BASE BOTTOM-UP CLIMATE ADAPTATION STRATEGIES TOWARDS A SUSTAINABLE EUROPE

Title: Process tool for testing and evaluating future plans for adaptation – using storylines and pathways for adaptation to CC across Europe

Summary: This deliverable show how findings from modeling, case studies and the RCP-SSP story line framework can be brought together to inform adaptation policies across Europe using a step by step process tool. The steps of the tool are explained and implemented for 4 regional storylines (Northern-Arctic, North-Western, Central-Eastern and Southern-Mediterranean Europe) and three combined socio-economic and climate scenarios with different adaptation and mitigation challenges. In this way, main BASE results from top-down modeling, case-study analysis and policy development are brought together showing some general trends in management challenges and pathways of responses to move forward. At the same time it is illustrated that the diverse local and sectorial challenges can be informed by these storylines and pathways but need to be tackled by local participatory policy development.

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Deliverable author(s): Ad Jeuken, Mikael Hildén, Maaike van Aalst, Laurens Bouwer, Marianne Zandersen, Luis Garrote, Volker Meyer, Filipe Alves, Eliska Lorencova, Harm Duel, Jarl Kind, Tim Taylor, Aline Chiabai

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0 Executive Summary

This deliverable presents the BASE process tool for testing and evaluating adaptation action. The application of the tool shows how BASE results and similar pieces of information can be placed within and used to develop further storylines on adaptation in Europe. The storylines are “narratives of plausible futures including climate change, socio-economic developments and adaptation actions.” The storylines are used as a frame in the BASE process tool to combine logical stories of external developments and sectorial responses which form pathways of adaptation action.

The process tool combines research in BASE that offers insights into adaptation at many different levels with modelling examining Europe wide or regional conditions for adaptation and a wide set of cases that have explored adaptation at specific localities and for specific sectors.

The BASE process tool approaches storylines and pathways through triangulation, which refers generally to the combination of quantitative and qualitative methods of enquiry to get a better view of the adaptation challenges and opportunities in different sectors. The tool triangulates different types of qualitative information such as the generic descriptions of the SSP (Shared Socio-economic Pathways), the specific description of BASE cases, and different types of quantitative modelling such BASE modelling exercises and the Representative Concentration Pathways (RCPs).

Specific combinations of RCPs and SSPs give an overall frame for testing and evaluating adaptation action. The BASE process tool is demonstrated using the following combinations:

- ‘fossil fuelled or market driven development’ (SSP5) and high end emission (RCP8.5);
- ‘middle of the road’ (SSP2) and moderate emissions (RCP 4.5) and finally
- ‘regional rivalry or fragmentation’ (SSP3) and high end emissions (RCP8.5).

These are a subset of all possible combinations of RCPs and SSPs and have been selected for the view they offer on possibly emerging challenges for adaptation. The high emission scenarios (RCP 8.5) combined with SSP5 and SSP3 allow for a reflection on the consequences of a failure to reach the objectives of the Paris climate agreement (2015) under two very different sets of socio-economic conditions. The combination of RCP4.5 and SSP2 illustrates what can be achieved

through the Paris agreement[1], without making assumptions of a complete and rapid transition to a global economy with drastically reduced or even negative greenhouse gas emissions.

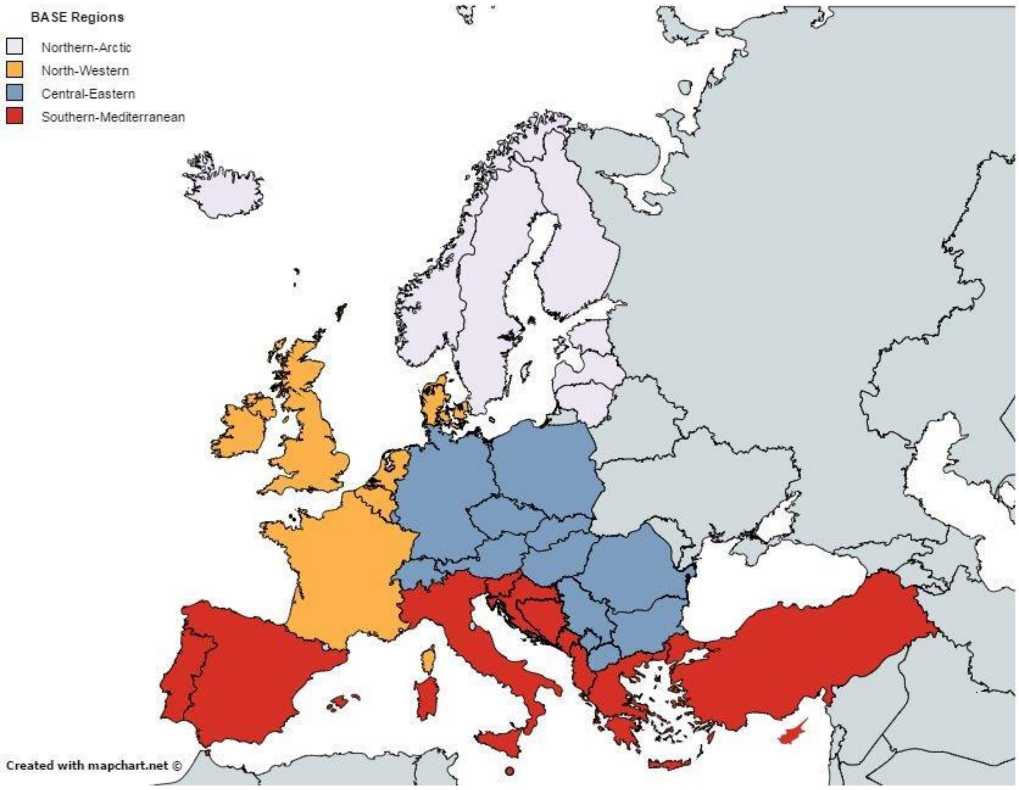
The time perspective focuses on the development until mid-century as this is a realistic time frame for most decisions on active adaptation actions. The idea of adaptation pathways furthermore foresees several decision points in time, each of which will be affected by the interpretation of changes and impacts ahead. The geographical extent of the analysis broadly covers the EU, with a partial extension to countries that are members of the EEA. The extension is partial as some sources of data are more limited for non-EU-countries. The specific results from the BASE case studies are furthermore limited to a subset of EU countries.

For the purpose of the discussion the area has been divided into four regions

- **Northern-Arctic**: Iceland, Norway, Finland, Sweden, Estonia, Lithuania, Latvia
- **North-Western**: UK, France, Belgium, Netherlands, Denmark, Ireland
- **Central-Eastern**: Germany, Poland, Austria, Hungary, Czech Republic, Slovakia, Switzerland, Romania, Bulgaria, FYR Macedonia, Kosovo, Serbia, Luxembourg
- **Southern-Mediterranean**: Portugal. Spain, Italy, Greece, Slovenia, Bosnia-Herzegovina, Croatia, Montenegro, Albania, Turkey, Malta, Cyprus

[1] According to IPCC's AR5 under RCP4.5 still a temperature increase between 1.7 and 3.2 ^{o}C can be expected, leaving considerable likeliness off not meeting the 1.5 or 2 degree target.

The development in terms of climate change is expected to differ within the regions. It is also sensitive to the particular RCP/SSP combination.



Northern-Arctic Europe

Northern and Arctic Europe are expected to experience the highest average temperature increases relative to current temperatures and thus many aspects of the northern-arctic environment may change. Yet the societal vulnerability to climate change has so far generally been considered to be relatively modest due to a high adaptive capacity. The interviews[2] conducted for this deliverable confirmed the view of a significant adaptive capacity, but also that this may require changes in practice.

Special conditions prevail in the Arctic with indigenous people adapting to climate change and to changing socio-economic conditions. The adaptation needs of traditional livelihoods may require, for example, spatial reallocation, which may lead to increasing conflicts with an increased exploitation of natural resources such as forests or minerals. These tensions are likely to be accentuated under fossil-fuelled development story line, where climatic conditions may facilitate

[2] Interviews conducted May 11-12 2016.

exploitation and where rapid economic growth makes it profitable to exploit also remote mineral resources. This suggests that strategic spatial and economic planning important also in adaptation to climate change.

It will become increasingly important to develop policy level adaptation pathways that can flexibly adjust not only to changing climatic conditions but also to shifts in the wider socio-economic and political context. Especially the open Nordic economies are dependent on changes in the global economy and political constellations. Because of these dynamics it is important to consider how a desirable development can be stabilised. For example, social, political and technological innovations may in the best of cases make the middle of the road story line easier to achieve, and it may open new opportunities for the Nordic countries that have a strong tradition in developing measures for environmental protection.

North-Western Europe

The main message is that all storylines show similar trends but with varying intensity: Urbanisation continues, flooding probability increases as well as temperature, agricultural production is affected and GDP grows until 2050. Although the storylines look broadly similar, there are also some significant differences. For example, population grows in 'fossil-fuelled development', while this growth is much smaller in 'middle of the road' and can even decrease in 'regional rivalry'. These differences have, together with the bio-physical changes, implications for adaptation.

In all storylines adaptation measures are needed to deal with the impact of increased flooding, drought and heat stress. North-Western Europe differs from Northern-Arctic Europe in that droughts and water stress are likely to be of greater significance. In general adaptation measures will be most urgent in 'fossil-fuelled development' due to the impact of climate change on almost all sectors and the intensification of land use. In the storyline 'regional rivalry' measures are almost as urgent, but under this storyline many countries or regions will lack the means to undertake costly adaptation measures. This underlines the importance of recognising the wider socio-economic development in adaptation policies.

Under the storyline 'fossil-fuelled development' policy instruments that require investments in adaptation or adaptive capacity are likely to be more acceptable than under the storyline 'regional rivalry'. Policy instrument based on European subsidies, or instruments that emphasise co-benefits between adaptation and other societal objectives are likely to be favoured under a regional rivalry story line. The middle of the road story line implies significant effort spent on mitigation, which may bring it closer to the 'regional rivalry' story line in terms of spending devoted to adaptation (but the adaptation challenge itself is lower since climate impacts are less).

Central-Eastern Europe

Under all scenario storylines, the rise in average temperature is assumed to bring about the need for adaptation actions, further intensified by higher occurrence of weather extremes such as drought episodes and floods. In general, Central European countries will need to adapt to temporally and spatially uneven distribution of precipitation, leading to potentially rising occurrence of floods on the one hand, and water shortages on the other. Consequently, the adaptive capacity of the countries on all governance levels requires to be increased in order to be able to deal with precipitation and water supply-related challenges.

The scenario storylines for Central Europe presume substantial changes in population levels in most of the countries regions, with subsequent socio-economic and environmental challenges. Another distinctive trend, common to all storylines, is intensive urbanization, especially under the 'fossil-fuelled development'. Heat waves and heat islands in the cities will challenge vulnerable segments of the population by heat stress in urban environments, particularly affecting elderly people and those with chronic diseases. Increasing income inequality and continuing societal stratification are likely to affect adaptation. The development of the technological base for adaptation is likely to face significant obstacles especially under the 'regional rivalry' story line due to market fragmentation and low priority of investments into research and development. These aspects will affect the planning of climate change adaptation measures, which will likely require solutions robust to social and economic changes within the society.

According to all storylines explored here, ecosystems will be challenged by agricultural intensification and growing demands for agricultural products, as well as pollution and continuous environmental degradation. In order to reduce subsequent decline in the provision of ecosystem services, it is vital to focus on ecosystem-based solutions to climate change adaptation.

Southern-Mediterranean Europe

The available projections for climate change identify southern Europe and the Mediterranean areas as the European area that will be most severely hit by climate change. Mediterranean countries will be significantly affected especially under the RCP 8.5 scenario with a hotter, more instable and less rainy climate that will put significant pressure on water systems and all economic activities that depend on it, agriculture in particular. The key difference between the different storylines lies in the population and economic scenarios. The 'fossil-fuelled development' and 'regional rivalry' reflect two very different pathways. While in 'fossil-fuelled development' we have rising population, economic development and urbanization, 'regional rivalry' is characterised by slowly growing or even declining populations, little or no economic growth and potentially even decreased urbanization. While in the fossil fuelled development significant investments are needed and possible in order to adapt water, infrastructure and energy systems, such investments are mostly non-existent under regional rivalry. Simply-put 'fossil-fuelled development' is likely to embark on a grey adaptation pathway while 'regional rivalry' will, out of necessity, consider a green and soft adaptation as people may even leave highly vulnerable cities and return to local-scale traditional farming practices with small investments and low energy consumption per capita.

In all storylines migratory dynamics will be present and highly important. Under all story lines strong immigration from the North of Africa is expected to continue, and under RCP 8.5 an increasing share of the immigration or attempted immigration will be climate change driven. Eventually the total population may increase in some countries such as Spain, contributing significantly to increase the stress over water and energy. Under ‘regional rivalry’ emigration and lower birth rates from the Mediterranean countries may result in a net loss of population, with important implications for urban planning and water management.

Tourism and exports are expected to continue to play an important role in sustaining economic development in the Mediterranean region. Warming may result in extended beach use periods at a growing environmental and economic cost. In ‘regional rivalry’ both economic activities will slow down and even decrease due to geo-political conflicts and turmoil’s as well as disinvestment from high energy/water demanding industries.

All of the storylines presented suggest that the development of future adaptation pathways face significant challenges. The ‘fossil-fuelled development’ might eventually come at very high costs for both societies and ecosystems.

The emerging general picture

The BASE process tool contrasts the different storylines against one another. Under RCP 8.5 that underlies the storylines ‘Fossil-fuelled development’ and ‘Regional rivalry’ many of the consequences of significant climate change are likely to be apparent by the middle of the century and thus causing significant challenges for societies in terms of adaptation. The essential difference between ‘Fossil-fuelled development’, ‘Regional rivalry’ and the ‘Middle of the road with active mitigation’ is that mitigation is assumed to progress more rapidly under the ‘Middle of the Road’ story line. As a consequence climate change progresses more slowly with less pronounced extremes. This means that adaptation is easier and can progress at a slower pace. At the same time one should note that also under RCP 4.5 changes are likely and thus there is also under RCP4.5 a need for adaptation action.

Economic growth is assumed to be strongest in the storyline ‘Fossil-fuelled development’ (SSP5), modest in “Middle of the road with active mitigation’ and low or even negative in ‘Regional rivalry’. This creates very different conditions for adaptation (See Figure below). Under ‘Fossil-fuelled development’ and “Middle of the road with active mitigation’ countries are assumed by and large to have the means to respond to immediate adaptation needs. However, this also needs to be considered in the light of public-private sector development. If societies aim for a reduction of the public sector and emphasize the private sector, costly adaptation actions will focus on actions where cost-benefit ratios are high and private interest and resources can be mobilised (including opportunities to benefit from the climate change). Poorer areas will under such development depend on innovative cheap adaptation, or suffer from the adverse consequences of climate change.

Under ‘Regional rivalry’ poor economic conditions are assumed to prevail and these will most likely be reflected in accentuated internal inequalities as public resources to support adaptation are diminished. The lack of resources for adaptation may lead to ever increasing adaptation needs. Initially the adaptation needs are strongest in the storyline ‘Fossil-fuelled development’ because expanding economic activities are likely to encounter new exposures to climate change and adaptation needs. With time the greatest needs may appear under ‘Regional rivalry’ as, for example, critical infrastructure is becoming more vulnerable to climate change as a consequence of poor maintenance.

It is important to recognise that the story lines do not represent fixed paths. Thus the actual development may shift from the current path of slow economic growth to one of more rapid growth or even greater regional rivalry. These potential switches between the storylines may be even more important to consider than the individual storylines. Some of the processes that can cause these switches are identified in the Figure below. For example, one can assume that the ‘Fossil-fuelled development’ is unstable in the sense that it clearly does not meet current understanding of sustainable development, unless accompanied by truly revolutionary decoupling of resource use from economic growth. Thus it can slide into “Regional rivalry’ if resources are depleted or the costs of the consequences of climate change starts to hamper growth. Similarly the ‘Middle of the road with active mitigation’ can slide into ‘Regional rivalry’ if political turmoil makes international climate negotiations come to a standstill.

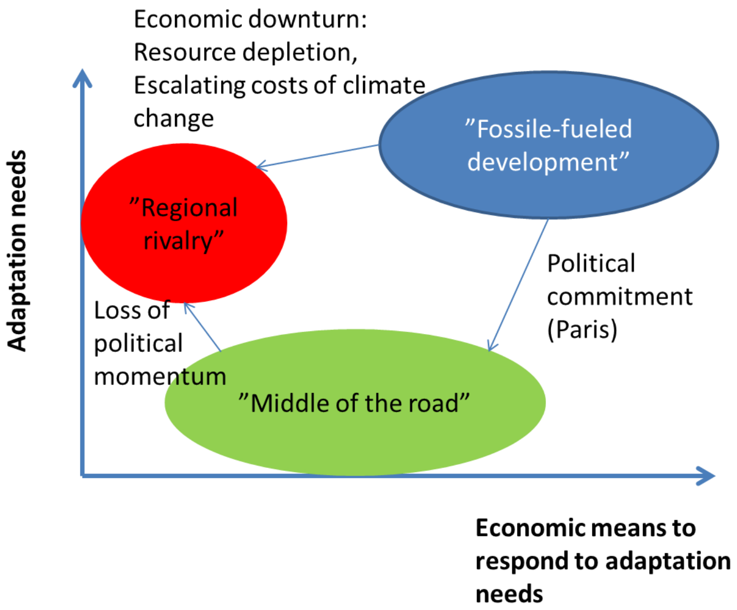


Figure The relative positions of the storylines with respect to adaptation needs and the economic means to respond to them.

Adaptation measures will be most urgent under the RCP8.5 scenarios, but the adverse consequences of climate change are expected to be greatest under the storyline of ‘Regional rivalry’ as available resources are expected to dwindle. Under the ‘Fossil-fuelled development’-storyline other impacts such as those affecting biodiversity or leading to the depletion of natural resources may contribute to the adverse consequences of climate change.

The overall conclusion is that an important challenge for publicly funded R&D&I is to identify innovative low cost actions for adaptation that can deal adequately with extreme events and conditions that rapidly divert significantly from current average conditions and that can be applied also where economic means are lacking, for example in rural areas hit by depopulation. It is not only a question of developing the technical means, but also to explore forms and processes for adaptation governance that provides incentives for private actors to take action in time.

Developing and evaluating adaptation pathways and adaptation governance

The triangulation approach of the BASE process tool places available information a wider regional context. Observations of a mismatch between cases and broad regional scenarios are particularly instructive as they underline the diversity that is characteristic of many climate change impacts also within regions. Of particular interest is what challenges current management practices face and how appropriate adaptation pathways can be developed.

The BASE process tool responds to the apparent need to combine different types of information. None of the individual pieces of information can on its own provide a complete picture for developing adaptation governance. The pieces of information needs to be placed in a general frame that recognises both the general patterns and local specific characteristics to support the identification of practical policy adaptation pathways at different levels of governance from the local to the European level. The BASE process tool thereby supports dynamic implementation of adaptation policies, also recognising that not only climate change but also wider socio-economic and technical developments will determine the feasibility and effectiveness of the adaptation actions. The BASE process tool therefore underlines the need for reflexive learning that regularly revisits the underlying assumptions and conclusions on how to steer adaptation and supports participatory policy development.

Remaining Challenge

In practice it proved to be challenging to combine many layers of information even within a systematic framework as provide by the process tool. At the local level, where ‘here and now’ are dominating, climate uncertainty as reflected in the RCPs plays a role, but already existing problems are the real driver. Therefore, or the local level the BASE process tool may merely serve to provide background information, but in most cases it is likely that many decisions first and foremost reflect the case specific context. This calls for participatory policy development that the BASE process tool can support.

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1 Introduction

1.1 Objectives

This deliverable provides a process tool for testing and evaluating adaptation action. It demonstrates how BASE results can be placed within and used to further develop storylines on adaptation in Europe in order to test and evaluate future plans for adaptation. The process tool is applied to show how the findings on impacts, adaptation responses and its costs and benefits from D6.3 (Pan-European model results) and D5.2 (Case study results) can be placed in a framework provided by scenarios for emission and socio-economic development. In this way the deliverable contributes to the general BASE objectives: “to support coherent, multi-level, multi-sector integrated adaptation policies” and “to support policy guidelines by integrating lessons from past experiences, case studies, insights provided by modeling”

The need for a process tool is emphasized by the current situation in the field of adaptation to climate change which is all but static. Countries are actively developing strategies and plans and are monitoring their action (EEA 2014; EEA 2015; OECD 2015). The processes of adaptation are complex (Eriksen, Nightingale, and Eakin 2015) and following them at a general level of strategies and scenarios gives an incomplete picture of what transitions may be occur as the result of adaptation. Complex transitions may gradually create new conditions and trajectories; manifest as multiple but inter-related pathways of change and response at different social or spatial scales (Fazey et al. 2015). Studies of socio-technical transitions also suggest that complex interactions between different levels from cases (niches) to broad regulatory regimes are the rule (Geels and Schot 2007).

The research in BASE offers insights into adaptation at many different levels with modelling examining Europe wide or regional conditions for adaptation and a wide set of cases that have explored adaptation at specific localities and for specific sectors. The primary objective of this deliverable is thus to present a BASE process tool that allows for reflexive interpretation of the BASE-findings within the RCP-SSP framework, with a particular emphasis on how different story lines affect possible adaptation pathways at different levels of governance from the local to the European level. The purpose of the process tool is first to show how diverse ads also partly incompatible observations can be used in a wider context by linking the BASE findings with the RCPs and SSPs. The second purpose is to provide a base for reflecting on specific challenges of adaptation pathways actions across Europe. A core set of climate adaptation pathways is analyzed in order to identify robust and flexible climate adaptation strategies and resulting roadmaps for implementation of adaptation measures to changing conditions.

The BASE process tool brings together the different aspects of the project from both a top-down and bottom up perspective and helps to explore differences in adaptation between regions and sectors.

1.2 Starting from RCPs and SSPs

Projections and scenarios are the core of this process tool. Projections of climate change are important for all adaptation activities. The current reference scenarios of climate change are the Representative Concentration Pathways (RCPs). The RCPs provide a consistent set of trajectories for future atmospheric composition and land use change up to the year 2100 against which adaptation measures and pathways can be judged. The four RCPs are named according to their radiative forcing level in the year 2100 (Moss et al. 2010; van Vuuren et al. 2011) and they illustrate different emission levels and resulting greenhouse gas concentrations

- In RCP 8.5 GHG emissions increase over time, and the scenario represents developments leading to high greenhouse gas concentration levels and temperature increase in the range of 3.2-5.4^{o}C at the end (EOC) of the century (Fuss et al., 2014).
- In RCP6.0 the total radiative forcing is stabilized at 6.0 W/m^2 (T increase 2.0-3.7 ^{o}C at EOC) shortly after 2100 and the scenario assumes that GHG emissions are gradually curbed.
- In RCP 4.5 the total radiative forcing is also stabilized at 4.5 W/m^2 shortly after 2100 without overshooting the long-run radiative forcing target level based on an assumption of more rapid reduction of GHGs than under RCP6.0.(T increase 1.7-3.2 ^{o}C at EOC)
- In RCP2.6 low greenhouse gas concentration levels are reached. Its radiative forcing level peaks around 3 W/m^2 by mid-century, and declines to 2.6 W/m^2 by 2100, corresponding to approximately 1 ^{o}C (T increase 0.9-2.3 ^{o}C at EOC) temperature increase above pre-industrial levels. This will require net negative CO_2 emissions in the latter half of the 21st century.

Adaptation is, however, not solely driven by climate change. From the local to the global level climate-related risks and vulnerabilities depend on the interaction of changing climatic conditions with socio-economic changes. Thus demographic, economic, technological, environmental and political changes are important for the consequences of climate change (van Ruijven et al. 2014). The integration of climatic and socio-economic scenarios therefore allows for a richer understanding of adaptation challenges and pathways, provided that future socio-economic conditions can be projected. Integrated analyses enable a discussion of the relative importance of changes in different dimensions, such the accumulation of assets in flood-prone areas versus changes in the frequency of floods of a certain magnitude. At the same time the inclusion of socio-economic scenarios increases the number of variables, making the choice between adaptation actions more difficult.

To provide a frame for the socio-economic reflections a coherent set of five global pathways describing potential alternative socio-economic futures has been developed. These are known as Shared Socioeconomic Pathways (SSPs) (O'Neill et al. 2015; O'Neill et al. 2014). The five SSPs do not focus on climate policies or the impact of climate change in their underlying assumptions. Instead their main purpose is to describe plausible future evolutions in key socio-economic variables that together create challenges for climate change mitigation and adaptation (see Figure 1). Each SSP been developed based on qualitative descriptions of potential future changes in demographics, human development, economy and lifestyle, policies and institutions, technology, and environment and natural resources and quantifications of some of these key variables such as population growth, GDP and urbanisation. The SSP storylines have been developed based on expert opinions (O'Neill et al. 2015) and the quantified variables result have been produced through modelling efforts (Cuaresma 2015; Dellink et al. 2015; Jiang and O'Neill 2015; KC and Lutz 2015; Leimbach et al. 2015).

The five SSPs have been generally described as follows:

- SSP1 'Sustainability — Taking the Green Road': low population growth associated with educational and health improvements, reductions in global inequality, increasingly effective international cooperation. Increasing environmental awareness that leads to improved resource efficiency, a boost in green technologies, and low energy demand.
- SSP2 'Middle of the Road': social, economic and technological trends do not significantly differ from historical patterns. Moderate population growth, slow progress towards achieving sustainability goals, and the persistence of fossil fuel dependency as well as income inequalities.
- SSP3 'Regional Rivalry — A Rocky Road': increased nationalism, regional conflict, weak international cooperation and more authoritarian forms of government in parts of the world. Strong population growth in developing countries, low economic development with islands of moderate growth but also widespread poverty, limited environmental concerns, and growing resource intensity and fossil fuel use.
- SSP 4 'Inequality — A Road Divided': highly unequal development across world regions and countries with an increasing gaps between regions. Wealthy regions have high education levels, high technological development and moderate economic growth, whereas poor regions are characterised by low levels of education, slow economic development, weak institutions and increasing social unrest.
- SSP 5 'Fossil-fuelled Development — Taking the Highway': rapid economic, technological and social development that is driven by increasingly integrated global markets, and based on the strong exploitation of fossil fuels and resource-intensive lifestyles. Global population growth peaks and declines in the 21st century. Technological development is expected to be able to address environmental consequences.

Figure 1 The mapping of the SSPs relative to challenges for mitigation and adaptation (O'Neill et al. 2015)

The combinations of RCPs and SSPs form storylines can be defined as: *the qualitative and descriptive component of a scenario, which create images of future worlds.[..] What they do try to achieve is to stimulate, provoke, and communicate visions of what the future could hold for us. They aim for creativity, rigor, internal coherence, and plausibility (*Rounsevell et Metzger, 2010).

The value of such storylines is seen to be threefold (Alcamo, 2008; Swart et al., 2004; Bowman et al., 2013; Weijermars et al., 2012; Schoemaker, 1993):

i) When these storylines are developed through engagement of experts and stakeholders, they combine multiple perspectives and sources of expertize;

ii) Are key for communicating the results of scenario exercises;

iii) Represent a much broader picture than quantitative models and encapsulate a number of subtler aspects, such as governance, institutional changes or specific behaviour

2 The process tool combining scenarios, storylines, observations and pathways

The BASE process tool that this deliverable presents and applies is based on the following steps

1. Setting the scene: Selecting projections for climate change and socio-economic development (Chapter 3)
2. Choose a time frame
3. Specify the geographical level and focus for the analysis
4. Identify areas of governance and management that are of particular interest (Section 3.2)
5. Populate the matrices formed by the combination of 1-4 with information from a) modelling; b) case study findings; c) literature and d) interviews (Chapter 4)
6. Apply the findings from step 5 to obtain an overview of the adaptation scene (Chapter 5)
7. Use the findings to reflect on or modify adaptation policies and governance (Chapter 6)

A key task of the BASE process tool is to bring together different pieces of information and evidence in order to create the frame for testing and evaluating future plans for adaptation. The process tool is based on **triangulation**, which refers generally to the combination of quantitative and qualitative methods of enquiry (Maxwell 2016).

The process tool employs triangulation to combine both different types of qualitative information such as the generic descriptions of the SSP storylines (O'Neill et al. 2015; van Vuuren and Carter 2014) and the specific description of BASE cases (BASE case study documentation), and different types of quantitative information such as that available from the IIASA data base[1] on SSPs and the findings of the BASE modelling exercises (Deliverable 6.3). Additional information on specific sectors such as energy development has been obtained from several sources (McKinsey&Company 2010; World Energy Council 2013; Zachmann et al. 2012; EC 2015) in order to get an overview of the likely changes. There is also information on impacts and vulnerability and scenarios in the web-tool of the CLIMSAVE-project (Harrison, Holman, and Berry 2015).[2]

The base of the triangulation is provided by choosing specific combinations of RCPs and SSPs that give an overall frame for the analysis. We have chosen the following combinations:

- 'fossil fuelled or market driven development' (SSP5) and high end emission (RCP8.5);
- 'middle of the road' (SSP2) and moderate emissions (RCP 4.5) and finally
- 'regional rivalry or fragmentation' (SSP3) and high end emissions (RCP8.5).

Within the context of BASE, these are basic storylines that are defined as: *narratives of plausible futures including climate change, socio-economic developments and adaptation actions. These storylines tell the combined logical story of external developments and sectorial responses*" to stress the adaptation component central for BASE.

