungary, Romania and Slovakia. Most of the mountainous part is predominantly rural, while there are some large cities in the plain (two cities above 300,000 inhabitants).

The climate in the catchment area of the Tisza River is varied and ranges from oceanic to Mediterranean and continental climate zones. The differences are particularly stark in terms of precipitation. In mountainous areas the annual average of precipitation is over 1,000 mm, in the lowlands, however, even below 500 mm. Therefore droughts are a major challenge in the low-lands. According to the latest climate scenarios precipitation will decrease and annual mean temperatures increase, thus exacerbating the drought problem. The temporal distribution of both warming and precipitation changes is also expected to change. Dry periods will be followed by sudden, heavy rainfalls and an increase in severe river floods is expected.

The sensitivity to climate change also varies according to climatic, geographic and demographic features of the different parts of the Tisza River Basin. In the lowlands increasing drought problems will have serious consequences for the urban centres and agriculture, which is still a significant sector of the regional economy. In the mountainous parts climate change will especially impact on valuable protected areas (overall more than 20% of the Tisa catchment area are Natura 200 areas), leading to decreasing biodiversity.

Based on a comprehensive assessment of exposure, sensitivity and adaptive capacity in the Tisza River Basin, the case study will focus on river-related (floods, inland water) and agricultural impacts, followed by an analysis or exploration of adaptation strategies suitable for this multi-national river system.

Mediterranean Spain

The Spanish Mediterranean coast, together with the Balearic Islands, is the most important tourist area of the country and a key pillar of the Spanish economy. It is also densely populated and includes several urban agglomerations. In total it is home to almost half of the population of Spain.

The climate in the case study area is already characterised by high temperatures and low precipitation. According to the latest IPCC report precipitation is estimated to further diminish in the coming decades. This applies especially to the warmest months of the year, when local water consumption is the highest. But also flood episodes and stronger storm surges are expected.

These climate changes would affect coastal regions that have experienced rapid urban growth and land-use changes. The key driver of these changes is tourism, which accounted for most of the hotels, apartments, villas and campsites built along the coast in the past four decades. Some of these touristic facilities but also the beaches may be damaged if coastal storm surges do indeed become more frequent and stronger. Moreover, the intensified water scarcity especially in the summer months might severely impact on tourism which also has its annual peak in the summer.

Embedded in the comprehensive exposure, sensitivity and adaptation analysis this case study will therefore put a special focus on the linkages between precipitation, water consumption and tourism. Different modalities of tourism will be analysed (e.g. large beach hotels, golf resorts, apartments and villas) in terms of their water consumption patterns. This will be followed by an analysis of existing and potential water resources in the study area. Finally these water resources and climate change induced water supply problems will be related to possible adaptation and mitigation strategies for the different types of tourism.

9. Research work until the draft final report

This research project is aiming at the development of new regional typologies with respect to climate change. In order to achieve this goal the analyses to be carried out within the different project actions will consider the results of the analysis of regional exposure to climatic stimuli. This involves the analysis of regional sensitivities particularly with respect to the economic dimension as well as the analysis on adaptation potentials of European regions. Within all of these thematic fields the development of indicators has already advanced and the subsequent working phase will aim to analyse spatial variation across Europe's territory linking regional sensitivity to exposure to climatic stimuli and thus gaining evidence on potential impacts. In addition, case studies will further contribute to a deeper understanding on climate change effects on regional economies as well as adaptive capacities.

The results of this work will be described within the draft final report. The draft final report will comprise a detailed assessment on regional impacts concerning the regional economic sensitivity as well as the other five sensitivity dimensions. Furthermore, analysis results on adaptive capacity will be presented. For the final report these results will be further aggregated towards regional vulnerability typologies. During the whole project work maps will be created illustrating the regional variation of the indicators developed over the European territory. These maps are part of the reports but will also be used in course of other project publications. Finally, policy recommendations will be given.

