Climate Change **Adaptation**

Background report to the IA Part I

Problem definition, policy context and assessment of policy options

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1 EXECUTIVE SUMMARY

1.1 Problem definition

The target of the European Union is to stabilize the global mean temperature to 2 °C above pre-industrial levels. However, according to science (e.g. Adger et al., 2007; Copenhagen Diagnosis, 2009) even a global increase of 2°C will result in impacts (and some can be observed already today, e.g. decrease in permafrost extent or glacier melt) to which adaptation will be needed on European to local level.

One of the most important consequences of climate change will be the increase in the frequency and magnitude of extreme events such as floods, droughts, windstorms and heat waves. Climate change may also trigger other hazards in which climate or weather conditions play a fundamental role, such as snow avalanches, landslides and forest fires.

Current and projected impacts in Europe, together with their related costs, suggest that climate change will — either directly or indirectly — test the vulnerability of European society with economic, environmental, societal, geopolitical and technological risks. The security, health and quality of life of European citizens are at the core of the matter and climate change constitutes an additional pressure that challenges most of the components of human and natural systems.

A range of (EU funded and other) projects and exchange with stakeholders have led to an improved understanding of certain aspects of climate change impacts, vulnerabilities and adaptation with potential effects on certain policy areas/sectors which have been assessed in detail in the context of developing an EU Adaptation Strategy and are summarized in the following:

1.1.1 Climate impacts on economic sectors and systems

Climate change and climate variability are projected to have a substantial effect on **agricultural** production both in terms of crop yields (with an overall yield gain in the EU of 17% in 2020) and the location where different crops can be grown. For some areas projections for a range of emission scenarios show a 30- 50% increase in suitable area for grain maize production in Europe by the end of the 21st century). On the opposite crop productivity is expected to decrease where seasonal precipitation decreases significantly such as in the Mediterranean and Southeast Europe.

Effects on **forestry** due to climate change include increased risk of biotic (pests and diseases) and abiotic (droughts, storms and fires) disturbances to forest health. Main potential impacts include: i) Changing tree species distributions in Europe; ii) Northwards and upwards (mountains) expansion of broadleaved deciduous species; iii) Increasing threats for specialized plant communities; iv) Thermophilic plant species becoming more common, while cold-tolerant species decline and v) Indigenous conifers may be replaced in large areas of

Western and Central Europe by deciduous tree having an influence on the quality of water. The impacts of climate change will vary throughout the different geographic regions of Europe, with forest fires likely to dominate in Southern Europe and the limited diversity of tree species in boreal forests enhancing the risk of significant pest and disease impacts.

Consequences of climate change will both be negative and positive for **transportation infrastructure** such as for rail, road, shipping and aviation, but will differ from region to region. In particular, the projected increase in frequency and intensity of weather and climate extremes, such as heavy rain (e.g. causing floods), heavy snowfall, extreme heat and cold, drought and reduced visibility can enhance negative impacts on the transport infrastructure, causing injuries and damages as well as economic losses. But also some beneficial impacts on transport due to climate change can be expected, such as reduced snow fall for most European regions improving traffic conditions. However, the vulnerability of the transport sector is also influenced by human behaviour and societal changes as the kind of mobility chosen by individuals is also influencing the vulnerability of the sector.

The impact of climate change is particularly pertinent to the **construction sector** given the life expectancy of buildings, both in terms of new developments and the existing built environment to climatic changes. Major threats to construction and buildings requiring short-term action can be aggregated to: i) Extreme precipitation which can be expected European wide (e.g. leading to water intrusion, damage to foundations and basements, destruction of buildings); ii) Summer heat, especially in South Europe (e.g. leading to material fatigue, decreased comfort and health, high energy use for cooling); iii) Exposure of constructions to heavy snowfall and iv) Rising sea levels that increase the risk of flooding in particular as many European cities are located next to the shore or rivers.

Climate threats for the European **energy system** do already exist and are projected to increase. Climate change is and will be impacting the security of electricity supply due to disruption within the distribution grids (e.g. extreme events) but also increased vulnerabilities in the supply (e.g. increased water scarcity will impact bioenergy and hydropower). These impacts will be aggravated due to i) Increasing interconnection of grid-dependent European internal energy market and thus increasing amounts of transmitted energy/less domestic supply in many regions; ii) Projected further shift towards increasing electricity demands and according shifts in primary energy consumption and iii) Increasing share of renewable energy generation.

Climate change will lead to new **disaster risk** 'landscapes' and distribution of hot spots. Economic losses related to different types of disasters in the EU (most prominently heat waves, flooding and storms) show an increasing trend, which is mostly attributed to the increase in vulnerable assets.

1.1.2 Climate impacts on environmental and human systems

For **soils** climate change may aggravate erosion, decline in organic matter, salinization, soil biodiversity loss, landslides, desertification and flooding. The effect of climate change on soil carbon storage can be related to changing atmospheric CO_2 concentrations, increased temperatures and changing precipitation patterns. Extreme precipitation events, fast melting of snow or ice, high river discharges and increased droughts are all climate related events which influence soil degradation. Deforestation and other human activities (agriculture, skiing) also play a role. Saline soils are expected to increase in coastal areas as a result of salt water intrusion from the seaside, because of rising sea levels and (periodically) low river discharges.

There is clear evidence to show that **biodiversity** is already responding to climate change and will continue to do so. Species respond individualistically, with direct impacts including changes in phenology, species abundance and distribution, community composition, habitat structure and ecosystem processes. Climate change is also leading to indirect impacts on biodiversity through changes in the use of land and other resources. These may be more damaging than the direct impacts due to their scale, scope and speed and include: habitat fragmentation and loss; over-exploitation; pollution of air, water and soil; and spread of invasive species. They will further reduce the resilience of ecosystems to climate change and their capacity to deliver essential services, such as climate regulation, food, clean air and water, and control of floods or erosion.

Climate change will impact Europe citizen´s **health**, animal (livestock) and plant (food security) health as well as cause (damage) costs related to direct and indirect health impacts. The most important health effects from future climate change are projected to include i) Increases in summer heat related mortality (deaths) and morbidity (illness); ii) Decreases in winter cold related mortality (deaths) and morbidity (illness); iii) Increases in the risk of accidents and wider well-being from extreme weather events (floods, fires and storms); iv) Changes in the disease burden e.g. from vector-, rodent-, water- or food-borne disease; and v) Changes in the seasonal distribution of some allergenic pollen species, range of virus, pest and disease distribution.

For **inland water,** floods, droughts and water scarcity have already affected large parts of the EU and have an important impact on socio-economic developments. In the future, climate change is likely to change water availability and global warming will probably increase both the number and magnitude of hydrological extremes. Under a scenario that assumes that current socio- economic developments will remain, the percentage of area under severe water stress is expected to increase in all regions until 2050, with major changes in particular in Eastern, Western, and Southern Europe. Increasing water withdrawals are the main cause in Eastern and Western Europe. In Southern Europe a decrease in water availability due to climate change exacerbate the situation. Overall, this situation is most severe during summer when river flows are low and will decrease further due to climate change. Extreme flood events are expected to increase in Eastern Europe, leading to loss of life and higher flood damages.

Climate models, confirmed by current observations, suggest that climate change will have a profound effect on **coastal zones** and marine areas through i) Sea level rise between 0.18m and 0.58m by the end of 21st century; ii) Changes in ocean currents; iii) Coastal erosion (expected to increase due to climate change through the above mentioned sea-level rise as well as increased frequency in storms); iv) Sea surface temperatures; v) Eutrophication and vi) Ocean acidification. The potential changes to coastal zones and marine areas will not only affect aquatic flora and fauna, but also coastal economic development and human well-being. Increases in sea-level have the potential to negatively impact economic growth as well as destroy physical infrastructure such as housing and roads.

1.1.3 Climate impact on social issues

The impact of temperatures increase, changes in precipitation regimes and sea-level rise will affect – directly or indirectly – **productivity and viability** of nearly all economic sectors across the EU. Rising temperatures and erratic weather pattern will in many places reduce the land and natural capital productivity. More frequent and intense heat waves, and altered transmission seasons and geographic range of important vector-borne diseases will lower labour productivity. As a result of sea level rise and increased intensity of climate extremes, physical capital assets will be more frequently impaired and important lifelines disrupted with wide reaching economic and social consequences. The GDP losses in the most affected EU Member States may top 9% in 2050 if the world is to warm up by 4°C. Agriculture, tourism and ecosystem services provision are among the most concerned sectors.

With respect to **food security**, the FAO has stated that the climate change influences on global food production and security are likely to be insignificant. For many years the EU has been a net food importer. Today the EU's overall trade is in fairly close balance (livestock and cereals), for many product groups the EU still remains a substantial importer (Fruit, vegetables, cotton, tobacco, oilseeds and oils). Raising food prices could become a concern. A study by Parry et al. (1999) suggests that a reduction in agricultural production due to increasing temperatures and associated impacts could lead to an increase in food prices and higher risk of hunger particularly in arid and sub-humid tropic areas. In the case food prices rise dramatically, the EU could increase the agricultural area used for growing cereals; in particular, by cultivating abandoned land or shifting from biofuel and livestock production to more cereals.

Climate change impacts might affect people's **daily lives** in terms of employment, housing, health, water and energy access as well as the implementation of gender equality and other human rights. However these impacts are not too well understood at the EU level. Research leads to the conclusion that the people most vulnerable to social impacts of climate change will be those: living in places at risk; already socially deprived (e.g. by poor health, low income, inadequate housing, lack of mobility); or disempowered (by lack of awareness, adaptive capacity, support services and exclusion from decision-making).

1.1.4 Climate impacts on the private sector

The **private sector** is defined as privately owned or controlled companies, organisations and entities. Climate change will have a range of impacts on businesses. Impacts are expected to fall disproportionately on SME's including disrupting business operations, property damage, disruption to supply chains and infrastructure leading to increasing costs of maintenance and materials, and raising prices. In other cases, climate change may also offer new business opportunities for products and services that would help people to adapt in the form of expanding market share and creating wealth in communities (innovation and job creation) and accessing new finance streams (increased public funding and financial products and services).

1.2 Main arguments stressing the need of an EU Adaptation Strategy

The key rationale for an EU adaptation strategy can be summarised as follows:

- There is an issue of economies of scale in the case of capacity-building, research, information and data gathering and knowledge transfer. Further there is a huge potential for fostering experience exchange and learning from each other.
- Climate policy 'mainstreaming', 'proofing' and 'integration' are increasingly important in EU policy making, reflecting the view that adaptation to climate change cuts across various policy areas/sectors that are affected by climate change. Thus, to allow synergies and decrease the costs of adaptation, EU instruments in place with relevance for adaptation should be reviewed and modified to cope with current and future impacts of climate.
- Climate impacts and adaptation affect single market and common policies. The private sector is responsible for a large proportion of decisions and investments that determine the resilience or vulnerability of the economy, environment and society to climate change. The private sector has the potential to play a major role in adaptation to climate change as a consumer of adaptation solutions, a provider of financial resources, and a source of innovative products, services (such as insurance services, technical assistance, etc.) and solutions to manage and mitigate risks more effectively. To activate this potential the EU can have a major stake. Furthermore, ensuring that infrastructure as the backbone of economy and free trade is made more climate-resilient is a key issue of European relevance.
- Several climate change impacts and adaptation measures have cross-border dimensions. However cross-border and/or transnational cooperation in developing national adaptation policies is currently almost non-existent Therefore, coordination over different political, legal and institutional settings as well as over different information management approaches and financial arrangements, is needed. This is also important as climate change vulnerabilities and adaptation trigger a new framework for solidarity.
- The lack of human and financial resources and the lack of political commitment/will have been identified as key barriers for adaptation. EU programmes could support Member State resources for adaptation.

1.3 Objectives of an EU Adaptation Strategy

The **general aim** of the EU Adaptation Strategy is to most effectively contribute to a more climate resilient Europe. This means enhancing the preparedness and capacity to respond to the impacts of climate change of the EU, its Member States and regions, focusing in particular on transboundary issues and sectors that are closely integrated at EU level through common policies.

To meet this general aim, three specific objectives have been identified, each one broken down into two operational objectives.

1. **Better informed decision making**: the EU Adaptation Strategy should further the understanding of adaptation, improve and widen the knowledge base where knowledge gaps have been identified and enhance dissemination of adaptation-related information.

2. **Increasing the resilience of the EU territory**: the EU Adaptation Strategy should promote adaptation action at sub-EU level, and support and facilitate exchange and coordination. In doing so, the Strategy should address cross-border climate impacts and adaptation measures.

3. **Increasing the resilience of key vulnerable sectors:** the EU Adaptation Strategy should develop initiatives for a consistent and comprehensive integration of climate change adaptation considerations into sectors that are closely integrated at EU level through common policies.

1.4 Problem definition, policy options and assessment of main economic, environmental and social impacts

In analysing the challenges of EU adaptation efforts and climate change impacts, specific problems were identified which are critical in taking forward action to meet the general aim and specific objectives of the EU Adaptation Strategy. It is assumed that none of the problems will be solved by 2020 without specific EU action. In order to address each problem the following policy options are proposed and assessed in terms of economic, social and environmental impacts.

The following tables present each of the identified problems with proposed policy options and summarize their main expected impacts.

Table 1: Brief description of problem 1 with corresponding policy options and their main expected impacts

Problem 1: Research, data and knowledge generation			
Brief problem description	**No policy change / No EU action**	**Policy option**	**Main expected economic, social and environmental impacts**
Currently information related to adaptation to climate change is unsystematically collected and processed at different levels. Therefore information is often patchy and several knowledge gaps exist. Further shortcomings relate to data sharing and linking relevant information bases to Climate-ADAPT, un-coordinated overlaps between different research streams of EU funding, varying approaches of modelling climate change impacts and thus not allowing comparability, missing collection of data and information from the national, regional and local level (including the issue of language barriers).	No policy change: • Research on climate change adaptation would remain patchy and un-coordinated and resting with various initiatives without a common approach. • Climate-ADAPT will not link to other information sources as existing technical problems of interoperability are expected to be solved.	Guidance document for developing and setting up interfaces between Climate-ADAPT and other databases	• Avoided costs for data integration into Climate-ADAPT, reduced costs for the end users in compiling and processing data due to increased data availability • Cost savings due to better quality control of data in-put and through making the application development faster and easier • Increased data sharing and cooperation among researchers and data providers
		Develop a knowledge gap strategy in collaboration with MS	• Increased costs for collecting information and organising the process, reduced costs due to better coordination of research funds • Enhanced cooperation among MS, COM and research institutions • Improved knowledge generation in particular in relation to policy needs
		Developing a common climate vulnerability assessment in the EU	• Reduces the options to deal with uncertainty • Lack of funding for those research groups, which do not follow this common approach

Table 2: Brief description of problem 2 with corresponding policy options and their main expected impacts

Problem 2: Knowledge dissemination			
Brief problem description	**No policy change / No EU action**	**Policy option**	**Main expected economic, social and environmental impacts**
Enabling societies to adapt to climate change will require establishing systems that transfer relevant information from the EU to national and down to the local level and vice versa. Climate-ADAPT has been established as a platform to serve the purpose of providing access to and disseminating up-to-date knowledge in climate change impacts and adaptation. Even though Climate-ADAPT already serves as a rich knowledge base, the necessity for further improvements are acknowledged both in terms of content and dissemination activities.	No policy change: ▪ Climate-ADAPT will be further financed under the MFF and the EEA (supported by ETC CCA) will ensure regular maintenance and updating of Climate-ADAPT. ▪ Reporting of generated knowledge to Climate-ADAPT would depend on voluntary efforts by the different research institutes, own resources of the EEA (supported by ETC CCA) and the Commission to collect information and data. ▪ Beyond 2014 it remains unclear how Climate-ADAPT will further develop and which dissemination activities will be carried out. No EU action: ▪ After 2013 Climate-ADAPT is not updated anymore, and so the information currently available	Improve Climate-ADAPT beyond BAU by regular voluntary updates by MS on adaptation activities, information on insurance and business, and on national risk assessment	▪ Avoided costs for data integration into Climate-ADAPT, reduced costs for the end users in compiling and processing data due to increased data availability ▪ Cost savings due to better quality control of data in-put and through making the application development faster and easier ▪ Increased data sharing and cooperation among researchers and data providers
		Set up and liaise with events such as conferences and meetings to support the exchange between science and policy in the field of climate change adaptation	▪ Additional costs for organising new events ▪ increased interaction and exchange between researchers and decision makers
		Propose a legal action to set up national information platforms on adaptation and link them to Climate-ADAPT	▪ Additional costs for reporting and quality assurance ▪ Saved costs for the user for collecting information ▪ Better access and dissemination of information