The process tool can obviously be applied to any combination of RCPs and SSPs. The chosen ones have been selected for the view they offer on possibly emerging patterns. The high emission scenarios (RCP 8.5) combined with SSP5 and SSP3 allow for a reflection on the consequences of a failure to reach the objectives of the Paris climate agreement (2015) under two very different sets of socio-economic conditions. The combination of RCP4.5 and SSP2 illustrates what can be achieved through the Paris agreement, without making assumptions of a complete and rapid transition to a global economy with drastically reduced or even negative greenhouse gas emission.

The choice of timeframe is important in using the process tool. Here the chosen time perspective focuses on the development until mid-century as this is a realistic time frame for most decisions on active adaptation actions. The idea of adaptation pathways furthermore foresees several decision points in time, each of which will be affected by the interpretation of changes and impacts ahead. When the temporal perspective extends beyond the middle of the century, the number of possibilities increases so much that the findings of the models and cases can only be taken as indicative of certain patterns.

The geographical extent of the analysis in broadly covers the EU, with a partial extension to countries that are members of the EEA. The extension is partial as some sources of data are more limited for non-EU-countries. The specific results from the BASE case studies are furthermore limited to a subset of EU countries.

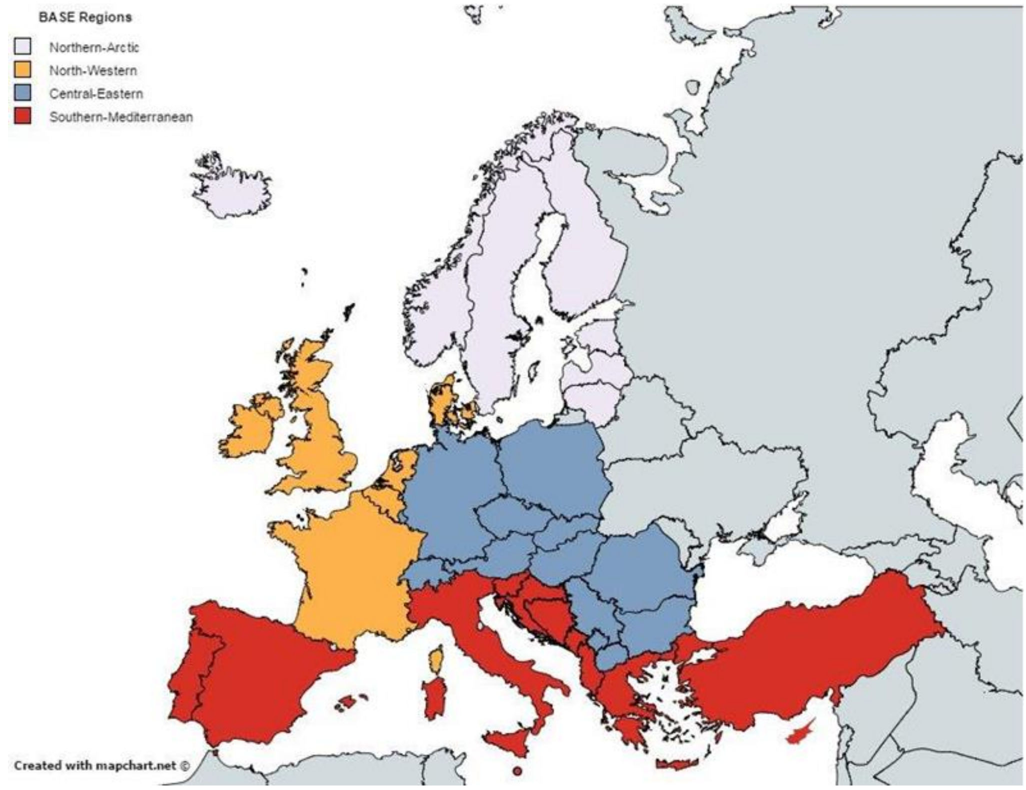


Figure 2 Regional division chosen for the storylines

For the purpose of the discussion the area has been divided into four regions

- **Northern-Arctic**: Iceland, Norway, Finland, Sweden, Estonia, Lithuania, Latvia
- **North-Western**: UK, France, Belgium, Netherlands, Denmark, Ireland
- **Central-Eastern**: Germany, Poland, Austria, Hungary, Czech Republic, Slovakia, Switzerland, Romania, Bulgaria, Macedonia, Kosovo, Serbia, Luxembourg
- **Southern-Mediterranean**: Portugal. Spain, Italy, Greece, Slovenia, Bosnia-Herzegovina, Croatia, Montenegro, Albania, Turkey, Malta, Cyprus

These regions correspond broadly to the geographical regions used by the EEA and the IPCC (EEA 2012; Hewitson et al. 2014). The BASE-project activities do not fully cover all the regions and cannot be seen to be fully representative. The triangulation approach aims at placing the BASE observations in the wider regional context. Observations of a mismatch between cases and broad regional scenarios are particularly instructive as they underline the diversity that is characteristic of many climate change impacts also within regions (Müller Schmied et al. 2016).

The nature of climate change impacts, the adaptation actions and the possible **adaptation pathways differ within sectors**. It is therefore of particular interest to focus on sectors. There have been a large number of studies of the impacts and vulnerabilities of specific sectors and those have been compiled by, for example, the EEA and the IPCC AR5 (Füssel, Hildén, and Jol 2013; IPCC 2014). Here we focus on the particular challenges that the management of the sectors experience, i.e. we ask to what extent current management practices have to be changed in order develop appropriate adaptation pathways. The management challenges that are of interest include the following:

- Urban areas
- Rural settlements
- Housing
- Hydropower production
- Water resources
- Agriculture
- Forests and forestry
- Coastal areas and resources
- Health care
- Biodiversity

The development and diffusion of green innovations is a cross cutting management issues that is of particular interest for R&D policy and management as shown by recent calls under Horizon2020. BASE has not been able to analyse cases that would cover all of the management challenges for all regions, and all management challenges are not equally important in all regions. The triangulation approach has provided a key to the identification of salient features of the possible adaptation pathways and that related management challenges. In summary we bring together 4 different layers of information

1. Direct stories emerging from literature on impact and adaption challenges based on earlier studies using SSP and RCP. This is a literature review step of which the results for all sectors mentioned above is described in chapter 3.

2. The Model analysis that is performed under task 6.3 in BASE provides additional quantitative information for selected sectors water management, agriculture and health

3. The sectorial storylines as described under 2 in addition complemented with results from BASE case study. The combination of 2 and 3 is described in Chapter 4

4. Interviews with policy experts from the 4 regions that are described have been held to gather critical reflection on the story lines and its envisaged use. In total 12 interviews were held. The reflections of the interviewees are incorporated in the summarized storylines in Chapter 5

Finally the accumulated information is used to modify the adaptation policies and governance to create a dynamic learning process where the process tool supports reflection on policy pathways (Chapter 6). In this the BASE process tool makes extensive use of the dynamic policy pathways approach, which combines approaches of adaptation pathways and adaptive policy making (Haasnoot et al. 2013).

3 Setting the scene: The climate impacts, the regional storylines and the adaptation challenges

This Chapter shows how the basic starting points are assembled for the BASE process tool. The main projected regional climate variables and their changes set the frame for the adaptation challenges.

3.1 Main Climate Impacts per Region and RCP

The BASE process tool requires an explicit consideration of the specific biophysical changes that are projected to arise under different RCPs.

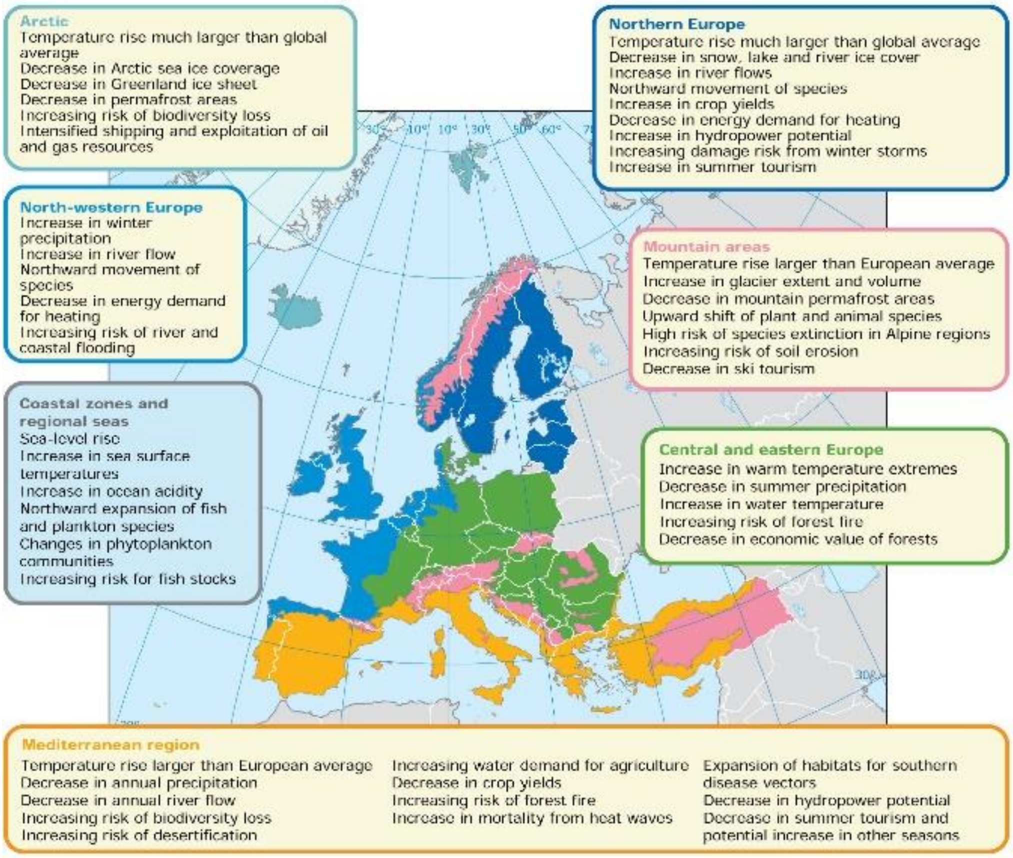


Figure 3 Key impacts on European systems and sectors of climate change during the 21st century for the main biogeographic regions of Europe (EEA, 2012)

Northern-Arctic Europe

Under RCP 8.5 the temperatures are projected to rise in north more than global average, even 6 degrees with increasing annual precipitation (20%) by the end of the century. Both temperature and precipitation are projected to increase especially during the winter months, (average 8 degrees and 35 %). Changes are more pronounced in northern parts of the region. There is increased cloudiness. Sea level rise combined with storms increase risk of storm surges and other floods in coastal areas. Under RCP 4.5 the temperatures will rise in north more than global average but at a slower rate than under RCP 8.5. Projections suggest ca.3-4 ^{o}C and annual precipitation increases (15%) by the end of the century. Both temperature and precipitation increase especially during the winter months, (average 5 degrees and 20 %). Changes are more pronounced in northern parts of the region. There is increased cloudiness and strong winds. Sea level rise combined with storms increase risk of storm surges and other floods in coastal areas, but somewhat less than under RCP 8.5.

Under RCP 8.5 annual flooding peaks change seasonally especially in northern parts of the area. There are more riverine floods in autumn and more pluvial floods in summer, but spring peaks decrease in areas where snow mass is reduced. Some urban areas are projected to face relatively frequent challenges of flooding. In the summer longer drought periods are possible. Under RCP4.5 a similar but slower development is projected.

North-Western Europe

Under RCP 8.5 heavy rains will increase in all countries with around 20 % in the winter and with around 10% in the summer. The number of summer days will increase. There are more frequent and more floods as well as more droughts. Salinization of groundwater and surface water also increases partly due to overexploitation of groundwater and partly due to less discharge of the rivers in the summer. Under RCP 4.5 heavy rain does increase in the region by 10 % in the winter and less in the summer. There is a trend of a decrease in the discharge in rivers. The increase of heavy rains causes more frequent and more extreme floods but moderate compared to RCP8.5.

Central-Eastern Europe

Under RCP 8.5 the mean annual temperature is projected to increase by 3.7 to 5.2 °C by 2100. Annual precipitation is projected to increase by approximately 10%, with high regional and seasonal variations. Climate extremes, particularly heat waves, droughts and heavy precipitation are supposed to increase, while the average number of cold spells and frost days decreases. As a consequence of the rise in average temperatures, the occurrence of heat waves increases during summers. Global mean sea level rise is projected in the range between 0.48-0.82 metres.

Under RCP 4.5, mean annual temperature increases by 1.6 to 3.2 °C in Central and Eastern Europe. Average annual precipitation increases by 3 %. The occurrence of heat waves moderately increases under this scenario. Global mean sea level rise is projected in the range between 0.36-0.63 metres.

In RCP8.5 average annual water availability is supposed to increase due to rising precipitation rates; however, the temporal distribution of water availability is highly irregular. The increase in river discharges and floods are expected, while the duration and intensity of droughts is projected to increase in central Europe.

In RCP4.5 annual water availability remains stable or slightly increases, with lower flows in summer and high flows in winter. The occurrence and severity of flood events increases, particularly caused by spring floods.

Southern-Mediterranean

In RCP8.5 the temperatures are projected to rise in average 4 ºC and in some regions more than 7ºC by the end of the century. Annual Precipitation will decrease 10 % to 25 % by the end of the century while extreme precipitation events may increase 5 % to 10 %, meaning less water but falling in smaller periods of time and more floods. The number of heat waves per year will double. Seasonal patterns will shift and storms and extreme events will occur with more intensity and frequency. Droughts will also increase in their duration and frequency. Water scarcity will be a permanent reality and pressure.

In RCP4.5 the temperatures are projected to rise in average 2 ºC and in some regions more than 4ºC. Precipitation will become more unpredictable and while in some regions annual average precipitation will remain constant in other it may decrease up to 20 %. Heavy precipitation will also be more unpredictable and some regions may show an increase of 15 % whereas other may remain the same. The number of heat waves will significantly increase in about 50 %. Climate in general will become more unpredictable with seasonal patterns changing towards additional heat and less frost but eventual increase in storms.

3.2 Overview of assumptions and adaptation challenges

The storylines provide the wider context for the BASE process tool. They arise from different assumptions concerning the development in the following dimensions: socio economic development, climate, water, agriculture, coastal areas, cities, health and ecosystems. For each dimension key factors of change have been identified (Table 1).

The process tool compares possible developments for regions and sectors from an adaptation point of view by contrasting the chosen basic storylines, in this case:

Storyline 1: SSP5 and RCP 8.5 “Fossil-fuelled development”

Storyline 2: SSP2 and RCP 4.5 “Middle of the road”

Storyline 3: SSP3 and RCP 8.5 “Regional rivalry”

The overall argument in storylines 1 and 3 is one of failure in mitigation policies but with two different premises and outcomes. In storyline 1 the economy is assumed to develop very favourably with growing population and GDP whereas in storyline 3 parts of the world are assumed to suffer from an economic downturn, with global emissions nevertheless rising rapidly. In northern

Europe this would be reflected in very slow economic growth and stagnating, even declining, population. In storyline 2 at least moderate success is assumed for policies aiming at mitigation, and both economic growth and population growth continue at a moderate rate.

Table 1. Assumptions on development in the three chosen storylines across regions and sectors.

Topic/Sector	Storyline	Northern and Arctic	North-Western	Central and Eastern	Southern-Mediterranean
Population change	Fossil-fuelled development	Significant growth (40 %)	Significant growth (>40 %)	Modest growth (7 %)	Growth 20 %
	Middle of the road	Moderate growth (18 %)	Moderate growth (21 %)	Small decline (-4 %)	Growth 14 %
	Regional rivalry	Stable	Stable	Decline (-15 %)	Growth 10 %
Urbanisation	Fossil-fuelled development	Increase from 65-93 % to 85-98 %	From 61-97 % to > 90 % (Ireland 83 %)	From 55-85% to 81-95 %	From 48-78(94 Malta)% to 78-92 (99) %
	Middle of the road	to 80-98%	to 78-98 %	to 71-95 %	to 72-88 (99)%
	Regional rivalry	to 70-98 %	to 68-98 %	to 62-94 %	to 57-80 (98) %
Economic growth	Fossil-fuelled development	More than 200 % increase	More than 200 % increase	Approx 140 % increase	More than 200 % increase
	Middle of the road	Approx. 160 % increase	Approx 140 % increase	Approx 77 %	Approx 140 % increase
	Regional rivalry	Approx 60 % increase	Approx 50 % increase	Approx 40 % increase	Approx 60 % increase
Primary energy consumption	Fossil-fuelled development	Increase	Increase	Increase	Increase
	Middle of the road	Stable-increase	Decrease	Stable-Decrease	Stable-Increase
	Regional rivalry	Stable-Decrease	Stable-Decrease	Stable-Decrease	Stable-Decrease

Energy production	Fossil-fuelled development	Nuclear and Increase in forest based renewables, wind and solar	Nuclear, fossil + CCS and Increase in wind, solar and biomass based. Addressing seasonal cooling water scarcity	Fossil + CCS and increase in wind, solar and biomass based. Addressing seasonal cooling water scarcity	Nuclear, fossil + CCS and Increase in solar and wind based
	Middle of the road	Increasing share of forest based renewables, wind and solar	Increasing share of wind, solar and biomass based	Increase share of wind, solar and biomass based	Increasing share of solar and wind based
	Regional rivalry	Largely maintenance of current system including coal	Largely maintenance of current system including fossil energy. Coping with seasonal cooling water scarcity	Largely maintenance of current system including coal. Coping with seasonal cooling water scarcity	Largely maintenance of current system including fossil energy. Coping with seasonal cooling water scarcity
Changes in cities and infrastructure	Fossil-fuelled development	Major growth of urban areas and associated infra	Major growth of urban areas and associated infra	Some growth of urban areas and associated infrastructure	Growth of urban areas and associated infrastructure
	Middle of the road	Growth of urban areas and associated infrastructure	Growth of urban areas and associated infrastructure	Modification of urban areas and associated infrastructure	Growth of urban areas and associated infrastructure
	Regional rivalry	Modification of urban areas and associated infrastructure	Modification of urban areas and associated infrastructure	Some dismantling of infrastructure in depopulated areas	Some growth of urban areas and associated infrastructure
Water management	Fossil-fuelled development	Flood risk management investments,	Large flood risk management	Large flood risks management investments,	Large investments for managing water

		hydropower Optimization	investments	hydro power Optimization	scarcity and flash flood risks
	Middle of the road	Development of management practices to climate proof specific priority areas - focus on river and pluvial floods	Development of management practices to climate proof specific priority areas – focus on river and pluvial floods	Development of management practices to climate proof specific priority areas – focus on river and pluvial floods	Development of management practices to climate proof specific priority areas- focus on pluvial floods and droughts
	Regional rivalry	Coping through change of practice	Coping through change of practice	Coping through change of practice	Coping through change of practice
Management of agriculture and forestry	Fossil-fuelled development	Investments into intensification of use of resources, exploiting new opportunities in agriculture and forestry	Investments into intensification of use of resources, exploiting new opportunities	Investments into intensification of use of resources exploiting new opportunities and changing farming systems	Investments into radically changing farming systems
	Middle of the road	Gradual adjustment to changing condition	Gradual adjustment to changing conditions	Gradual adjustment to changing conditions	Changing farming practices
	Regional rivalry	Efforts to cope with changing conditions	Efforts to cope with changing conditions	Efforts to cope with changing conditions	Efforts to cope with changes and decline of agriculture
Coastal management	Fossil-fuelled development	Major commercial infrastructure development including housing based on liberalized planning	Major commercial infrastructure development including urban expansion. Coastal protection emphasised	Relatively little coastal areas, but where exist infrastructure development including urban expansion and coastal protection	Major commercial infrastructure development including urban expansion. Coastal protection in selected areas.

	Middle of the road	Moderate infrastructure development in specific areas	Moderate infrastructure development in specific areas, focus on coastal protection	Limited development and maintenance of existing structures	Moderate infrastructure development in specific areas, focus on coastal protection
	Regional rivalry	Limited infrastructure development, partial abandonment	Development in important hubs, e.g. Rotterdam, maintenance of existing infrastructure	Limited infrastructure development, partial abandonment	Limited infrastructure development in high priority areas such as Venice, focus on coastal protection
Development and diffusion of green innovations	Fossil-fuelled development	Large investments in new forest based bioeconomy; renewable energy	Large investment into transport system solutions; renewable energy and other new energy solutions (CCS, fusion)	Large investment into transport system solutions; renewable energy and other new energy solutions (CCS, fusion)	Large investment into transport system solutions; renewable energy and other new energy solutions (CCS, fusion). Responses to water scarcity.
	Middle of the road	Gradual transformation of existing economy towards a low carbon path, Technology and also forest based products a focal area for innovations	Gradual transformation of existing economy towards a low carbon path. Technology and service + agriculture based bioeconomy dominate	Gradual transformation of existing economy towards a low carbon path. Technology and service + agriculture based bioeconomy dominate	Gradual transformation of existing economy towards a low carbon path. technology and service + agriculture based bioeconomy dominate
	Regional rivalry	Limited innovations, continued use of fossil fuels	Fragmented important innovations, continued use of fossil fuels	Fragmented important innovations, continued use of fossil fuels	Fragmented important innovations, continued use of fossil fuels
Health care	Fossil-fuelled	Significant investments in	Significant investments in	Significant investments in	Significant investments in

	development	new facilities and technologies	new facilities	new facilities	new facilities
	Middle of the road	Remodeling and expanding existing facilities	Remodeling and expanding existing facilities	Remodeling and expanding existing facilities	Remodeling and expanding existing facilities
	Regional rivalry	Maintenance of existing facilities to the extent possible, increasing inequality	Maintenance of existing facilities to the extent possible, increasing inequality	Maintenance of existing facilities to the extent possible, increasing inequality	Maintenance of existing facilities to the extent possible, increasing inequality
Ecosystem management	Fossil-fuelled development	Intensification of use of forest and mineral resources	Intensification of land use	Intensification of land use	Intensification of land use
	Middle of the road	Development of a sustainable circular resource economy, forests and marine ecosystem services	Development of a sustainable circular resource economy, focus on rural and marine ecosystems	Development of a sustainable circular resource economy, focus on rural and mountain ecosystems	Development of a sustainable circular resource economy, focus on rural and mountain and marine ecosystems
	Regional rivalry	Extractive use of forest and marine resources and ecosystems	Extractive use of rural, marine resources and ecosystems	Extractive use of rural and mountain resources and ecosystems	Extractive use of rural , mountain and marine resources and ecosystems

3.3 Overview of management challenges across sectors and regions

From an adaptation point of view the essential questions is what management challenges emerge and how they differ across the story lines. Management is here understood as the operational practice within the sectors, including the concrete actions that are taken to ensure that the sector copes with a changing climate. The management of a sector is thus a concrete outcome of its wider governance.

In the BASE process tool the management challenges are tentatively derived from the regional storylines by combining the information on the developments with knowledge of the specific sectors (Table 2). There is considerable variation within regions and also sectors and thus the general colour coding is indicative at best. The overview suggests, however, that economic development plays a clear role in the management challenges, with scarce resources possibilities to benefit from any positive development and capacities to respond to adverse changes are restricted. Rapid economic development as assumed in the fossil-fuelled development does on the other hand create greater pressures on, for example land and resource use than a slow economic development. The main opportunities are assumed to arise in the northern part of Europe where climate change may, for example, open up new opportunities for agriculture, increase production of hydropower and reduce heating demand.

Table 2. Justification for major management challenges related to climate change vulnerabilities. Green: mainly positive opportunities; Yellow: balance of negative challenges and positive opportunities; Orange: more negative challenges than opportunities; Red: mainly negative challenges.

Topic/Sector	Storyline	Northern and Arctic	North-Western	Central and Eastern	Southern-Mediterranean
Management of urban areas	Fossil-fuelled development	Large investments to reduce vulnerability in existing and rapidly expanding urban areas	Large (private) investments to reduce vulnerability in existing and rapidly expanding urban areas	Investments to reduce vulnerability in existing and rapidly expanding urban areas	Investments to reduce vulnerability in existing and rapidly expanding urban areas
	Middle of the road	Investments to reduce vulnerability in existing and expanding urban areas	Investments to reduce vulnerability in existing and expanding urban areas	Investments to reduce vulnerability in existing urban areas	Investments to reduce vulnerability in existing and expanding urban areas
	Regional rivalry	Management for low or no cost reduction of vulnerability in existing urban	Management for low or no cost reduction of vulnerability in existing urban	Management for low or no cost reduction of vulnerability in existing and depopulated	Management for low or no cost reduction of vulnerability in existing and expanding urban

		areas	areas	urban areas	areas
Management of rural settlements	Fossil-fuelled development	Investments to reduce vulnerability especially in rapidly expanding periurban areas	Investments to reduce vulnerability especially in rapidly expanding periurban areas	Investments to reduce vulnerability especially in rapidly expanding periurban areas	Investments to reduce vulnerability especially in rapidly expanding periurban areas
	Middle of the road	Investments to reduce vulnerability especially in expanding periurban areas	Investments to reduce vulnerability especially in expanding periurban areas	Investments to reduce vulnerability especially in periurban areas	Investments to reduce vulnerability especially in expanding periurban areas
	Regional rivalry	Coping with vulnerability especially in periurban areas	Coping with vulnerability especially in periurban areas	Coping with vulnerability in depopulating periurban and rural areas	Coping with vulnerability especially in periurban areas
Management of energy consumption in housing	Fossil-fuelled development	Managing fast growing cooling demands	Managing fast growing cooling demands	Managing fast growing cooling demands	Managing fast growing cooling demands
	Middle of the road	Managing reduced heating need, increasing cooling demands	Managing reduced need, increasing cooling demands	Managing reduced need, increasing cooling demands	Managing increasing demand for cooling
	Regional rivalry	Managing reduced heating need. Responding to increasing cooling demands with limited resources	Managing reduced heating need. Responding to increasing cooling demands with limited resources	Managing reduced heating need. Responding to increasing cooling demands with limited resources	Managing increasing demand for cooling with limited resources
Management of hydropower production	Fossil-fuelled development	Optimization of new opportunities in relation to RES increase	Optimization of mostly increased flow	Managing partial reduction of production	Coping with reduction of production

	Middle of the road	Optimization of new opportunities in relation to increase of RES	Maintenance of facilities, changing role in relation to RES	Coping with partial reduction of production	Coping with reduction of production
	Regional rivalry	Development and maintenance	Benefiting from increase and coping with partial reduction of production	Coping with partial reduction of production	Coping with reduction of production
Powerproducti on with boilers	Fossil-fuelled development	Responding to increasing share of renewables-extreme event vulnerabilities	Responding to increase of cooling water temperatures	Responding to increase of cooling water temperatures	Responding to increase of cooling water temperatures and water scarcity
	Middle of the road	Responding to increasing share of renewables-extreme event vulnerabilities	Responding to increase of cooling water temperatures	Responding to increase of cooling water temperatures	Responding to increase of cooling water temperatures
	Regional rivalry	Increasing share of renewables-extreme event vulnerabilities	Responding to increase of cooling water temperatures	Responding to increase of cooling water temperatures	Responding to increase of cooling water temperatures and water scarcity
Water management	Fossil-fuelled development	Benefit from reduced spring flood peaks, managing increased risks of winter and pluvial floods	Managing increased risks of pluvial and river floods coping with increased droughts	Managing increased risks of pluvial and river floods coping with increased droughts	Managing increased risks of pluvial and river floods coping with increased severe droughts
	Middle of the road	Benefit from reduced spring flood peaks, managing increased risks of pluvial floods	Managing increased risks of pluvial and river floods coping with increased droughts	Benefiting from reduced extreme floods, coping with pluvial floods and droughts	Managing increased risks of pluvial and river floods coping with increased droughts
	Regional rivalry	Benefit from reduced spring flood peaks,	Managing increased risks of pluvial and	Managing increased risks of pluvial and	Managing increased risks of pluvial and river

		managing increased risks of winter and pluvial floods	river floods coping with increased droughts	river floods coping with increased droughts	floods coping with increased severe droughts
Management of agriculture	Fossil-fuelled development	Introduction of new cultivars, benefiting from expanding growing season, coping with pests, increasing world market prices	Introduction of new cultivars, benefiting from expanding growing season, coping with wet conditions and increasing pests	Introduction of new cultivars, benefiting from expanding growing season, coping with drought, hydrological extremes and pests	Managing increasing temperatures, severe water shortage, heat stress, investments can benefit from changing seasons
	Middle of the road	Introduction of new cultivars, benefiting from expanding growing season, coping with pests	Introduction of new cultivars, benefiting from expanding growing season, coping with drought and pests	Introduction of new cultivars, benefiting from expanding growing season, coping with drought and pests	Managing increasing temperatures and droughts, some benefits from changing seasons
	Regional rivalry	Limited Introduction of new cultivars, benefiting from expanding growing season, coping with severe pests and increasingly changing other growing conditions	Limited Introduction of new cultivars, benefiting from expanding growing season, coping with severe pests and increasingly changing other growing conditions	Limited Introduction of new cultivars, benefiting from expanding growing season, coping with severe pests and increasingly changing other growing conditions	Coping with severe water shortage, heat stress and changing other adverse growing conditions
Forest management	Fossil-fuelled development	Increasing growth rate of forests, increasing demand for wood based products, successful change to a bioeconomy	Management of increased growth and demand for sustainable forest based products, adjustment to changing conditions	Management of increased growth and demand for sustainable forest based products, adjustment to changing conditions	Management of droughts, high temperatures and increased forest fire risks.