9.1 Milestones by partners and actions

Research activities	*Finalised until*
Partner 1 (TU Dortmund)	
2.3 Sensitivity assessment (all except economic sensitivity):	
• Data availability for all sensitivity indicators checked or missing values estimated	02/2010
• Final list of sensitivity indicators agreed	04/2010
• Data projections/scenarios up to year 2100 modelled and calculated	06/2010
• Sensitivity maps for all sensitivity indicators/scenarios produced and validated	07/2010
• Aggregated sensitivity maps for the sensitivity dimensions produced	07/2010
2.1, 2.3 and 2.4: Impact assessment	
• Impact maps for each exposure/sensitivity linkage produced	08/2010
• Delphi survey on weighting of sensitivity indicators for each exposure type concluded	08/2010
• Aggregated impact maps by exposure type produced	08/2010
2.5: Vulnerability assessment	
• Vulnerability maps for each exposure type produced	09/2010
• Aggregated vulnerability map produced	09/2010
• Methodological preparations for vulnerability typology finalised	09/2010
• Methodological preparations for vulnerability scenarios based on different adaptation strategies developed	09/2010

Partner 2 (Geological Survey of Finland)
2.1, 2.2, 2.3 Exposure, Sensitivity and Impacts Assessment

- Input to scientific discussions and support concerning methodological issues, data sources and interpretation. continuous

2.6: Case study : Coastal aquifers

- Pilot study for the groundwater case study in Finland completed 02/2010
- Guidelines for other case study areas presented 03/2010
- Coastal aquifer assessments in other case studies completed 06/2010
- Assessment of the results 08/2010
- Case study report submitted 9/2010
- Inputs for Draft Final Report contributed 12/2010

Partner 3 (Norwegian Institute for Urban and Regional Research)
2.2 Framework for sectoral economic sensitivity

- Guidelines for cost benefit application in case studies produced 02/2010

2.6: Case study: Bergen

- Vulnerability assessment completed 03/2010
- Sectoral economic analyses completed 06/2010
- Adaptation capacity and measures completed 10/2010
- Case study report submitted 10/2010
- Inputs for Draft Final Report contributed 11/2010

Partner 4 (Newcastle University)
2.3 Analysis of regional economic sensitivity

- Linking exposure indicators to economic sectors completed 01/2010
- Identifying economic sensitivity indicators completed 03/2010
- Data availability check completed and data compiled 03/2010
- Data analysed and interpreted 06/2010
- Regional sectoral economic sensitivity report submitted 08/2010
- Inputs for Draft Final Report contributed 11/2010

Partner 5 (Potsdam Institute for Climate Impact Research)
2.1, 2.2, 2.3 Exposure, Sensitivity and Impacts Assessment

- Input to scientific discussions and support concerning methodological issues, data sources and interpretation. continuous

2.6: Case study : NRW

- List and description of possible sensitivity indicators 04/2010
- Sensitivity maps of selected indicators 06/2010
- Impact maps for each exposure/sensitivity linkage produced 10/2010
- Aggregated impact maps by exposure type produced 10/2010
- Vulnerability maps for each exposure type produced 11/2010

- Aggregated vulnerability map produced 11/2010
- Interpretation of vulnerability results completed 11/2010
- Case study report submitted 10/2010
- Inputs for Draft Final Report contributed 11/2010

Partner 6 (Helsinki University of Technology, YTK)

2.4.1: Review of adaptation and mitigation policies

- Draft policy review 02/2010
- Final review on adaptation and mitigation policies 04/2010
- Analysis of implications to adaptive and mitigation capacity 06/ 2010

2.4.2: Analysis of adaptive and mitigation capacity

- Data gathering and feasibility checks for adaptive capacity complete 03/2010
- Data gathering and feasibility checks for mitigation capacity complete 04/2010
- Final list of adaptive and mitigation capacity indicators produced 05/2010
- Final Adaptive capacity maps and report submitted 07/2010
- Final Mitigation capacity maps and report submitted 08/2010
- Inputs for Draft Final Report contributed 11/2010

Partner 7 (Budapest University of Technology and Economics)
Partner 8 (VÁTI Hungarian Public Nonprofit Company for Regional Development and Town Planning)
Partner 9 (National Institute for Territorial and Urban Research, Romania)
Partner 10 (Agency for the Support of Regional Development Košice, Slovakia).