Problem 2: Knowledge dissemination			
Brief problem description	**No policy change / No EU action**	**Policy option**	**Main expected economic, social and environmental impacts**
	becomes obsolete quickly. ▪ National platforms will gain importance, and data and information related to adaptation will be spread out in various databases at EU and national level.		▪ Reduces the options to deal with uncertainty ▪ Lack of funding for those research groups, which do not follow this common approach

Table 3: Brief description of problem 3 with corresponding policy options and their main expected impacts

Problem 3: Strengthen adaptation efforts at all levels and enhance co-operation			
Brief problem description	**No policy change / No EU action**	**Policy option**	**Main expected economic, social and environmental impacts**
The objective of the EU's Adaptation Framework is to improve the EU's resilience to deal with the impact of climate change. The framework respects the principle of subsidiarity and supports overarching EU objectives on sustainable development. In order to strengthen adaptation, three areas of action have been identified 1) national level, 2) cross-border issues 3) regional and local level. Current adaption efforts take place on all levels of governance but vary in content and approaches and often lack sufficient coordination.	**No policy change:** ▪ Several more Member States will adopt a National Adaptation Strategy. They will likely differ in terms of scope, level of ambition and agreed financing of adaptation measures and also the timeframe for implementation. ▪ Trans-boundary issues will remain a gap in most of the strategies. ▪ Some countries might develop sectoral approaches only, covering only certain sectors, others might include adaptation in existing management plans such as biomass action plan, sustainable development	Guidelines on developing adaptation strategies	▪ Marginal costs for the elaboration ▪ Costs savings can be achieved due to drawing on lessons learned from other MS and state-of-the-art approaches
		Use LIFE+ funding for cooperation and experience exchange in relation to the development and implementation of National Adaptation Strategies and climate risk assessments	▪ All impacts depending on the extent MS take advantage of the funding to exchange information
		Use LIFE+ funding for Lighthouse projects and pilot implementation of cross-sectoral policies	▪ All impacts depending on the extent MS take advantage of the funding to exchange information

Problem 3: Strengthen adaptation efforts at all levels and enhance co-operation			
Brief problem description	**No policy change / No EU action**	**Policy option**	**Main expected economic, social and environmental impacts**
	plans, etc.). ▪ In particular due to the lack of financing on the national level it is assumed that regional and local approaches will prevail. Communities, regions will develop their own approaches, leading to an in-homogeneous pattern of adaptation efforts within a MS. This might lead to greater economic, social and territorial disparities counteracting with the community objectives on cohesion.		

Table 4: Brief description of problem 4 with corresponding policy options and their main expected impacts

Problem 4: Mainstreaming CC adaptation considerations into EU policies			
Brief problem description	**No policy change / No EU action**	**Policy option**	**Main expected economic, social and environmental impacts**
An assessment carried out in the context of the service contract supporting the development of the EU Adaptation Strategy has shown that mainstreaming efforts in some key EU sectors have been achieved in line with what was proposed in the EC 2009 White Paper and beyond. Nevertheless, the assessment also concludes that only a limited number of legislative acts are currently considering climate change. In some areas likely to be affected by climate change mainstreaming has not yet taken place, including social and education policies, tourism, fisheries and trade, in the framework regulating standards and the private sector. In the	**No policy change:** ▪ Mainstreaming activities remain implemented on an ad hoc basis. No priorities in terms of sectors will be set and no specific mainstreaming legislation (e.g. mandatory sectorial coverage) would be proposed. ▪ Under this scenario water, environment, agriculture and forestry would develop their own agendas to integrate climate change. Other sectors such as health, social or fishery will clearly lack behind and only a few legal attempts can be	Listing mainstreaming priorities in EU legislation and policy initiatives by 2020 and engage with relevant stakeholders	▪ Impacts depending on concrete actions proposed, costs are considered as marginal
		Set new calendar for revision of key EU legislation	▪ Impacts depending on concrete actions proposed, costs are considered as marginal
		Institutionalise mainstreaming at EU level by providing guidelines for Commission internal IA procedure on how to consider climate change adaptation considerations for amendments and new EU policies	▪ Impacts depending on the uptake of the option, costs are considered as marginal ▪ Supports mainstreaming at an early stage of policy development ▪ Might reduce maladaptive decisions

Problem 4: Mainstreaming CC adaptation considerations into EU policies			
Brief problem description	**No policy change / No EU action**	**Policy option**	**Main expected economic, social and environmental impacts**
case of energy (only TEN-E), transport (only TEN-T) or health only limited efforts have been achieved so far.	expected. ▪ Due to lack of leadership of the European Commission, Member States would develop their own approaches for mainstreaming leading to increasing disparities between Member States. **No EU action:** ▪ No more mainstreaming takes place in the future. The current achievements (existing legislation and proposals by the Commission) are considered as final. Further mainstreaming will remain an issue to be dealt by the Member States only with the Commission having the role of an observer.		

Table 5: Brief description of problem 5 with corresponding policy options and their main expected impacts

Problem 5: Vulnerability of Infrastructure			
Brief problem description	**No policy change / No EU action**	**Policy option**	**Main expected economic, social and environmental impacts**
Europe´s infrastructure has enormous value, both directly as a capital asset and indirectly as an essential element contributing to a productive economy. The main threats posed by climate change to infrastructure assets include damage or destruction from extreme events, which climate change may exacerbate; coastal flooding and inundation from sea level rise; changes in patterns of water availability; and effects of higher temperature and changing precipitation/river run-off on operating costs, including effects in temperate areas currently characterized by permafrost conditions. Within the EU Adaptation Strategy, only infrastructure related to transport, energy, ICT, buildings and green infrastructure has been further addressed. The above mentioned threats are barely reflected in respective policies at EU level and thus need further attention for future mainstreaming efforts to secure	No policy change: ▪ The proposed TEN-E and TEN-T guidelines will be adopted and that climate change needs to be taken into account for new projects. However, although both guidelines include references to climate change, they do not provide for clear advice on how to consider future climatic change and develop appropriate adaptation measures in practice. ▪ For the transport and energy sector it is assumed that national and regional approaches will prevail, but differ among Member States. ▪ For all constructions falling under EUROCODES it is expected that some Member States will modify their national Annexes.	Mainstream climate change into EU wide standards	▪ Low costs and a high potential to improve climate resilience of infrastructure ▪ Strengthens adaptive capacity and climate impact preparedness and responses in the private sector ▪ Might trigger new studies and increased cooperation among MS and infrastructure operators
		Impose mandatory requirements in terms of resilience of current and future infrastructure projects	▪ Anticipated high investment costs are expected to be outweighed by the long term benefits ▪ Ensures mainstreaming of CC adaptation into construction, transport and energy sectors ▪ Might trigger new studies and increased cooperation among MS and infrastructure operators

Problem 5: Vulnerability of Infrastructure			
Brief problem description	**No policy change / No EU action**	**Policy option**	**Main expected economic, social and environmental impacts**
climate-resilient infrastructure in Europe.	▪ For green infrastructure several EU policies have taken up the issue (e.g. Water Framework Directive, Floods Directive, Biodiversity Strategy, CAP regulation 2014-2020, Cohesion Policy 2014-2020), but the lack of coordination among the above mentioned Directives is unlikely to change under the current situation.		

Table 6: Brief description of problem 6 with corresponding policy options and their main expected impacts

Problem 6: Capture the potential of the market			
Brief problem description	**No policy change / No EU action**	**Policy option**	**Main expected economic, social and environmental impacts**
Climate change exposes the private sector to a range of risks to their operation, profitability and growth opportunities. The impacts from these risks may be systemic (at the whole economy level); sector / industry-wide or company-specific. In the absence of EU action there is an expectation that the gap between those organisations able and willing to take adaptation actions and those left behind will grow. Some of the largest trans-national corporations, and those in certain sectors, have begun to appreciate the potential threat and opportunity presented by climate change. However by 2020 large sectors and a great many small and medium sized enterprises will be unable to make the necessary adaptation measures making them increasingly vulnerable to the effects of unavoidable climate change. In the absence of measures from the EU this gap will widen – creating market obstacles for those left behind.	No policy change: ▪ By 2020 large sectors and a great many small and medium sized enterprises will be unable to make the necessary adaptation measures making them increasingly vulnerable to the effects of unavoidable climate change. In the absence of measures from the EU this gap will widen – creating market obstacles for those left behind.	Engage with commercial banks	▪ Mostly indirect impacts on social, environmental and economic issues ▪ Financial institutions and banks might communicate adaptation-related information with their customers and supply chain partners ▪ Facilitates long-term investment in climate resilience
		Explore market based approaches	▪ Depending on the definition and application of the market based approaches ▪ Can foster ooperation between different authorities but also with the private sector

Problem 6: Capture the potential of the market			
Brief problem description	**No policy change / No EU action**	**Policy option**	**Main expected economic, social and environmental impacts**
		Legislative actions requiring companies to undertake risks assessments along their supply chains	▪ Cost savings if adaptation measures are implemented; ▪ Job creation for certification ▪ No social and environmental impacts are expected ▪ Has the potential to improve climate resilience if the option is taken up in a broader sense and adaptation actions are implemented

1.5 Monitoring and evaluation

The monitoring and evaluation process is based on three main elements: i) Publication of relevant information on Climate-ADAPT, ii) Reporting under Art 16 of the proposal revising the monitoring mechanism established under Decision No 280/2004/EC of the European Parliament and of the Council (EC, 2004a) by replacing that Decision, iii) By 2017, the Commission will publish a report in 2017 on all indicators mentioned below. The aim is to look at the achievements over the first five years of the strategy as part of the mid-term evaluation, and this can be used as the evidence base to inform the revision of the strategy.

The current timeline over which the Strategy will be monitored is from 2013 to 2020. For each of the 3 objectives of the EU Adaptation Strategy indicators are proposed to monitor progress:

- For objective 1: *Better informed decision making* indicators are recommended for i) the take-up of Climate-ADAPT as well as for ii) monitoring the implementation of research activities on adaptation and research dissemination.
- For monitoring objective 2: *Increasing the resilience of the EU territory* indicators are suggested for i) Commission-funded cross-border/multi-Member States projects on adaptation; ii) Cross-border/transnational, national, regional and city adaptation policies published; and iii) Uptake of adaptation measures in Member State policies.
- Indicators for monitoring objective 3: *Increasing the resilience of key vulnerable sectors* include i) EC policy integration, ii) Awareness and capacity of private sector and iii) Market based instruments for adaptation.

2 INTRODUCTION

The European Commission intends to develop a comprehensive EU Adaptation Strategy with the general aim to enhance the preparedness and capacity to effectively address the impacts of climatic change in the EU, its Member States, regions and cities, down to the local level.

The preparation of the EU Adaptation Strategy is supported from December 2011 until February 2013 by the project contract “Support to the development of the EU strategy for adaptation to climate change” (CLIMA.C.3/SER/2011/0026) undertaken by the Environment Agency Austria (EAA) together with AEA Technology plc (AEA), Alterra, FEEM Servizi Srl (FEEM) and Fresh Thoughts Consulting (FT).

The general aim of the project is to provide best support to the development of the EU Strategy for Adaptation to Climate Change. Therefore, the following objectives have been carried out within the support project:

- **Objective 1**: Furthering the understanding of adaptation, improving and widening the knowledge base and enhancing access to adaptation related information → *This objective feeds into objective 1 of the EU Adaptation Strategy: Better informed decision making.*
- **Objective 2**: Support the development of a strategic approach to adaptation action and mainstreaming of adaptation into policies at EU level → *This objective feeds into objective 3 of the EU Adaptation Strategy: Increasing the resilience of key vulnerable sectors.*
- **Objective 3**: Support to the development of a strategic approach to the national implementation of climate adaptation requirements, and support to and facilitation of exchange between Member States, regions, cities and all other relevant stakeholders. → *This objective feeds into objective 2 of the EU Adaptation Strategy: Increasing the resilience of the EU territory.*
- **Objective 4**: Support the development of a strategic approach to capturing the potential of the market, market-based instruments, risk management instruments and the private sector in strengthening adaptive capacity and climate impact preparedness and responses. → *This objective feeds into objective 3 of the EU Adaptation Strategy: Increasing the resilience of key vulnerable sectors.*
- **Objective 5**: Provision of effective direct support and input to the Impact Assessment, the stakeholder consultations and the inter-service consultations and the Communication on the EU Adaptation Strategy.

The background report to the Impact Assessment is split into two parts:

- Part I – Problem definition, policy context and assessment of policy options

Part I of the background document shall inform the IA with information on the problem definition and policy context as well as the assessment of policy options.

- Part II – Stakeholder Involvement

Part II will comprise an overview of all stakeholder consultations and the analysis of the public consultation. Part II will be presented as a stand-alone document.

2.1 Approach used for part I of the background report

The following approach was used in order to provide relevant information for the Impact Assessment as presented in this background report:

A comprehensive **literature review** focused on information available for the European context (e.g. outcomes of project funded by the European Framework Programme, EC service contracts, INTERREG projects, etc.) with regard to capturing state-of-the-art information for Europe. This review has been undertaken for the following policy areas that have been pre-selected by the EC to be addressed by the EU Adaptation Strategy: Agriculture, Rural development and Food security, Forestry, Ecosystem based adaptation and Biodiversity, Soil, Water, Marine and Coastal zones, Construction/Buildings, Transport, Energy, Disaster Risk Reduction, Health, Social issues, Jobs/Employment, Private market, EIA/SEA. The policy areas Cohesion and cities are dealt with in separate EC service contract and are therefore not presented in this background report. The information gathered for all selected policy areas/sectors shall particularly form the basis for the Impact Assessment, inform relevant EU policies for future integration of climate change considerations and further contribute to the knowledge base established with the European Climate Adaptation Platform - Climate-ADAPT[1].

[1] http://climate-adapt.eea.europa.eu/

Further, a dedicated subcontract has been issued to explore the **potential of insurance for adaptation**. Results are presented in chapter 3.7.

Modelling has been performed for the specific question of the cost of inaction as well as costs and benefits of adaptation (cf. chapters 3.1.7. and 3.1.8).

Stakeholder/Experts meetings were seen as important elements in the development process of the strategy with the aim to exchange information and raise awareness in the context of the EU Adaptation Strategy (i.e. capacity building for adaptation) and to get input on expectations and needs. **Stakeholder involvement activities** included lunch seminars with line DGs, workshops with Member States, the private sector and further stakeholder dialogues for specific themes, such as scenarios and climate modelling, standards, insurance and forestry. Interaction and exchange with stakeholders and experts should also provide for quality assurance of the information presented to inform the Impact Assessment. Details of all stakeholder events can be found in Part II of the background report.

The **feedback from the COM services** was an important component in developing the background information for the Impact Assessment. Feedback was gained in two ways: discussions and input at various project meetings (e.g. inception meeting, progress meeting) attended by COM services and feedback in written form in the course of several feedback loops.

2.2 Structure of background report part I

This background report Part I presents the outcomes of the project which are of relevance for the preparation for the Impact Assessment to the EU Adaptation Strategy. The main results can be summarised as follows:

- Information on the problem definition and policy context (for various environmental and human, social and economic issues) (cf. chapter 3);
- Main arguments stressing the need of a EU Adaptation Strategy (cf. chapter 4);
- Objectives of an EU Adaptation Strategy (cf. chapter 5);
- Potential policy options and analysis of potential economic, social and environmental impacts (cf. chapter 6);
- Monitoring and evaluation (cf. chapter 7).