	Middle of the road	Management of increased growth and demand for sustainable forest based products, adjustment to changing conditions	. Management for increasing demand for ecosystem services, adjustment to changing conditions	Management of increased growth and demand for sustainable forest based products, adjustment to changing conditions	Management of droughts, high temperatures and increased forest fire risks.
	Regional rivalry	Stagnating to decreasing demand for high value products, extreme events, increasing risks of pest outbreaks	Management for increasing demand for ecosystem services, adjustment to changing conditions	Stagnating to decreasing demand for high value products, extreme events, increasing risks of pest outbreaks	Management of droughts, high temperatures and increased forest fire risks with scant resources
Coastal management	Fossil-fuelled development	Steering coastal development, developing protection for SLR, benefiting from transport and summer tourism	Steering coastal development, developing protection, benefiting from transport and summer tourism	Coastal management overall a limited issue, management of Baltic coast for extremes	Management for coping with extreme events, increasing salt water intrusion , loss of summer tourism, benefiting from other seasons
	Middle of the road	Steering coastal development, developing protection for SLR, benefiting from transport and summer tourism	Steering coastal development, developing protection for SLR, benefiting from transport and summer tourism	Coastal management overall a limited issue, management of Baltic coast potential for transport and summer tourism	Steering coastal development, developing coastal protection, loss of summer tourism, benefiting from other seasons
	Regional rivalry	Management for coping with extreme events, limited benefits	Management for coping with extreme events, SLR, limited benefits	Coastal management overall a limited issue, management of Baltic coast for extremes	Management for coping with extreme events, increasing salt water intrusion , loss of summer tourism
Management	Fossil-fuelled	Management of	Management of	Management of	Management of

of health care	development	health system to help rapidly increasing elderly population to cope with heat waves and other extreme events, some benefits from reduced cold. Dealing with increased risks of vector borne diseases	health system with declining resources to help rapidly Increasing elderly population to cope with heat waves and other extreme events,. Some benefit from reduced risk of cold. Dealing with increased risks of vector borne diseases	health system with rapidly declining resources to help rapidly Increasing elderly population to cope with heat waves and other extreme events. Some benefit from reduced risk of cold. Dealing with increased risks of vector borne diseases	health system with declining resources to help rapidly Increasing elderly population to cope with extended heat waves and other extreme events. Dealing with increased risks of vector borne diseases.
	Middle of the road	Management of health system to help Increasing elderly population to cope with heat waves, reduced risk of cold	Management of health and DRR systems to help especially an Increasing elderly population to cope with heat waves and other extreme events, reduced risk of cold	Management of health system to help especially an Increasing elderly population to cope with heat waves and other extreme events, reduced risk of cold	Management of health system to help especially an Increasing elderly population to cope with heat waves and other extreme events
	Regional rivalry	Management of health system with declining resources to help rapidly Increasing elderly population to cope with heat waves and other extreme events, benefiting from reduced risk of cold. Dealing with increased risks of vector borne diseases	Management of health system with declining resources to help rapidly Increasing elderly population to cope with heat waves and other extreme events, benefiting from reduced risk of cold. Dealing with increased risks of vector borne diseases	Management of health system with rapidly declining resources to help rapidly Increasing elderly population to cope with heat waves and other extreme event. Some benefit from reduced risk of cold. Dealing with increased risks	Management of health system with declining resources to help rapidly Increasing elderly population to cope with extended heat waves and other extreme events. Dealing with increased risks of vector borne diseases.

				of vector borne diseases	
Biodiversity management	Fossil-fuelled development	Management benefiting from strengthening of southern species, but facing decline of northern species and habitats with scant resources. Intensification of land use.	Managing consequences of habitat and species shifts coupled with intensification of land use	Managing consequences of habitat and species shifts coupled with intensification of land use	Managing consequences of habitat and species shifts coupled with intensification of land use
	Middle of the road	Management for balancing different ecosystem services increasing connectedness to address vulnerability,	Management for balancing different ecosystem services increasing connectedness to address vulnerability,	Management for balancing different ecosystem services increasing connectedness to address vulnerability,	Management for balancing different ecosystem services increasing connectedness to address vulnerability, challenges from invasive species
	Regional rivalry	Management benefiting from strengthening of southern species, but facing decline of northern species and habitats with scant resources	Managing consequences of habitat and species shifts with scant resources	Managing consequences of habitat and species shifts, loss of Alpine species with scant resources	Managing consequences of habitat and species shifts abd prolifereating invasive species with scant resources
Development and diffusion of green innovations	Fossil-fuelled development	Despite fossil fuel dominance, investment in large-scale innovations for sustainable and resilient resource efficiency of renewable natural	Managing large-scale innovations for sustainable and resilient urban development and renewable energy	Managing large-scale innovations for sustainable and resilient urban development and renewable energy	Managing large-scale innovations for sustainable and resilient urban development and renewable energy

		resources.			
	Middle of the road	Managing innovations for sustainable and resilient resource efficiency of renewable natural resources	Managing innovations for sustainable and resilient urban development and renewable energy	Managing innovations for sustainable and resilient urban development and renewable energy	Managing innovations for sustainable and resilient urban development and renewable energy
	Regional rivalry	Management of climate change related innovation potential with constrained resource base	Management of climate change related innovation potential with constrained resource base	Management of climate change related innovation potential with constrained resource base	Management of climate change related innovation potential with constrained resource base

4 Integrated analysis of specific sectors

For the BASE process tool to provide added value to the generic analysis provided by the general projections and story lines it is essential to bring in additional information on sectors and regions, and to include detailed information from specific cases. This Chapter illustrates the use of information from the BASE case studies and specific sector based modelling studies.

4.1 Integrating BASE cases

The BASE process tool aims at maximal use of available information, even when the pieces of information are not strictly comparable. This section examines in particular how the context bound BASE-cases fit into the overall framework. A detailed overview of how BASE cases have been contributed to the sectorial management challenges and responses in the region can be found in appendix 2.

The aim of the top-down and bottom-up approach of BASE has been to substantiate findings on economic costs of adaptation and associated policy recommendations at the EU level with empirical evidence and economic data from both models and case studies. The process tool uses also bottom-up information.

This section demonstrates how the bottom-up information can be used to examine to what extent the (economic) outcomes of the different case studies support the SSP/RCP storylines and related management challenges to adaptation. The different approaches and economic evaluation are discussed with a particular focus on the extent to which it is possible to scale up findings to the European level.

The presentation is structured around the main findings on how one can use bottom up information:

1. When defining the economic costs and benefits of adaptation at the EU level, a bottom-up approach (use of case studies) offers added value compared to only using large-scale models
2. A harmonised stepwise approach helps to examine adaptation options across cases and scenarios (SSPs/RCPs)
3. Case study findings are generally very site and context specific and as such difficult to upscale to the EU level
4. Cases offer insightful information on substantiation of storylines and EU adaptation policies
5. There is an overall fit with the case study findings and the regional storylines and inherent challenges

1. When defining the economic costs and benefits of adaptation at the EU level, a bottom-up approach (use of case studies) offers an added value compared to only using large-scale models

The economics of adaptation frequently refers to the possibilities to avoid or minimise costs that would otherwise occur as a result of climate change (Watkiss et al. 2015). The main objective of economic assessments is to compare the costs of different adaptation options with their benefits, i.e. the avoided climate change impacts, in order provide support for decision makers in finding the most efficient solutions to reduce climate change impacts. Several studies have provided costs estimates for the consequences of climate change generally and also for specific sectors (Steininger et al. 2015; Ciscar et al. 2014; Mima, Criqui, and Watkiss 2011; Black et al. 2011; EC 2014). The damage functions that relate economic costs to climate change are a key feature of these studies. The top-down modelling in BASE has developed this approach further with several different sector models (D3.2, D3.3) and also by dealing with uncertainties (D3.4). Results of the top-down models are described in D6.3 and summarized with regard to the storylines in Chapter 3 of this report.

However, for the evaluation of site-specific adaptation measures at the local level – and this is where decisions on adaptation measures are usually taken - the top-down models are mostly too coarse, i.e. they are not able to estimate the impacts of specific local scale measures such as local dikes and barriers, backflow valves or dry-proofing of houses or detailed urban construction plans. The spatial resolution of the top-down models is also generally too low to provide information on site-specific baseline-option.

The analyses of cases provide information on how costs and benefits are formed at the local level and how they are distributed. This information is particularly important for local decision makers that look for alternatives on how to innovatively improve adaptive capacity.

2. *A harmonised stepwise approach helps to examine adaptation options across cases and scenarios (SSPs/RCPs)*

All case studies followed a stepwise approach in evaluating their specific adaptation options (see D5.2), consisting of

1. Preliminary risk assessment
2. Identification of adaptation options
3. Selection of the evaluation method and the evaluation criteria
4. Data collection
5. Evaluation and prioritization of options

The purpose of this stepwise approach was to harmonize the process of economic evaluation and other methodical aspects as much as possible. However, this approach also allowed for some degrees of freedom to adjust the evaluation process to the specific needs and framework conditions of each case study. This led to variation that created some difficulties in using the results as such in the BASE process tool matrices. Thus qualitative reflection and expert judgement was needed to fit case information to the process tool.

Case specific variation arose, for example, in step 3, for which the general guidance was that evaluation criteria should reflect all relevant positive effects (benefits) but also the negative effects (costs) measures could have (BASE Deliverable 5.2). In general this would include the investment and re-investment costs as well as maintenance costs of the alternative measures, their benefits it terms of damage reduction regarding the primary climate impact, but also potential co-benefits (and co-costs) such as potential environmental, social and economic side effects (e.g. environmental impacts of a dike on floodplain ecosystems). In detail, however, the types of costs and benefits varied between the different case studies, depending on the types of measures considered, the specific risk addressed and local context conditions (see BASE D5.2, section 2.3 for an overview of the costs and benefits considered in the different case studies).

It turned out that the detailed sources of cost and benefit data were often highly case-specific (see D5.2, Table 2.7 for a detailed overview). Impact assessment models were often used to estimate the benefits (in terms of avoided impacts) of the alternative measures, in particular for flood risk assessments in different case studies (e.g. the Planning KIT DPRD in the Rotterdam case study) but also heat stress assessments (URBAHT in Jena and Prague), water scarcity assessments (WAAPA in the Doñana case study) or ecosystem service assessments (InVEST model in the Czech green roof and Alentejo case study). To reproduce the impacts of local measures these models were more detailed in terms of spatial resolution than the models used in D6.3 for the Europe-wide assessments of climate impacts.

Also with regard to the climate and socio-economic scenarios used, variation arose depending on the level of detail required, data availability and if case studies were retrospective or prospective.

Climate data

The single most used climate data set were the CORDEX simulations with the SMHI regional model RCA4-v1 and the boundary conditions from the global climate model CNRM-CM5 for the AR5-IPCC emission scenarios RCP4.5 and RCP8.5. This particular data set was selected as, at the time, it was the only model with the appropriate domain (entire European continent) and with a spatial resolution which was adequate for a substantial number of cases, i.e. about 14 km x 14 km. Data was provided for selected case studies by BASE partner CMCC (Scoccimarro & Gualdi, 2014).

Still, some case studies needed information on particular climate parameters which could not have been retrieved from the data set provided and/or data with a higher spatial resolution. For some cases implausible deviations from historic data and / or projections so far available raised some doubts regarding the validity of the data for some regions provided[3].

Some cases (Jena, Prague) decided to use climate data based on an ensemble of global climate models rather than using single model data to better take into consideration inherent uncertainties. These case studies used climate projection data from the Coupled Model Intercomparison Project - Phase 5 (CMIP5) provided by the KNMI Climate Explorer.4 The Leeds case study opted for the central estimate of the UKCP09 climate projections with a grid resolution of 25 km.

Socio-economic scenarios (SSPs)

Although the guidance asked to consider at least two socio-economic scenarios, only few case studies were able to do this. In most case studies, detailed data for the different SSPs was lacking. The Spanish case studies as well as the Leeds case study applied the SSPs 2 and 5 and the Rotterdam case study use corresponding “steam” and “rest” scenarios.

In the Green roof case study, different scenarios for land use change taken from the ALARM project were used. The Kalajoki river basin water quality case study applies four agricultural adaptation scenarios (baseline, successful adaptation, moderate adaptation, little adaptation) and an economic agricultural sector model DREMFIA was used for modelling of the scenarios (Lehtonen 2013).

All other case studies were asked at least for a qualitative interpretation on how their results would likely change for different SSPs.

3. *Case study findings are generally very site specific and as such difficult to upscale to the EU level*

The BASE case findings, such as the costs and in particular benefits of adaptation options on the local level are highly context-specific, as they depend very much on the case study’s specific risk and exposure to climate-related threats as well as the baseline scenario used, e.g. pre-existing protection, the timeframe of the evaluation, which is chosen in accordance with the lifetime of particular adaptation measures respectively stakeholder and/or decision maker needs, etc. This means that the comparability and also transferability of results is still rather limited, due to site-specific context conditions.

One of the main conclusions from BASE Deliverable 5.2 therefore was that a simple transfer of case study results *in general* is not scientifically sound, unless not only methods applied, but also all of the case-specific conditions are comparable. A specific adaptation option, which turned out to

[3] For example for the Jena case study data for some parameters, e.g. precipitation related data and global radiation, differed substantially from ECHAM simulations. In general the calibration of ECHAM is considered to be particularly accurate in the re-analysis of measured data for Germany.

[4] Multi-model mean of historical climate data and projections for RCP 4.5, RCP 8.5 of 37 GCMs.

be efficient in one case might be highly inefficient in another case. On the other hand, D5.2 results showed that it is worth taking the effort to carry out economic evaluation processes, which are adjusted to the specific needs and context of each case.

4. *Cases offer insightful information on substantiation of storylines and EU adaptation policies*

Despite the difficulties in generalising from cases some trends could be identified in the results for the different risks addressed (see D5.2, section 3.1 and also tables 2.5 and 3.1 for some figures for the different risks). For example, case study results show that in large cities with a high concentration of people and values exposed to flood risk, large structural flood risk mitigation measures seem to be highly efficient, compared to the business-as usual.

Although case study results are not representative for a whole region, they can nevertheless be used to illustrate how different storylines can affect the results regarding the need of adaptation and the choice of an appropriate adaption measure.

5. *There is an overall fit with the case study findings and the regional storylines and inherent challenges*

Although nearly all case studies considered different climate scenarios in their assessment results, only a few case studies provided quantitative data for the different SSPs (Rotterdam, Madrid and Holstebro). It was nevertheless possible to obtain at least qualitative statements on how the different storylines would affect management challenges and the ranking of potential adaptation options. This demonstrated that the process tool could benefit from diverse information and also provide a frame for interpreting case information.

4.2 Model landscapes

Modelling offers a way to generalise findings and to assemble information in a coherent way for making sector specific assessments. Models and model results are therefore an essential element of the BASE process tool that aims at testing and evaluating future plans for adaptation. But the focal areas of the models differ. They map out different parts and aspects of adaptation needs and possibilities. Thus they provide model landscapes that can be used to build up the view of the adaptation challenges. This section illustrates three sector modelling approaches used in BASE. Sections 4.3-4.6 demonstrate how they can, jointly with case study information, contribute to the overall understanding of the adaptation actions within the BASE process tool framework.

4.2.1 Riverine Flood Risk Assessment

The riverine flood risk assessment in BASE is based on the GLOFRIS model, a global risk estimation method for rivers developed by Winsemius et al. (2013) and a flood damage model based on the model developed for the JRC (Huizinga, 2007). The flood hazard analysis produces flood hazard maps and future flood risks at a coarse scale (0.5 x 0.5 degree) using an ensemble of five climate models for RCP4.5 and 8.5. The flood volumes are converted into high resolution inundation depth maps (1 x 1 km) that account for current flood protection levels across Europe (Scussolini et al. 2015). Damages are assessed using a modified version of flood damage functions for EU states where damage functions for each of five different land use categories relate floodwater depths to damage fractions within each land use category. Maximum damages are linked to each of the damage functions and scaled to country level using GDP data. Output of the damage model include maximum damage maps at different return periods (2 to 1000 years) and annual expected flood damage costs, measured in M EUR and % GDP.

The effect of adaptation measures in reducing damages and vulnerability is compared to a reference strategy, where the estimated existing protection level is maintained, but not upgraded as climate progresses over the century (Jongman et al., 2014), whereas adaptation measures seek to maintain current protection level under future climates. Two types of adaptation are considered: i) flood prevention by heightening and improving dikes, dams and levees to at least maintain current protection levels and improve to a minimum standard of at least 1:100 years and ii) vulnerability reduction by dry-proofing urban residential, commercial and industrial buildings in areas with frequent flooding, i.e. a flood protection level lower than 1:25 years.

Calculation of costs of adaptation includes both the i) flood damages *after* adaptation and ii) costs of implementing adaptation measures, while benefits of adaptation correspond to the value of avoided impacts. Two calculation methods have been applied in valuing flood prevention: One applies the method by Rojas et al. (2013) assuming that flood protection measures would be carried out in areas where the Benefit Cost Ratio (BCR) reaches at least 4:1. The other approach follows Ward et al. (in prep.) where dike heightening are put in place where required in order to maintain the current protection level (at least 1:100 year) and costs are determined accordingly. Vulnerability reduction by dry-proofing buildings is made to accommodate a water level of 1.5 meters. Output of the adaptation costing exercise comprise total simulated flood costs (i.e. damages) without adaptation and costs of implementing adaptation measures, both in absolute costs (M EUR) and by European climate region. These absolute costs do not differentiate between SSPs. Damage costs of flood prevention are subsequently scaled to percentage of projected GDP by SSP2, SSP3 and SSP5. The change in GDP is taken to reflect both the increase in value of individual assets and the number of assets.

Benefit valuation of avoided damages is calculated as the flood damages *without* adaptation minus damages *with* adaptation for each of the two investigated adaptation measures. Output is provided in absolute terms (M EUR) and relative to GDP. For adapted buildings, SSPs are not taken into account.

Figure 4 below provides an overview of the riverine flood risk framework with inputs, outputs and main assumptions. For a more detailed description of the model set up, pls. refer to Jeuken et al. (2016) and Iglesias et al. (2014).

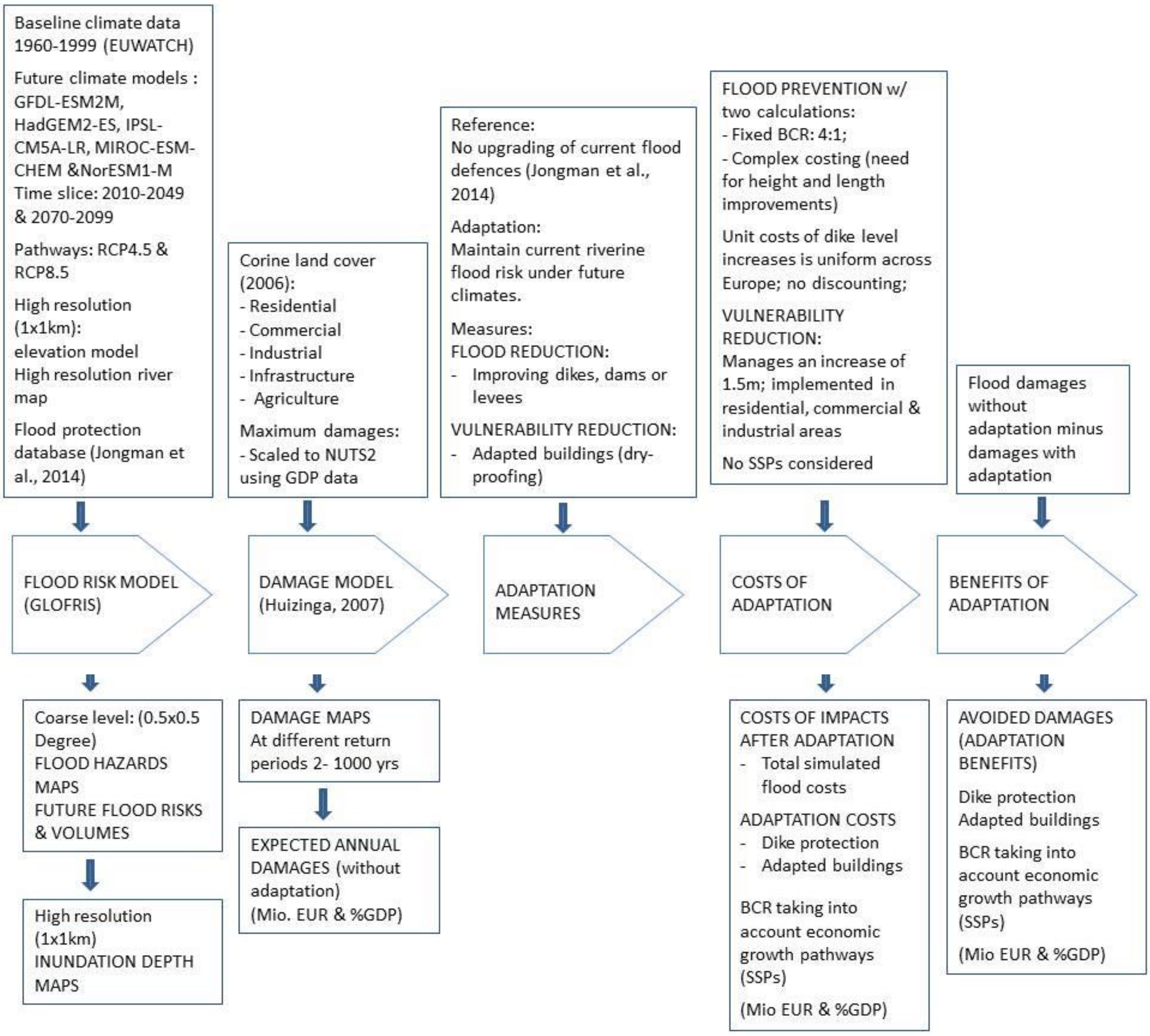


Figure 4 Mapping of riverine flood risk model framework

4.2.2 Agricultural Model Framework (SARA)

The *Supporting Agricultural Modelling in Regions for Adaptation to climate change* (SARA) framework links agricultural productivity, crop choice, land use and water availability in an economic framework that is applied to estimate the effects of management changes in terms of land productivity and water availability on the economic value of agricultural production. The SARA framework takes into account climate and population change, economic development and technological and social evolution for the time periods 2040 and 2070.

A suite of physical models are linked (ClimateCrop, WAAPA, Crop share and Land Use models) together with a socio-economic model (Value of agricultural production) to estimate agricultural production for both rainfed and irrigated agriculture. While rainfed agriculture is conditioned by climatic factors and evaluated using the Climate Crop and Crop Share models, irrigated agriculture is mostly conditioned by climate and water availability and therefore investigated using the WAAPA model.

Total value of agricultural production (defined here as fraction of GDP) is estimated by statistically relating economic activity, population and basic structural agricultural variables with projections of cultivated area and productivity from the physical models. Agricultural production value is estimated for the full combination of the socio-economic pathways SSP2, SSP3, SSP5 and the climate futures RCP4.5 and 8.5. For a technical description of the SARA framework, pls. refer to Jeuken et al. (2015) and Iglesias et al. (2014).

With the prediction of damages of climate change on the total value of agricultural production in the baseline and for future scenarios, the final step is to include adaptation measures and estimate the costs and benefits of implementing adaptation strategies in European agriculture. Two measures have been selected for the analysis: i) *improved management* involving improving resiliency and adaptive capacity; development of innovation and technology to improve practices and reduce costs; and improve water use efficiency to increase water availability; ii) *irrigation development* in areas not currently irrigated but already equipped for irrigation.

Calculation of costs of adaptation includes both i) costs of damages on agricultural production *after* adaptation and ii) the costs of implementing adaptation measures, while benefits of adaptation correspond to the value of avoided damages. Costs of adaptation measures in rain fed agriculture is based on the required additional increase in crop productivity due to technology or management to compensate for climate change damages, derived from the elasticity of crop yield versus economic contribution of agriculture to GDP. For irrigated agriculture, adaptation costs arise with the required additional irrigation development needed to compensate for the decrease in crop productivity. These adaptation costs are estimated on the basis of standard costs for irrigation development. Figure 5 overleaf visualises the connections, inputs and outputs of the suite of models in the SARA framework. For the full analysis of the results of the SARA framework, pls. refer to Iglesias et al. (2014).

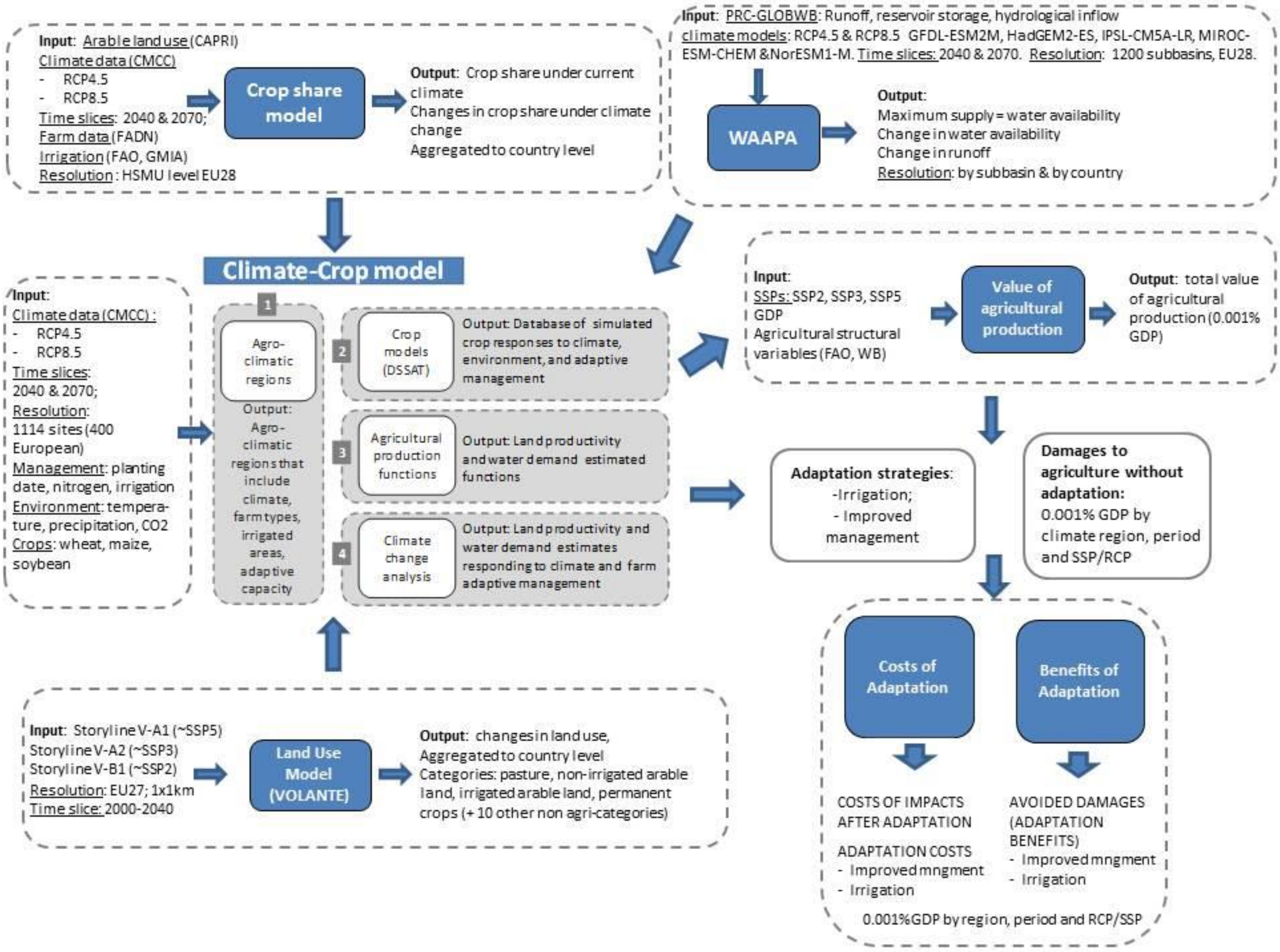


Figure 5 mapping of agriculture model framework (SARA)

Health Risk assessment

Climate change impacts on health, adaptation measures and costs and benefits of adaptation was analysed for the EU with regard to increases in heat waves and salmonella infections. Heat waves cause higher mortality rates due to increased risks of cardiovascular and respiratory diseases. Heat health warning systems is one way of reducing health impacts of a heatwave by giving alerts, advisories and emergency measures to mitigate the impacts of a heatwave on health. The health assessment developed an exposure response function based on Ebi (2008). Increased temperatures also lead to increased incidences of salmonella infections from food and subsequent increases in morbidity rates. Adaptation measures include health campaigns to avoid infections and hospital treatments.

For both health impacts, exposure response functions are developed, linking temperature thresholds to expected mortality (heat stress) and morbidity (salmonella) for a high-end scenario

(SSP5/RCP85). Damages of increased heat stress and salmonella infections in SSP5/RCP8.5 are then valued in absolute monetary terms and in terms of relative growth rates per capita. Given the adaptation measures defined, costs and benefits of adaptation are estimated. Costs include the costs of implementing adaptation measures and residual damages, i.e. the increases in mortality and morbidity that cannot be avoided with the given adaptation measures. Benefits equal the value of avoided mortality and morbidity through adaptation measures.

Figure 6 below provides an overview of the health risk framework with inputs, outputs and main assumptions. For a more detailed description of the model set up, see Jeuken et al. (2016) and Iglesias et al. (2014).