2.6: Case study: Tisza River Basin

- Climate change sensitivity analysis completed 04/2010
- Sectoral impact analysis completed 06/2010
- Adaptive capacity and strategies analysis completed 10/2010
- Typology of climate change vulnerability completed 10/2010
- Stakeholder workshop conducted 05/2010
- Case study report submitted 10/2010
- Inputs for Draft Final Report contributed 11/2010

Partner 11 (Autonomous University of Barcelona)

2.6: Case study: Mediterranean Spain

- Climate change sensitivity analysis completed 04/2010
- Regional workshop-consultation among partners involved in the Tisza river case study 05/2010
- Sectoral impact analysis completed 06/2010
- Adaptive capacity and strategies analysis completed 10/2010
- Typology of climate change vulnerability completed 10/2010
- Case study report submitted 10/2010

- Inputs for Draft Final Report contributed 11/2010

Partner 12 (The Netherlands Environmental Assessment Agency)

2.6: Case study: Netherlands

- Data collection completed 09/2010
- Comparison of JRC and Dutch flood risks completed 07/2010
- Analysis of adaptive capacity completed 07/2010
- Case study report submitted 10/2010
- Inputs for Draft Final Report contributed 11/2010

Partner 13 (Swiss Federal Research Institute WSL)

2.6: Case study: Alpine Space

- Literature review completed 03/2010
- Detailed methodological preparations completed 03/2010
- Data collection and analysis completed 09/2010
- Case study report submitted 10/2010
- Inputs for Draft Final Report contributed 11/2010

9.2 Contents of the draft final report

A Executive summary

1 Vulnerability assessment: key messages and findings

2 Options for climate change mitigation and adaptation policies

3 Need for further research

B Report

1 Main results of pan-European vulnerability assessment

2 Main options for climate change mitigation and adaptation policies

3 Key analysis / diagnosis / findings and the most relevant indicators and maps

4 Explanation differences compared to ESPON 2006

5 Issues for further analytical work and research, data gaps to overcome

C Scientific report

1 Detailed results of comprehensive and integrated vulnerability assessment

- Variations in different individual climate change parameters and impacts on types of European regions in physical, social, environmental and cultural terms
- Impacts of climate change on different sectors of regional and local economies as well as regional and local infrastructures
- Adaptive capacities of different type of regions
- Degree of vulnerability of different types of European regions to climate change
- The interdependencies among different types of European regions

2 Territorial potentials for the mitigation of climate change in different types of European regions

- Mitigation and adaptation measures to be applied in the different types of European regions to cope with climate change
- Contributions of territorial policies to mitigation
- Implications for
    - Lisbon and Gothenburg strategy
    - Territorial agenda
    - Implementation of White Paper on Adapting to Climate Change
    - Structural Funds
    - National and regional level

3 Social and cultural implications of the possible developments

4 New development opportunities for European regions in the wake of climate change

5 Detailed results of case studies

- Bergen
- Coastal Acquirers

- The Netherlands
- North Rhine-Westphalia
- Tisza River Valley
- Alpine Space
- Coastal Mediterranean Spain
- Cross analysis and lessons learned for pan-European analysis

6 Enhancement of the scientific platform

7 Documentation of the scientific work undertaken

Annexes to the Scientific report

- List of indicators developed and datasets provided to the ESPON Database
- List of maps and tables
- List of missing data
- List of abbreviations and glossary
- List of references, including the use of results from projects outside the ESPON 2013 Programme
- List of publications of the TPG members resulting from the implementation of the Targeted Analysis
- Additional maps not included in the core text of the report
- Bibliography