The following Annexes comprise complementary information and background knowledge, detailed tables and model descriptions:

- Glossary (cf. Annex 1);

- Climate change damage costs overview (cf. Annex 2);
- The ICES model (cf. Annex 3);
- The improved AD-WITCH model (cf. Annex 4);
- Relevant climatic drivers and their potential impacts in regard to environmental, economic and social issues per policy area/sector (cf. Annex 5);
- Case studies on jobs and employment (cf. Annex 6);
- Adaptation options per policy area/sector (cf. Annex 7);
- Critical knowledge gaps per policy area/sector (cf. Annex 8);
- Integrating adaptation into EU policies (cf. Annex 9);
- Social impacts of climate change (cf. Annex 10);
- Social influences on adaptive capacity (cf. Annex 11);
- The Munich Re weather loss data (cf. Annex 12);
- Insurance Company Reporting (cf. Annex 13).

3 PROBLEM DEFINITION AND POLICY CONTEXT

3.1 What is the issue or problem that may require action?

3.1.1 Climate scenarios

For analytical purposes it is established practice to work with a number of scenarios to capture the range of possible futures relevant for a specific objective or policy question. In other words, for different sectoral questions different scenarios are available that cannot be compared or combined directly, but can inspire an informed debate about specific future-related questions. Mainly for reasons of time and resource constraints, researchers often only use a limited selection of models and scenarios. E.g., the PESETA project (Ciscar, et al, 2009, 2011) analysed two out of the six IPCC scenarios (A2, B2) for two global circulation models (GCMs), while ESPON Climate (2011)[2] limits the analysis to only one scenario and one GCM-RCM combination. In these studies, possible futures are only partly covered.

For the analysis of potential climate change impacts in Europe, usually the IPCC SRES[3] scenarios are still used for the global socio-economic context (Nakicenovic & Swart, 2000). Even if these scenarios were developed more than ten years ago and have been criticized[4], they can still be considered to capture the range of possible futures in terms of socio-economic development and associated greenhouse gas emissions, and hence they are still providing a relevant context for regional scenarios and a sound basis for long-term climate impact analysis. Their main input assumptions relate to development of population, income and technology, and their output includes energy consumption and greenhouse gas emissions. In 2010, the development of a new set of global scenarios started (Shared Socio-economic Pathways or SSPs) but results are not yet available. The SRES scenarios were used as the basis for new scenarios for other assessments (e.g. the Millennium Ecosystem Assessment, cf. Carpenter, et al, 2005; and the UNEP-GEO, cf. UNEP, 2007) or country specific scenarios (e.g. national scenario exercises in Finland, The Netherlands, and the United Kingdom). In late 2000s, the IPCC adopted an alternative approach to climate scenarios, the so-called representative concentration pathways (RCP) (cf. further down in this chapter).

The uncertainties are large, particularly with respect to precipitation. Figure 1 shows that not only the band width over the coming decades is very wide and includes both increases and decreases of precipitation, but also the effect of mitigation (reflected by the E1 scenario runs) does not lead to a significant departure from the “no-policy” range in the coming decades.

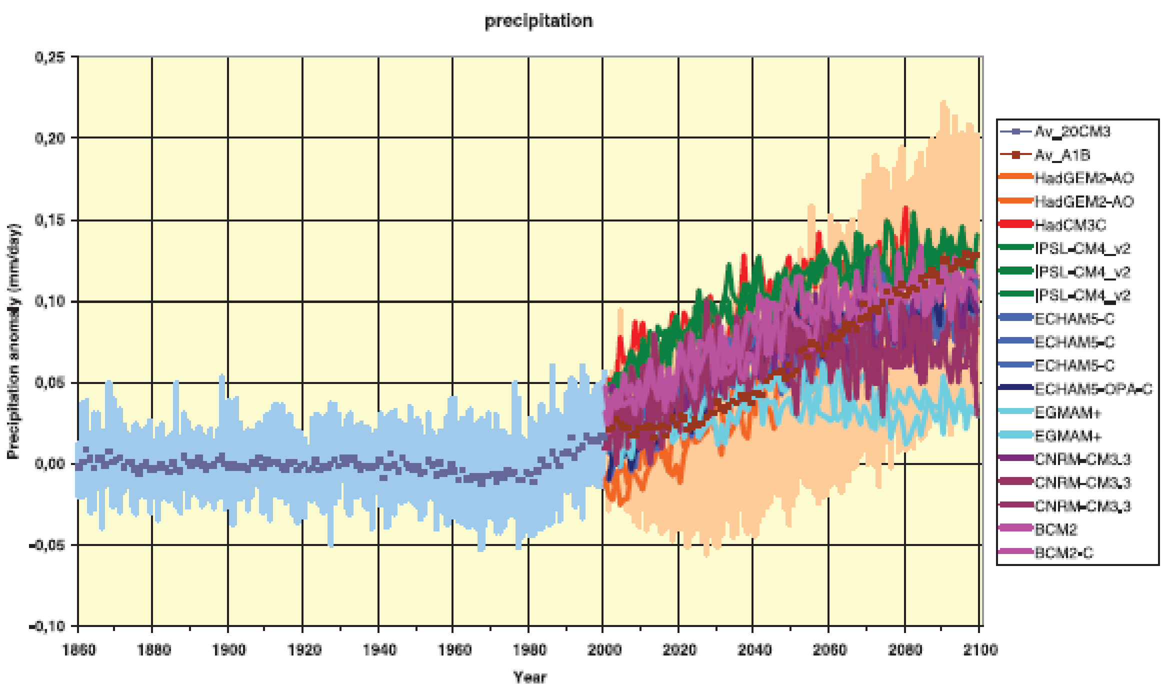
[2] http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/climate.html

[3] SRES: Special Report on Emissions Scenarios, see also http://www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/emission/index.htm

[4] Initially they were suggested to be too high, and later to be too low, but recent analysis suggests that especially at the global level they still very well capture the range of possibilities, while the actual emissions fall within their range (van Vuuren & Riahi, 2008).

The latter also applies to temperature, to a slightly lesser extent. Nevertheless, from the perspective of impact assessment it is important that the signal of the multi-model mean in the ENSEMBLES project is positive in all parts of Europe for near-surface temperature and is much larger than the standard deviation. Therefore the increase in temperature can therefore be interpreted as a robust signal (Goodess, et al, 2009), whereas the attribution of natural disasters to climate change remains a methodological problem.

Figure 1: The global annual mean precipitation in 20C3M, A1B and E1 for the Stream 2 simulations (deviation from 1861–1890 mean). For 20C3M and A1B only, the average and range (minimum and maximum of all models for each year) of the simulations are displayed, and for E1 the individual model runs (Source: Goodess, et al, 2009)



For precipitation, a pattern in Europe with two regimes, roughly spoken increased precipitation in the North and decreased precipitation in the South, can also be interpreted as a robust one. The number of models agreeing on an increasing precipitation signal reaches sixteen out of sixteen for the northern increase, and only two to four out of sixteen disagree with the decrease in the south (Goodess, et al, 2009). More recent regional climate modelling work in the context of the ClimateCost project suggests that uncertainties may be larger than estimated during ENSEMBLES[5].

The uncertainty in projecting future climate change also leads to wide variations in the level of damage costs and also affects the costs and benefits of adaptation (cf. ClimateCost policy

[5] http://www.ensembles-eu.org/

brief 1[6]). Another recent project in which additional regional climate model analysis was done with the objective to explore spatial climate impacts is ESPON Climate (2011), covering only one GCM-RCM combination and one scenario (A1B). Interestingly, ESPON (2011) dropped the initial idea to also analyse the SRES B1 scenario, suggesting that the likeliness of this relatively low emissions scenario would be low, even if it would not meet the formal EU 2 degrees target (Altvater, et al, 2011).

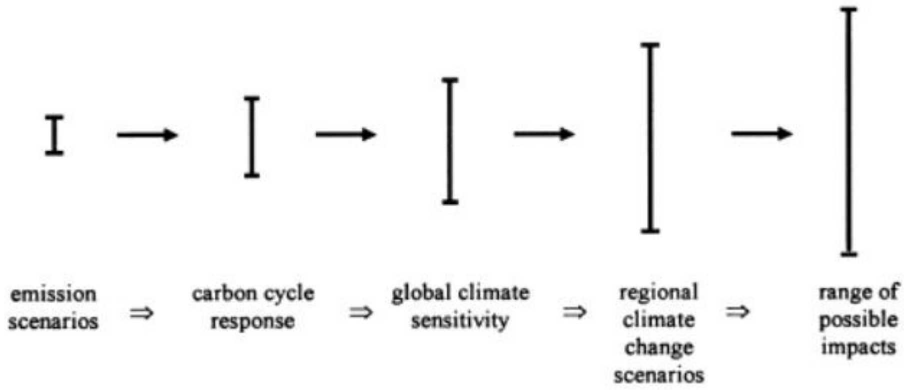
The 'representative concentration pathways' (RCP) depict an alternative approach to developing scenarios. It starts with four future (2100) radiative forcing (i.e. the change in the balance between incoming and outgoing radiation to the atmosphere, caused by changes in atmospheric constituents, such as carbon dioxide) (Moss, 2010). Not only the long-term concentration levels are of interest, the new scenarios consider the trajectories (thus 'pathways') of reaching the predetermined levels. Any given radiative forcing pathway may correspond to multiple emission scenarios that take into account different combination of economic, technological, demographic, policy and institutional drivers. Four RCP scenarios were selected: (1) a very high emission scenario leading to 8.5 W/m2 (watts per square meter), (2) a high stabilization scenario leading to 6 W/m2, (3) an intermediate stabilization scenario leading to 4.5 W/m2, and (4) a low mitigation scenario (2.6 W/m2). The RCP2.6 pathway is representative of mitigation scenarios aiming to limit the increase of global mean temperature to 2 degrees C. Van Vuuren et al. (2011) show that the scenario is technically feasible, if the cumulative emissions of greenhouse gases from 2010 to 2100 are reduced by 70% compared to a baseline scenario. Van Vuuren et al. (2012) provide further details how RPCs can be translated into a set of emissions scenarios.

3.1.2 Uncertainties

Uncertainty has a large variety of sources. It derives from climate models, from the assessment of climate impacts (cf. Figure 2), and from the policy context of decision-making. Some of these uncertainties have to do with imperfect knowledge (called "epistemic uncertainties") other relate to the intrinsic variability in the climate system (called "stochastic uncertainties").

[6] http://www.climatecost.cc/images/Policy_brief_1_Projections_05_lowres.pdf

Figure 2: Cascade of uncertainties: Range of major uncertainties typical in impact assessments showing the "uncertainty explosion" as these ranges are multiplied to encompass a comprehensive range of future consequences, including physical, economic social and political impacts and policy responses (in Moss & Schneider, 2000, modified after Jones, 2000 and the "cascading pyramid of uncertainties" in Schneider, 1983)



The treatment of uncertainty related to climate and climate change has had a fairly recent evolution. Within the IPCC, recent developments have come to put this issue quite high on both scientific and political agendas. In response, the United Nations and the IPCC have recently commissioned a Committee to review and report on the processes and procedures of the IPCC[7]. This report has a full chapter dedicated to the issue of "evaluation of evidence and treatment of uncertainty", where several remarks and key recommendations are made to the IPCC in order to improve the way the Panel deals with and communicates uncertainty. As an immediate consequence and having in mind the planned IPCC Fifth Assessment Report (AR5 -– three volumes to be released in 2013 and 2014), these recommendations were taken into consideration in a "guidance note to authors, on how to consistently treat uncertainties" (Mastrandrea, 2010) recently issued by the Panel.

The AR5 will rely on two metrics for communicating the degree of certainty in key findings (IPCC, 2010):

- Confidence in the validity of a finding, based on the type, amount, quality, and consistency of *evidence* (e.g. mechanistic understanding, theory, data, models, expert judgment) and the degree of *agreement*. Confidence is expressed qualitatively.
- Quantified measures of uncertainty in a finding expressed probabilistically (based on statistical analysis of observations or model results, or expert judgment).

[7] Climate Change Assessments: Review of the Processes and Procedures of the IPCC. Committee to Review the Intergovernmental Panel on Climate Change. InterAcademy Council, Amsterdam, the Netherlands, October 2010. Available at: http://reviewipcc.interacademycouncil.net/report.html

It's not only the IPCC that has, in the past, addressed the issue of uncertainties in relation to climate and climate change research. Several international reviews and initiatives on the issue of uncertainty assessment and communication have been carried out over recent years. Examples of this sort of guidance have been developed not only in fields directly dealing with climate, but also on for several other disciplines:

- In 2008, the U.S. Climate Change Science Program (CCSP) released a Synthesis and Assessment Product (Morgan, et al, 2008) dealing with the methodological aspects of incorporating scientific uncertainty in climate decision making. The primary objective was to provide a tutorial to the climate analysis and decision-making communities on current good practice in describing and analyzing uncertainty in climate related problems;

- In the European landscape within developing and launching the EU Climate-ADAPT platform, specific guidance became available on how to deal with uncertainty in adaptation planning in March 2012[8].

- CIRCLE-2 has started a joint initiative on the issue of dealing with and communicating uncertainties in climate change and climate adaptation[9].

- The UK has a long history in dealing with the question of uncertainties (e.g. Willows & Connell, 2003). The UKCP09[10] provides probabilistic climate projections – different future climate outcomes that have different strengths of confidence associated with them.

- In January 2012, the first edition of the UK Climate Change Risk Assessment (CCRA) has been released – report to be updated every five years. The report addresses over 100 impacts from different sectors.

- A series of reports on "Guidance for uncertainty assessment and communication"[11] were developed in 2003 by the Netherlands Environmental Assessment Agency (PBL) and the National Institute for Public Health and the Environment (RIVM) (Janssen & van der Sluijs, 2003).

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[8] http://climate-adapt.eea.europa.eu/web/guest/uncertainty-guidance
[9] Cf. www.circle-era.eu for more information
[10] http://ukclimateprojections.defra.gov.uk/content/view/1115/500/
[11] RIVM/MNP Guidance for Uncertainty Assessment and Communication Series (2003), RIVM/PBL, Bilthoven, the Netherlands.

3.1.3 Information problems and knowledge gaps

Political decision making should be based on evidence and robust information. Therefore a sufficient knowledge base is needed. Adaptation to climate change is a relatively new policy area where several issues are not fully known yet or the level of information is patchy.

Knowledge gaps clearly limit decision making as they increase uncertainty. Therefore it is important to close these knowledge gaps in the coming years.

During the supporting the development of the EU Adaptation Strategy project's engagement with Member States in 2012, the following barriers related to information and knowledge gaps to developing national adaptation policies were identified:

- **Fundamental understanding of what adaptation is**

Understanding of what adaptation is by decision-makers still remains a barrier, as still mitigation and adaptation aspects are mixed up. Experience in working with stakeholders at regional and local level also shows that there is need to achieve a mutual understand that action they are already undertaking are in fact already adaptation activities without being called adaptation. The lack of knowledge base was identified as a major barrier to developing a national adaptation policy in Central/Eastern European Countries (i.e. collection of other project's data with a new 'label' called adaptation).

It was also reported that there is a lack of understanding of what adaptation is by the scientific community in some countries and that it is not only about action, but having a strong scientific knowledge base behind it to inform planning and decision-making.

- **Partial lack of dedicated research, which is also hard to identify**

Member States, in particular from Southern Europe, highlighted that a rich source of information exists, but is disperse and not easily accessible. Further, research on particular issues relevant to major threats in different parts of Europe is not taken up sufficiently by national research programmes and communities to sufficiently inform the development of adaptation policies.

Also for the private sector the lack of accurate and reliable information often hinders the uptake of adaptation investment because of a lack of awareness of climate-change related risks in the first place and even when awareness exists, the inability to model the risks and their impacts satisfactorily in order to inform investment decisions (cf. chapter 4.5).

In general, critical knowledge gaps that might impede taking action on adaptation can be structured in the following way:

1) Climatic science or socioeconomic scenarios: Knowledge gaps relate to
    - Climatic model limitations
    - Uncertainties related to emission scenarios

- Missing physical understanding
- Land use developments
- Changes in demographic development
- Changes in technology and technological development
- Economic developments
- Migrations developments

The bigger these gaps are, the more difficult it is to conclude on potential impacts.