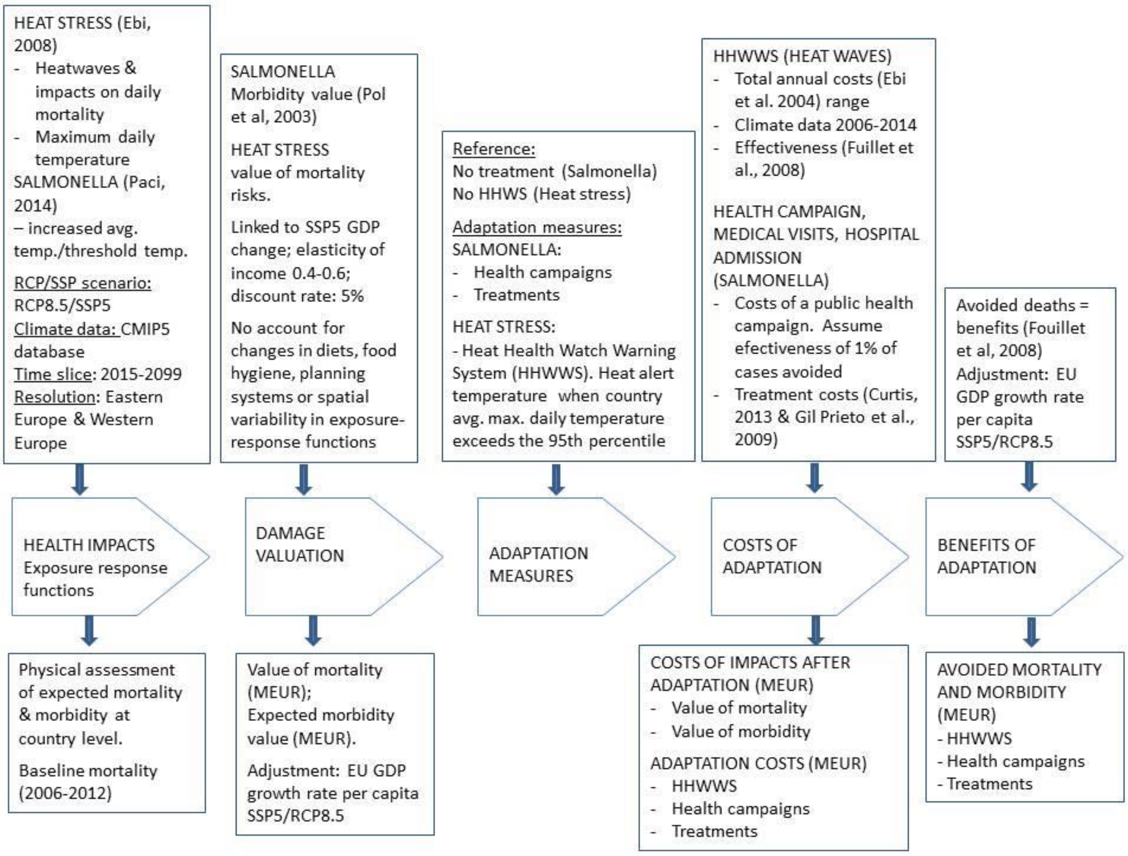


Figure 6 mapping of Health (Heat & Salmonella)

4.3 Flood Risks

This section examines at risk of flooding and what management challenges these risks present in combination with socio-economic vulnerability. The main quantitative input originates from the EU scale riverine flood risk analysis and does not incorporate pluvial and coastal flooding. The flood risk modelling can be used to examine how regional challenges related to flooding differ in Europe. Also information from case studies is added to enrich the view of flood risk development and management.

The flood risk challenges and solutions per region:

Northern-Arctic Europe

As is indicated in Section 3.1 flood risks outside the main flooding period in spring are likely to increase in the Northern-Arctic region with shifts in season from spring peaks to summer pluvial and autumn or winter riverine flooding. The projected flood risks by the BASE models confirm this picture and show a modest increase with roughly 25 % of expected annual damage suggesting that the decrease of damages occurring from spring peaks is overcompensated by damages occurring due to autumn riverine floods. The case study for Kalajoki river in Finland is showing an opposite trend in projected flood risk. Based on modelling exercises, the flood with the 100 year return period is projected to decrease on average 17 % in 2010–2039 and 18 % in 2070–2099 whereas the pan-European analysis suggest an overall increase of floods over Finland. This could also imply that other flood frequencies (f.e. 1/500 or 1/1000) will become more important.

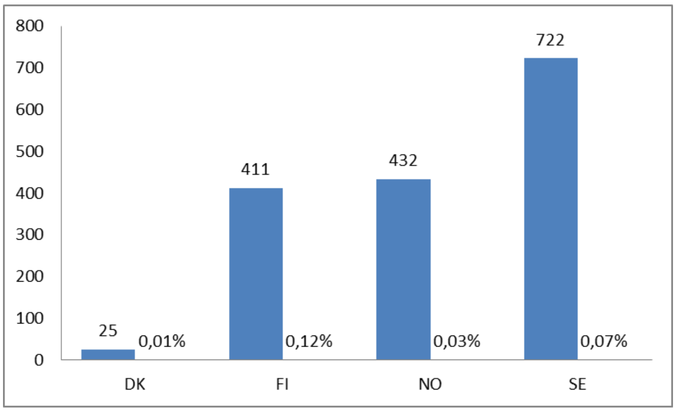


Figure 7 Expected Annual riverine flood damage at the end of the century under RCP 8.5 for selected countries (million Euros and percentage of GDP)

The riverine flood damages in relation to GDP are relatively modest (Figure 7). Under SSP5 the budgets that are available for flood risk management investments are relatively high. Under SSP 2 more scarce budgets need to be targeted to climate proof specific priority areas. Under SSP 3 there is not much room for investments and society is asked to cope with more frequent floods. However the BASE flood risk model analysis shows that by generally increasing protection levels to 1/100 for the Nordic countries brings down the Annual Expected Damages considerably. The total regional annual expected damage at the end of the century might be reduced from 1600 to 400 Million EUR/year, in this way largely overcompensating the effects of climate change. However, also large investments are required. The analysis shows that there are some countries for which the costs of maintaining the baseline flood protection level under climate change (and introducing a minimum of 100 years protection) do not outweigh the benefits for different SSP scenarios. This is especially the case for the year 2030, when between 12 (RCP4.5) and 13 (RCP8.5) countries the costs of adaptation are higher than the project benefits.

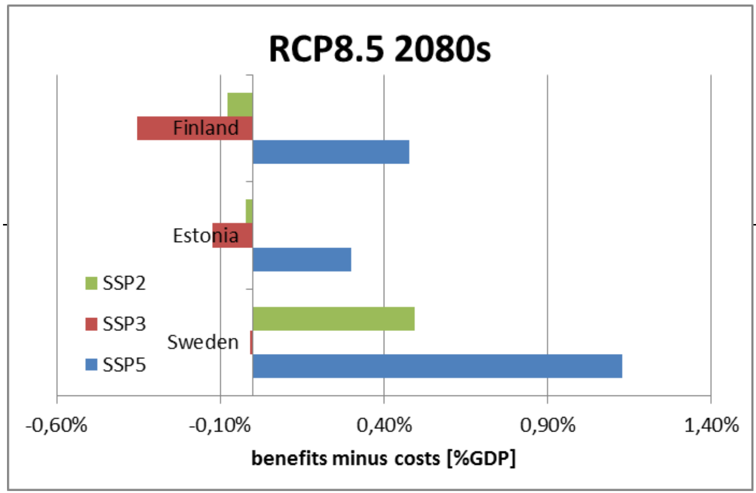


Figure 8 Benefits minus costs for flood protection (up to 1/100 Europe wide) for selected countries (for more detail see Jeuken et al. 2016)

This is very different for the year 2080, when almost for all countries the benefits outweigh the costs except for 3 under the Fragmented world scenario (SSP3)(Figure 8). For Estonia, Finland and Sweden the adaptation costs in 2080s remain higher than the benefits. Two things can be concluded from this:

- Cost and benefits of adaptation should be considered over a longer timespan than 50 years especially in case of infrastructures such as dikes with a long life-time.
- The study assumes uniform protection levels across the river basins. However, it may not be necessary to raise protection levels across all of the sparsely populated countries such as Sweden, Norway or Finland. Targeted investments to better protect urban areas are sufficient and will improve overall benefit-costs ratios.

The latter is clearly illustrated by the Kalajoki case study in which expansion of dikes and other permanent flood protection structures as well as additional measures to increase the capacity to store water and regulate flow are planned. This allows better protection of expanding urban areas and increases the capacity to deal with increasing winter floods in particular. Land use regulations to direct new buildings should further prevent increase of damage due to changing land use. Analyses conducted in the case-study showed that benefits of such a targeted effort are likely to outweigh the investment costs.

North-Western Europe

Information in Section 3.1 indicates that flood risks are likely to increase in NW Europe. This increase is confirmed by the BASE riverine flood risk modelling exercise showing that the Annual Expected Damages may increase roughly in between 100 % to 225 % compared to current risk; from 4,5 Billion to 9-14 Billion EUR (Figure 9), the lower estimates under RCP4,5 and at the first half of the century. However, there are differences within the region. Thus riverine floods in Denmark do not generally cause large damages since rivers are short and small and slopes are not so steep. A local exception is the town of Holsterbro where regular floods occur and an increase of floods under climate change is projected and some adaptation options are under consideration. A much more prominent risk for Denmark is the increase of pluvial flooding, as was illustrated by the case study of Copenhagen.

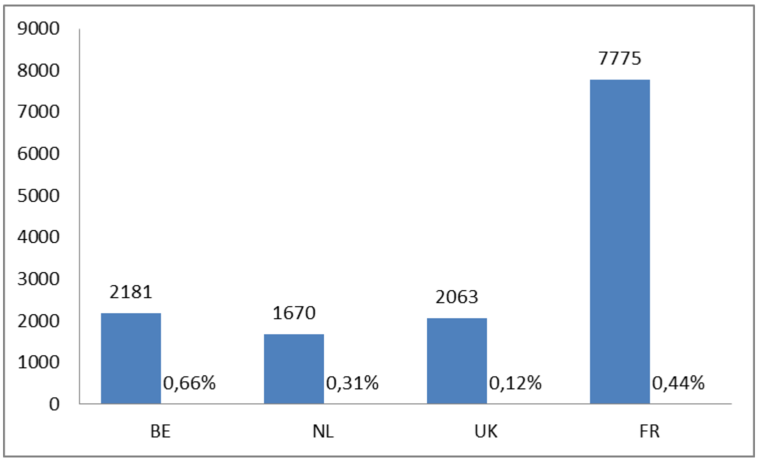


Figure 9 Expected Annual riverine flood damage at the end of the century under RCP 8.5 for selected countries (million Euros and percentage of GDP)

Flood risks are considerably higher in the selected countries listed in Figure 9 than in Northern-Arctic Europe both in terms of absolute value as well as percentage of GDP. The increase of risk under RCP 4.5 is only moderately smaller than under RCP8.5 indicating that projections are relatively robust. This is also confirmed by the case study of Rotterdam in which also both the low and high CC scenarios indicate an increase of river discharges of similar magnitude and thus flood risks. In the Leeds Area, river discharges may increase between 20-50 % as was confirmed by local estimations.

By raising protection levels to 1/100 the average damage decreases from 14,000 to 350 million EUR per year at the end of the century under an RCP8.5 scenario (Note that for large parts of Western Europe protection levels are already higher than 1/100). This time benefit costs ratios are positive for all countries in the region at the end of the century. Still the same conclusion holds: BCRs are likely to increase if measures are prioritized and targeted according to where risks are reduced the most. The Rotterdam case study (being representative of current Dutch FRM policy) illustrates this. Protection levels are adapted to the risk levels as long as the costs are not outweighing the benefits (in terms of avoided damage and casualties). Dike reinforcement projects are also planned in order of their cost effectiveness. This kind of prioritization becomes more and more important under a regional rivalry scenario when budgets are limited. Studies from the Netherlands also indicate that room for river measures (which also effectively cause protection levels to increase) are generally more costly than raising dikes. At the same time these types of measures are likely to have more added benefits in terms of landscape quality and enhanced ecosystem services. In addition, these conclusions cannot be easily up-scaled to other countries, since for example land prices will differ considerably.

In the Holsterbro case it was found that for all proposed measures (using agricultural land for retention in combination with a dam to protect the town from flooding) the costs outweigh the benefits, except under a SSP5 scenario (fossil fuelled development). Under a Middle of the road scenario and regional rivalry scenario these investments are not likely to be cost-effective and other low cost options to better cope with the floods are more likely.

Adapted building (flood proofing buildings in such way that damage is avoided below flood depths of 1.5 meter) is another measure explored in the BASE riverine flood risk analysis. This measure can reduce damages especially in urban areas where flood depths are usually limited and fit well within policies that place larger responsibility on private actors. These types of measures can also be stimulated by lowering insurance premiums. When government budgets become limited, in the regional rivalry scenario, or when the role of private investments deliberately is chosen to become larger (i.e. in fossil-fuelled development) more countries may decide to shift responsibilities to private parties to better cope with the impacts of floods.

However, the BCRs of this measure are generally worse than for dike enforcements indicating that targeting this measure to specific areas where they are efficient is important. In addition, flood proofing buildings should be accompanied by flood proofing infrastructure. As is shown in the case study for Sheffield, transport, ICT and energy infrastructure play an important role in limiting indirect damages from flooding.

Central-Eastern Europe

Also in Central-Eastern Europe, riverine flood risks are likely to increase but uncertainties surrounding the projections are generally large. In Prague (info from case study), the average annual rainfall in the last 20 years has increased by approximately 5 % compared to 1961-1990. The temporal variability of average daily precipitation in the two decades has increased in the warm half of the year and decreased during winter months. For the city of Prague, the potentially greatest climate change related issues are extreme precipitation causing floods, and an increase in heat stress due to an increasing number of tropical days and tropical nights.

On average, the flood risks in Central Eastern-Europe projected by the BASE models increase with 37 % in the first half of the century to 61 % at the end of the century compared to the current climate. In terms of percentages of GDP the flood risks in the central-eastern European region are among the highest in Europe, increasing from 0.18 % now to almost 0.30 % on average in the second half of the century. Also in absolute terms, current Annual Expected Damages is 8 billion Euro/year, Central/Eastern Europe is ranked highest (but note that this region also covers the largest territory) (Figure 10).

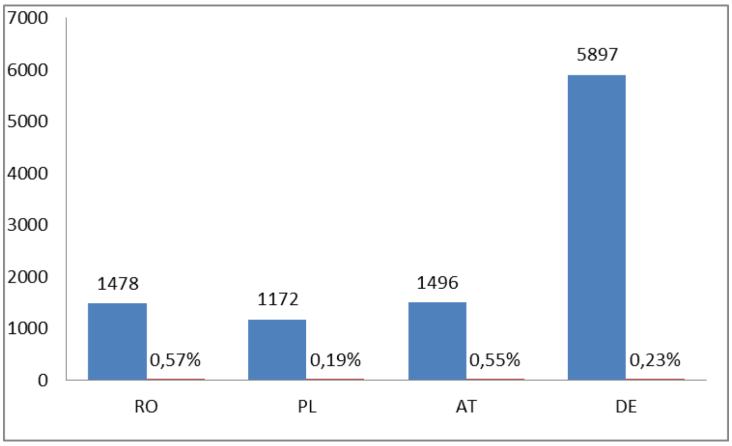


Figure 10 Expected Annual riverine flood damage at the end of the century under RCP 8.5 for selected countries (million Euros and percentage of GDP)

Regional differences are large with relatively larger damages in for example Romania and Austria (see Figure 10) and mostly similar trends of increasing flood risks over time (here Romania is an exception as risks roughly remain the same throughout the century).

Raising protection levels in Central-Eastern Europe to a minimum of 1/100 is causing damage levels to drop to 50 % of current Annual Expected Damages even under a RCP8.5 scenario for the end of the century. In contrast with for example region North these investments seem to be justifiable also from the positive benefit cost ratios under all scenarios. The fact that Central-Eastern Europe has been facing considerable flood damages over the past decade with floods in the Elbe and Sava and Danube catchments, may indicate that current protection levels are not sufficient.

For example, after the first big flood in 2002, damages in Saxony, Germany amounted to around 6.2 billion EUR, while in the second flood 2013, damages were "only" 1.9 billion EUR although the event itself was roughly the same size (Freistaat Sachsen 2002 & 2013). One main reason was indeed that protection levels in 2002 were mostly quite low. After 2002 a huge investment program in flood protection was implemented and this was probably one main reason that damages in 2013 were much lower in Saxony. However, this may have raised damages downstream in Saxony-Anhalt in 2013 , as there was not so much "retention" in Saxony anymore, and Saxony-Anhalt itself had not invested that much in flood protection. The official goal in Saxony is to protect all settlements against floods with a return period of 100 years, but within this investment program, measures were prioritised and so far only around 400 (with high and medium priority) out of 1600 measures are implemented (Freistaat Sachsen 2002 & 2013, Sächsisches Staatsministerium für Umwelt und Landwirtschaft 2005). It can be expected that for other countries in central Europe this situation is similar, or in those the lagging behind, worse.

The case study for Prague shows that investing in flood protection (to maintain 1/500 protection level under CC) in the city of Prague also leads to high benefits and positive BCRs. It is expected that for an economically attractive city like Prague even under less positive economic development scenarios there will be sufficient resources for keeping up a 1/500 protection level. This suggests that in a fragmented world the main economic centers will be the last to refrain from investments in flood protection

From the BASE model analysis also flood proofing buildings appears to be a beneficial strategy able to restrict damages to the current level even under high climate change scenarios.

Southern-Mediterranean

Notwithstanding a steady decline in annual precipitation, extreme precipitation events may increase in the Southern-Mediterranean region, meaning an increased likelihood for floods. In RCP4.5, precipitation will become more unpredictable and while in some regions annual average precipitation will remain constant, it may decrease up to 20 % in other regions. Heavy precipitation will also be more unpredictable and some regions may show an increase of 15 % whereas other may remain the same.

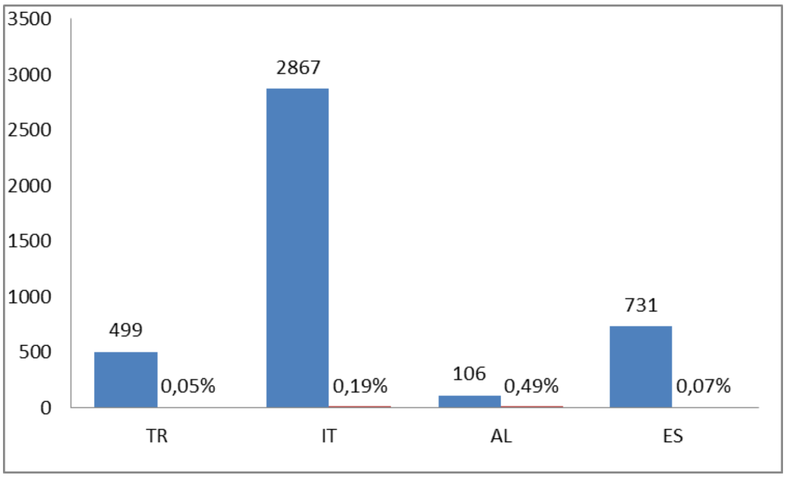


Figure 11 Expected Annual riverine flood damage at the end of the century under RCP 8.5 for selected countries (million Euros and percentage of GDP)

The Southern-Mediterranean region will experience an overall 55-60% increase in EAD from riverine floods at the end of the century, with a total damage increase from 2.8 to 4.4 Billion per year in terms of average share of GDP that is an increase from 0.07% to 0.11%. This damage is the lowest of all 4 regions although in an individual country like Italy flood damages may be large (Figure 11). Whereas the total annual precipitation decreases flood risks are increasing except for the eastern Mediterranean countries like Turkey and Greece. Increasing protection levels by building dikes can be achieved with BCRs larger than 1 for all countries in the Southern region if benefits are considered until the end of the century. For a country like Italy, BCRs>1 are already achieved in the short term. Like in other regions, BCRs of adapted building are slightly lower but on average larger than 1 in a RCP8.5 scenario for the end of the century for all three SSPs.

4.4 Water availability and shortage

This section further describes how the storylines for water availability can be more fully understood by integrating modelling results and additional case study examples. Figure 12 presents results from the WAAPA model (see section 4.2) on surface water availability as an indicator for potential water shortages. However, this indicator is rather complicated and has some limitation for specific hydrological circumstances. In addition, availability of groundwater resources is not included. Therefore, before results per regions are presented, it is necessary to look closer at the saliency of the modelling results.

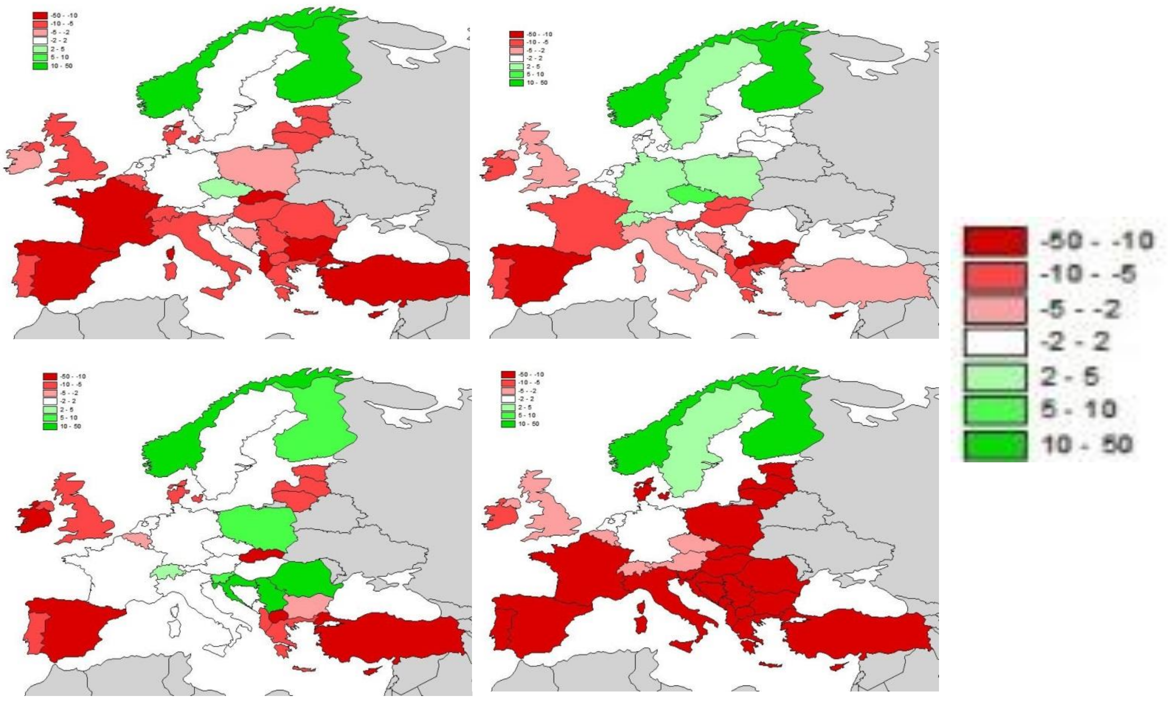


Figure 12 Average results by country of changes in surface water availability. Emission scenarios RCP4 (top) and RCP8 (bottom), in short term (left) and long term (right) time slices. Source: Jeuken et al., 2016.

Water availability is determined by:

- ***River runoff*** – determines the inflow to the surface water system and is calculated and is calculated with the hydrological model as is described in deliverable 6.3 (Jeuken et al. 2016). The results are based on an average of 5 GCMs. There is a large spread in projections of river run-off driven by these different GCMs. In general the smaller the river the larger this type of uncertainty. Therefore results for the countries with small rivers like Denmark and Baltic states should be handled with care. The ***seasonal variability*** of runoff is of key importance since it is important in relation to water demand of sectors (when is the water needed) and the reservoir operation. This could affect irrigation and hydropower. Summer low flows may also lead to salinization in deltas and become critical to sustain required environmental flows. The seasonal variability can increase even if annual runoff is increasing.

- ***Management of*** water storage infra-structure such as ***reservoirs***. WAAPA uses certain assumptions on reservoir operations in the rivers affecting how the inflow is being distributed over time and to downstream sub-basins (Garotte et al.2011). The methodology was mainly devised for the Mediterranean, where reservoir regulation is the key to surface water availability, and now applied to the whole of Europe. In central Europe water availability does not depend so much on reservoirs and it makes less sense to apply this type of analysis in the region. Likewise in a country like the Netherlands the interconnection between rivers and the flood plain provides buffer zones that sustain low flows allowing for water abstractions when natural inflows decrease. It is in fact a storage system that is not computed as “reservoir” in the model, but pretty efficient in flat areas. For this type of countries the changes in runoff may be more meaningful than changes in “availability” as computed by the WAAPA model.
- ***Ground water levels*** – In the BASE project no European scale groundwater model is used. Instead changes in annual runoff are used to scale current GW availability. This is a very rough but reasonable proxy as GW levels like annual runoff depends on the long term (year to year) changes in precipitation/evaporation.

Figure 13 illustrates the above, showing the average values of changes in runoff and availability obtained compared to the individual model projections for scenario RCP4 short term. It is clearly shown that any combination of annual runoff and water availability is possible and that the spread among different GCM’s can be large and even contradictory. This spread is larger than the spread between different RCPs.

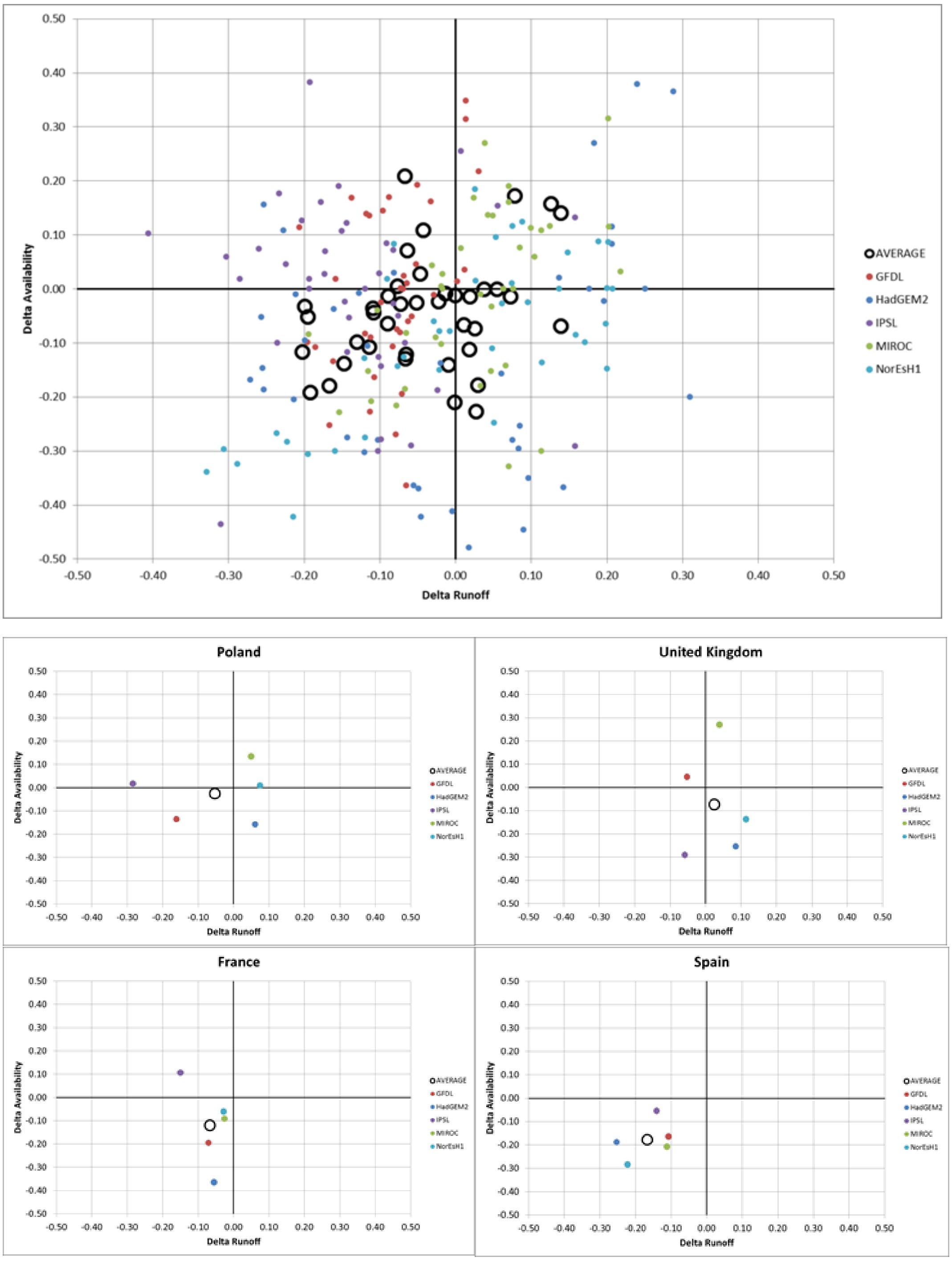


Figure 13 Changes in annual runoff versus WAAPA calculated water availability for the model ensemble average (circles) and the individual GCMs (coloured dots) for RCP4.5 short term. Upper panel shows all country results and the lower panels show results for individual countries.

The spread among different GCMs can be seen as a measure for the robustness of the result. For example the results for Spain shown in Figure 13 lower panels are much more robust (show more agreement) than those for Poland. To cope with all these factors determining risks on reduced water availability, we developed some new indicators as shown in Table 3.

Table 3 Overview water availability risks per country per region and per climate scenario (RCP short and long term).