2) Impacts: Knowledge gaps related to impacts have been further subdivided into:

- Limits in modelling the impacts
- Potential environmental impacts
- Potential social impacts
- Potential economic impacts

Within the knowledge gaps on impacts, a ranking might refer to the magnitude of the impact, the time-frame and the geographical area affected.

3) Adaptation: Knowledge gaps related to adaptation and related measures can be related to:

- Lack of available adaptation benchmark measures
- Lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve
- Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness)
- Lack of knowledge on the impact of adaptation measures on society and economy
- Lack of cost information
- Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures
- Residual damages after adaptation measures
- Factors determining adaptive capacity

In all cases the availability of data is important to consider. The filling of several knowledge gaps requires detailed data for processing, which is often lacking.

A compilation of critical knowledge gaps per policy area/sector that are addressed by the EU Adaptation Strategy can be found in Annex 8.

3.1.4 Main changes in climatic conditions and their likelihood for different regions in Europe

Climate change can cause threats and opportunities for Europe. The main climatic drivers are temperature rise, changes in precipitation patterns, changes in intensity and frequency of extreme weather events (extreme precipitation, heat waves, cold spells, storms), sea level rise and changing wind patterns (Altvater, et al, 2011a).

The average temperature in Europe has continued to increase. Temperature average over the land areas in the last decade (2002-2011) was 1.3°C above the pre-industrial level, which makes it the warmest on record. Annual average land temperature over Europe is projected to continue increasing by more than global land temperature during the 21st century. With the largest temperature increase projected over eastern and northern Europe in winter and over Southern Europe in summer. Extremes of cold have become less frequent in Europe while warm extremes have become more frequent. Since 1880 the average length of summer heat waves over Western Europe doubled and frequency of hot days almost tripled (EEA, 2012c).

Annual precipitation trends in the 20th century showed an increase in Northern Europe (10–40%) and a decrease in some parts of Southern Europe (up to 20 %) (EEA, 2008c; Del Rio, et al, 2011). At the continental scale, winter snow cover extent has a high variability and a non significant negative trend over the period 1967-2007 (Henderson & Leathers, 2010).

High-temperature extremes (hot days, tropical nights, and heat waves) have become more frequent, while low temperature extremes (cold spells, frost days) have become less frequent in Europe (EEA, 2011c) based on Climate Research Unit (CRU) gridded datasets HadCrut3 (land and ocean) and CruTemp3 (land only). In Eastern Europe summer 2010 was exceptionally hot, with an amplitude and spatial extent that exceeded the previous 2003 heat wave (Barriopedro, et al, 2011). These two heat waves revised the seasonal temperature records over approximately half of Europe.

Climate change has far-reaching consequences and is one of the key drivers of global environmental change. Current and projected impacts in Europe, together with their related costs, suggest that climate change will — either directly or indirectly — test the vulnerability of European society with economic, environmental, societal, geopolitical and technological risks[12]. The security, health and quality of life of European citizens are at the core of the matter and climate change constitutes an additional pressure[13] that challenges most of the components of human and natural systems.

[12] Economic risks: volatility in food and raw material prices; under-investment in infrastructure; economic downturn. Environmental risks: droughts and desertification, extreme whether, water scarcity. Societal risks: diseases, pandemics, migration. Geopolitical risks: terrorism, corruption, governance gaps. Technological risks: information gaps (WEF, 2012).

[13] Together with equally important issues such as freshwater extraction, urban sprawl, lifestyles and other forms of socio-economic development and land use changes, agricultural intensification, use of natural capital and loss of biodiversity.7 SOER 2010 Thematic assessment | Adapting to climate change The European environment | State and outlook.

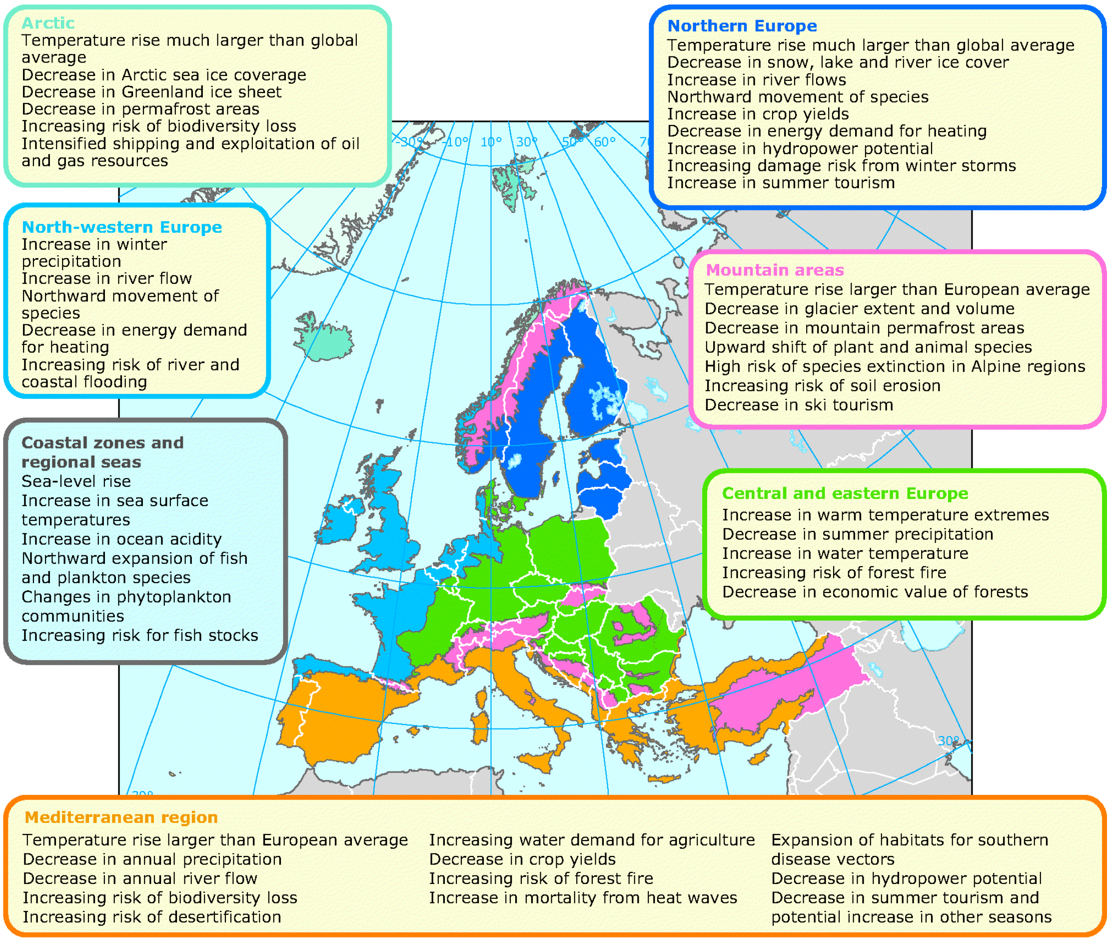
Human systems in Europe are expected to be heavily affected by health problems and fatalities as a result of heat waves, floods, etc.; unbearable costs of damage to communities, infrastructures and the built environment from, for example, droughts and water scarcity; the loss of economic opportunities from, inter alia, lower crop yields. Climate change will directly or indirectly affect all economic sectors, regions and citizens, although to different degrees depending on their coping and adaptive capacities as well as their location. The consequences of climate change will also have feedback effects on socio-economic developments, such as settlement patterns especially in regions and areas that are particularly vulnerable, such as coastal zones, flood plains, mountains and cities as well as the Mediterranean basin and the Arctic.

Drivers of socio-economic development in Europe also have the potential to exacerbate the impacts of climate change. For example land cover and land use changes such as urban sprawl and soil sealing may heighten the effects of floods, heat island effects and heat waves on urban systems or food systems could be impacted by water scarcity.

Natural systems provide vital ecosystem goods and services for many human activities including agriculture, forestry and the supply of clean water (EEA, 2010g).

The impacts of climate change vary considerably across Europe, in terms of the regions, territories and sectors affected (cf. Figure 3). Vulnerable regions include the Arctic, Northern, North-western and Central-eastern Europe, the Mediterranean region, together with cities and urban areas, mountains and many coastal zones and European seas.

Figure 3: Key observed and projected climate change and impacts for the main regions in Europe (Source: EEA Report | No 12/2012: Climate change, impacts and vulnerability in Europe 2012 (EEA, 2012d))



Even a global temperature increase of 2°C by the end of this century would still result in major impacts to which the world and Europe need to adapt. The main past and projected impacts, vulnerabilities and hotspots are (EEA, 2010i):

The Arctic

The Arctic faces major changes including a higher than average temperature increase, a decrease in summer sea ice cover and thawing of permafrost. The reduction of ice cover is accelerating and projected to continue to impact the local natural and human systems. It also opens up business opportunities that could put an additional burden on the environment such as extensive oil and gas exploration and the opening of new shipping routes. Thawing of permafrost has the potential to seriously affect human systems, by, for example, creating infrastructural problems. The fragile Arctic ecosystems have suffered significantly from above average temperature increases and these impacts are expected to continue.

Northern Europe

Projections suggest less snow and lake and river ice cover, increased winter and spring river flows in some parts (e.g. Norway) and decreases in other parts (e.g. Finland), and greater damage by winter storms. Climate change could offer opportunities in northern Europe, at least in the short and medium terms. These include increased crop variety and yields, enhanced forests growth, higher potential for electricity from hydropower, lower energy consumption for heating and possibly more summer tourism. However, more frequent and intense extreme weather events in the medium to long term might adversely impact the region, for example by making crop yields more variable.

North-western Europe

Coastal flooding has impacted low-lying coastal areas in north-western Europe in the past and the risks are expected to increase due to sea-level rise and an increased risk of storm surges. North Sea countries are particularly vulnerable, especially Belgium, Denmark, Germany, the Netherlands and the United Kingdom. Higher winter precipitation is projected to increase the intensity and frequency of winter and spring river flooding, although to date no increased trends in flooding have been observed.

Central and Eastern Europe

Temperature extremes are projected to be a key impact in central and Eastern Europe. Together with reduced summer precipitation this can increase the risk of droughts, and is projected to increase energy demand in summer. The intensity and frequency of river floods in winter and spring (in various regions) is projected to increase due to increases in winter precipitation. Climate change is also projected to lead to higher crop-yield variability and increased occurrence of forest fires.

Mediterranean region

The Mediterranean region has been subject to major impacts over recent decades as a result of decreased precipitation and increased temperature, and these are expected to worsen as the climate continues to change. The main impacts are decreases in water availability and crop yields, increasing risks of droughts and biodiversity loss, forest fires and heat waves. Increasing irrigation efficiency in agriculture can reduce irrigation water withdrawals to some degree but will not be sufficient to compensate for climate-induced increases in water stress. In addition the hydropower sector will be increasingly affected by lower water availability and increasing energy demand, while the tourism industry will face less favourable conditions in summer. Environmental flows, which are important for the healthy maintenance of aquatic ecosystems, are threatened by climate change impacts and socio-economic developments.

Cities and urban areas

In previous years, increasing urban land take and urban population growth have in many places increased the exposure of European cities to different climate impacts such as heat waves, flooding and droughts. The impacts of extreme events such as the flooding of the river Elbe (2002) or the urban drainage flood in Copenhagen (2011) demonstrate the high vulnerability of cities to extreme weather events, even though it is not possible to attribute these specific events to anthropogenic climate change. In the future, on-going urban land take, growth and concentration of population in cities, and an aging population, contribute to increase further the vulnerability of cities to climate change. Urban design, urban management and enhancing green infrastructure may partly address these effects.

Mountain areas

The increase in temperature is particularly large in many mountain regions, where loss of glacier mass, reduced snow cover, thawing of permafrost and changing precipitation patterns, including less precipitation falling as snow, have been observed and are expected to increase further. This could lead to an increase in the frequency and intensity of floods in some mountain areas (e.g. in parts of Scandinavia) that can impact people and the built environment. Additional projected impacts include reduced winter tourism, lower energy potential from hydropower in southern Europe, a shift in vegetation zones and extensive biodiversity loss. Plant and animal species living close to mountain tops face the risk of becoming extinct due to the inability to migrate to higher regions.

The retreat of the vast majority of glaciers also affects water availability in downstream areas.

Coastal zones and European seas

The projected sea-level rise and possible increased frequency of severe storm surges may have major impacts on low lying coastal areas across Europe. Observed and projected increases in sea surface temperature will lead to the northward movement of species and changes in the distribution of phytoplankton biomass. Fish stocks in many seas are already under pressure from over-fishing. Allocations of quotas are based on historic catch patterns and these may need to be revised due to climate change. For further information please cf. chapter 3.2.2.5.

3.1.5 Climate hazards

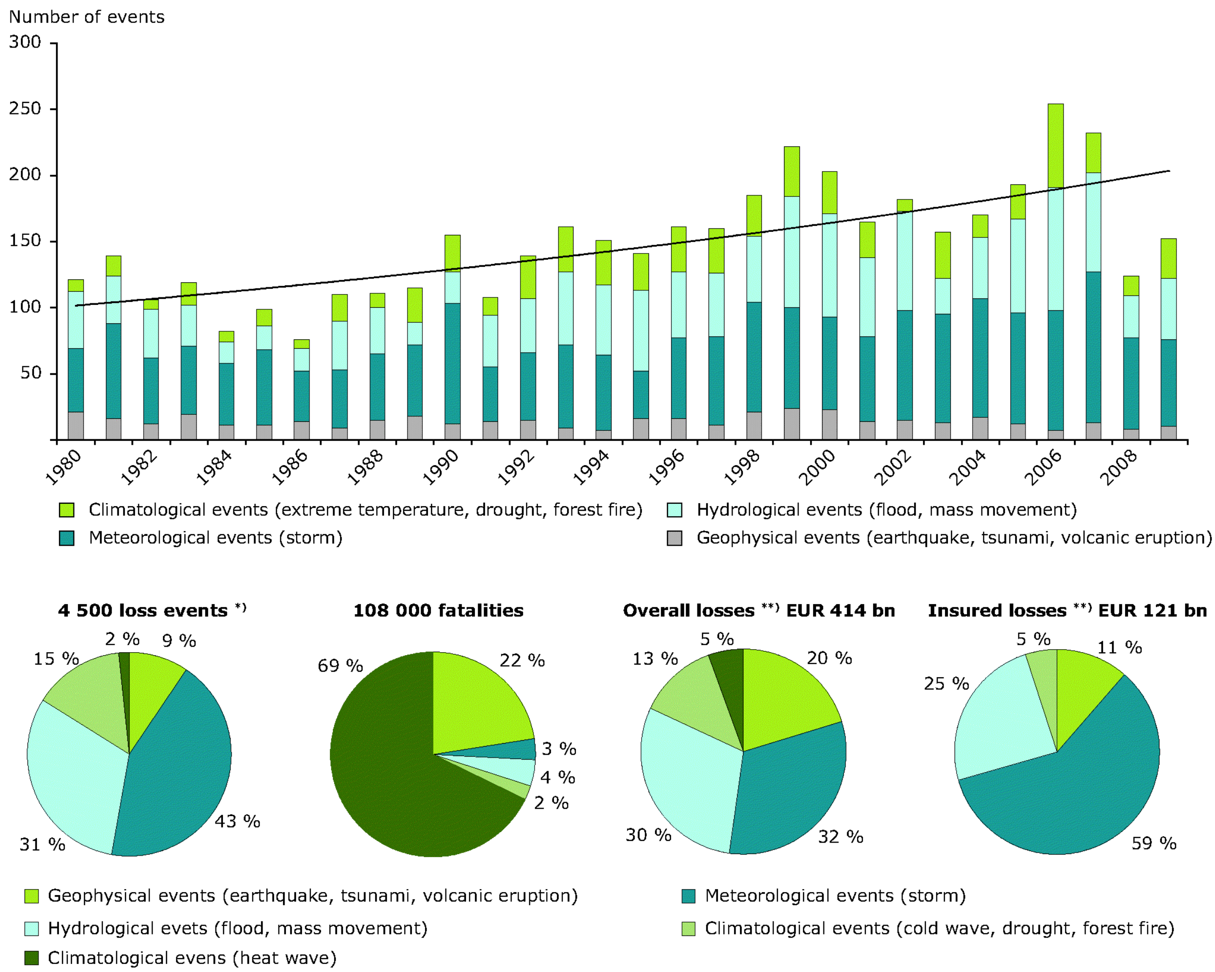
According to the IPCC (2007a), one of the most important consequences of climate change will be the increase in the frequency and magnitude of extreme events such as floods, droughts, windstorms and heat waves. Climate change may also trigger other hazards in which climate or weather conditions play a fundamental role, such as snow avalanches, landslides and forest fires. The recently published special report by IPCC on 'Managing the risks of extreme events and disasters to advance climate change adaptation' (SREX) (IPCC, 2012b) concerns the interaction of climatic, environmental, and human factors that can lead to impacts and disasters, options for managing the risks posed by impacts and disasters, and the important role that non-climatic factors play in determining impacts. On the latter, the SREX emphasizes that character and severity of impacts from climate extremes depend not only on the extremes themselves but also on exposure and vulnerability.

The SREX (IPCC, 2012b) also states evidence from observations gathered since 1950 of changes in some extremes. Confidence in observed changes in extremes depends on the quality and quantity of data and the availability of studies analyzing these data. It consequently varies across regions and for different extremes. The Special Report identifies a likely increase in the frequency of heavy precipitation events or proportion of total rainfall. SREX also identifies, with medium confidence, an increase in the length or number of warm spells or heat waves.

If we compare the projected increase with the present risk we see that climate-related risk already has a prominent role in damage as well as human fatalities. The EEA`s report on the European environment – state and outlook 2010 (EEA, 2010i) shows that according to the NatCatSERVICE (2010[14], cf. Figure 4) about 90 % of the disasters due to natural hazards that occurred in Europe since 1980 and 80 % of the economic losses were caused by hydro-meteorological or climatological hazards. In part, this conclusion may be related to the general absence of major geophysical hazards, such as large earthquakes or volcanic eruptions in Europe, with some exceptions in the North (Iceland) and South (Italy, Greece).

[14] http://www.munichre.com/en/reinsurance/business/non-life/georisks/natcatservice/default.aspx

Figure 4: Disasters caused by natural hazards in EEA member countries, 1980–2009 (Source: EEA, 2010i, based on NatCatSERVICE, 2010[14])



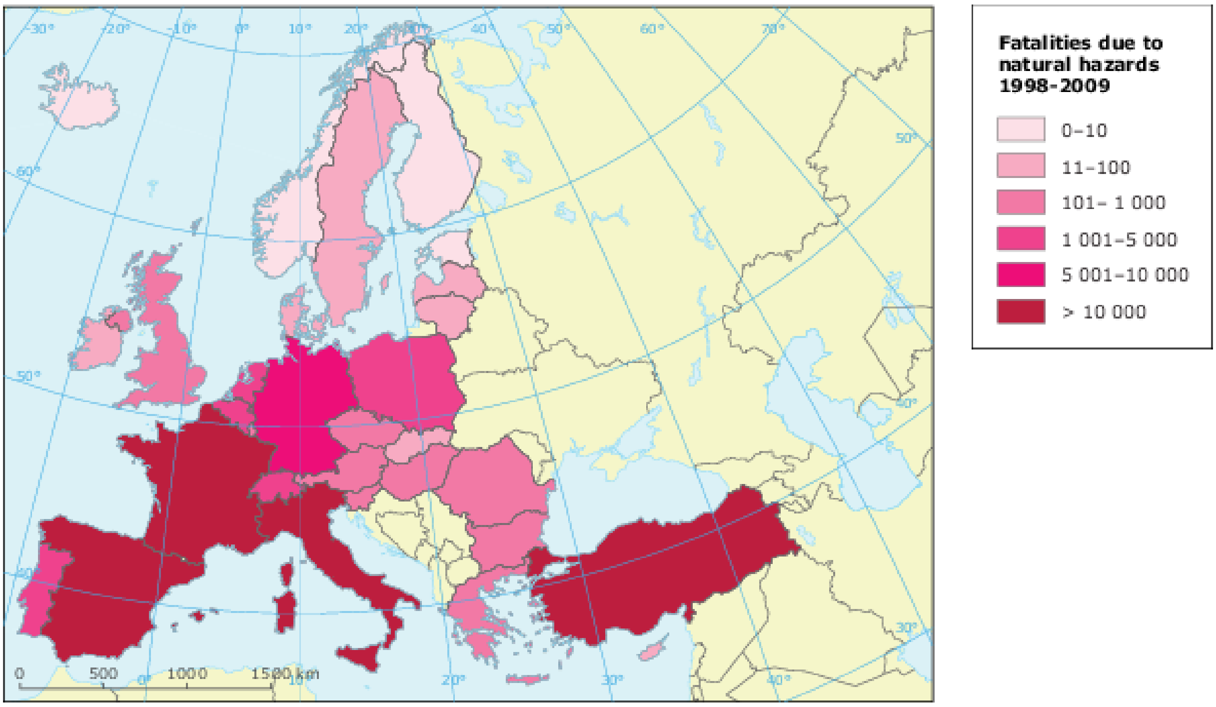
Out of all types of natural disasters, flooding and storm events result the most significant amounts of economic losses relative to other types of disasters in the EU (25% by flooding and 32% by storms). Economic losses due to storms in Europe between 2003 and 2009 are estimated at 20 billion Euro (EEA, 2010f). There is an increasing trend in storm losses which is attributed to socio-economic factors. Economic losses due to major flooding events between 2003 and 2009 were 17 billion Euro (EEA, 2010f). These losses show an increasing trend, which is attributed to the increase in vulnerable assets and not to climate change. The most significant flooding events in terms of economic losses were in the UK in the summer of 2007 (4 billion), in Switzerland, Austria and Germany in 2005 (2.8 billion) and in France in December 2003 (1.6 billion). More than 325 major river floods (including flash floods) have been reported for Europe since 1980, of which more than 200 have been reported since 2000 (EM-DAT, 2012). The rise in the reported number of flood events in the recent decade results mainly from better reporting and from land-use changes. Floods have resulted in more than 2 500 fatalities and have affected more than 5.5 million people in the period from

1980 to 2011. Direct economic losses over this same period amounted to more than EUR 90 billion (based on 2009 values) (EEA, 2012d).

The most prominent natural hazard with regard to human fatalities is heat waves. The heat wave of the summer 2003 claimed lives of a tremendous number of people on the continent, with over 70.000 excess deaths being reported in 12 Western and Central European countries (EEA, 2008c). Heat waves were also responsible for numerous fatalities in the summers of 2006 in Western Europe and the summer of 2007 in Eastern Europe.

The impact of natural hazards in terms of fatalities is not uniform throughout Europe, with France and Italy mourning more than 20.000 fatalities each, followed by Turkey (over 18.000 fatalities) and Spain (more than 15.000 fatalities). The death toll reflects impact of different natural hazards and is thus only informative. Altogether, with the exception of heat waves, human fatalities tend to concentrate mostly in Eastern and Southern Europe (cf. Figure 5).

Figure 5: Number of human fatalities caused by natural hazards in Europe in 1998–2009 as shown in EM-DAT (Source: EEA, 2010i)



The number and impacts of weather and climate - related events increased significantly between 1998 and 2009, while geophysical hazards appeared to have remained more stable (EEA, 2010i). While it is currently impossible to determine accurately the proportion of losses attributable to climate change (EEA, 2008c), the contribution of the climate change factor could increase in future, since climate change is projected to continue.

The SREX report (IPCC, 2012b) finds with a high level of confidence that economic losses from weather- and climate-related disasters have increased in the long-term, as people and economic assets have been increasingly exposed to risks. For example, more people are living where they may be adversely affected by disasters.

The ESPON Climate project shows that a significant driver of potential future disparities is the degree of adaptive capacity for tackling climate change. This is highly differentiated across Europe with peripheral regions in the east and south of Europe showing a low level of adaptive capacity.

3.1.6 Climate change as a multi-sectoral and cross-cutting issue

The consideration of climate change and the development of adaptation strategies has been based on a sectoral approach with the thought that each department needs to "take on climate change" as an additional task (CIRCLE, 2009[15]). However, learning from the experiences of diverse national developments in Europe, interactions between adaptation actions undertaken independently by different policy areas and sectors have the potential to give rise to substantial synergies and conflicts. Table 7 provides an overview of these potential interlinkages. In more detail, interactions are addressed in the description of all policy areas/sectors under chapter 3.2.

Table 7: Interactions between various sectors/themes addressed in the Impact Assessment to the EU Adaptation Strategy in relation to climate change adaptation

Sector/themes affecting others	Agriculture and Food security	Forestry	Ecosystem-based adaptation & biodiversity	Soil and natural resources	Inland water	Marine and coastal zones	Construction/Buildings	Transport	Energy	Disaster Risk Reduction	Health	Social Issues	Jobs/Employment	Private sector, market, insurance, finance
Agriculture and Food security														
Forestry														
Ecosystem-based adaptation & biodiversity														
Soil and natural														

[15] 1st International CIRCLE Workshop on Climate Change Adaptation in Budapest - http://www.circle-era.eu/np4/%7B$clientServletPath%7D/?newsId=252&fileName=CIRCLE_NAS_Workshop_Outcomes.pdf

Sector/themes affecting others	Agriculture and Food security	Forestry	Ecosystem-based adaptation & biodiversity	Soil and natural resources	Inland water	Marine and coastal zones	Construction/Buildings	Transport	Energy	Disaster Risk Reduction	Health	Social Issues	Jobs/Employment	Private sector, market, insurance, finance
resources														
Inland water														
Marine and coastal zones														
Construction/ Buildings														
Transport														
Energy														
Disaster Risk Reduction														
Health														
Social Issues														
Jobs/ Employment														

Since all possible interactions between the direct and indirect impacts of climate change on the environment, society and economy cannot be forecasted precisely, there is a need to focus on flexible adaptation strategies, plans, actions and measures that favour 'no regrets'[16] options to avoid maladaptation[17].

The ability to adapt to climate change is underpinned by the environment, which demands integrated action across all policy areas/sectors of the economy and must be considered in all interventions supported by the EU. Indeed, the EC White Paper on adapting to climate change (EC, 2009a) highlights that it is important for the EU and Member States *"To promote strategies which increase the resilience to climate change of health, property and the productive functions of land, inter alia, by improving the management of water resources and*

[16] Options that would generate net social and/or economic benefits irrespective of whether or not anthropogenic climate change occurs.

[17] Maladaptation is defined by the IPCC (the Intergovernmental Panel on Climate Change) as "a change in natural or human systems that leads to an increase rather than a decrease in vulnerability."

ecosystems". This is further spelt out in the new EU biodiversity strategy to 2020 (EC, 2011b), which goes on to state that *"Ecosystem-based approaches to climate change mitigation and adaptation can offer cost-effective alternatives to technological solutions, while delivering multiple benefits beyond biodiversity conservation"*.

The policy areas/sectors mainly threated by climate change impacts each might follow different objectives leading to proposals for adaptive actions that could potentially create negative side effects for another policy area/sector if not coordinated. Agriculture, water infrastructure and availability, disaster management, health and safe infrastructure (transport, energy) are among the key areas that will have to respond to climate change impacts that have interrelated effects. Thus, effective policy responses need to be aware of the cross-cutting nature of climate change and develop balanced proposals for adaptation action at EU, national, regional and local levels.

There is, therefore, a clear need for coordination across a wide range of political, legal and institutional settings, as well as different information-management approaches and financial arrangements. As existing institutional settings at national level might be challenged by these complex and far-reaching cross-cutting issues, support at a European level is required in order to promote rapid and synergistic adaptation.

3.1.7 The costs and benefits associated with climate change impacts

3.1.7.1 Introduction

In recent years, a number of studies have investigated the costs and benefits of climate change for Europe. Most of these studies have either adopted a sectoral focus, or have assessed the cost of damages in a specific EU country. Studies can be top-down – i.e. assessing the costs of damage from an economy-wide perspective based on economic models, or bottom-up – i.e. estimating the costs of damage in specific sectors.

Several economic reviews are available on the impact of climate change:

- Stern (2006) states that if human society does not act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more.
- Aaheim et al. (2010) assessed the global impact of climate change for the E1 scenario. This scenario closely represents the achievement of the EU target to limit climate change. The conclusion of this report is that the impacts are modest, but unevenly distributed. Under an E1 scenario rich and fast growing regions are expected to gain, while the poorest regions bear the largest losses (Aaheim, et al, 2010).

- For Europe, the PESETA project has calculated the impact of climate change for different sectors. It is one of the few projects that use a consistent set of scenarios and assumptions. The results have been aggregated to the European economy. According to Ciscar et al. (2009) the annual damage of climate change to the EU economy in terms of GDP loss is estimated to be between 20 billion € for the 2.5°C scenario and 65 billion € for the 5.4°C scenario with high sea level rise. The damages in GDP terms underestimate the actual losses (Ciscar, et al, 2009). Currently, a follow-up to the PESETA project is incorporating new climate scenarios and an expanded set of sectoral analyses, but results are not yet available.

- The Conhaz project[18] assessed the costs of natural hazards. This project provides more insight into cost assessment methods, which is needed for integrated planning, budgeting and policy action prioritisation for the various natural hazards but does not produce any values in monetary terms. The project has found that not all cost categories (especially non-market impacts) or impacts on all sectors are sufficiently included in analyses, and more efforts are needed to comprehensively approach the costs of natural hazards. In order to comprehensively capture this variability in cost assessment methods.

An overview of climate change damage costs is given in Annex 2 (Table 52).

Natural disasters can be regarded as key variable of climate impact, i.e. damage costs. Hydro-meteorological events (storms, floods, and landslides) account for 64 % of the reported damage costs due to natural disasters in Europe since 1980; climatological events (extreme temperatures; droughts and forest fires) account for another 20 % (EEA, 2012d). However, it is difficult to determine accurately the proportion of damages that are attributable to climate change. Further, it is important to note that the existing estimates of loss to the natural hazards are to be considered lower bound estimates (IPCC, 2012b) because many impacts, such as loss of human lives, cultural heritage, and ecosystem services, are difficult to value and monetize, and thus are either omitted or only poorly reflected in estimates of losses.

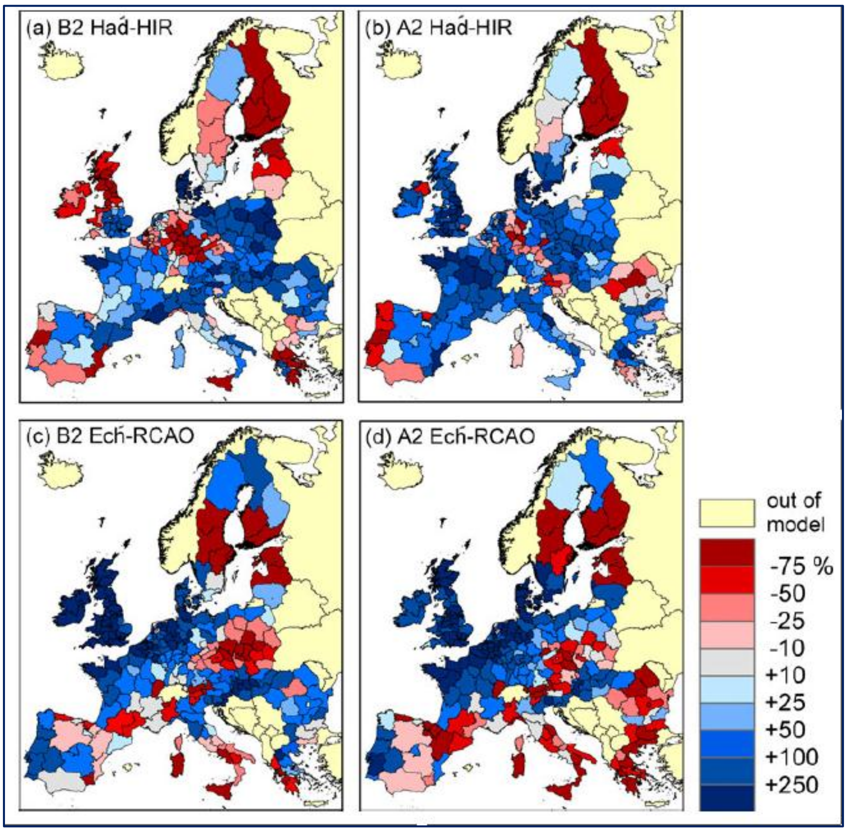
Projections suggest potentially large costs of combined climate change impacts and socio-economic developments in Europe, particularly due to increases in coastal and river flooding, heat waves and energy demand (for cooling). The most costly impacts differ strongly across Europe. In southern parts of Europe the most costly impacts are increases in energy demand and heat waves, in Western Europe coastal flooding and heat waves, in Northern Europe coastal and river floods and in Eastern Europe river floods (EEA, 2012d).