	QUADRANT				Impact				Risk1				Agreement				Risk2			
	RCP4.5-ST	RCP4.5-LT	RCP8.5-ST	RCP8.5-LT	RCP4.5-ST	RCP4.5-LT	RCP8.5-ST	RCP8.5-LT	RCP4.5-ST	RCP4.5-LT	RCP8.5-ST	RCP8.5-LT	RCP4.5-ST	RCP4.5-LT	RCP8.5-ST	RCP8.5-LT	RCP4.5-ST	RCP4.5-LT	RCP8.5-ST	RCP8.5-LT
Central/East																				
Macedonia	-2	-2	-2	-2	1,0	1,3	1,2	2,1	-2	-3	-2	-4	1,1	1,0	1,0	1,2	-2	-3	-2	-5
Bulgaria	-2	-2	-2	-2	1,2	1,2	1,2	2,0	-2	-2	-2	-4	1,5	1,0	0,8	0,9	-3	-2	-2	-4
Slovakia	-2	-2	-2	-2	0,7	0,5	0,7	1,2	-1	-1	-1	-2	1,0	1,5	1,1	0,9	-1	-1	-2	-2
Romania	-2	1	1	-2	0,6	0,6	1,0	1,3	-1	1	1	-3	0,9	1,0	0,8	1,5	-1	1	1	-4
Hungary	-2	-2	1	-2	0,4	0,4	0,4	1,0	-1	-1	0	-2	0,6	0,7	1,0	1,3	0	-1	0	-3
Russia C	-1	-1	-1	-1	0,8	0,8	0,9	1,0	-1	-1	-1	-1	0,8	0,5	0,5	0,7	-1	0	0	-1
Serbia	-2	1	1	-2	1,0	1,0	1,8	1,6	-2	1	2	-3	0,9	1,0	0,7	0,6	-2	1	1	-2
Ukraine	1	1	1	-2	0,6	0,2	0,6	0,9	1	0	1	-2	1,0	1,3	1,7	1,8	1	0	1	-3
Poland	-2	1	1	-2	0,3	0,3	0,4	0,6	-1	0	0	-1	1,0	1,0	1,0	0,9	-1	0	0	-1
Austria	-2	1	1	-2	0,1	0,1	0,2	0,4	0	0	0	-1	0,9	1,4	1,6	1,3	0	0	0	-1
Switzerland	-1	1	2	-2	0,3	0,2	0,2	0,2	0	0	0	0	1,0	1,3	1,5	1,2	0	0	1	-1
Czech Republic	1	1	1	-2	0,3	0,4	0,2	0,3	0	0	0	-1	1,1	1,4	1,3	1,4	0	1	0	-1
Belarus	1	1	1	-2	0,5	0,5	0,9	0,8	0	1	1	-2	0,6	0,7	0,6	0,5	0	0	1	-1
Germany	-2	1	2	-2	0,1	0,5	0,1	0,1	0	0	0	0	1,0	1,4	1,7	1,6	0	1	0	0
Moldova	1	1	1	1	1,1	1,0	1,5	1,3	1	1	1	1	0,4	0,5	0,6	0,9	0	1	1	1
North/Arctic																				
Latvia	-1	-1	1	-2	1,1	0,5	0,3	0,1	-1	0	0	0	0,5	0,4	0,5	0,5	-1	0	0	0
Estonia	-1	-1	-1	-1	0,2	0,3	0,0	0,1	0	0	0	0	1,3	1,0	0,9	0,9	0	0	0	0
Lithuania	-1	2	1	-2	0,1	0,3	0,1	0,4	0	1	0	-1	0,6	0,6	0,4	0,5	0	0	0	0
Sweden	-1	2	-1	2	0,4	0,4	0,3	0,4	0	1	0	1	1,4	1,1	1,1	1,1	0	1	0	1
Finland	2	2	2	2	0,9	1,1	0,6	1,1	2	2	1	2	1,3	0,8	0,9	0,7	2	2	1	1
Norway	2	2	2	2	1,0	0,8	0,8	1,0	2	2	2	2	1,4	1,6	1,7	1,5	3	3	3	3
Russia N	2	2	2	2	1,0	1,3	1,0	1,4	2	3	2	3	1,6	2,2	1,0	0,9	3	6	2	3
South/Mediteranean																				
Spain	-2	-2	-2	-2	1,2	1,4	1,3	2,5	-2	-3	-3	-5	1,9	1,7	1,0	1,5	-5	-5	-2	-7
Portugal	-2	-2	-2	-2	1,4	1,5	1,5	2,5	-3	-3	-3	-5	1,4	1,1	0,7	0,9	-4	-3	-2	-5
Greece	-2	-2	-2	-2	1,0	1,1	1,2	1,9	-2	-2	-2	-4	1,5	1,6	1,2	1,1	-3	-3	-3	-4
Albania	-2	-2	-2	-2	0,8	0,7	0,8	1,6	-2	-1	-2	-3	1,4	1,3	1,8	1,2	-2	-2	-3	-4
Turkey	-2	-2	-2	-2	0,8	0,8	1,0	1,4	-2	-2	-2	-3	1,1	0,9	0,8	0,9	-2	-2	-2	-3
Italy	-2	-2	1	-2	0,6	0,5	0,5	1,1	-1	-1	1	-2	2,3	2,5	4,4	2,1	-3	-3	2	-5
Croatia	-2	-2	1	-2	0,5	0,4	0,8	1,0	-1	-1	1	-2	1,0	1,0	1,9	1,6	-1	-1	1	-3
Bosnia and Herzegovina	-2	1	1	-2	0,6	0,5	0,5	1,2	-1	0	1	-2	1,1	0,7	1,2	1,1	-1	0	1	-3
Slovenia	-2	-2	1	-2	0,2	0,3	0,5	0,9	0	-1	0	-2	0,9	1,2	1,6	1,0	0	-1	1	-2
Montenegro	1	-2	1	-2	0,4	0,4	0,3	0,8	0	-1	0	-2	1,5	1,0	1,5	1,3	1	-1	1	-2
West																				
France	-2	-2	-2	-2	0,7	0,6	0,4	1,1	-1	-1	-1	-2	1,3	1,6	1,9	2,0	-2	-2	-2	-5
Belgium	-2	-2	-2	-2	1,0	0,1	0,4	0,5	-2	0	-1	-1	1,2	1,6	1,1	1,1	-2	0	-1	-1
Ireland	-1	-1	-1	-1	0,6	0,8	1,3	0,6	-1	-1	-1	-1	1,5	0,9	1,3	2,3	-1	-1	-2	-1
Luxembourg	-2	1	-2	-2	0,7	0,1	0,5	0,8	-1	0	-1	-2	0,9	1,3	1,3	1,0	-1	0	-1	-1
Netherlands	-1	-1	-2	-2	0,9	0,2	0,4	0,4	-1	0	-1	-1	0,9	1,6	1,1	0,9	-1	0	-1	-1
Denmark	-1	-1	-1	-1	0,3	0,2	0,3	0,3	0	0	0	0	1,4	1,4	1,1	1,0	0	0	0	0
United Kingdom	-1	-1	-1	-1	0,4	0,1	0,3	0,2	0	0	0	0	0,8	0,9	1,1	1,0	0	0	0	0

Notes: THE FINAL RISK INDEX (RISK2) IS COMPOSED OF THE FOLLOWING COMPONENTS: COLUMN QUADRANT = COMBINED INDEX OF RUNOFF (X) AND WAAPA WATER AVAILABILITY (Y). SCORES: 2: BOTH INCREASE, 1: X DECREASES, Y INCREASES, -1: X INCREASES, Y DECREASES, -2: BOTH DECREASE. COLUMN DISTANCE GIVES THE RELATIVE SIZE OF ABOVE MENTIONED INCREASE OR DECREASE (> 1 MEANS LARGER THAN AVERAGE). COLUMN RISK 1 IS THE ROUNDED PRODUCT OF QUADRANT AND DISTANCE. COLUMN AGREEMENT GIVES AN INDICATION ON THE RELATIVE AGREEMENT BETWEEN THE 5 GCM PROJECTIONS USED TO DRIVE THE RUNOFF AND WAAPA MODEL (> 1 MEANS BETTER THAN AVERAGE AGREEMENT). COLUMN RISK 2 FINALLY IS THE PRODUCT OF RISK 1 AND AGREEMENT. IF THE ABSOLUTE VALUE OF RISK 2 IS HIGHER THAN RISK 1 THE RESULT IS MORE ROBUST THAN AVERAGE AND VICE VERSA.

The indicators basically summarize what can be seen in Figure 13. The risk (***Risk 1***) is judged highest when both runoff and availability are reduced (negative values). Opportunities for higher water availability arise when both increase. Increase of availability is weighted higher than a decrease in runoff (leading to positive values) and vice versa. Finally, the indicator ***Risk 2*** includes the robustness of the results (see appendix 1 for a more detailed explanation).

The countries at larger risk are (in this order) Spain, Portugal, Macedonia, Greece, Bulgaria, Albania, France, Italy and Turkey. They are mostly Mediterranean countries and this is in agreement with other findings. Then we find countries like Slovakia, Ireland, Belgium, Luxembourg, Croatia, Romania, with mild risk. Northern Arctic countries like Sweden, Finland, Norway and Russia show a robust, however mild increase in water availability.

Northern-Arctic Europe

Northern Europe will likely see an increase of water availability over the year both from surface as well as ground water sources. Together with the increasing temperatures, this offers opportunities for agricultural practices. RCP4.5 seems to lead to larger increase of water availability than RCP 8.5

North-Western Europe

In contrast to Northern-Arctic Europe, North-Western Europe is likely to experience also some very mild decrease in water availability especially during the summer season. This is confirmed by the WAAPA analysis in BASE. However the robustness of the results is weak except for France.

Within the BASE case study of Ijssel lake in the Netherlands, management responses to droughts were evaluated. By making water level regulation more flexible and increase pumping capacity on the long term, a larger buffer of freshwater can be created to bridge summer droughts. In additions regions depending on this large buffer are also stimulated to increase the regional water buffers by local measures. Such a strategy fits in policies shifting responsibilities from the government to private parties.

Central-Eastern Europe

Water availability is seriously decreasing towards the end of the century especially under RCP 8.5 for a number of countries in South Eastern Europe like Romania, Macedonia and Bulgaria. For the bulk of the more Northern Central countries the model analysis shows no clear signal. In general under RCP8.5 water availability is decreasing in the second half of the century while for all other scenarios there might be even increases. Such huge range of projections complicates decision making on water infrastructure and will ask water demanding sectors to remain flexible and increase their resilience to extreme drought events by measures such as increase of water retention and change in irrigation practices in agriculture. It is expected that climate change will have substantial impact on agro-climatic conditions. In South Moravia the agro-climatic conditions for next decade will be characterized by temperature increase in combination with substantial water deficit. Subsequently, changing climate will also influence provision of ecosystem services, apart from provisioning services, regulating services (e.g. water regulation, erosion control, pest regulation) and cultural services (e.g. recreation, aesthetic value) will be affected (Brázdil et al. 2015).

Southern-Mediterranean

Droughts will increase in their duration and frequency. Water scarcity will be a permanent reality and pressure. The main water management challenge for the Southern region is water availability. The WAAPA model analyses show a clear increase of water shortages throughout all scenarios leading to a decrease in agricultural productivity. BASE case studies in the region (Alentejo, Cascais, Madrid, Donana) all recognize this and propose measures to improve water transport systems (Cascais), local waterbuffering (Alentejo), improved water management (Donana).

4.5 Agriculture

This section illustrates the kind of information that sector based modelling on agriculture can provide for the BASE process tool. The basic drivers are derived from climate models which are combined with regional information on crops, growing seasons and land use.

4.5.1 Impacts

Climate stressors relevant for the agricultural sector and adaptation challenges relate to the changes in growing season length, temperature, precipitation, soil moisture and evapotranspiration over growing season (Huntley, 1995; Pearson et al., 2002.). Flooding of agricultural land and sea level rise are related to these stressors. See also main climate impact projections by region in Section 3.1.

Projected impacts of climate change on agriculture vary across crops, regions and adaptation scenarios. IPCC 5AR (IPCC, ch7, 2014) finds evident effects of climate change on crop and terrestrial food production in several regions of the world. In some of the high-latitude regions, positive trends are evident while large negative crop yield sensitivities exist to extreme daytime temperatures around 30˚C. In temperate regions, the major crops of wheat, rice and maize will without adaptation be negatively affected for local temperature increases of 2˚C.

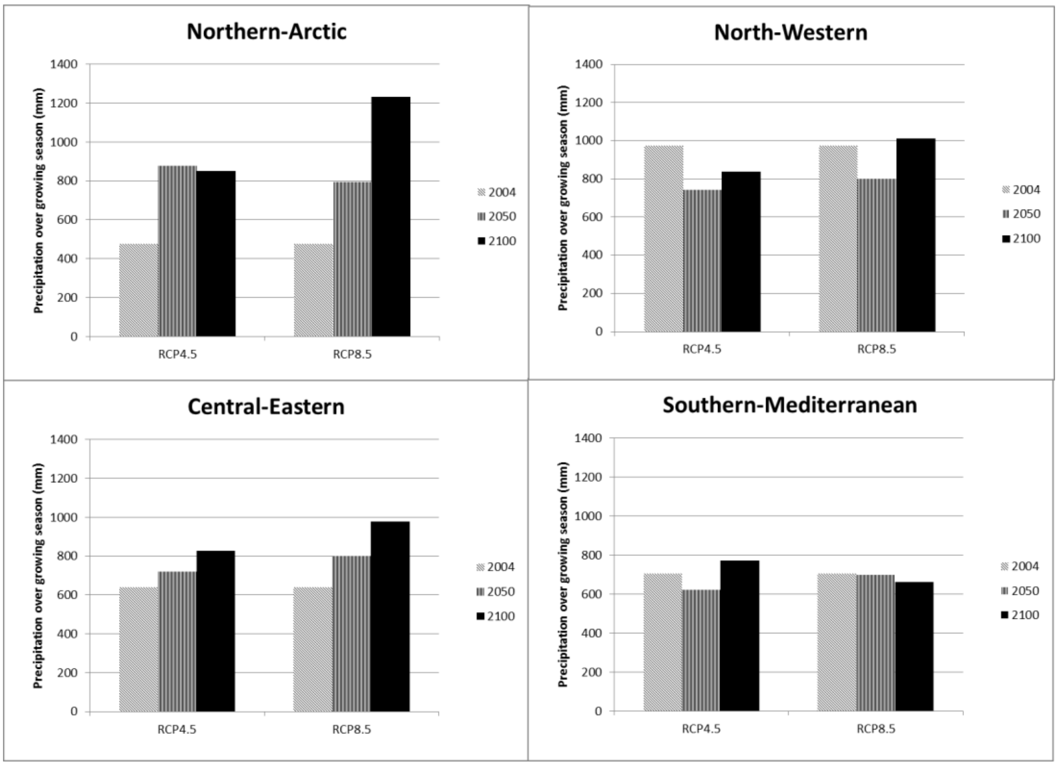
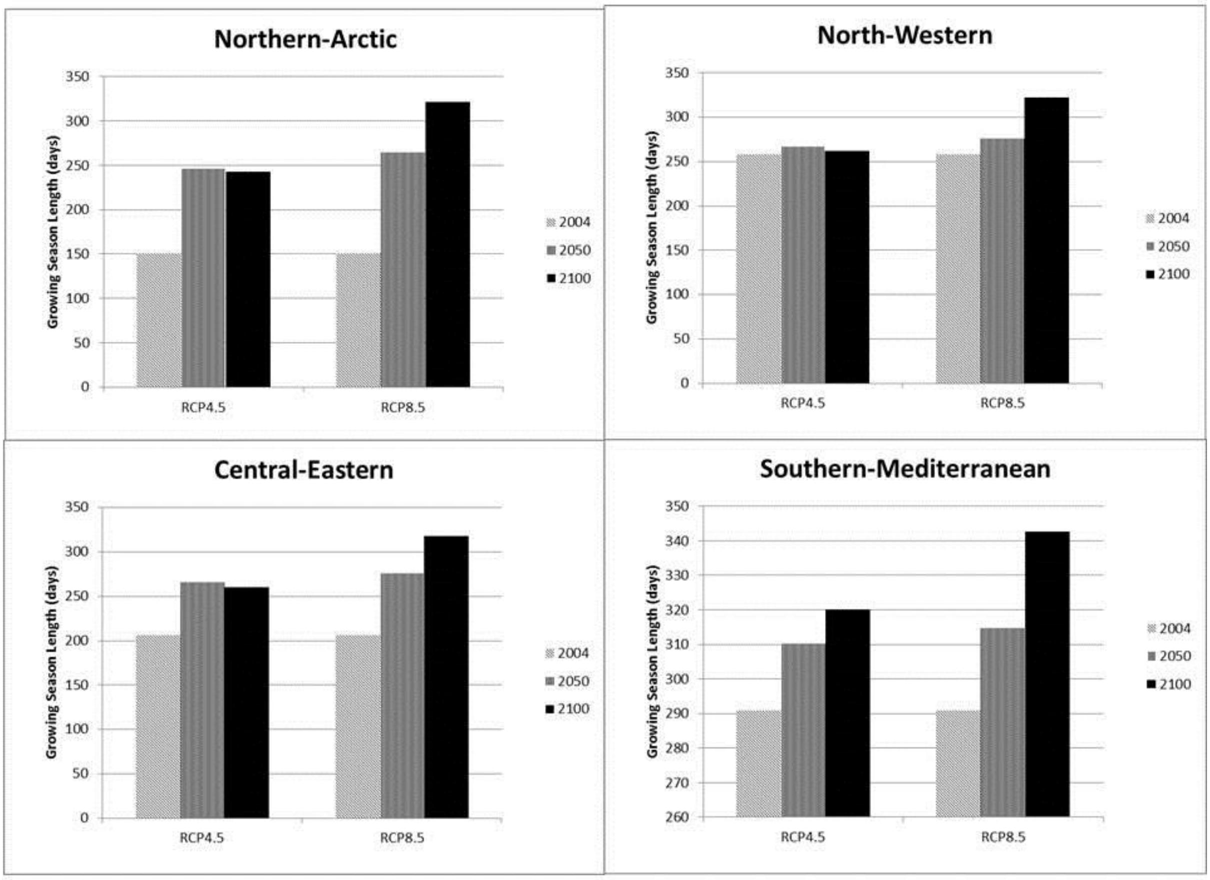


Figure 14 Precipitation over growing season by climate region and scenario. Climate data source: Scoccimarro & Gualdi, 2014.

The climate projections (Sections 3.1) indicate that precipitation over the growing season will increase in the Northern-Arctic region and Central Eastern Europe while North-Western Europe is expected to experience the strongest reduction in the short term. Predictions in RCP4.5 for the short term show significantly stronger changes than in RCP8.5 in Northern-Artic, Southern-Mediterranean and North Western Europe (Figure 14).

In the short term, Northern-Arctic Europe could experience an increase of precipitation over the growing season by 66 % in RCP8.5 and 84 % in RCP4.5, while Central Eastern Europe could expect a more moderate increase of 12 % in RCP4.5 and 25 % in RCP8.5. North-Western Europe would need to adapt to significant average decreases in growing season precipitation of 24 % in RCP45 and 18 % in RCP8.5 while the expected decline in Southern-Mediterranean is estimated to 12 % in RCP4.5 and 1 % in RCP8.5. The trends are identical in the long run, but with stronger changes. A surprising result of the climate model results is an increase in growing season precipitation in the long run for the Southern-Mediterranean region. These descriptive statistics do not uncover the variability in precipitation during the growing season.

Figure 15 Growing season length by climate region and scenario. Climate data source: Scoccimarro &



Gualdi, 2014 .

As climate warms, the length of the growing season increases across all regions and periods. The most pronounced changes would be in the Northern-Arctic region with a doubling of growing season length by 2100 in RCP8.5, followed by Central-Eastern Europe with more than 50 % increase. All regions could by then have more than 300 days within the growing season. Practically no changes are projected in the short term for North-Western Europe. RCP8.5 shows a consistent higher imprint on changes than RCP4.5; the opposite pattern of precipitation during growing season where RCP4.5 shows the overall strongest changes (Figure 15).

Agricultural land use across the four climate regions shows three large categories of crops: grassland, cereals and other arable produce (2004). In the North-Western and Central-Eastern part of Europe, grassland dominates (48 % and 39 % respectively), while other arable produce are prevalent in Northern-Arctic (48 %) and in Southern-Mediterranean (41 %). Maize occupies the largest shares of crops in Central-Eastern and Norther-Arctic regions (close to 7 %), while vegetables represent a significant share in Southern-Mediterranean (5 %) (See

Figure 16).

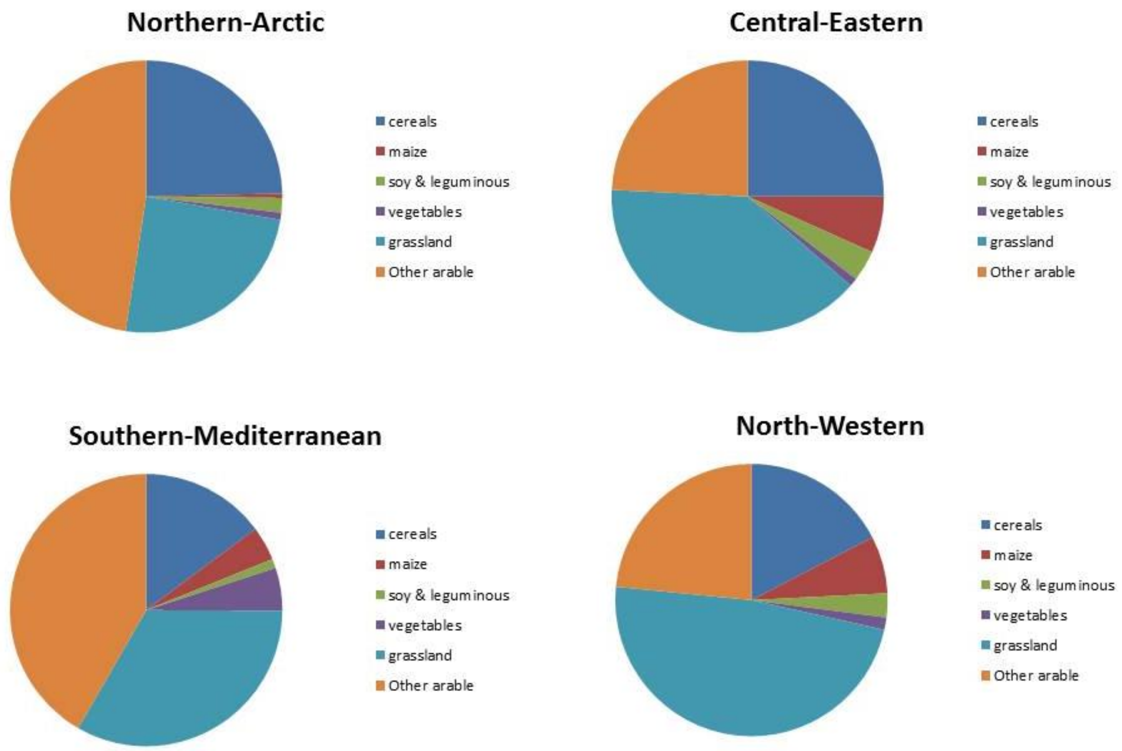


Figure 16 Reported crop shares by climate region (2004). Note: Other arable comprise Fodder root crops, Oher fodder on arable land, Pulses, Potatoes, Sugar beet, Apples, Pear and Peaches, Citrus fruits, Olives for oil, Table olives, Tables grapes, Tables wine, Fallow land, Flowers, Flax and Hemp, Tobacco, Other oilseeds, Other marketable crops, Nurseries.

4.5.2 The agricultural management challenges and solutions per region

Section 4.2 describes the SARA model framework, which is the basis for the following description of regional challenges and solutions.

***Northern-Arctic Europe*[5]**

Crop share trends

RCP4.5 projections applied in the crop share model show that 'other arable[6]' as the dominant crop type will decrease significantly by 14 % in the short term and less so in the long term (9 %), covering some 40-43 % of total agricultural land. The second most dominating group of crops, grassland and cereals, which cover some 25 % of agricultural land each, are projected to shift significantly. Grassland would increase by 40 % in the short term but less so in the long term (28 % increase), reaching 32-35 % of agricultural land cover, while the share of cereals would decrease by 16 %, occupying some 20 % of agricultural land by end-century. Maize is a crop that would benefit significantly from a changing climate in the northern-arctic, where the share would more than double over time (250 % in the short term and 264 % in the long term). The share of soy & leguminous and vegetables would decrease, most strongly in the short term.

RCP8.5 projections of future crop shares show a larger decreasing share of other arable crops in the short term (-14 %) and a lower decrease in the long term (4 %). Other arable crops will remain the largest crop type (46 %). As in RCP4.5, grassland and maize expands, while cereals, soy& leguminous decrease. Grassland would increase from the current 25 % of agricultural land area to 33-34 % over the century. Maize would occupy between 2 and 3 % of agricultural land area over the century, up from the current 0.5 %. The share of cereals would reduce from current 25 % to 22 % in the short term and 15 % in the long term.

Land use trends – Land use differs significantly within this region with crop land only being marginal in Norway, Finland and Sweden (2 % in Norway and ca. 6 % in Finland and Sweden is crop land), while crop land in the Baltic countries covers between 20 % (Estonia) and 40 % (Lithuania). The Land Use model results indicate that cropland is only projected to expand to a modest degree in the short term in RCP4.5 in the Nordic countries (between 1 to 5 %) and decrease strongly in the RCP4.5 long term in Norway (-21 %) and Sweden (-17 %). In RCP8.5

[5] Iceland, Norway, Finland, Sweden, Estonia, Lithuania, Latvia

[6] Fodder root crops, Oher fodder on arable land, Pulses, Potatoes, Sugar beet, Apples, Pear and Peaches, Citrus fruits, Olives for oil, Table olives, Tables grapes, Tables wine, Fallow land, Flowers, Flax and Hemp, Tobacco, Other oilseeds, Other marketable crops, Nurseries

losses in agricultural land is more pronounced and increasing over the century reaching losses of close to one third in Norway and Sweden and -15 % in Finland. Agricultural land in the Baltic countries is projected to decrease dramatically in the RCP4.5 by more than half in Latvia and Lithuania and about three quarters in Estonia over the century. The long term impact of climate on land use in RCP4.5 is however very modest.

Crop productivity trends – the Climate Crop model results show an increase of agricultural productivity in the Northern-Arctic region. The most pronounced increase in productivity is projected to occur in Norway, Finland and Sweden with increasing productivity over the century and a higher productivity in RCP8.5 than in RCP4.5. Stongest increases are expected in Finland and Sweden with 36 – 38 % productivity increase in the long term in RCP4.5 and 47 to 51 % in the long term in RCP8.5. The Baltic countries would experience more modest productivity increases of up to 10 % in the long term in RCP4.5 and 12 % in the long term in RCP8.4.

Water availability – The WAPAA model results indicate a moderate increase of run-off in Norway, Sweden and Finland but a significant decrease in the Baltic countries in the short term in RCP4.5 and with increasing effects in RCP8.5.

Economic impacts of climate change and adaptation – The estimation results of climate damages to agriculture show positive impacts in the North Artic region. For all countries in the region, agriculture benefits at an increasing rate over time with more pronounced benefits under the high end climate pathway. SSPs do not appear to play a role in the level of the benefits. Largest benefits are estimated for Finland in the long term in RCP8.5 of close to 0.7 % GDP followed by Sweden (0.3 % GDP), Estonia (close to 0.2 % GDP) and Norway (0.1 % GDP). Negligible impacts of a changing climate is found in Estonia and Lithuania in RCP4.5

***North-Western Europe*[7]**

Crop share trends

RCP4.5 projections applied in the crop share model show that grassland as the dominating crop type will be reduced by 7 % in the short term and more in the long term (14 %). Grassland remains the dominating activity in future. The climatic conditions have a positive impact on the extension of maize, vegetables and other arable crops in the short term while the long term would be beneficial for all crops types with the exception of grassland. In relative terms, vegetables would increase the most by close to 80 % in the short term and 58 % in the long term, reaching between 2.6 % and 2.3 % of total crops in the region. The share of maize is projected to increase significantly by 30 %

[7] UK, France, Belgium, Netherlands, Denmark, Ireland

in the short term but only to increase by 18 % in the long term compared to 2004. Cereals and soy/leguminous produce decrease in the short term by ca. 10 %.

Compared to RCP4.5, the trend towards reduced grassland area is amplified under RCP8.5 with 15 % reductions in the short term and up to 25 % reduction in the long term. The share of all other crop types increases over the short term. Over the long term, cereals would be reduced significantly by 25 %, while vegetables would increase strongly to reach 5 % of crop shares in the long run (increase of over 200 %). Also maize would expand, by 18 % in the short term and 46 % in the long run. This is a similar picture for other arable crops, which would expand by 10% in the short term and dramatically increase by 42 % over the long term compared to 2004. The general picture of crop shares shifts under RCP8.5 in the long term with grassland no longer the largest fraction of crop types, and other arable produce representing the largest share.

Land use trends – Under RCP4.5 North-Western countries experience a general decrease in agricultural land, which is intensified in the long term. The decrease of agricultural land is more intense in RCP4.5 than in RCP8.5.In RC4.5, UK, Ireland, Denmark and Belgium would experience an agricultural land decrease by 5-10 % in the short term and France a decrease by 2-5 %. Over the long term in RCP4.5, all countries would experience a decrease of agricultural land of between 10 and 50 %.

Crop productivity trends – UK, Denmark and the Netherlands would experience an increase in crop productivity due to climate change in RCP4.5 in both the short and long term. Especially the UK and Denmark could expect significant crop productivity increases of 10-12 % in the short term and 14-17% in the long run, respectively. France however, would experience a crop productivity decrease of 6-8% over the century, while Ireland and Belgium very modest changes. In RCP8.5, changes are more negative for Belgium and less positive for the UK and Denmark. Also the decrease in productivity in France is slightly less in RCP8.5.

Water availability - decreases in water availability are expected in the RCP4.5 short term for all countries with the exception of the Netherlands. France could experience a decrease in availability of 10-50% in the short term under RCP4.5 but more lenient reduced water availability in the long term (5-10 %). In RCP8.5, France and the Netherlands will have only small changes while the UK, Ireland, Belgium and Denmark would see a reduced availability.