A study conducted by Feyen et al. (2012) indicates for EU27 as a whole, that current expected annual damages (EAD) of approximately €6.4 billion are projected to increase to €14–21.5 billion (in constant prices of 2006) by the end of this century, depending on the

[18] http://conhaz.org/

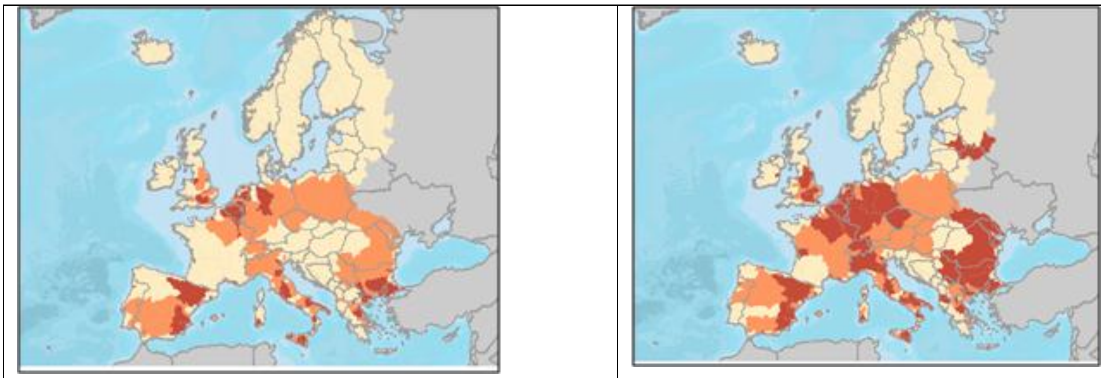
scenario. The number of people affected by flooding is projected to rise by approximately 250,000 to 400,000.

Figure 6: Relative change in expected annual damages (averaged over administrative level NUTS2) between scenario (2071–2100) and control period (1961–1990) for climate scenarios B2 Had-HIR (a), A2 Had- HIR (b), B2 Ech-RCAO (c) and A2 Ech-RCAO (d). Source: Feyen, et al, 2012



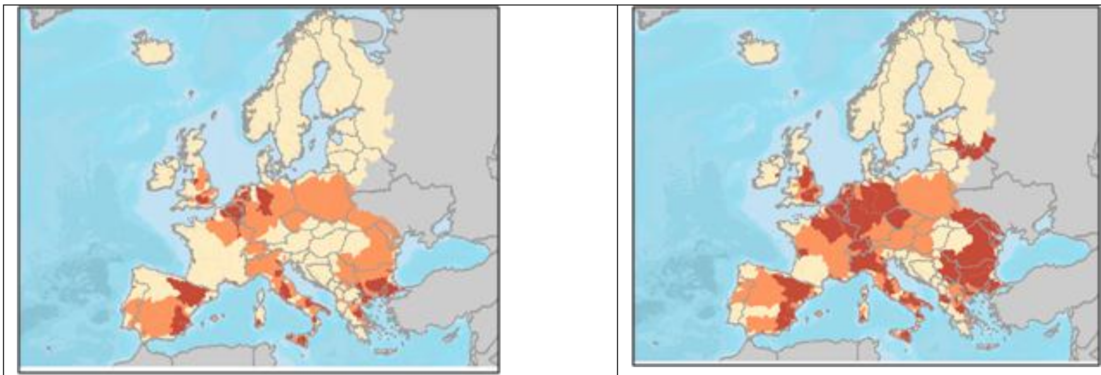
Floerke et al. (2011) analysed the Europe's vulnerability to low flow and water stress. In the 'Economy First' scenario where little attention is given to the implementation of sustainable approaches for water management, water stress shows a markedly increase for the 2050s across much of Europe compared to the actual situation. In this scenario, not only a range of demand management measures is captured but also the impact of climate change upon water availability (cf. Figure 7).

Figure 7: Water stress, annual, baseline, median of GCM-RCM combinations (left), Water stress, annual, 2050 Economy First (IPCM), median of GCM-RCM combinations (right). Source: Floerke et al, 2011



Bosello et al. (2012), analysing the economic impacts of sea level rise, found significant losses and increase in the incidence of coastal flooding. By the end of the century Malta has the largest relative land loss at 12% of its total surface area, followed by Greece at 3.5% land loss. Economic losses are however larger in Poland and Germany ($483 and $391 million, respectively). Coastal protection is very effective in reducing these impacts and optimally undertaken leads to protection levels that are higher than 85% in the majority of European Member States.

Figure 8: Water stress, annual, baseline, median of GCM-RCM combinations (left), Water stress, annual, 2050 Economy First (IPCM), median of GCM-RCM combinations (right). Source: Floerke, et al, 2011



3.1.7.2 Economic consequences of climate change impacts - Modelling results

The following research describes a climate change integrated impact assessment exercise, whose economic evaluation is based on a CGE approach and modelling effort.

Computable General Equilibrium (CGE) models are increasingly used to assess costs and benefits associated with climate change impacts[19].

The appeal of such tools is the explicit modelling of market interactions between sectors and regions (inter industry and international trade flows are accounted for by databases relying upon input output Social Accounting Matrices). This allows tracing adjustment mechanisms in the whole economic system triggered by a "shock" concerning initially just one part of it (region or sector). Putting it differently, not only direct costs, but also higher-order effects can be determined.

Following this approach, the Intertemporal Computable Equilibrium System (ICES) CGE model (Eboli, et al, 2010) is hereby used as a unifying platform to assess the economic consequences of a wide set of climate change impacts in the EU as they have been estimated by some recent research projects and initiatives, partly integrated with original research.

Impact types considered are those originated by: sea-level rise, changes of energy demand, of crops productivity, of fish stock productivity, of tourism flows, ecosystem losses, flooding and health. Information on all the impacts mentioned, except those on health and flooding, is available at the global level and with a detail roughly compatible with that of ICES, the CGE model used. Data on health and flooding are available for the EU only.

The relevant information is extracted from a set of top-down researches performed within EU FP6 and 7 projects and other research initiatives: primarily the ClimateCost project, complemented with the SESAME project, the PESETA project, and part of original research.

Impacts are also economically assessed for a 2 °C and 4 °C warming scenarios, both are assumed to occur in 2050.

In the following, section 3.1.7.2.1 briefly introduces the model used and the baseline scenario, section 3.1.7.2.2 presents simulation results and section 3.1.7.2.3 concludes. Annex 3 provides more detailed information on the ICES model, describes the impacts assessed, the data used and sources as well as the implementation of climate change impacts into the ICES CGE model.

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[19] For a partial list, see e.g. Deke et al. (2002), Darwin & Tol (2001), Bosello et al. (2007) on sea-level rise; Bosello et al. (2006) on health; Darwin (1999), Ronneberger et al. (2009) on agriculture; Berritella et al. (2007), Calzadilla et al. (2008) on water scarcity; Bosello et al. (2009) on sea-level rise, agriculture, health, energy demand, tourism, forestry; Aaheim & Wey (2010) on sea-level rise, agriculture, health, energy demand, tourism, forestry, fisheries, extreme events, energy supply; Ciscar, (2009) on sea-level rise, agriculture, tourism, river floods.

3.1.7.2.1 The ICES CGE Model and baseline scenario

ICES is a recursive-dynamic CGE model improving upon the static structure of the GTAP-E model (Burniaux & Troung, 2002). The calibration year is 2004, data come from the GTAP7 database (Narayanan & Walmsley, 2008) and the simulation time is 2004-2050.

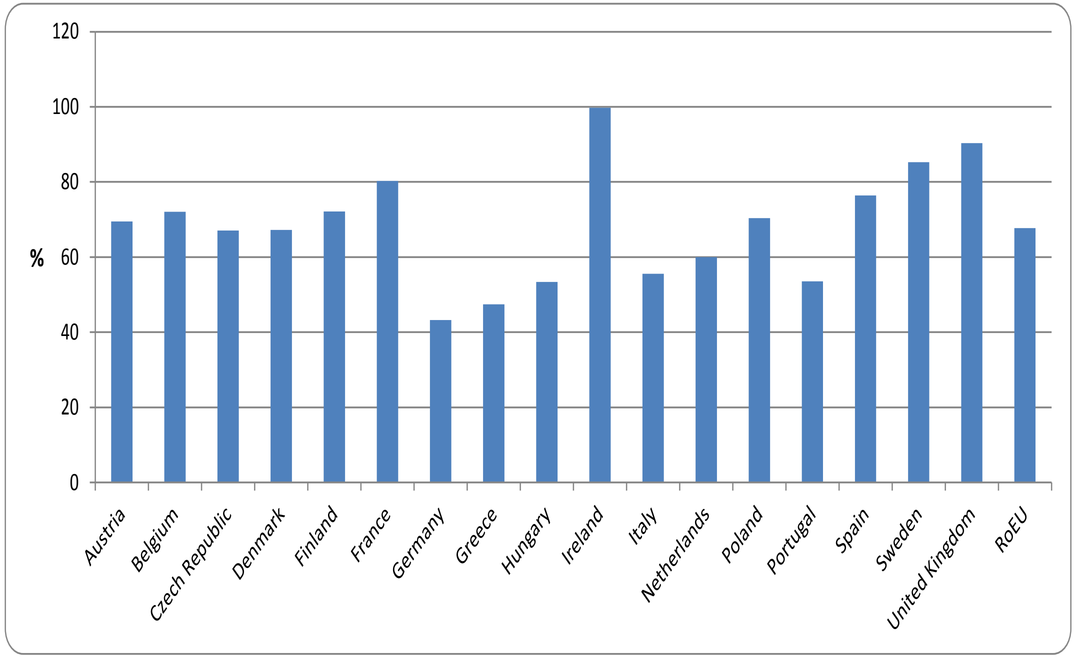
Table 8 reports region and sector aggregations for this study. Regions have been chosen in order to detail as much as possible the EU countries, whereas industries' detail is the closest possible to the sectoral impacts estimated by source studies.

Table 8: Regional and sectoral coverage of the ICES model (for this study)

<table>
<tr><th>Countries/Regions</th><th>Sectors</th></tr>
<tr><td>Austria</td><td rowspan="18">Agriculture
Timber
Fishing
Coal
Oil
Gas
Oil Products
Electricity
Other Industry
Transportation
Residential
Market Services
Public Services</td></tr>
<tr><td>Belgium</td></tr>
<tr><td>Czech Republic</td></tr>
<tr><td>Denmark</td></tr>
<tr><td>Finland</td></tr>
<tr><td>France</td></tr>
<tr><td>Germany</td></tr>
<tr><td>Greece</td></tr>
<tr><td>Hungary</td></tr>
<tr><td>Ireland</td></tr>
<tr><td>Italy</td></tr>
<tr><td>Netherlands</td></tr>
<tr><td>Poland</td></tr>
<tr><td>Portugal</td></tr>
<tr><td>Spain</td></tr>
<tr><td>Sweden</td></tr>
<tr><td>UK</td></tr>
<tr><td>RoEU</td></tr>
</table>

EU GDP national and regional growth rates reported in Figure 9 derive from the 2012 Ageing Report issued by EU Commission (EC, 2012e). Population trends (Figure 10) also replicate the 2012 Ageing Report for EU27. For non-EU27 regions, population evolves according to UN (2011a).

Figure 9: Baseline GDP growth rates by country (% change 2004-2050)



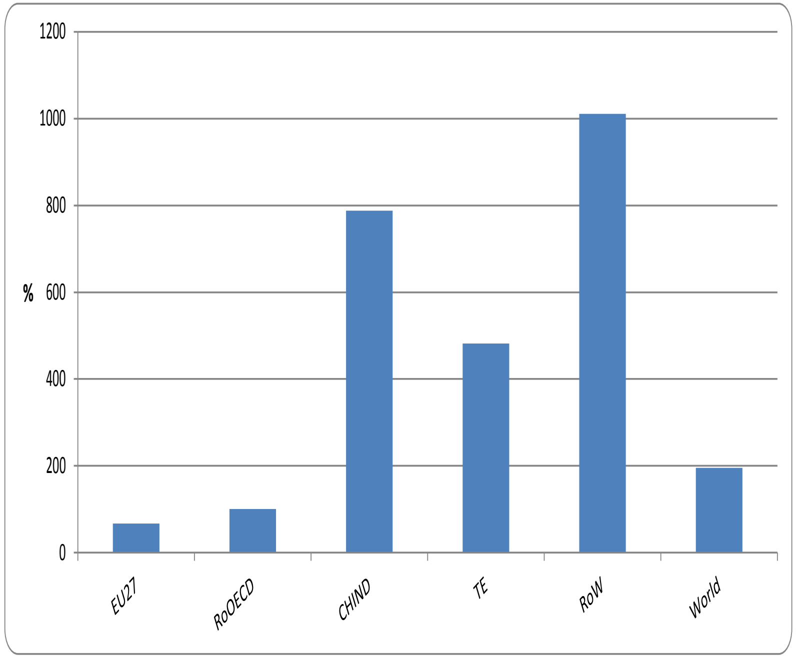
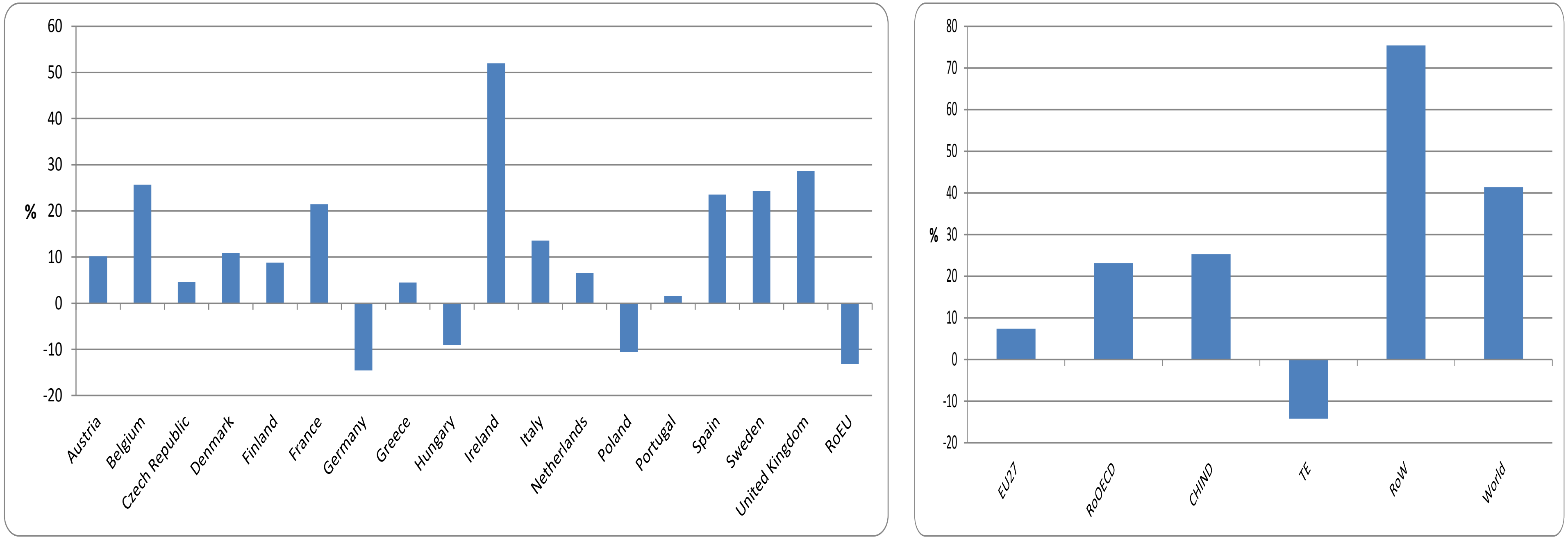


Figure 10: Baseline population growth rates by country (% change 2004-2050)



3.1.7.2.2 Results

Figure 11 reports climate change dynamic impact on the EU GDP. Figure 12 and Figure 13 report GDP impacts in 2050 for the 2°C and 4°C temperature increase scenarios and the decomposition of impacts by category.

The EU 27 as a whole experiences a GDP loss of the -0.16% and the -0.74% in the 2°C and 4°C cases respectively[20].. Impacts therefore are not linear in temperature. They are also rather moderate in aggregate[21]. However, they are highly differentiated by country, ranging from the +0.56% of GDP in Denmark to the -1.76% in Greece in the 2°C temperature increase scenario; from the +0.59% of GDP in Finland to the -6.24% in Greece in the 4°C temperature increase scenario. In general they are slightly positive or basically null in the Northern European countries (Denmark, Finland, Germany, Sweden, the UK), negative in the Southern EU, highlighting its higher vulnerability. Among impacts type, agriculture clearly dominates, followed by tourism and ecosystem. These three impacts together build more than 70% of the final GDP result in the majority of the EU countries. At the EU level, however, positive and negative agricultural impacts almost compensate each other. Interesting is also country specific vulnerability. For instance, in Greece and Spain, agriculture and tourism impacts are by large the more concerning; agriculture is less of an issue in Italy, Belgium and Poland, where on the contrary tourism and ecosystem losses there appear to be more important.

Table 9 and Table 10 report climate change **impacts on sectoral production**. These tend to follow generally the direction of the climatic shocks, but not always. In fact they are the final resultant of all the climatic shocks jointly implemented. Therefore, impacts interactions and aggregate effects also play a role in determining the final outcome. A straightforward example is what happens in the energy sectors in the 4°C case. Take for instance Greece: household electricity demand is expected to increase because of a strong cooling effect; however the final production of the sector is negative. Indeed Greece experiences a severe aggregate GDP loss because of climate change which prevails on any single shock. Accordingly also its total energy demand, including that of electricity net of the cooling effect, declines. Aggregate GDP effects are also the major drivers of production performances in the “industry” macro-sector which is directly affected just by a very tiny productivity decline induced by increased expected losses from floods.

Some results can be presented as follows:

- the negative performance of agricultural sectors especially in Spain, Greece, Portugal (-8.7%, -8.5%, -5.2% respectively in the 2°C temperature increase scenario n 2050) and partly in Italy and France (-2.7%, -2.3% respectively in the 2°C temperature increase scenario in 2050);

[20] The loss for the world as a whole is larger: -0.7% and -1.8% of GDP in 2050 for 2°C and 4°C respectively.

[21] Note that only river flooding are included in the assessment and just for the EU countries and that catastrophic events are not considered.

- the negative impacts on the service sector in the same countries (-2.08% in Greece, -1.01% in Spain, -0.97 in Portugal, -1.34% in Italy in the 2°C 2050) encompassing recreational tourism services which are negatively hit;
- the decline in fishery production in Italy and Spain (-8.3%, -3.9% respectively in the 2°C scenario in 2050);
- the generalized prevalence of production contraction in the energy sectors driven as said by the slump of world energy demand. Note also that industrial production is negatively affected in Denmark and Finland (-0.8%, -3.1% respectively in 2050 in the 2°C temperature increase scenario) notwithstanding the positive GDP impact of climate change in those countries. This is another case where rebound effects play a role. The contraction in world demand can in fact impact negatively industrial production also in those countries where climate change is in fact positive.

Table 11 and Table 12 report **effects on labour demand**. It is important to stress that the ICES CGE model depicts a "Walrasian", perfectly clearing/full employment labour market. The first and most obvious consequence is that unemployment is not modelled. The second is that any shock on the labour market implies just a re-distribution of the labour forces from those sectors whose production, and factor prices, are declining more in relative terms, toward those sectors where the opposite happens. Accordingly, one or more sectors will be always gaining in terms of labour demand. This said, the redistribution of the labour force could indirectly provide some insights of possible tensions on the labour market that climate change may originate. Higher labour demand contractions (Table 11[22]) are concentrated in the agricultural sector especially in Greece (-5.7%), Spain (-5.9%) and Portugal (-2.7%); in the fishing sector in Italy (-7.9%) and Spain (-4.5%); in the service sector in Hungary (-1.3%), Italy (-0.7%) and Portugal (-0.5%). Industrial labour demand declines particularly in Finland (-4%), Sweden (-1.6%) and Hungary (-1.4%); energy sectors tend also to expel labour force. To conclude, Figure 14, Figure 15 and Table 13 report climate change impacts on world prices, Figure 16 and

[22] The comments on Table 12 are similar qualitatively.

Figure 17 on terms of trade. Prices highlight a generalized decline consistently with the demand decrease at the world level induced by GDP contraction. The reduction is particularly evident for the forestry and fishing products and for energy commodities. Agricultural prices show an opposite trend however, as the land scarcity induced by flooding and sea-level rise and the decreased land productivity especially at the mid-low latitudes induces a negative supply-side effect more than offsetting the reduced demand.

This has direct implication for terms of trade. In general, EU countries which are, broadly speaking, energy importers and food exporters, benefit from the price shifts and gain. Exceptions are those Southern countries like Greece, Spain, Portugal and also Italy where the GDP contraction is particularly high and domestic prices decreases more compared to imported prices.

Figure 11: Climate change impacts on EU real GDP (% change wrt baseline) - 2 °C and 4 °C temperature increase

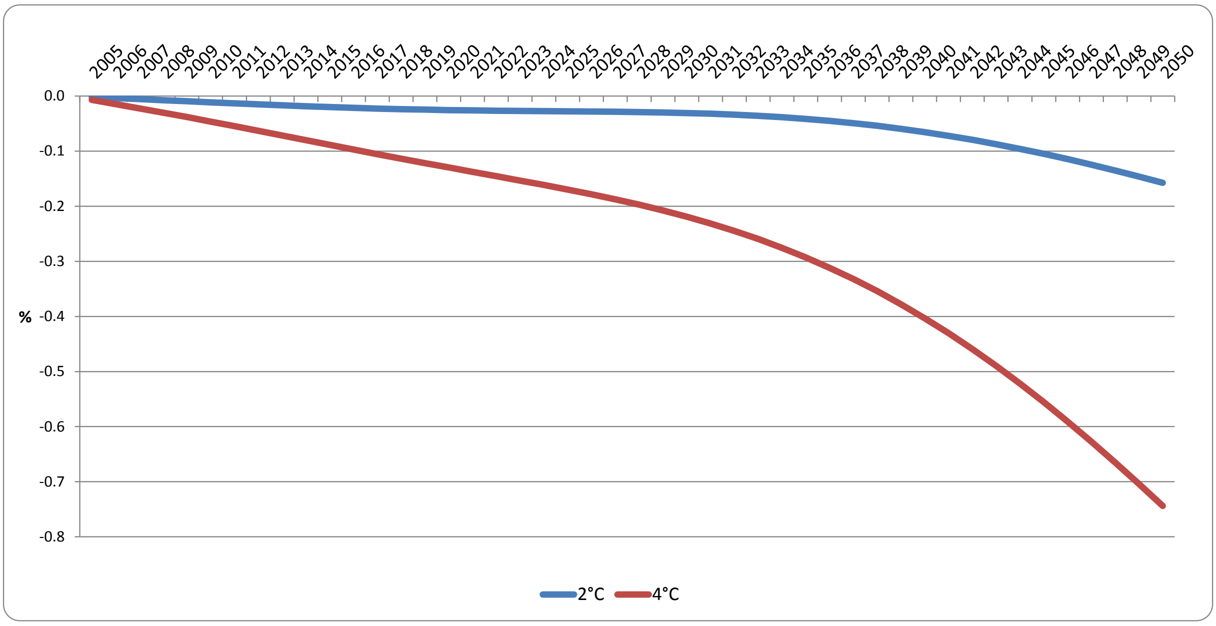


Figure 12: Climate Change impacts on real GDP (% change wrt Baseline) and impact decomposition. 2°C temperature increase ref. year 2050

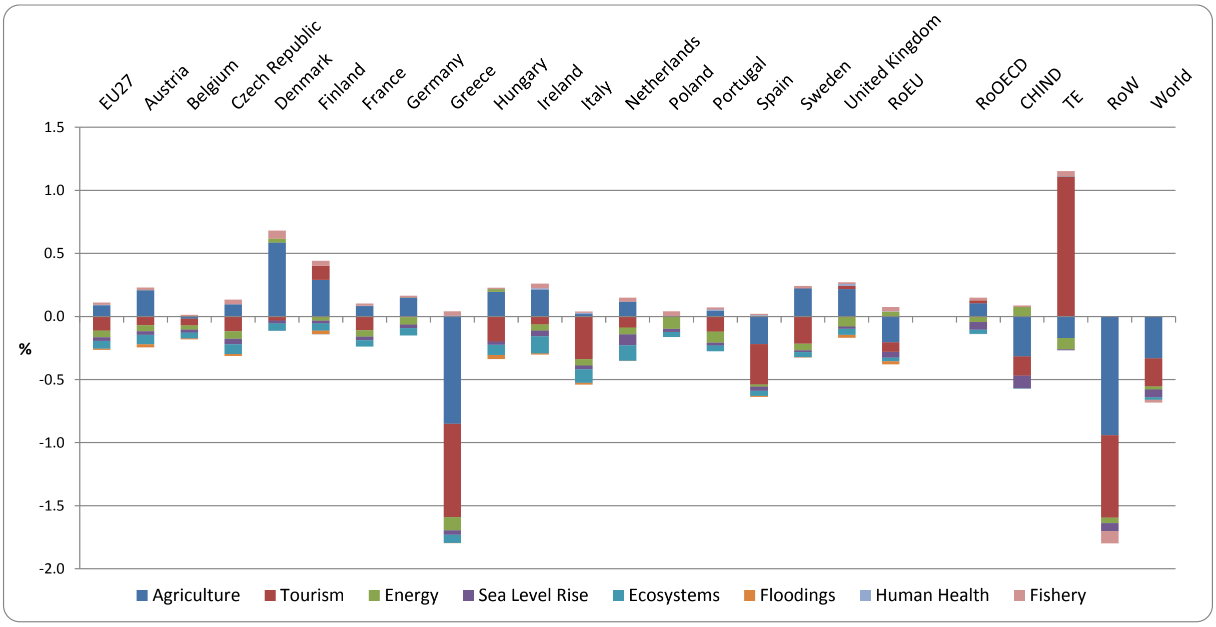


Figure 13: Climate Change impacts on real GDP (% change wrt Baseline) and impact decomposition. 4°C temperature increase ref. year 2050

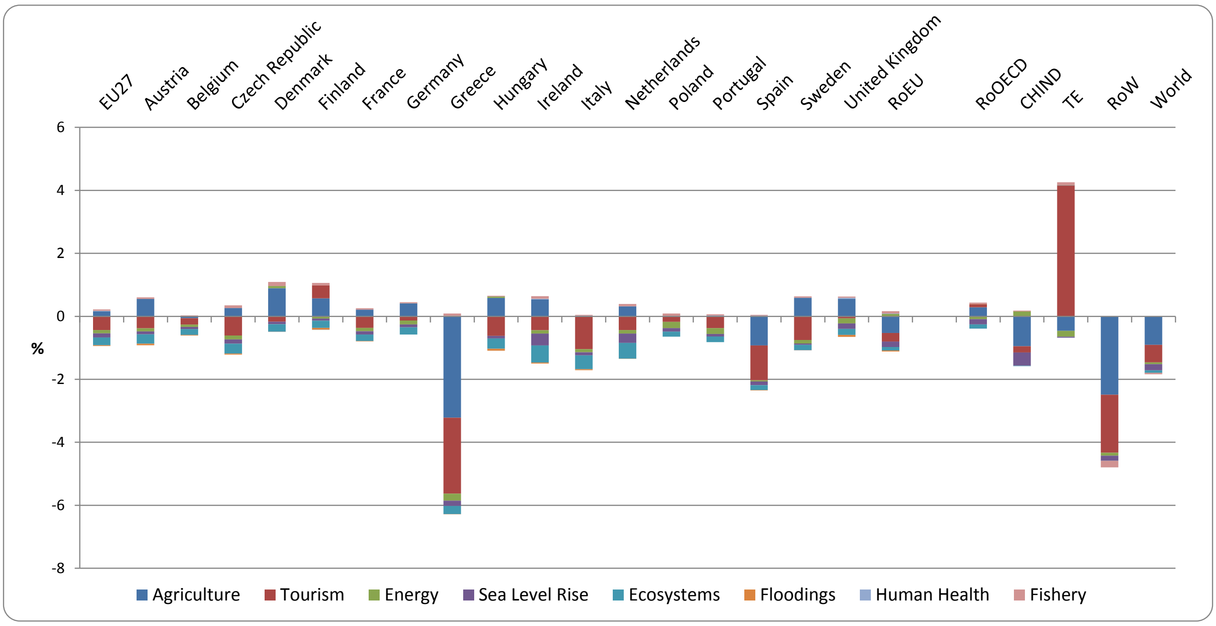


Table 9: Sectoral Production in 2050 (% change wrt Baseline) - 2 °C temperature increase scenario

	Agri-culture	Forestry	Fishing	Coal	Oil	Gas	Oil_Pcts	Electricity	Industries	Transport	Resi-dential	Mkt Services	Public Services
Austria	5,47	-1,10	-0,62	-0,01	-0,02	-1,23	0,37	-0,34	-0,10	-1,25	-0,69	-0,07	0,09
Belgium	-1,58	-1,06	-1,44	0,01	-0,02	-0,09	0,09	-0,08	0,46	-0,28	-0,24	-0,45	-0,13
Czech Republic	-0,03	-1,38	-1,39	-0,02	-0,02	-0,15	0,32	-1,12	0,01	-0,60	-0,06	-0,24	0,12
Denmark	13,46	-2,71	3,71	-0,01	-0,06	-0,45	0,82	0,67	-0,84	-1,87	0,46	-0,01	0,50
Finland	19,09	-2,19	8,85	-0,04	-0,06	-3,63	0,91	-1,00	-3,08	-1,85	-0,72	0,86	1,04
France	-2,33	-2,04	-1,21	0,05	-0,01	-0,28	0,30	0,39	0,70	-0,16	-0,17	-0,28	-0,15
Germany	0,38	-2,68	-0,81	-0,03	-0,02	-0,69	0,27	-0,65	-0,38	-0,73	-0,44	0,20	0,12
Greece	-8,47	-1,95	-0,80	0,21	0,09	0,13	-0,25	0,72	-0,49	4,74	-3,66	-2,08	-1,40
Hungary	2,11	-3,57	-2,77	0,03	-0,06	1,09	0,49	1,79	-0,86	-0,66	0,12	-0,72	0,07
Ireland	-0,11	-2,65	-1,56	0,00	-0,02	-0,64	0,30	0,12	0,35	-0,73	-0,01	-0,60	-0,07
Italy	-2,66	-0,98	-8,27	0,11	0,01	0,35	0,20	1,87	1,78	0,30	-0,79	-1,34	-0,97
Netherlands	0,81	-2,17	3,65	0,00	-0,03	-0,14	-0,50	-0,06	-0,20	-0,45	-0,29	-0,41	-0,03
Poland	-0,40	-1,45	1,14	-0,01	-0,01	-0,58	0,35	-0,82	-0,35	-0,52	-0,04	0,00	0,29
Portugal	-5,26	-2,51	-3,34	0,10	0,01	0,59	0,33	2,10	2,80	0,45	-0,99	-0,97	-1,34
Spain	-8,74	-0,78	-3,91	0,09	0,04	-0,60	-0,04	2,79	2,98	1,36	-3,05	-1,01	-1,16
Sweden	17,12	-1,86	4,61	-0,01	-0,01	-0,22	-0,01	-1,23	-1,41	-1,38	-2,06	0,69	0,36
United Kingdom	3,60	-1,71	0,35	-0,01	-0,04	-0,60	0,11	-0,37	-0,55	-0,74	-0,53	0,28	0,15
RoEU	1,85	-4,61	-2,61	-0,09	-0,12	-0,65	-0,21	-0,72	-1,04	-1,22	0,25	-0,59	0,19
RoOECD	-1,21	-2,73	2,42	-0,02	-0,07	-0,42	0,92	0,85	-2,30	-1,06	-1,23	1,08	0,09
CHIND	0,03	-0,57	-0,60	0,04	0,00	0,24	0,52	0,30	0,13	-0,59	-0,93	-1,45	-0,57
TE	-1,14	-0,31	0,54	-0,02	-0,03	-0,52	0,28	-1,55	-0,60	0,01	-1,13	3,11	0,50
RoW	-1,85	-0,26	-0,97	0,03	0,02	0,13	-0,88	1,27	-1,31	0,10	-2,03	-2,24	-1,11