Economic impacts of climate change and adaptation

Economic damages to agriculture in North-Western Europe are very dependent upon the socio-economic drivers in the SSPs and less on the climate change pathway. The highest damages are projected to happen under SSP5 and the lowest under SSP3 (See previous section for the rationale).

Under SSP5 (taking the highway), in the short term, damages to the region would arrive at 183-184 (0.001 % GDP) and 198-203 (0.001 % GDP) in the long term (across the two RCPs). SSP3 (regional rivalry), damages would be the lowest: 19 (0.001 %) in the short term and 17-27 (0.001 % GDP) in the long term across the RCPs. Under SSP2, damages vary substantially across RCPs.

Under RCP4.5 damages of climate change range from 112 to 198 (0.001 %) over the century while in RCP8.5 damages are as low as 20 (0.001 % GDP) in the short term and 202 (0.001 % GDP) in the long term.

Improved agricultural management would reduce economic damages to agriculture. In the Northern-Western region, improved management would be the most effective compared to the other regions. Damages from climate change can be almost completely compensated under SSP3 by using improved management. Irrigation is another contributing measure to reduce climate damages. Although its effect on reducing damages is far more limited than improved management, it contributes to reducing damages by 5-23 (0.001 % GDP) under SSP2; 5-8 (0.001 % GDP) under SSP3 and 23-25 (0.001 % GDP) under SSP5.

Under SSP2 and SSP5, only moderate negative impacts would occur after adaptation, while adaptation in SSP3 shows an almost complete recovery of damage costs using management.

Central-Eastern Europe [8]

Crop share trends

Taking only the climate signals into account, under RCP4.5, the share of agricultural vegetable production is likely to change the most in terms of crop shares: +99% by 2050 and +61% by 2100 compared to 2004. Other arable produces[9] would also have improved climatic conditions leading to increased shares of +29% by 2050 and +25% by 2100 compared to 2004. All other crop shares would decrease with the exception of maize, which could see a small increase of +4% in the short term.

Under RCP8.5 the share of vegetable produce would increase the most, as under RCP4.5, but more intensely: 61% in the short term and as much as 186% in the long term. The share of maize would increase significantly in the long term by 34%. Other arable produce increases by 25% in the short term and 45% up to 2100. All other crops decrease moderately in the short term (6-11%) and in the long term especially cereals decrease significantly by more than a third (38%).

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[8] Germany, Poland, Austria, Hungary, Czech Republic, Slovakia, Switzerland, Romania, Bulgaria, Macedonia, Kosovo, Serbia, Luxembourg

[9] Other arable: Fodder root crops, Oher fodder on arable land, Pulses, Potatoes, Sugar beet, Apples, Pear and Peaches, Citrus fruits, Olives for oil, Table olives, Tables grapes, Tables wine, Fallow land, Flowers, Flax and Hemp, Tobacco, Other oilseeds, Other marketable crops, Nurseries

The two regions in Czech Republic, South Moravia & Usti, are already among of the driest regions in the country with an annual precipitation of ca. 450mm. Climate change projections point towards more intensive dry periods. The traditional Czech hop production is concentrated in the Usti region, hosting 73% of national hop production. Hop yields have been estimated to decrease by 7-12% 2051-2100; and quality of the produce to decrease by 13-32% [D5.1 p58], making this a vulnerable activity in the region.

The agricultural model analyses at European scale predict an increasing share of other arable crops (which includes hops) under both climate pathways; but declining productivity under RCP8.5 and in the long term of RCP4.5. This appears to be in line with the findings in the case study. Water availability may increase under RCP4.5 but remain stable in the short term under RCP8.5 or worsen in the long term. While the improvement of irrigation is cheap in the region because the equipment is in place (but underutilised), the largest potential to reduce climate damages is found in improving management, where about half the expected damages can be avoided.

Land use trends – under RCP4.5 countries experience a general decrease in agricultural land, which is intensified in the long term. Especially CH, OST, HUN experience the highest reductions in agricultural land (10-50%). The trend is less pronounced under RCP8.5, where only Germany appears to experience a small decrease of 2-5% in the long term.

Crop productivity trends – In general, Central European countries experience an increase in agricultural productivity. Particularly CH, OST, HUN experience productivity increases of between 2-10% under RCP4.5 and between 5-50% under RCP8.5 over the century. ROM would increase productivity under RCP4.5 and long term scenario for RCP8.5. The more northern countries within central-eastern European countries tend to experience either no changes in productivity (DEU, POL, CZE, SVK under short term RCP4.5; DEU, POL under long term RCP4.5 and POL under short term RCP8.5. Under RCP8.5, DEU, CZE and SVK experience a decrease between 2-10% across the century while POL may experience a small decrease in productivity in the long term (2-5%).

Water availability – shows a very mixed picture for Central Europe. Some countries would have no changes in water availability (DEU under RCP8.5 and short term RCP4.5; CZE, OST and HUN under RCP8.5 short term) while other countries would experience increases in water availability (POL & CZE under RCP4.5 long term and POL under RCP8.5 short term) and yet other countries would experience increased water scarcity (all countries except from DEU under RCP8.5 long term; POL & SVK under RCP4.5 short term and SVK under RCP4.5 long term).

Economic impacts of climate change and adaptation

Economic damages to agriculture in Central-Eastern Europe are among the lowest in Europe, apart from Northern Europe which has 0% damage to agriculture. Damages, measured as 0.001% of GDP, range between 31 and 60 across RCPs and SSPs. The highest damages are projected to happen under SSP5, mostly because it is linked to the higher increase in GDP and economic activity, and therefor exerts the greatest pressure on natural resources. Across climate pathways, damages are significantly higher under RCP8.5.

Improved agricultural management would reduce economic damages to agriculture. In Central-Eastern Europe, improved managed would not outweigh the damages, but would more than half the damage costs. This is generally the trend across RCPs and SSPs.

Improved irrigation development can also contribute to reducing economic damages to agriculture. However, the potential is limited by water availability and hence the damage reduction effects are compared to improved management much smaller. For Central-Eastern countries, the damage reduction range between 3-7 (0.001 % GDP). Costs of irrigation improved is in this region the lowest as the equipment is already in place, but since the collapse of the communist economy, irrigation is underutilised. Costs range between 2-3 (0.001 % GDP).

In summary, the Central-Eastern European region shows minor negative impacts, when adaptation is accounted for. There is a large potential for improving management as an effective adaptation strategy with damages reduced by more than 50%, particularly for SSP2 and SSP3. In a SSP5 world, damage reductions are slightly lower.

***Southern Mediterranean*[10]**

Crop share trends

RCP4.5 projections applied in the crop share model show that 'other arable[11]' as the dominant crop type will remain relatively stable over the century with a negligible change by mid-century and a 3 % increase by end of century, covering some 42 % of total agricultural land. The second most dominating crop, grassland, is projected to decrease by 6 % in the short term and by 9 % in the long term, occupying some 30 % of agricultural land by end-century. Cereals, covering 15 % of agricultural land, may increase by 12 % in the short term compared to 2004 but decrease in the long term by 8 %. Relatively large increases may be the result of climate change for maize in the long term (ca. 40 %) and for soy & leguminous (32-56 %). Share of vegetables in the long run may increase by 16 %.

In RCP8.5 projections, other arable crops increase significantly over the long term by 21 % to cover 42 % of total agricultural land, while remaining stable in the short term. Grassland remains

[10] Portugal, Spain, Italy, Greece, Slovenia, Bosnia-Herzegovina, Croatia, Montenegro, Albania, Turkey, Malta, Cyprus

[11] Fodder root crops, Oher fodder on arable land, Pulses, Potatoes, Sugar beet, Apples, Pear and Peaches, Citrus fruits, Olives for oil, Table olives, Tables grapes, Tables wine, Fallow land, Flowers, Flax and Hemp, Tobacco, Other oilseeds, Other marketable crops, Nurseries

the second largest crop type but with significant decreases of 12 % in the short term and more than a third in the long term, reaching 22 % of total agricultural land. As in RCP4.5, cereals may first experience an expansion in the medium term, albeit lower than in RCP4.5, of 5 % followed by a significant decrease (38 %), much stronger than in RCP4.5. Maize, soy & leguminous and vegetables all experience increasing shares. Maize and vegetables are projected to cover each more than 5 % in the short term and 6-10 % of agricultural land in the long term. Soy & leguminous, covering about 1% of agricultural area today, may double the area in the medium term.

Land use trends - In RCP4.5 Southern-Mediterranean countries experience a general decrease in agricultural land, which is intensified in the long term. The decrease of agricultural land is more intense in RCP4.5 than in RCP8.5. In RC4.5, Spain, Portugal and Turkey may have insignificant changes in land use with regard to agricultural land in the short term and moderate changes of between 2 and 5 % decrease in the long term. Far more significant negative changes in agricultural land use may occur in Italy, Croatia, Bosnia & Herzegovina and Albania with losses of between 10 and 50 % in the long term. In RCP8.5, Turkey may experience a significant increase in agricultural land of 5-10 % while Spain in the short term and Spain, Croatia, Bosnia & Herzegovina, Montenegro and Serbia may experience decreasing agricultural land area of up to 18 %.

Crop productivity trends – Turkey is the only country in this region, where agricultural productivity is projected to increase by 4-5% across both RCPs and time horizons. In the other countries, agricultural productivity is projected to decrease in the short term by 4-7 %. Only in Montenegro is the decrease close to 10 %. In the long term, productivity decreases somewhat more, but decreases remain below 12 % (Portugal and Serbia experience the strongest declines). In RCP8.5, productivity declines substantially by between 10 and 24 % across countries in the short term (excl. Turkey). In the long term, productivity declines are dramatic with up to one third less output. Particularly Greece and Spain are heavily impacted in the long term. Slovenia and Italy may experience the least productivity declines of 14-17 %.

Water availability – Southern-Mediterranean countries are projected to experience a general decrease of water availability. In RCP4.5, decreases in run-off amount to 13-14 % on average with Portugal, Spain and Serbia as the hardest affected (ca. 18-22 % decrease). In RCP8.5, decreases are more pronounced with on average 15 % decrease in the short term and 21% decrease in the long run. Greece, Turkey, Portugal, Macedonia, Spain and Serbia endure the largest decreases in runof of between 27-35 % decrease.

Economic impacts of climate change and adaptation - Economic damages to agriculture in Southern-Mediterranean Europe are very dependent upon the socio-economic drivers in the SSPs and less on the climate change pathway. The highest damages are projected to happen under SSP5 and the lowest under SSP3.The agricultural sector in the Southern-Mediterranean region is the most affected region in Europe, with impacts close to 1% in some scenarios. Impacts are higher in the RCP8 emission scenario and long term and comparatively smaller in the RCP4 scenario and in the short term.

Under SSP5 (taking the highway), in the short term, damages to the region would arrive at close to 0.5% of GDP regardless of climate scenario and 0.7-0.8 % GDP damage in the long term. SSP3 (regional rivalry), damages would be the lowest across the SSPs but the highest within Europe within this scenario: 150-163 (0.001 %) in the short term and 152-313 (0.001 % GDP) in the long term for TCP4.5 and RCP8.5 respectively. Under SSP2, damages are higher than under SSP3 but lower than in SSP5. In RCP4.5, damages of climate change range from 334 - 481 (0.001 %) in the short term across RCPs and between 434(0.001 % GDP) and as high as 594 (0.001 % GDP) in the long term for RCP4.5 and RCP8.5 respectively.

Improved agricultural management would contribute to reducing economic damages to agriculture. These damage reductions in terms of GDP are greatest in the Southern-Mediterranean region, but this is because this region is affected the most. The Southern Mediterranean region is where adaptation is least effective, with reductions smaller than 50 % of damage under SSP5 for the long term scenario. Irrigation development may also reduce damages from climate change, but is comparatively much smaller because irrigation is severely limited by water availability. Across, Europe, the largest damage reductions of applying irrigation development is found in the Southern-Mediterranean region with damage reductions ranging between 20 and 56 (0.0001 % GDP) across RCPs and time horizons. However, the highest costs of this adaptation measure are also found in this region, ranging between 7 and 20 (0.001 % GDP), making the efficiency very small.

Figure 17 summarises the level of avoided damages through improved management and irrigation for the four climate regions under different climate impacts and period. Figure 18 to Figure 20 illustrate the impacts and challenges in European agriculture in relation to land use change, crop change, changes in surface water availability and changes in agricultural productivity. See also Jeuken et al. (2016) for a more thorough presentation of the model results.

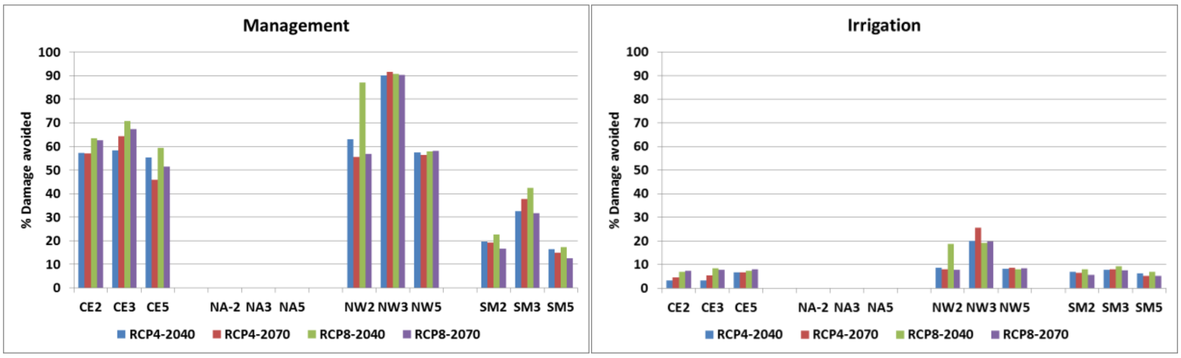


Figure 17 Damage avoided through adaptation for the management (left) and irrigation (right) strategies. Source: Jeuken et al., 2016.

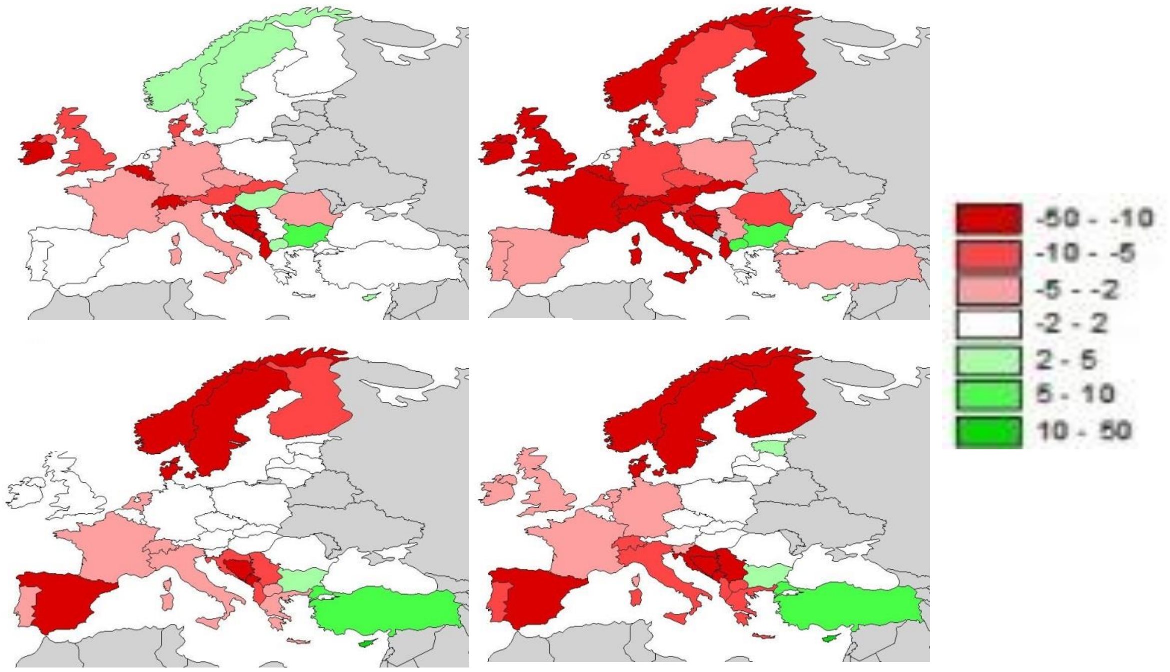


Figure 18 Average results by country of changes in agricultural land. Emission scenarios RCP4 (top) and RCP8 (bottom), in short term (left) and long term (right) time slices. Source: Jeuken et al., 2016.

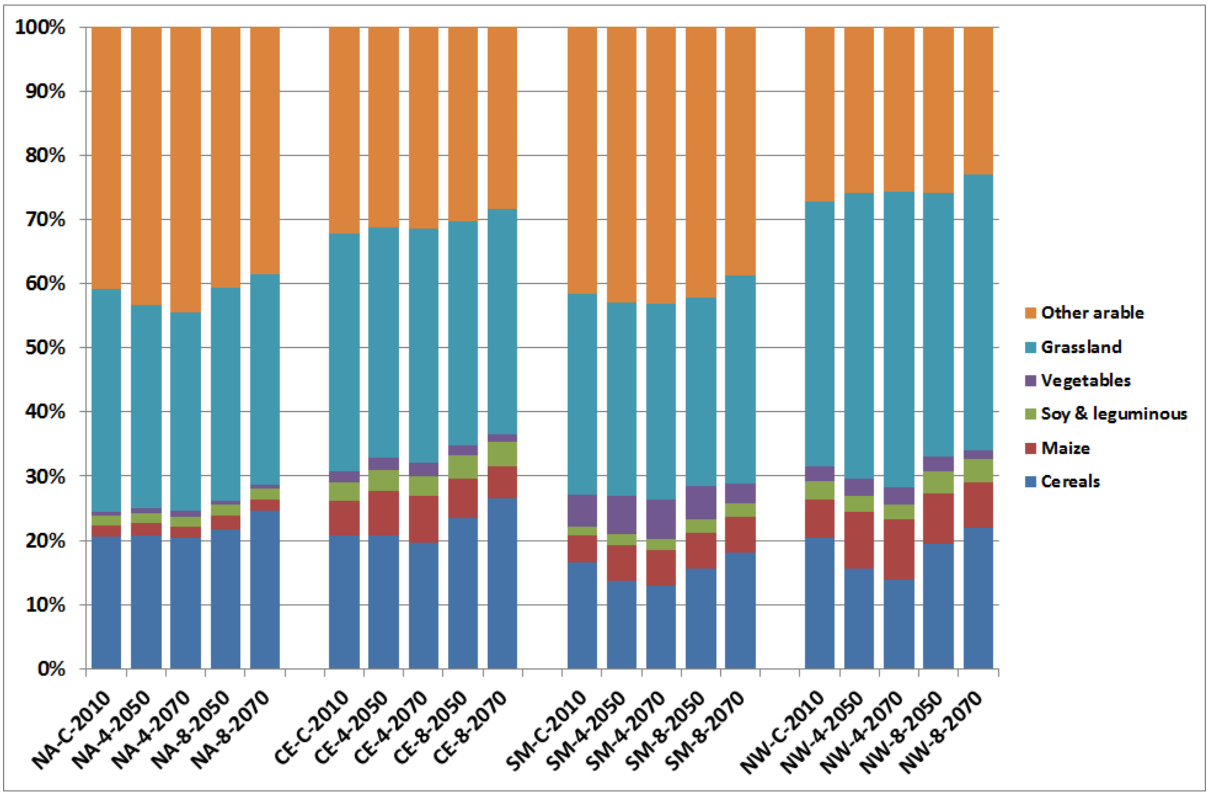
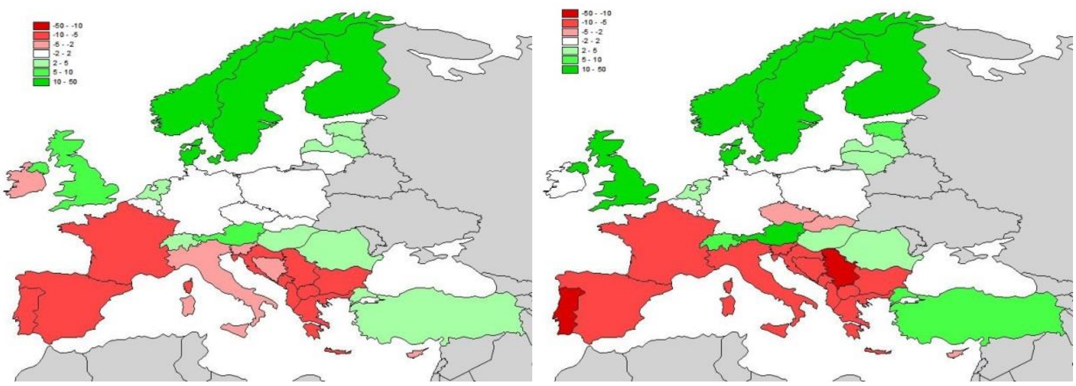


Figure 19. Simulated changes in land use shares by region (NA: North Artic, CE: Central Europe, SM: Southern Mediterranean and NW: North West). C-2010: Baseline, 4-2050: RCP4, short term, 4-2070: RCP4, long term, 8-2050: RCP8, short term, 8-2070: RCP8, long term



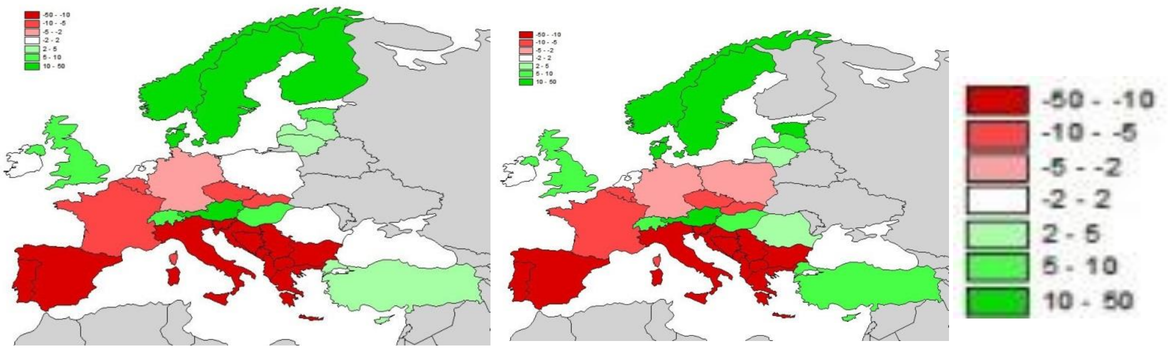


Figure 20 Average results by country of changes (%) in agricultural productivity. Emission scenarios RCP4 (top) and RCP8 (bottom), in short term (left) and long term (right) time slices. Source: Jeuken et al., 2016.

4.6 Health (Heat and Salmonella)

This section shows how health effects and adaptation measures can be examined for the BASE process tool. The examples provided and discussed are heat stress and salmonella, which have been studied within BASE. The choice was made to focus on these as, for example, diarrhea and malaria impacts are projected to be small or negligible in Europe. Section 4.2 presents an overview of the model framework applied. Both an EU level analysis (see section 4.2 and Bosello and De Cian, 2014) and case studies are used to support the development of storylines.

Both heat stress associated with heat waves and salmonella are directly related to temperature increase. As is indicated in section 3.1 temperatures are rising consistently across all projections and scenarios. For both health effects the summer extreme temperatures are most decisive. These also are expected to rise over whole Europe but in Southern Europe (4-7 degrees C in 2100) and to a lesser extent Central Europe (4-5 degrees C in 2100) in particular.

Heat stress

An increase of extreme temperature as well as longer heat waves observed with climate change would exacerbate mortality (McMichael et al., 2006; Peng et al., 2011; Wu et al., 2014). High temperatures in summer result in excess premature death of the population, those people whose death is unexpected during this time period, (Kovats and Hajat, 2008) and also in an excess displaced mortality of the most susceptible, those people whose death has been displaced by a few days or weeks (Hajat et al., 2005; Saha et al., 2014). The heat stress has been analysed at the European level for two regions, Eastern European EU countries and Western European EU countgries.Given the uncertainty attached to the estimation of the displaced mortality rate, we use 2 rates: 40 % and 65 %.

Table 4 Discounted impacts of heat due to mortality, under RCP 8.5 and SSP5, 2015-2099

	Displaced mortality 40%		Displaced mortality 65%	
Billion euros (€2013)	3% Discount Rate	5% Discount Rate	3% Discount Rate	5% Discount Rate
Eastern Europe	202	85.7	117.9	50
Western Europe	749.1	322.5	437.1	188.2
Europe	951.2	408.3	555	238.2

Source: Jeuken et al (2016)

Table **4** reports the discounted impacts of heat over the period 2015-2099 for the 2 EU regions. As expected by the model construction, the higher the displaced mortality the lower the impacts.

Heat Health Warning Systems (HHWS) give early alerts, advisories and emergency measures to mitigate the impact of a heat wave and its effects on health. They can be set up at national or city level. In order to estimate the costs and benefits of HHWS at European level, only the national scale has been considered.

Table 5 benefits and costs of HHWS, under RCP 8.5 and SSP5, 2015-2099 Discounted (DCR=5%). (Source: Jeuken et al. 2016)

	Benefits	Costs
Million euros (€2013)	Billion euros (€2013)	Million euros (€2013)
Eastern Europe	34 (30-38)	22 (5.1–38.8)
Western Europe	127.9 (112.9-143)	141.9 (32.6-251.1)
Europe	162 (142.9-181)	163.9 (37.8-289.9)

Note: in parentheses, low and upper bounds

It is estimated that the total costs of a HHWS (fix and variable costs) vary in a factor of 7. For a 5 % discount rate it varies from 38 to 290 million euros (Table 5). However clear from the analysis is that whatever discount rate or displaced mortality criterion is used the Benefit cost ratio of these systems are high and present a low regret measure to be taken.

At city level this is also confirmed by the case study for Madrid. In a scenario of acclimatisation (the population is adapting to higher heat stress levels) total deaths are reduced by 9,6 % (RCP4.5) and 19,3 % (RCP8.5). The cost-benefit ratio is always positive under all scenarios and assumptions of monetary valuation, with benefits largely exceeding the costs, which confirms that heat health watch warning systems are a low regret measure to reduce the health impacts of heat waves. Nevertheless, it is important that acclimatization is incorporated properly, the critical temperature (Tcrit) above which to activate the system has to be periodically revised, together with the expected attributable health risks, to guarantee the effectiveness of the measure and to avoid additional costs of implementation of the system when it is not necessary.

A range of other options are considered at case study level in Madrid, Jena and Prague– notably green roofs and green blue spaces, but these are hard to generalise to European level analysis. Under SSP2 and SSP3 there is lower growth of population and economy which lowers the benefits in general of measures to reduce heat stress and avoid displaced mortality while the costs remain similar. This was shown in the case study of Madrid however the HHWS remains a cost effective measures. Green roofs and green and blue spaces pose extra costs for private developers but can in the end deliver public benefits which however remain uncertain.

Salmonellosis

For Salmonellosis, we focussed on the costs and benefits of adaptation in the European Union. TABLE 6 shows the present value costs and benefits of adaptation to salmonellosis over the period 2015 to 2099. It can be seen that the costs vary significantly by country, reflecting the spatial distribution of salmonella and that in general in the cooler countries the BCR may be lower than in warmer countries for public health campaigns. Because of the way the analysis has been conducted, the BCR for treatment does not vary by country. Overall costs of treatment may be €20.7 billion in the period 2015 to 2099 (at a 3 percent discount rate), whereas costs of public health campaigns may be €458 million over the same period. The BCR ranges from 4.3 to 21.4 for treatment (mid value 9) and 13.8 to 28.9 for public health campaigns (mid value 17.9).

Table 6 (taken from Jeuken et al. 2016) Costs and benefits of 2 adaptation measures reduce Salmonellosis under increasing climate change (RCP8.5 end of century)

	Option 1: Treatment									Option 2: Public health campaign						
Country	GP visit cost	Hospital cost	Total cost	Benefit: Value avoided death (mid VSL)	Benefit: Avoided death (low VSL)	Benefit: Avoided death (high VSL)	B/C ratio (mid VSL)	B/C ratio (low VSL)	B/C ratio (high VSL)	Cost	Benefit (mid VSL)	Benefit (low VSL)	Benefit (high VSL)	B/C ratio mid VSL	B/C ratio (low VSL)	B/C ratio (high VSL)
Austria	88.8	161.4	250.2	2247.0	1070.0	5349.9	9.0	4.3	21.4	8.3	99.2	76.3	159.5	12.0	9.2	19.2
Belgium	183.2	333.2	516.5	4638.7	2208.9	11044.4	9.0	4.3	21.4	12.2	204.8	157.5	329.2	16.8	12.9	26.9
Bulgaria	116.2	211.3	327.6	2942.0	1401.0	7004.8	9.0	4.3	21.4	5.5	129.9	99.9	208.8	23.5	18.1	37.7
Cyprus	30.1	54.7	84.8	761.3	362.5	1812.6	9.0	4.3	21.4	0.9	33.6	25.9	54.0	37.7	29.0	60.6
Czech Republic	128.5	233.6	362.1	3252.4	1548.8	7743.8	9.0	4.3	21.4	9.7	143.6	110.5	230.9	14.8	11.4	23.8
Denmark	53.6	97.4	151.0	1356.0	645.7	3228.5	9.0	4.3	21.4	5.5	59.9	46.1	96.2	10.8	8.3	17.4
Estonia	8.8	16.0	24.8	222.6	106.0	530.0	9.0	4.3	21.4	1.1	9.8	7.6	15.8	9.3	7.2	15.0
Finland	31.2	56.7	87.9	789.2	375.8	1879.2	9.0	4.3	21.4	5.3	34.8	26.8	56.0	6.5	5.0	10.5
France	1147.8	2087.1	3234.9	29053.5	13835.0	69175.0	9.0	4.3	21.4	64.3	1282.5	986.7	2062.2	19.9	15.3	32.1
Germany	906.8	1649.0	2555.9	22955.1	10931.0	54655.1	9.0	4.3	21.4	68.2	1013.3	779.6	1629.3	14.9	11.4	23.9
Greece	215.0	391.0	606.0	5442.4	2591.6	12958.1	9.0	4.3	21.4	8.6	240.2	184.8	386.3	27.9	21.5	44.9
Hungary	161.7	294.0	455.7	4093.0	1949.1	9745.3	9.0	4.3	21.4	8.5	180.7	139.0	290.5	21.4	16.4	34.3
Ireland	51.5	93.7	145.2	1303.9	620.9	3104.4	9.0	4.3	21.4	4.4	57.6	44.3	92.5	13.1	10.1	21.1
Italy	1267.1	2304.2	3571.3	32075.3	15273.9	76369.7	9.0	4.3	21.4	57.4	1415.9	1089.3	2276.7	24.7	19.0	39.6
Latvia	14.0	25.4	39.4	353.6	168.4	841.9	9.0	4.3	21.4	1.4	7.3	3.7	16.8	5.1	2.6	11.6
Lithuania	21.0	38.1	59.1	530.9	252.8	1264.0	9.0	4.3	21.4	2.0	23.4	18.0	37.7	11.8	9.1	19.0
Netherlands	194.2	353.1	547.2	4914.8	2340.4	11701.8	9.0	4.3	21.4	15.4	216.9	166.9	348.8	14.1	10.8	22.6
Poland	416.9	758.2	1175.1	10554.2	5025.8	25129.1	9.0	4.3	21.4	31.9	465.9	358.4	749.1	14.6	11.2	23.5
Portugal	204.6	372.1	576.8	5180.0	2466.7	12333.4	9.0	4.3	21.4	8.2	228.7	175.9	367.7	27.8	21.4	44.7
Romania	301.2	547.7	848.9	7624.6	3630.7	18153.7	9.0	4.3	21.4	16.5	336.6	258.9	541.2	20.4	15.7	32.7
Slovakia	61.9	112.6	174.6	1567.7	746.5	3732.6	9.0	4.3	21.4	4.4	69.2	53.2	111.3	15.6	12.0	25.0
Slovenia	29.9	54.3	84.2	756.3	360.2	1800.8	9.0	4.3	21.4	1.8	33.4	25.7	53.7	18.1	13.9	29.1
Spain	988.1	1796.8	2784.9	25012.5	11910.7	59553.5	9.0	4.3	21.4	40.9	1104.1	849.5	1775.4	27.0	20.8	43.5
Sweden	59.1	107.4	166.4	1494.8	711.8	3559.1	9.0	4.3	21.4	10.4	66.0	50.8	106.1	6.3	4.9	10.2
UK	692.4	1259.2	1951.6	17528.3	8346.8	41734.0	9.0	4.3	21.4	65.7	773.7	595.3	1244.1	11.8	9.1	18.9
Total	**7373.6**	**13408.3**	**20781.9**	**186650.0**	**88881.0**	**444404.8**	**9.0**	**4.3**	**21.4**	**458.7**	**8230.8**	**6330.8**	**13240.0**	**17.9**	**13.8**	**28.9**

Summary across storylines

A challenge for the application of the process tool is that modelled impacts of heatwaves and salmonellosis only exist at a very course scale, and hence there are significant uncertainties in the values. These have been presented as impacts for Eastern and Western Europe – to fit the AD-WITCH model. The uncertainties as to the critical temperature threshold and the costs of heat-health warning systems prevent presenting results for heatwaves in particular at a more detailed level. Quantitative estimates are only presented above for the fossil fuelled development storyline at the course aggregated level. This means that the following assessment at a finer regional level is based on qualitatively informed by the quantitative analyses at a coarser scale and auxiliary information. .

Northern-Arctic Europe

Heatwaves in the Northern and Arctic region are likely to have limited impact on health compared to other regions, because of the lower baseline temperatures. However, heat impacts are not excluded. In Finland there have been studies of about the heat health effects of the 2010 heat wave, suggesting increased mortality. The likelihood is that heatwaves may become more frequent, but given the relatively low base, the heat effects are likely to get most attention under the fossil-fuelled development storyline as there is significant growth in the population and the greatest increase in per capita incomes (which affect willingness to pay for health). Under the other storylines impacts of heatwaves on health may be modest (but heat alert systems may still have benefit cost ratios greater than 1).

The picture is likely similar for salmonellosis, as increases in temperature are greatest under fossil fuelled development and regional rivalry and so the number of days above the temperature threshold for salmonellosis is likely to be greatest. As in all cases for health, we have only estimated this for the fossil fuelled development storyline. New facilities and technologies may reduce salmonellosis under fossil-fuelled development – and so mitigate the costs to some extent.

North-Western Europe

Heatwaves in the North-Western region are, similarly to the Northern-Arctic region, likely to have a moderate impact on health compared to other regions, because of lower baseline temperatures. Population increase under fossil-fuelled development is greatest (>40 %) leading to a significant increase in the population at risk, while under the middle of the road storyline a moderate increase in population occurs. Economic growth will also increase the value of health greatest under the fossil-fuelled development storyline, so coupled with this storyline the absolute monetary health impacts are likely to be most significant under this case. Under the regional rivalry scenario increased inequalities may also play a part, as those who are most vulnerable are likely to be most at risk under this scenario. .

For salmonellosis, increases in temperature are greatest under fossil fuelled development and regional rivalry and so the number of days above the temperature threshold is likely to be greatest. As in all cases for health, we have only estimated this for the fossil fuelled development storyline. Significant increases in incomes and population under fossil-fuelled development are likely to increase the costs associated with salmonellosis, although improvements in technologies may offset this somewhat.

Central- Eastern Europe

On balance, the population at risk in Central- Eastern Europe is likely to increase less or even fall across the scenarios – which when coupled with lower increases in incomes under all storylines means that the increases in health costs due to climate change are likely to be smaller under this scenario (indeed the overall absolute cost may decline if the relative decline in population is large enough).

Increased incidence of heatwaves may be significant, however, particularly under RCP8.5 for the case of fossil-fuelled development and regional rivalry. The baseline temperatures and incidence of heatwave is likely greater in Central and Eastern Europe than in Northern counterparts.

Southern-Mediterranean

For the Southern-Mediterranean region, moderate growth in populations may increase the population at risk somewhat, while increases in incomes may increase willingness to pay for health. Under regional rivalry, the increasing inequality may be an issue – as healthcare is less adapted. Increased incidence is most significant under the fossil-fuelled development, however, due to the relative population increase under this scenario.

5 Key messages on regional differences in adaptation challenges

An essential step in the BASE process tool is bringing together all the different pieces of information in order to provide as coherent a view as possible on the adaptation challenges in the different regions. This overview can be refined further in dialogues with experts and stakeholders. In applying the process tool such interviews were conducted with selected stakeholders. Reflections at the case level were also obtained from a stakeholder workshop held in Brussels June 9 2016 that discussed specific cases and reflected on how general the findings were.

5.1 Overview of similarities and differences in the storylines

Under RCP 8.5 that underlies the storylines 'Fossil-fuelled development' and 'Regional rivalry' many of the consequences of significant climate change are likely to be apparent by the middle of the century and thus causing significant challenges for societies in terms of adaptation. The essential difference between 'Fossil-fuelled development', 'Regional rivalry' and the 'Middle of the road with active mitigation' is that mitigation is assumed to progress more rapidly under the 'Middle of the Road' story line. As a consequence climate change progresses more slowly with less pronounced extremes. This means that adaptation is easier and can progress at a slower pace. At the same time one should note that also under RCP 4.5 changes are likely and thus there is also under RCP4.5 a need for adaptation action.

Economic growth is assumed to be strongest in the storyline 'Fossil-fuelled development' (SSP5), modest in "Middle of the road with active mitigation' and low or even negative in 'Regional rivalry'. This creates very different conditions for adaptation (Figure 21). Under 'Fossil-fuelled development' and "Middle of the road with active mitigation' the countries are assumed by and large to have the means to respond to immediate adaptation needs. Growth in population is greatest under fossil-fuelled development, and this in itself may increase the costs of adaptation as in the case of health impacts (Section 4.6). However, the differences also need to be considered in the light of public-private sector development. If societies aim for a reduction of the public sector and emphasize the private sector, costly adaptation actions will focus on actions where cost-benefit ratios are high and private interest and resources can be mobilised (including opportunities to benefit from the climate change). Poorer areas will under such development depend on innovative cheap adaptation, or suffer from the adverse consequences of climate change.

Under 'Regional rivalry' poor economic conditions are assumed to prevail and these will most likely be reflected in accentuated internal inequalities as public resources to support adaptation are diminished. The lack of resources for adaptation may lead to ever increasing adaptation needs. Initially the adaptation needs are strongest in the storyline 'Fossil-fuelled development' because expanding economic activities are likely to encounter new exposures to climate change and adaptation needs. With time the greatest needs may appear under ‘Regional rivalry’ as, for example, critical infrastructure is becoming more vulnerable to climate change as a consequence of poor maintenance.

It is important to recognise that the story lines do not represent fixed paths. Thus the actual development may shift from the current path of slow economic growth to one of more rapid growth or even greater regional rivalry. These potential switches between the storylines may be even more important to consider than the individual storylines. Some of the processes that can cause these switches are identified in Figure 21. For example, one can assume that the ‘Fossil-fuelled development’ is unstable in the sense that it clearly does not meet current understanding of sustainable development, unless accompanied by truly revolutionary decoupling of resource use from economic growth. Thus it can slide into “Regional rivalry’ if resources are depleted or the costs of the consequences of climate change starts to hamper growth. Similarly the ‘Middle of the road with active mitigation’ can slide into ‘Regional rivalry’ if political turmoil causes international climate negotiations to disintegrate.

It is also important to note that the storylines are not predictions, but ways of supporting reflection over possible consequences. Several of the interviewees thought that the storylines presented in here were ‘too negative’ and had a more optimistic view of the likely development.[12] From the point of view of the process tool this is not a problem as such, because additional storylines or modifications can be brought into the discussion. It shows, however, that it is important to be able to continue the discussions and incorporate additional information and reflection.

[12] Summary of interview findings, internal document

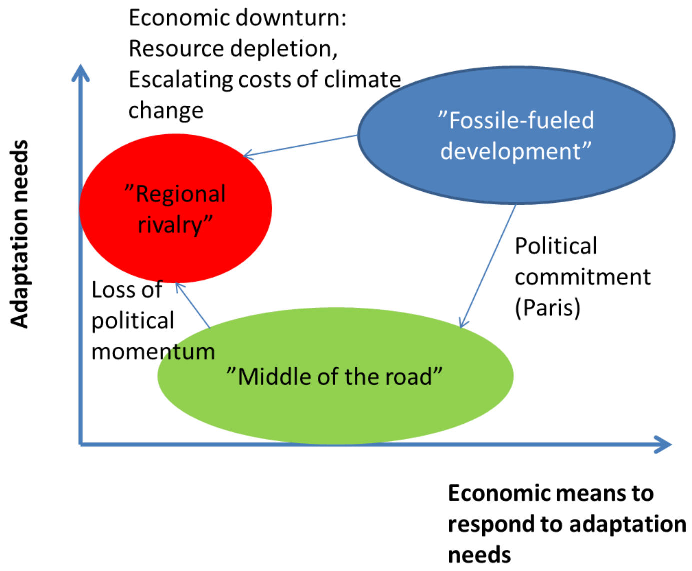


Figure 21. The relative positions of the storylines with respect to adaptation needs and the economic means to respond to them.

In all storylines an important challenge for publicly funded R&D&I is to identify innovative low cost actions for adaptation that can deal adequately with extreme events and conditions that rapidly divert significantly from current average conditions and that can be applied also where economic means are lacking, for example in rural areas hit by depopulation. It is not only a question of developing the technical means, but also to explore forms and processes for adaptation governance that provides incentives for private actors to take action in time. Interviewees pointed out that private initiatives are likely to take place and for these action the costs and benefits may be perceived very differently from those examined at the level of public expenditure.[13]

Adaptation measures will be most urgent under the RCP8.5 scenarios, but the adverse consequences of climate change are expected to be greatest under the storyline of 'Regional rivalry' as available resources are expected to dwindle. Under the 'Fossil-fuelled development'-storyline other impacts such as those affecting biodiversity or leading to the depletion of natural resources may contribute to the adverse consequences of climate change.

[13] Interview with Dutch adaptation expert.

5.2 Overview of differences in regional challenges and actions

The task of the BASE process tool is to bring together the elements that have been explored using different models, case studies, literature and qualitative analysis. The differences that different pieces of information highlight are of particular interest because they provide understanding of the need for flexibility and diversity in adaptation policies and actions. The overview shows that there are differences in the weight of different issues both due to the projected climatic conditions and the socio-economic development (Table 7).

The sector specific findings highlight diversity, but at the same time there are also common features and robust conclusions. For example favourable benefit to costs ratios could be identified for flood protection measures and heat warning systems under all story lines. This shows the need for proactive planning across regions. The role of autonomous adaptation is also significant as illustrated by changes in health effects (Section 4.6) and agriculture (Section 4.5).

Table 7. Examples of differences in adaptation challenges and issues across regions and sectors based on the findings in BASE (chapter 4).

Sector	Northern-Arctic	North-Western	Central-Eastern	Southern-Mediterranean
Flood risks	The main issue is not the peak fluvial floods, which may even decrease. Instead the increasing risk of floods outside the normal peak flood season and the increasing probability of pluvial floods are concerns.	Generally increasing flood risks, additional cost efficient solutions need to be developed. Large intra-regional differences respect to the need for and economic viability of adaptation measures	Increasing risk of extensive flood damages, but also high uncertainties with respect to the projections. Large intra-regional differences with respect to the need for and economic viability of adaptation measures	Flood risk likely to increase, but with significant differences within the region. Extreme climate events are the main cause of the floods with flash floods causing particular damage.
Water availability	Water scarcity is not projected to be a serious issue although	Water scarcity may occur in the summer time.	Water scarcities are likely to occur, but the intraregional	Water scarcity is likely to become a serious and permanent

	dry spells during increasingly warm summers are not excluded.		variation is large. There are also large differences between the climate projections.	issue for adaptation in the region.
Agriculture	Increasing rainfall during the growing season, which expands significantly. Productivity is expected to increase, but shifts in land use and cultivars are likely.	Decline in rainfall during the growing season, which does not expand significantly. Intraregional differences in productivity with both increases and decreases.	Moderate increase in rainfall during growing season, which expands. Generally modestly increasing productivity.	Decline in rainfall during the growing season, which expands. Significant decline in productivity.
Health (heat and salmonella)	Health effects are of moderate concern. Thresholds for heat effects are lower than in more southern regions.	Health effects are of moderate concern.	Health effects likely to increase at an individual level although the aggregate total may even be reduced, if population decline is rapid.	Health effects likely to increase. Specific concern for increased inequality.

Northern-Arctic Europe

Northern and Arctic Europe are expected to experience the highest temperature increases relative to current temperatures and thus many aspects of the northern-arctic environment may change.

Yet the societal vulnerability to climate change has so far generally been considered to be relatively modest due to a high adaptive capacity. The interviews[14] conducted for this deliverable confirmed the view of a significant adaptive capacity, but also that this may require changes in practice.

Special conditions prevail in the Arctic with indigenous people adapting to climate change and to changing socio-economic conditions. The adaptation needs of traditional livelihoods may require, for example, spatial reallocation, which may lead to increasing conflicts with an increased exploitation of natural resources such as forests or minerals. These tensions are likely to be accentuated under fossil-fuelled development story line, where climatic conditions may facilitate exploitation and where rapid economic growth makes it profitable to exploit also remote mineral resources. This suggests that spatial aspects are important also in adaptation to climate change.

It will become increasingly important to develop policy level adaptation pathways that can flexibly adjust not only to changing climatic conditions but also to shifts in the wider socio-economic and political context. Especially the open Nordic economies are dependent on changes in the global economy and political constellations. Because of the dynamics it is important to consider how a desirable development can be stabilised. For example, social, political and technological innovations may in the best of cases make the middle of the road story line easier to achieve, and it may open new opportunities for the Nordic countries that have a strong tradition in developing measures for environmental protection.

North-Western Europe

The main message is that all storylines show similar trends but with varying intensity: Urbanisation continues, flooding probability increases as well as temperature, agricultural production is affected and GDP grows until 2050. Although the storylines look broadly similar, there are also some significant differences. For example, population grows in 'fossil-fuelled development', while this growth is much smaller in 'middle of the road' and can even decrease in 'regional rivalry'. These differences have, together with the bio-physical changes, implications for adaptation.

In all storylines adaptation measures are needed to deal with the impact of increased flooding, drought and heat stress. North-Western Europe differs from Northern-Arctic Europe in that droughts and water stress are likely to be of greater significance. In general adaptation measures will be most urgent in 'fossil-fuelled development' due to the impact of climate change on almost all sectors and the intensification of land use. In the storyline 'regional rivalry' measures are almost as urgent, but under this storyline many countries or regions will lack the means to undertake costly adaptation measures. This underlines the importance of recognising the wider socio-ecionomic

[14] Interviews conducted May 11-12 2016.

development in adaptation policies. Interviews also raised the importance of innovation and technological development as factors that may make adaptation easier.[15]

Under the storyline 'fossil-fuelled development' policy instruments that require investments in adaptation or adaptive capacity are likely to be more acceptable than under the storyline 'regional rivalry'. Policy instrument based on European subsidies, or instruments that emphasise co-benefits between adaptation and other societal objectives are likely to be favoured under a regional rivalry story line. The middle of the road story line implies significant effort spent on mitigation, which may bring it closer to the 'regional rivalry' story line in terms of efforts devoted to adaptation.

Central-Eastern Europe

Under all scenario storylines, the rise in average temperature is assumed to bring about the need for adaptation actions, further intensified by higher occurrence of weather extremes such as droughts and flood episodes. In general, Central European countries will need to adapt to temporally and spatially uneven distribution of precipitation, leading to potentially rising occurrence of floods on the one hand, and water shortages on the other. Consequently, the adaptive capacity of the countries on all governance levels requires to be increased in order to be able to deal with precipitation and water supply-related challenges.

The scenario storylines for Central Europe presume substantial changes in population levels in most of the countries regions, with subsequent socio-economic and environmental challenges. Another distinctive trend, common to all storylines, is intensive urbanization, especially under the 'fossil-fuelled development'. Heat waves and heat islands in the cities will challenge vulnerable segments of population by heat stress in urban environments, particularly affecting elderly people and those with chronic diseases. Increasing income inequality and continuing societal stratification are likely to affect adaptation. One interviewee thought, however, that this is an overly pessimistic view of the likely development.[16] The development of the technological base for adaptation is likely to face significant obstacles especially under the 'regional rivalry' story line sue to market fragmentation and low priority of investments into research and development. These aspects will affect the planning of climate change adaptation measures, which will likely require solutions robust to social and economic changes within the society.

According to all storylines explored here, ecosystems will be challenged by agricultural intensification and growing demands for agricultural products, as well as pollution and continuous

[15] Interview with adaptation expert, UK

[16] Interview with adaptation expert, Germany

environmental degradation. In order to face subsequent decline in the provision of ecosystem services, it is vital to focus on ecosystem-based solutions to climate change adaptation.

Southern-Mediterranean Europe

The available projections for climate change identify southern Europe and the Mediterranean areas as the European area that will be most severely hit by climate change. Mediterranean countries will be significantly affected especially under the RCP 8.5 scenario with a hotter, more instable and less rainy climate that will put significant pressure on water systems and all economic activities that depend on it, agriculture in particular. The key difference between the different storylines lies in the population and economic scenarios. The ‘fossil-fuelled development’ and ‘regional rivalry’ reflect two very different pathways. While in ‘fossil-fuelled development’ we have rising population, economic development and urbanization, ‘regional rivalry’ is characterised by slowly growing or even declining populations, little or no economic growth and potentially even decreased urbanization. While in the fossil fuelled development significant investments are needed and possible in order to adapt water, infrastructure and energy systems, such investments are mostly non-existent under regional rivalry. Simply-put ‘fossil-fuelled development’ is likely to embark on a grey adaptation pathway while ‘regional rivalry’ will, out of necessity, consider a green and soft adaptation as people may even leave highly vulnerable cities and return to local-scale traditional farming practices with small investments and low energy consumption per capita.

In all storylines migratory dynamics will be present and highly important. Under all story lines strong immigration from the North of Africa is expected to continue, and under RCP 8.5 an increasing share of the immigration or attempted immigration will be climate driven. Eventually the total population may increase in some countries such as Spain, contributing significantly to increase the stress over water and energy. Under ‘regional rivalry’ emigration and lower birth rates from the Mediterranean countries may result in a net loss of population, with important implications for urban planning and water management.

Tourism and exports are expected to continue to play a crucial role in sustaining economic development in the Mediterranean region. Warming may result in extended beach periods at a growing environmental and economic cost. In ‘regional rivalry’ both economic activities will slow down and even decrease due to geo-political conflicts and turmoil’s as well as disinvestment from high energy/water demanding industries.

All of the storylines presented suggest that the development of future adaptation pathways face significant challenges in the southern-Mediterranean region. The ‘fossil-fuelled development’ might eventually come at very high costs for both societies and ecosystems.

6 Designing and implementing policy pathways

This Chapter summarises how the BASE process tool for testing and evaluating future plans for adaptation policy can be used to inform future policies and adaptation governance. In particular, it shows how the BASE process tool modifies and deepens the approach used in the Adaptation Support Tool of the Climate-ADAPT[17] portal.

The BASE process tool makes use of the dynamic policy pathways approach, which combines the adaptation pathways and adaptive policy making (Haasnoot et al. 2013). The basic idea is to assist the design of dynamic adaptive plans by making the pathways conditional on the emergence of specific conditions. The BASE process tool has been specifically set up to make the link between general features such as the unfolding severity of climate change impacts, the available resources to deal with impacts and the success of mitigation action. The policy pathways are thus framed by the SSPs and their regional and national interpretations (Chapter 5).

The Adaptation Support Tool of the Climate-ADAPT portal suggests that adaptation should be planned and carried out in six basic steps:

1) Preparing the ground for adaptation
2) Assessing risks and vulnerability to climate change
3) Identifying adaptation options
4) Assessing adaptation options
5) Implementation
6) Monitoring & Evaluation (M&E)

The Adaption Support Tool is designed primarily for setting up adaptation strategies and plans. The BASE process tool for testing and evaluating future plans for adaptation recognises the challenges that the planning of policies raise as policies cannot be fully designed in advance. Policies evolve and emerge in response to and as the result of dynamic political constellations. Haasnoot et al. (2013) note that *'policymakers sometimes choose to keep … targets vague, making it difficult to determine the efficacy of an action and pathway.'* Gibbs (2016) stresses the political risk of coastal adaptation pathways that can lead to inaction. This implies that it is difficult to design switches and 'best- before' rules for policies, because the political constellations can change the feasibility and relevance of a particular policy design. The design of the BASE process tool takes this into account by providing a framework within which new pieces of information can be used to revise testing and evaluation of policy options.

[17] http://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool [viewed June 25 2016]

Exploring policy alternatives makes sense in a process tool as such exploration make policies more transparent. The assessment can also highlight important features of the management challenges under different storylines (Chapter 3) as well as the differences between sectors (Chapter 4). For example, setting the norm for an acceptable flood risk will have implications for the benefit-cost ratios of measures under flood policies (Section 4.3) and will also have distributional impacts that entail political risks (see Gibbs 2016).

In ***preparing the ground for adaptation*** the Climate-ADAPT support tool stresses the need to obtain and assure high level support, setting up adequate coordination mechanisms and clarifying roles and responsibilities, exploring funding opportunities, identifying already available information and increasing awareness or understanding of climate change issues. The BASE process tool presented here suggests, however, first taking a step back to examine what kind of policies and pathways can be considered. The possible adaptation pathways are framed by projected climate change (Section 3.1), the socio-economic conditions (3.2) and their combination that create the management challenges (3.3). The possible pathways also differ in detail depending on the level of governance (local vs. European). The BASE case studies illustrate how the policies play out in practice and the diversity of cases provide a base for reflecting on how different pathways can play out (4.1).

The risk and vulnerability assessment should specify the issues that policy pathways need to pay attention to. The support tool approach and the BASE process tool approach do not differ significantly in this step, but the BASE cases highlight that although individual cases broadly fit the general regional patterns of adaptation challenges (4.1), significant local deviations from the broad patterns are possible and important. The case studies and the diversity in national policies underscore the need for reflection and flexibility in examining risks and vulnerabilities. The BASE process tool highlights the importance of intraregional variation and this was confirmed both by interviews and the BASE policy workshop.[18] By bringing in diverse pieces of information the BASE process tool provide a fuller picture of uncertainties. By contrasting different story lines the strength of evidence is brought up and through sector and case specific information the possible role of autonomous adaptation for risks and vulnerabilities is highlighted.

In identifying adaptation options both the support tool approach and the BASE process tool approach argues for an exploration of potential adaptation options and the identification of relevant actions, and their potential co-benefits. The BASE findings from cases and sectors further highlight that one also needs to recognise that each sector has its own institutions, including policy instruments, practice, actors and traditions. This background introduces a path dependency that

[18] Internal document of summary of interviews and notes from the outcome of the Brussels policy workshop June 9 2016.

constrains the set of available solutions to new challenges. Path dependencies also affect the choice of adaptation pathways that countries can undertake jointly.

In the EU the possible pathways are constituted in a multi-level governance setting from the local over the regional and national to the EU level. There are sector specific policies (BASE Deliverable 2.1) as well as general coordinating policies such as the EU adaptation strategy and its national and local counterparts. Some sector specific policies furthermore have explicit link to other sectors. For example land use policies are affected by and have an impact on other policies. The BASE process tool recognises the need to explore the range of options also from this perspective and provides the means for doing so through the combination of many diverse forms of information (see Chapter 4).

The assessment of adaptation options is part of both adaptation support tool planning and the dynamic policy pathway approach (Haasnoot et al. 2013). The difference is that the dynamic policy approach focuses on identifying a sequence of options that are conditional on the progress of climate change, triggers and ‘best-before’ dates for policies, whereas the support tool approach is based on a prioritization and compilation of options using detailed descriptions and criteria. The BASE process tool shows that the assessment also needs to reflect on the socio-economic conditions that significantly influence what polices and measures are feasible and that these external conditions may change (Chapter 5). The sector specific information that can be obtained from modelling and further illustrated by specific cases (Chapter 4) is essential in developing and assessing policy pathways. It may, for example, show that in some sectors autonomous adaptation can be supported through information and incentives thereby reducing the need for costly public adaptation measures.

The implementation is in the Climate-ADAPT support tool planning seen as a set of decisions on who should take action when and allocating sufficient resources for the activity. The policy pathways approach brings in conditionality and the idea of a ‘best-before’ also for policies (Haasnoot et al. 2013). This introduces elements of uncertainty and diversity, stressing the iterative nature of implementation. The BASE process tool recognises this through the need for reflection on changing external conditions. Such reflection can be supported by revising the story lines and populating them with concrete examples. This stresses the close connection between implementation and monitoring. It also helps to improve the story lines so that stakeholders can relate to them in progressing with adaptation.

Monitoring and evaluation are stressed both in the Climate-ADAPT support tool and the dynamic policy pathway approach (Haasnoot et al. 2013). The main objective of monitoring and regular review is to ensure that adaptation remains effective. The difference between the approaches is that guiding policy pathways requires greater attention to external conditions that signal the need for a policy change. By making the policy alternatives explicit it is possible to use monitoring and evaluation not only to maintain the effectiveness of adaptation actions but also to inform a wider social debate over what kind of adaptation should be favoured. Such a debate is particularly important for addressing political risks (Gibbs 2016) but also for framing adaptation in a wider sustainability discourse (Wise et al. 2014).

The development of the BASE process tool has not been based on empirical monitoring or ex-post evaluation, but it will be an important element in future applications. The specific findings at the level of sectors and cases (Chapter 4) allows those responsible for adaptation policies at different levels to focus their activities on salient features of the adaptation process. By placing adaptation in a wider framework of climate projections and socio-economic development (Chapter 3) the process tool helps in identifying relevant causal mechanisms.

7 Conclusions

The BASE process tool and its application in this deliverable has shown that findings of modelling, carefully examined cases and the RCP-SSP story line framework can be brought together to inform adaptation governance and policy development. Absar and Preston (2015) have argued for a Factor–Actor–Sector framework to reveal challenges and opportunities associated with the use of the SSPs and to explore the implications of alternative sub-national socioeconomic futures. The approach of the BASE process tool provides an analogous triangulation of information that fulfils the need for downscaling of the SSPs to support national and subnational adaptation governance. It enriches the downscaling with concrete examples that makes the downscaling tangible and salient for stakeholders as shown by the BASE policy workshop where discussions on cases helped participants to see the consequences of policy choices at the local level and to provide input for policy development.[19]

None of the individual pieces of information provides a sufficient knowledge base for developing adaptation governance. By using the diverse pieces of information in a process tool that places them in the general frame of story lines, both practical and broader policy adaptation pathways can be identified at different levels of governance from the local to the European level. The implementation of adaptation pathways will have to be dynamic, recognising that not only climate change but also wider socio-economic and technical developments will determine the feasibility and effectiveness of specific adaptation actions.

There is therefore a need for reflexive learning that regularly revisits the underlying assumptions and conclusions on how to steer adaptation. The interviews conducted with stakeholders saw a merit in using story lines to facilitate communication, especially with non-experts.[20] The BASE process tool is in particular intended for dealing with a wealth of heterogeneous pieces of information that can be very confusing and internally inconsistent when used individually. By placing the information in a wider framework it is easier to identify general patterns, robust policy measures and justified deviations from the general pattern.

The practical application of the BASE process tool has shown that it is challenging to combine many layers of information even within a systematic framework. The different pieces of information do not always fit and there is a need for expert judgement and reflection. This calls for participatory policy development that the BASE process tool can support. At the local level, where ‘here and now’ are dominating, climate uncertainty as reflected in the RCPs plays a role, but already existing problems are the real driver. For the local level the BASE process tool may provide some

[19] BASE policy recommendations, summer 2016

[20] Internal documents summarizing interviews

background information, but in most cases it is likely that many decisions first and foremost reflect the case specific context. Policies may, however, constrain the degrees of freedom in making decisions.

In testing and evaluating future plans for adaptation it is essential to examine the scale of their applicability, the flexibility needed for responding adequately to local or regional deviances from the general development either in terms of climate change or in terms socio-economic development that affects the impacts or possibilities to respond to climate change. The BASE process tool provides a framework for the testing and evaluation. The tool itself is generic and flexible. It is not a simple recipe for successful testing and evaluation and must therefore be adapted to the specific challenges. It also needs to be developed further in the light of accumulating findings from the monitoring of adaptation plans and policies. The ex-post monitoring and evaluation may help to reduce the complexity of the tool by identifying the main features that change in the temporal scale of interest.

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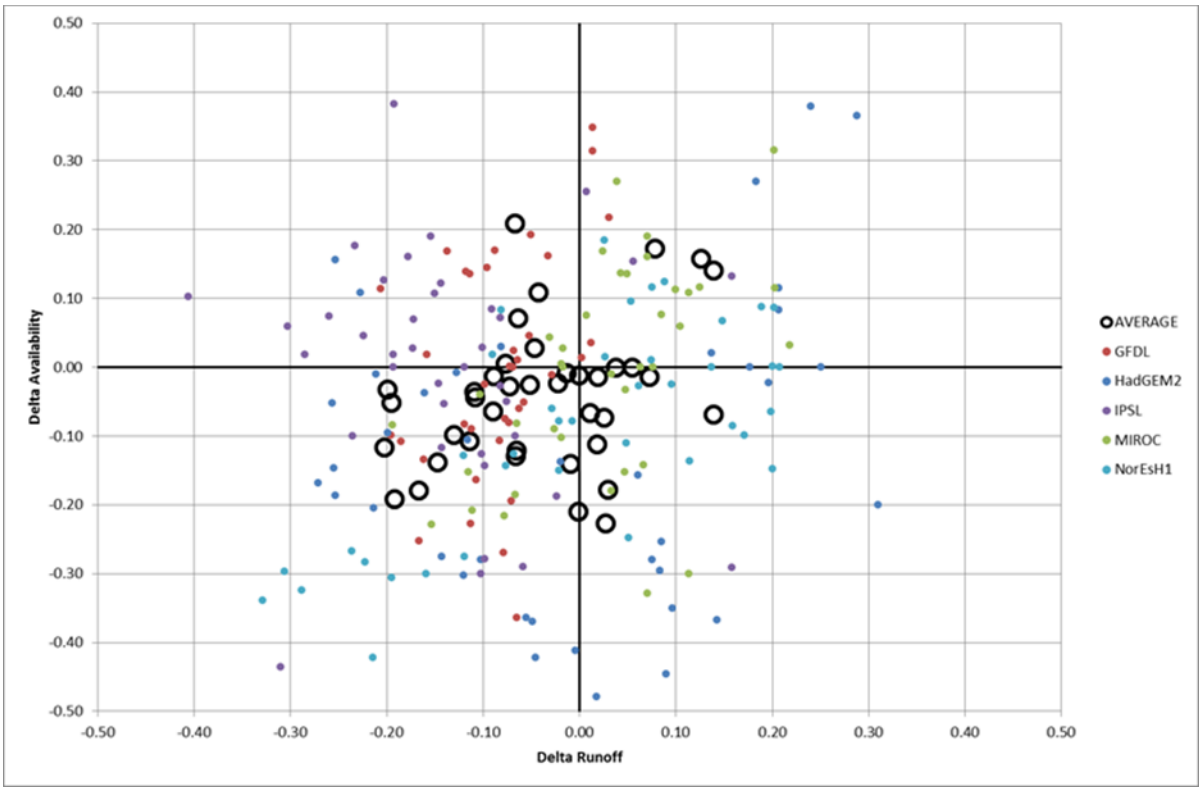
Appendix 1. Explanation on the water availability analysis.

Table 3 shown in section 4.4 presents results by country in a comprehensive way. Changes in runoff and changes in availability are both considered. For some countries, with little storage, changes in runoff are more relevant than changes availability (as calculated by the model WAAPA) for water management. In fact, water availability is only relevant if there is a significant reservoir storage and most water uses depend on it.



The analysis shown in table 3 is based on 5 indices: (1) quadrant, (2) intensity, (3) average risk, (4) agreement and (5) global risk. The meaning of these indices is explained below:

Quadrant

Countries are classified according to the projected average changes in runoff (horizontal axis) and water availability (vertical axis), according to the following criterion:

- 1st quadrant (positive change in runoff and positive change in availability): 2
- 2nd quadrant (negative change in runoff, but positive change in availability): 1

- 3rd quadrant (negative change in runoff and negative change in availability): -2
- 4th quadrant (positive change in runoff, but negative change in availability): -1

The first column in Table 3 shows this classification

Intensity

The intensity index is linked to the distance to the origin os the projected changes (the farther from the origin the more intense the effect). The distance is normalized by 0.2, meaning that a value of 20% change is taken as a reference value of 1 for the index. This is the second column in table 3, where the maximum value is (for scenario RCP8, long term) 2.5

Average risk

The third index is an estimate of risk corresponding to average projections. This index obtained by multiplying the two previous indices: quadrant and distance. The result is a classification that ranges from -5 (most damage) to +3 (most benefit), shown in the third column of table 2.

Agreement

The fourth index is an estimate of the level of agreement of projections made with different GCMs. It is based on the mean distance from each individual model projection to the average projection. The index is computed by dividing the average value of mean distance for all countries by the mean distance of the specific country. This would give a value of 1 (neutral) to projections made with average agreement among models, values less than one (less confidence) to projections made with less agreement than average among models, and values greater than one (more confidence) to projections made with more agreement than average among models. The range of values goes from 0.4 to 2.3. This index is shown in the fourth column of table 3.

Global risk

Finally, the global risk index is computed by multiplying the index obtained with average projections by the agreement index. This implies that the benefits or risks are reinforced if there is agreement among model projections. Values in the final column of table 3 range from -7 to +6. Red colors dominate this column, showing that, in general, projections imply less water availability..

Appendix 2 Case studies and Storylines

Validation of storylines with cases

Topic	Storyline	Northern and Arctic	Cases	Storyline cases	North-Western	Cases	Storyline cases	Central and Eastern	Cases	Storyline cases	Southern-Mediterranean	Cases	Storyline cases
Management of urban areas	Market driven development (SSP5 / RCP8.5)	Large investments to reduce vulnerability in existing and rapidly expanding urban areas	Kalajoki	Expansion of dykes and other permanent stuctures and consideration of additional measures for regulatory capacity to protect expanding urban areas and in particular to deal with potential winter floods. Land use regulations to direct new buildings.	Large (private) investments to reduce vulnerability in existing and rapidly expanding urban areas	Copenhagen Leeds	(A) Impacts for city will increase exponentially, significant increase of blue and grey adaptation in city required. Implementation will rely heavy on private sector (A) focus on grey infra development, high potential damages, most development in risky floodplains. Less interest in EBA approaches. There are some ad hoc green city actions, but the government is not supporting this with policy.	Investments to reduce vulnerability in existing and expanding urban areas	Prague	(A) further development of flood protection system. Also emphasis on green measures. New spatial developents in accordance with risks (B) higher average benefits	Investments to reduce vulnerability in existing and expanding urban areas	Cascais Venice	More pressure and reinforcement to implement adaptation due to increase cost associated with more severe climate and higher urbanisation (higher potential damage) More costly solutions needed due to tourist increases. Low income households do not have access to solutions. Tourists will drive local residents from centre, and creates income possibilities for middle class SLR requires increased investments in large scale protection
	Middle of the road (SSP2 / RCP4.5)	Investments to reduce vulnerability in existing and expanding urban areas	Kalajoki	Moderate increase in population of municiplaities in case study area (estimate of Statistics Finland http://tilastokeskus.fi/tup/seutunet/ouluetela_vaesto.html), improvement of flood protection. Land use regulations to direct new buildings.	Investments to reduce vulnerability in existing and expanding urban areas	Copenhagen Leeds	(A) adaptation policies will match increasing challenges. Intensity of urbanisation might put additional pressure on soundness and sufficience of adaptation plans The inequality between rich and poor increases and limited government investment goes to greening cities.	Investments to reduce vulnerability in existing and expanding urban areas	Prague	(A) demand for protection will increase . New spatial developments in accordance with risk (B) higher average benefits	Investments to reduce vulnerability in existing and expanding urban areas	Cascais Venice	slow spread of adaptation activities due to focus on mitigation investments. However, higher rates of urbanisation and more extreme climate will strengthen the need due to higher damage curves Maintenance of MOSE or alternative projects is in place
	Fragmentation (SSP3 / RCP8.5)	Management for low or no cost reduction of vulnerability in existing urban areas	Kalajoki	Urban areas unlikely to expand significantly, may even decline. Search for low cost solutions to maintain current flood protection.	Management for low or no cost reduction of vulnerability in existing urban areas	Copenhagen Leeds	(A) more severe challenges of flooding. Due to lack of economic means only few sectors are climate proof. n/a	Management for low or no cost reduction of vulnerability in existing and depopulated urban areas	Prague	(A) Prague will still have enough resources to implement adaptation. Only for high priority. Focus on efficient risk management and early warning system (B) benefits could be significant lower	Management for low or no cost reduction of vulnerability in existing and expanding urban areas	Cascais Venice	Assumes decreased revenues from the tourist sector + decreased population will lead to a slow down of adaptation activities due to economic pressures and lower damage curves SLR requires investments. Resources are limited. No maintenance of MOSE project, lower lying areas are increasingly abandoned
Management of rural settlements	Market driven development (SSP5 / RCP8.5)	Investments to reduce vulnerability especially in expanding periurban areas	Kalajoki	Expansion of dykes and other permanent stuctures and consideration of additional measures for regulatory capacity to protect expanding urban areas and in particular to deal with potential winter floods. Land use regulations to direct new buildings.	Investments to reduce vulnerability especially in expanding periurban areas			Investments to reduce vulnerability especially in periurban areas			Investments to reduce vulnerability especially in expanding periurban areas		
	Middle of the road (SSP2 / RCP4.5)	Investments to reduce vulnerability especially in expanding periurban areas	Kalajoki	Moderate increase in population of municiplaities in case study area (estimate of Statistics Finland http://tilastokeskus.fi/tup/seutunet/ouluetela_vaesto.html), improvement of flood protection. Land use regulations to direct new buildings.	Investments to reduce vulnerability especially in expanding periurban areas			Investments to reduce vulnerability especially in periurban areas			Investments to reduce vulnerability especially in expanding periurban areas		
	Fragmentation (SSP3 / RCP8.5)	Coping with vulnerability especially in periurban areas	Kalajoki	Population in case study are may decline. Search for solutions to maintain current flood protection	Coping with vulnerability especially in periurban areas			Coping with vulnerability in depopulating periurban and rural areas			Coping with vulnerability especially in periurban areas		
Management of hydropower production	Market driven development (SSP5 / RCP8.5)	Optimisation of new opportunities in relation to RES increase	Kalajoki	Changes of regulatory regime in regulated lakes, some small long term benefits	Optimisation of new opportunities in relation to RES increase			Coping with reduction of actual production			Coping with reduction of actual production		
	Middle of the road (SSP2 / RCP4.5)	Optimisation of new opportunities in relation to RES increase	Kalajoki	Changes of regulatory regime in regulated lakes, some small long term benefits	Maintenance of facilities, changing role in relation to RES			Coping with reduction of actual production			Coping with reduction of actual production		
	Fragmentation (SSP3 / RCP8.5)	Development and maintenance	Kalajoki	Adjustement of regulatory regime to better cope with changing floods, potential hydropower losses	Coping with reduction of actual production			Coping with reduction of actual production			Coping with reduction of actual production		
Water management	Market driven development (SSP5 / RCP8.5)	Benefit from reduced spring flood peaks, managing severely increased risks of pluvial flood, also due to increased exposure	Kalajoki	Spring peak may lower due to less snow and extended melting periods, pluvial floods not considered, but the frequency of the formation of ice dams may increase demanding management measures and costs	Managing severely increased risks of pluvial and river floods coping with increased droughts, also due to increased exposure, financial means available	Holstebro Rotterdam	highest NPV due to implementation measure More adaptation activities as flood risk increase (exposure and hazard will increase).Focus on structural measures. Central government will ony arrange flood adaptation and critical infra, other adaptation is subject to private/business initiatives	Managing increased risks of pluvial and river floods coping with increased droughts, limited financial means			Managing severely increased risks of pluvial and river floods coping with increased droughts, also due to increased exposure		
	Middle of the road (SSP2 / RCP4.5)	Benefit from reduced spring flood peaks, managing increased risks of pluvial floods	Kalajoki	Moderate lowering of snow melt flood, moderate increase in risk of ice dams	Managing increased risks of pluvial and river floods coping with increased droughts	Holstebro Rotterdam	high NPV due to implementation measures, but negative NPV with 5% discount rate Large scale investments will be less cost-effective and slow down due to lower cc and socio-economic growth. Adaptation will depend on sectoral initiatives. Focus on non-structural measures	Benefiting from reduced extreme floods, coping with pluvial floods and droughts			Managing increased risks of pluvial and river floods coping with increased droughts		
	Fragmentation (SSP3 / RCP8.5)	Benefit from reduced spring flood peaks, managing increased risks of winter and pluvial floods	Kalajoki	Spring peak may lower due to less snow and extended melting periods, pluvial floods not considered, but the frequency of the formation of ice dams may increase demanding management measures	Managing increased risks of pluvial and river floods coping with increased droughts, limited financial means	Holstebro Rotterdam	n/a Flood probability increases, but flood risk is mitigated due to decrease of exposure (less population, economic growth). Less financial means, Small, local adaptation is implemented instead of large scale (climate proof buildings, evacuation and green infra)	Managing increased risks of pluvial and river floods coping with increased droughts, limited financial means			Managing increased risks of pluvial and river floods coping with increased severe droughts, limited financial means		
Management of agriculture	Market driven development (SSP5 / RCP8.5)	Introduction of new cultivars, benefiting from expanding growing season, coping with pests, increasing world market prices	Kalajoki	Domination of animal husbandry, productivity of fodder increases, benefits from increasing global demand of meat							Managing increasing temperatures and droughts, some benefits from changing seasons	Doñada, Guadalquivir Basin	Technological measures dominate and governance measures may be optimised, as rural population has other choices besides agriculture. Less barriers to implement adaptation due to decrease of rural population
	Middle of the road (SSP2 / RCP4.5)	Introduction of new cultivars, benefiting from expanding growing season, coping with pests	Kalajoki	Domination of animal husbandry, modests increase of fodder productivity	Introduction of new cultivars, benefiting from expanding growing season, coping with drought and pests			Introduction of new cultivars, benefiting from expanding growing season, coping with drought and pests			Managing increasing temperatures and droughts, some benefits from changing seasons	Doñada, Guadalquivir Basin	Organization and governance measures dominate due to low pressure of rural livelihoods. Negative impacts cannot be compensated completely. Positive outcome if adequate technology is implemented
	Fragmentation (SSP3 / RCP8.5)	Limited Introduction of new cultivars, benefiting from expanding growing season, coping with severe pests and increasingly changing other growing conditions	Kalajoki	Animal husbandry dominant, declining prices of products	Limited Introduction of new cultivars, benefiting from expanding growing season, coping with severe pests and increasingly changing other growing conditions			Limited Introduction of new cultivars, benefiting from expanding growing season, coping with severe pests and increasingly changing other growing conditions			Coping with severe water shortage, heat stress and changing other adverse growing conditions	Doñada, Guadalquivir Basin	Large pressure on rural economic development due to increased rural population. Governance and organizational measures difficult due to fragmented policy devl and poor rural population. Large barriers to implement, possibly resulting in small compensation of negative impacts and collapse system
Forest management	Market driven development (SSP5 / RCP8.5)	Increasing growth rate of forests, increasing demand for wood based products, succesful change to a bioeconomy	Kalajoki	In parallel with maintenance of a fossil energy based economy, increasing forest growth is used to develop bioeconomy, investment also in wood and peat based energy production (Bionova 2012, Energy strategy for the region Ylivieska				Management of increased growth and demand for sustainable forest based products, adjustment to changing conditions			Management of droughts, high temperatures and increased forest fire risks.		
	Middle of the road (SSP2 / RCP4.5)	Management of increased growth and demand for sustainable forest based products, adjustment to changing conditions	Kalajoki	Active work to reduce the dependency on fossil energy (Bionova 2012, Energy strategy for the region Ylivieska, http://www.ysk.fi/alltypes.asp?d_type=1&menu_id=9746&menupath=9746#9746)	Management for increasing demand for ecosystem services, adjustment to changing conditions			Management of increased growth and demand for sustainable forest based products, adjustment to changing conditions			Management of droughts, high temperatures and increased forest fire risks.		
	Fragmentation (SSP3 / RCP8.5)	Stagnating to decreasing demand for high value products, extreme events, increasing risks of pest outbreaks	Kalajoki	Maintenance of status quo, declining population and economic activity may reduce use of forests	Management for increasing demand for ecosystem services, adjustment to changing conditions			Stagnating to decreasing demand for high value products, extreme events, increasing risks of pest outbreaks			Management of droughts, high temperatures and increased forest fire risks with scant resources		
						Copenhagen	(A) a stormsurge measure will be a necessity for businesses and citizens						

Topic	Storyline	Northern and Arctic	Cases	Storyline cases
Coastal management	Market driven development (SSP5 / RCP8.5)	Steering coastal development, developing protection for SLR and growing value, benefiting from transport and summer tourism		
	Middle of the road (SSP2 / RCP4.5)	Steering coastal development, developing protection, benefiting from transport and summer tourism		
	Fragmentation (SSP3 / RCP8.5)	Management for coping with extreme events, limited benefits		
Management of health care	Market driven development (SSP5 / RCP8.5)	Management of health system to help rapidly increasing elderly population to cope with heat waves and other extreme events, benefiting from reduced risk of cold. Dealing with increased risks of vector borne diseases		
	Middle of the road (SSP2 / RCP4.5)	Management of health system to help Increasing elderly population to cope with heat waves, reduced risk of cold		
	Fragmentation (SSP3 / RCP8.5)	Management of health system with declining resources to help rapidly increasing elderly population to cope with heat waves and other extreme events, benefiting from reduced risk of cold. Dealing with increased risks of vector borne diseases		
Biodiversity management	Market driven development (SSP5 / RCP8.5)	Management benefiting from strengthening of southern species, but facing decline of northern species and habitats with scant resources. Intensification of use of forest and mineral resources	Kalajoki (water quality)	Intensified agriculture coupled with changing climate increases nutrient loading, but means exist to counter adverse changes
	Middle of the road (SSP2 / RCP4.5)	Management for balancing different ecosystem services increasing connectedness to address vulnerability,	Kalajoki (water quality)	Changing climate increases nutrient loading, but means to counter adverse changes are actively developed
	Fragmentation (SSP3 / RCP8.5)	Management benefiting from strengthening of southern species, but facing decline of northern species and habitats with scant resources	Kalajoki (water quality)	Changing climate increases nutrient loading, and means to counter adverse changes are reduced
Development and diffusion of green innovations	Market driven development (SSP5 / RCP8.5)	Despite fossil fuel dominance, investment in large-scale innovations for sustainable and resilient resource efficiency of renewable natural resources.	Kalajoki	Multicriteria consideration of alternative solutions for adaptation, emphasis on preservation of cultural landscape
	Middle of the road (SSP2 / RCP4.5)	Managing innovations for sustainable and resilient resource efficiency of renewable natural resources	Kalajoki	Multicriteria consideration of alternative solutions for adaptation, emphasis on preservation of cultural landscape
	Fragmentation (SSP3 / RCP8.5)	Management of climate change related innovation potential with constrained resource base	Kalajoki	Little resources available for innovative solutions

Topic	Storyline	North-Western	Cases	Storyline cases
Coastal management	Market driven development (SSP5 / RCP8.5)	Steering coastal development, developing protection for SLR and growing value, benefiting from transport and summer tourism	Timmerdorfer strand - Germany	(A) Increase difficult due to unwillingness to reduce attractivenss for tourists (B) existing protection measures will reach its limits, increased damages (B) nature conservation/green corridor/wetlands will have new tourist infrastructure. Unavoidable damages will increase
			South Devon Coast	More finances and urgency from business to rerouting railway; costs of maintaining reinforcing current defences become untenable
	Middle of the road (SSP2 / RCP4.5)	Steering coastal development, developing protection for SLR, benefiting from transport and summer tourism	Copenhagen	(A) adaptation policies will match increasing challenges. Intensity of urbanisation might put additional pressure on soundness and sufficience of adaptation plans
			Timmerdorfer strand - Germany	(A) additional coastal protection potentially not implemented (B) already implemented adaptation still of high value. Avoided damages will still increase
			South Devon Coast	Climate impacts are manageable and resources available, but limited to high priority and impact. Stronger focus on 'no-regret' measures, with more time to react, focus on repair damage and reinforce existing defences
	Fragmentation (SSP3 / RCP8.5)	Management for coping with extreme events, SLR, limited benefits	Copenhagen	(A) economic means to addresss coastal challenges are significantly limited. Part of infrastructure might deteriorate
			Timmerdorfer strand - Germany	(A) solutions will be difficult, driven by increased number of tourists. Green measures might be an option (B) touristic benefits remain, although competition is increasing (B) limited benefits of already implemented coastal protection, increased damages (B) increased benefits of attractive coastal protection measures due to more tourists
			South Devon Coast	Lack of finance to fund much needed adaptation. High costs of mainataning / reinforcing defences. Railroad will be abandaned eventually, leading to disconnectivity of SW region and abandonement town
Management of health care	Market driven development (SSP5 / RCP8.5)	Management of health system to help rapidly Increasing elderly population to cope with heat waves and other extreme events, benefiting from reduced risk of cold. Dealing with increased risks of vector borne diseases	Jena	No intensification of public climate adaptation activities despite need. Private investments with different interests regarding costs, heat stress and aestetic aspects
			Leeds	most development in risky floodplains. Less interest in EBA approaches. Health is serious issue
			Cornwall	rise of incomes and increase of tourism. Higher temperatures will increase health risks, however technological advancements might be effective
			Cornwall	Although income rises, relative inequality might still lead to increase of mental health. Technological advancement might be beneficial. Extreme event impacts are minimised, reducing mental health risks
	Middle of the road (SSP2 / RCP4.5)	Management of health and DRR systems to help especially an Increasing elderly population to cope with heat waves and other extreme events, reduced risk of cold	Jena	limited resources, but less urgent need for adaptation. Stronger focus on no-regret. Slower increase in heat stress levels
			Leeds	There is more heat stress and local governments take specific actions, health systems are slowly privatised, and tropical diseases appear occasionally.
			Cornwall	Access to healthcare less than in SSP5, leading to lower expenditure on treatments. Moderate tourism increase and moderate temperature increases resulting to higher exposure
			Cornwall	marginal increases in improved mental health through reduced inequalities. Access to healthcare not optimal for some socio-econ groups
	Fragmentation (SSP3 / RCP8.5)	Management of health system with declining resources to help rapidly Increasing elderly population to cope with heat waves and other extreme events, benefiting from reduced risk of cold. Dealing with increased risks of vector borne diseases	Jena	Limited public resources, public adaptation restricted to local activities. Focus on low-cost solutions. Higher level of heat stress acceptance inevitable. Low priced grey measures might be preferred over green measures
			Cornwall	Significant population growth will increase population at risk however reduced tourism. Also reduced access to information on risk/prevention measures
			Cornwall	higher population growth and inequalities increases mental health risks, also due to inequalities in access to health care
Biodiversity management	Market driven development (SSP5 / RCP8.5)	Managing consequences of habitat and species shifts, intensification of land use		
	Middle of the road (SSP2 / RCP4.5)	Management for balancing different ecosystem services increasing connectedness to address vulnerability,		
	Fragmentation (SSP3 / RCP8.5)	Managing consequences of habitat and species shifts with scant resources		
Development and diffusion of green innovations	Market driven development (SSP5 / RCP8.5)	Managing large-scale innovations for sustainable and resilient urban development and renewable energy		
	Middle of the road (SSP2 / RCP4.5)	Managing innovations for sustainable and resilient urban development and renewable energy		
	Fragmentation (SSP3 / RCP8.5)	Management of climate change related innovation potential with constrained resource base		

Topic	Storyline	Central and Eastern	Cases	Storyline cases
Coastal management	Market driven development (SSP5 / RCP8.5)	Coastal management overall a limited issue, management of Baltic coast potential for transport and summer tourism		
	Middle of the road (SSP2 / RCP4.5)	Coastal management overall a limited issue, management of Baltic coast potential for transport and summer tourism		
	Fragmentation (SSP3 / RCP8.5)	Coastal management overall a limited issue, management of Baltic coast for extremes		
Management of health care	Market driven development (SSP5 / RCP8.5)	Management of health system to help rapidly Increasing elderly population to cope with heat waves and other extreme event, benefiting from reduced risk of cold. Dealing with increased risks of vector borne diseases		
	Middle of the road (SSP2 / RCP4.5)	Management of health system to help especially an Increasing elderly population to cope with heat waves and other extreme events, reduced risk of cold		
	Fragmentation (SSP3 / RCP8.5)	Management of health system with rapidly declining resources to help rapidly Increasing elderly population to cope with heat waves and other extreme event, benefiting from reduced risk of cold. Dealing with increased risks of vector borne diseases		
Biodiversity management	Market driven development (SSP5 / RCP8.5)	Managing consequences of habitat and species shifts, intensification of land use	GreenRoof - Czech republic	(A) Lowest development - interest in ecosystem based solutions low, extent of forest cover lowest.. Intensive tourism and economic growth exacerbate ecosystem state (B) negative CBA
	Middle of the road (SSP2 / RCP4.5)	Management for balancing different ecosystem services increasing connectedness to address vulnerability,	GreenRoof - Czech republic	(A) highest level of ecosystem-based adaptation measures (B) highest CBA
	Fragmentation (SSP3 / RCP8.5)	Managing consequences of habitat and species shifts, loss of Alpine species with scant resources	GreenRoof - Czech republic	not evaluated
Development and diffusion of green innovations	Market driven development (SSP5 / RCP8.5)	Managing large-scale innovations for sustainable and resilient urban development and renewable energy		
	Middle of the road (SSP2 / RCP4.5)	Managing innovations for sustainable and resilient urban development and renewable energy		
	Fragmentation (SSP3 / RCP8.5)	Management of climate change related innovation potential with constrained resource base		

Topic	Storyline	Southern-Mediterranean	Cases	Storyline cases
Coastal management	Market driven development (SSP5 / RCP8.5)	Management for coping with extreme events, increasing salt water intrusion , loss of summer tourism	Venice	More costly solutions needed due to tourist increases. Low income households do not have access to solutions. Tourists will drive local residents from centre, and creates income possibilities for middle class SLR requires increased investments in large scale protection
	Middle of the road (SSP2 / RCP4.5)	Steering coastal development, developing coastal protection, loss of summer tourism, benefiting from other seasons	Venice	Maintenance of MOSE or alternative projects is in place
	Fragmentation (SSP3 / RCP8.5)	Management for coping with extreme events, increasing salt water intrusion , loss of summer tourism	Venice	SLR requires investments. Resources are limited. No maintenance of MOSE project, lower lying areas are increasingly abandoned
Management of health care	Market driven development (SSP5 / RCP8.5)	Management of health system to help rapidly Increasing elderly population to cope with heat waves and other extreme event, benefiting from reduced risk of cold. Dealing with increased risks of vector borne diseases	Madrid	Largest benefits of measures due to highest health risks and population growth and an ageing population, risk of late / inefficient implementation measures
	Middle of the road (SSP2 / RCP4.5)	Management of health system to help especially an Increasing elderly population to cope with heat waves and other extreme events	Madrid	Relatively lower benefits of measures due to lower increase health risk and lower population growth
	Fragmentation (SSP3 / RCP8.5)	Management of health system with declining resources to help rapidly Increasing elderly population to cope with extended heat waves and other extreme events. Dealing with increased risks of vector borne diseases.	Madrid	n/a
Biodiversity management	Market driven development (SSP5 / RCP8.5)	Managing consequences of habitat and species shifts, intensification of land use		
	Middle of the road (SSP2 / RCP4.5)	Management for balancing different ecosystem services increasing connectedness to address vulnerability, challenges from invasive species		
	Fragmentation (SSP3 / RCP8.5)	Managing consequences of habitat and species shifts abd prolifereating invasive species with scant resources		
Development and diffusion of green innovations	Market driven development (SSP5 / RCP8.5)	Managing large-scale innovations for sustainable and resilient urban development and renewable energy		
	Middle of the road (SSP2 / RCP4.5)	Managing innovations for sustainable and resilient urban development and renewable energy		
	Fragmentation (SSP3 / RCP8.5)	Management of climate change related innovation potential with constrained resource base		