Table 10: Sectoral Production in 2050 (% change wrt Baseline Scenario) - 4 °C temperature increase

	Agri-culture	Forestry	Fishing	Coal	Oil	Gas	Oil_Pcts	Electri-city	Indu-stries	Transport	Resi-dential	Mkt Services	Public Services
Austria	6,42	-2,98	-2,11	-0,05	-0,09	-3,97	1,73	-1,35	-0,46	-3,01	-1,63	-0,49	0,63
Belgium	-3,89	-3,13	-4,93	-0,01	-0,08	0,01	0,67	-1,20	0,47	-0,56	-0,98	-1,21	0,04
Czech Republic	-0,08	-3,78	-4,57	-0,10	-0,08	0,06	1,20	-3,86	-0,57	-1,61	-0,44	-1,05	0,27
Denmark	12,07	-7,74	5,97	-0,03	-0,14	-1,14	1,82	1,13	-1,00	-2,78	-0,42	-0,30	0,81
Finland	16,83	-5,16	16,85	-0,10	-0,15	-8,31	2,22	-2,46	-6,75	-3,47	-1,28	2,64	3,69
France	-5,94	-6,06	-4,09	-0,04	-0,08	-1,76	1,24	-0,48	0,61	-0,77	-0,60	-0,77	-0,06
Germany	1,05	-7,57	-2,65	-0,11	-0,08	-2,14	1,59	-2,15	-1,53	-1,81	-0,75	0,24	0,62
Greece	-24,13	-4,70	-2,81	0,27	-0,11	-5,14	-0,94	-1,79	-3,61	16,61	-15,32	-6,54	-6,97
Hungary	3,99	-8,85	-8,39	-0,02	-0,24	1,66	0,81	2,86	-2,81	-1,64	0,21	-1,67	0,18
Ireland	-0,45	-7,07	-4,26	-0,04	-0,08	-2,50	0,88	-0,67	-0,02	-2,39	-0,71	-2,40	-0,43
Italy	-7,28	-2,28	-17,91	0,18	-0,03	-0,81	0,02	3,44	4,35	0,23	-4,86	-3,71	-3,17
Netherlands	1,89	-6,53	6,49	-0,03	-0,14	-0,72	-1,59	-1,24	-1,28	-0,76	-1,19	-1,64	-0,29
Poland	-0,93	-3,74	-0,22	-0,08	-0,07	-1,68	1,46	-2,11	-1,24	-1,22	-0,01	-0,43	0,72
Portugal	-15,75	-6,16	-10,48	0,22	0,01	0,89	0,50	3,91	7,98	1,59	-6,67	-2,30	-4,96
Spain	-22,96	-1,71	-9,23	0,19	0,08	-4,27	-0,98	4,55	7,59	3,62	-12,90	-2,66	-5,02
Sweden	16,00	-4,77	7,67	-0,02	-0,02	0,16	0,25	-3,67	-3,78	-3,17	-4,30	1,39	1,75
United Kingdom	3,62	-4,49	-0,07	-0,06	-0,16	-1,93	0,67	-1,41	-1,41	-1,84	-1,03	0,18	0,36
RoEU	4,71	-11,52	-10,45	-0,37	-0,42	-2,08	-0,68	-3,01	-3,56	-3,45	0,68	-1,44	1,09
RoOECD	-3,05	-8,09	3,37	-0,13	-0,27	-1,66	3,79	1,41	-7,31	-2,90	-2,03	2,69	1,16
CHIND	-0,31	-1,50	-1,53	0,06	-0,02	0,28	0,66	0,03	0,59	-1,56	-4,04	-3,51	-2,52
TE	-2,95	-0,95	1,15	-0,15	-0,15	-1,52	1,65	-3,61	-2,89	0,24	-2,54	10,93	2,51
RoW	-4,47	-0,75	-2,18	0,07	0,03	0,03	-3,17	1,11	-2,63	0,68	-7,82	-5,30	-4,39

Table 11: Labour demand in 2050 (% change wrt Baseline Scenario) - 2 °C temperature increase

	Agri-culture	Forestry	Fishing	Coal	Oil	Gas	Oil_Pcts	Electri-city	Indu-stries	Transport	Resi-dential	Mkt Services	Public Services
Austria	5,68	-1,83	-3,26	-0,19	-0,35	-1,53	-1,50	-0,69	-0,18	-2,03	-0,27	-0,08	0,18
Belgium	-0,24	-2,24	-3,28	0,10	-0,14	-0,27	-0,48	0,18	0,55	-0,38	0,18	-0,24	-0,11
Czech Republic	1,14	-1,66	-3,57	-0,13	-0,22	-0,38	-0,89	-1,37	-0,11	-1,14	0,09	-0,19	0,19
Denmark	12,40	-3,63	0,19	-0,33	-0,61	-1,70	-2,51	-0,39	-1,13	-3,63	0,26	-0,30	0,39
Finland	16,88	-3,40	3,89	-0,69	-0,89	-4,50	-4,08	-2,94	-4,03	-4,51	-1,68	0,07	0,84
France	-0,96	-2,87	-3,04	0,20	-0,14	-0,29	-0,34	0,50	0,76	-0,42	-0,04	-0,09	-0,07
Germany	1,23	-3,42	-3,27	-0,17	-0,36	-0,95	-1,30	-0,75	-0,39	-1,49	-0,29	0,40	0,19
Greece	-5,70	-1,93	-2,02	0,83	0,87	2,46	4,75	4,14	1,51	8,70	-1,31	1,26	-0,52
Hungary	2,66	-3,85	-4,50	0,12	-0,41	0,89	-1,67	0,98	-1,37	-2,15	-0,04	-1,26	-0,07
Ireland	0,71	-2,76	-3,24	-0,02	-0,27	-0,59	-0,90	-0,04	0,52	-1,54	0,33	-0,41	0,01
Italy	-0,93	-1,04	-7,93	0,50	0,12	0,65	0,87	2,46	2,18	0,96	0,72	-0,73	-0,90
Netherlands	1,70	-3,45	0,97	-0,04	-0,27	-0,27	-1,67	-0,21	-0,31	-1,15	-0,04	-0,14	0,10
Poland	0,67	-1,82	-2,89	-0,08	-0,25	-0,88	-0,85	-0,98	-0,35	-1,11	0,09	0,19	0,35
Portugal	-2,68	-3,16	-3,90	0,59	0,22	1,56	1,56	2,87	3,20	1,54	-0,24	-0,50	-1,27
Spain	-5,85	-0,91	-4,47	0,97	0,51	0,79	3,08	4,94	3,89	3,89	-2,08	-0,12	-0,80
Sweden	14,49	-2,49	0,01	-0,30	-0,60	-1,56	-2,80	-1,41	-1,62	-2,48	-2,06	0,63	0,34
United Kingdom	3,83	-2,64	-2,34	-0,19	-0,38	-1,04	-1,73	-0,59	-0,66	-1,72	-0,23	0,38	0,25
RoEU	2,36	-4,76	-7,03	-0,39	-0,55	-1,20	-2,64	-2,05	-1,69	-3,07	-0,22	-1,35	0,01
RoOECD	-0,86	-3,94	-0,98	-0,26	-0,61	-1,10	-2,42	-0,07	-2,54	-2,70	-1,14	1,06	0,06
CHIND	0,74	-1,20	-1,54	0,33	0,09	0,93	0,96	1,39	0,60	-0,16	-0,41	-1,02	-0,40
TE	-0,42	-0,95	-1,19	-0,18	-0,31	-1,70	-1,35	-2,78	-1,00	-0,78	-0,38	3,96	0,48
RoW	-0,07	-1,23	-1,96	0,79	0,55	1,31	2,42	3,67	0,11	2,31	-0,30	-0,92	-0,59

Table 12: Labour demand in 2050 (% change wrt Baseline Scenario) - 4 °C temperature increase

	Agri-culture	Forestry	Fishing	Coal	Oil	Gas	Oil_Pcts	Electri-city	Indu-stries	Transport	Resi-dential	Mkt Services	Public Services
Austria	8,16	-4,76	-9,65	-0,67	-1,17	-4,71	-4,49	-2,08	-0,35	-5,21	-0,25	0,10	0,93
Belgium	-0,37	-6,25	-10,21	-0,11	-0,73	-0,88	-2,79	-0,50	0,71	-1,48	0,73	-0,29	0,08
Czech Republic	3,09	-4,47	-10,50	-0,65	-0,89	-0,86	-3,51	-4,40	-0,64	-3,28	0,50	-0,27	0,77
Denmark	12,62	-9,92	-2,58	-0,71	-1,35	-3,73	-5,37	-0,44	-1,20	-6,18	-0,29	-0,21	0,81
Finland	15,26	-7,64	6,06	-1,62	-2,22	-9,94	-9,51	-6,16	-8,43	-9,06	-2,66	1,29	3,35
France	-2,47	-8,16	-9,23	-0,03	-0,84	-1,76	-2,72	-0,13	0,88	-2,47	0,19	0,10	0,39
Germany	3,38	-9,34	-9,40	-0,73	-1,35	-2,86	-4,36	-2,53	-1,51	-4,55	-0,03	1,22	0,95
Greece	-16,79	-4,57	-6,32	1,21	2,29	3,32	14,96	8,10	3,07	31,83	-7,80	5,21	-4,08
Hungary	5,80	-9,44	-12,60	-0,16	-1,43	1,34	-5,99	1,19	-3,67	-5,56	0,36	-2,16	0,15
Ireland	1,93	-7,31	-8,93	-0,44	-1,01	-2,12	-3,47	-1,12	1,33	-5,05	1,13	-0,95	0,05
Italy	-2,58	-2,40	-17,91	0,97	0,05	0,12	0,76	5,13	6,06	2,08	-0,49	-0,85	-2,96
Netherlands	4,46	-9,74	-1,43	-0,52	-1,07	-1,22	-6,11	-1,60	-1,49	-3,32	0,12	-0,17	0,44
Poland	1,98	-4,62	-9,03	-0,49	-0,97	-2,19	-3,19	-2,83	-1,08	-3,35	0,77	0,60	1,05
Portugal	-8,63	-7,40	-11,66	1,33	0,49	2,92	3,64	6,26	9,59	4,78	-3,31	-0,16	-4,64
Spain	-15,61	-1,84	-11,78	2,22	1,22	-0,63	7,30	10,91	10,68	11,15	-9,81	0,65	-3,83
Sweden	15,07	-6,19	-4,26	-1,02	-1,81	-3,85	-7,98	-3,76	-4,14	-6,17	-4,08	1,55	1,77
United Kingdom	5,37	-6,65	-7,46	-0,74	-1,25	-3,07	-5,28	-1,78	-1,55	-4,86	0,24	1,08	0,80
RoEU	6,14	-11,85	-20,68	-1,56	-1,91	-3,70	-8,82	-6,73	-5,12	-8,91	-0,48	-2,97	0,63
RoOECD	-2,33	-11,06	-5,51	-1,32	-2,20	-4,07	-8,10	-2,02	-8,01	-8,49	-1,18	2,84	1,18
CHIND	1,93	-3,07	-4,72	0,59	-0,06	1,11	0,48	2,28	1,91	-0,78	-1,68	-1,75	-1,92
TE	-1,49	-2,93	-2,10	-1,07	-1,49	-4,95	-6,11	-7,89	-4,60	-3,62	-0,45	13,24	2,27
RoW	0,38	-3,28	-6,04	1,86	1,28	2,31	4,56	6,94	1,21	6,25	-2,61	-1,38	-2,92

Table 13: World prices in 2050 (% change wrt Baseline Scenario) – 2 °C and 4 °C temperature increase

	2 °C	4 °C
Agriculture	2.00	5.42
Forestry	-5.60	-14.51
Fishing	-8.76	-25.43
Coal	-0.75	-4.03
Oil	-1.97	-7.12
Gas	-1.82	-5.50
Oil_Pcts	-1.93	-6.90
Electricity	-1.11	-3.44
Industries	-0.26	-0.89
Transport	-1.06	-3.34
Residential	0.46	2.89
Mkt Services	0.12	0.49
Public Services	-0.01	0.55

Figure 14: World prices: % change wrt baseline - 2 °C temperature increase

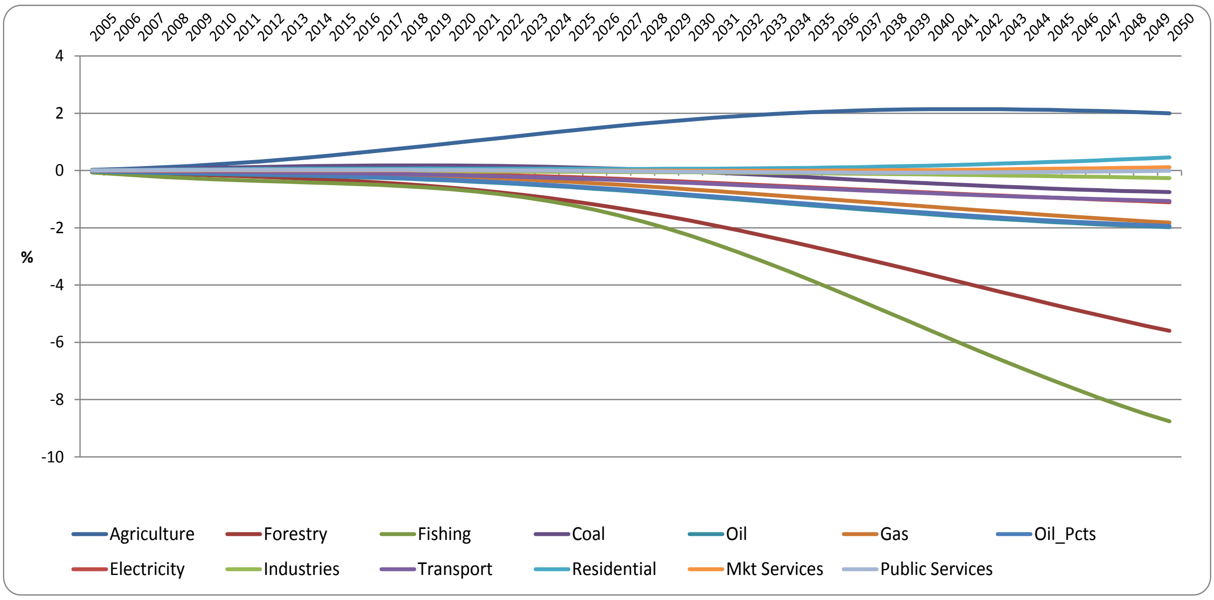


Figure 15: World prices: % change wrt baseline - 4 °C temperature increase

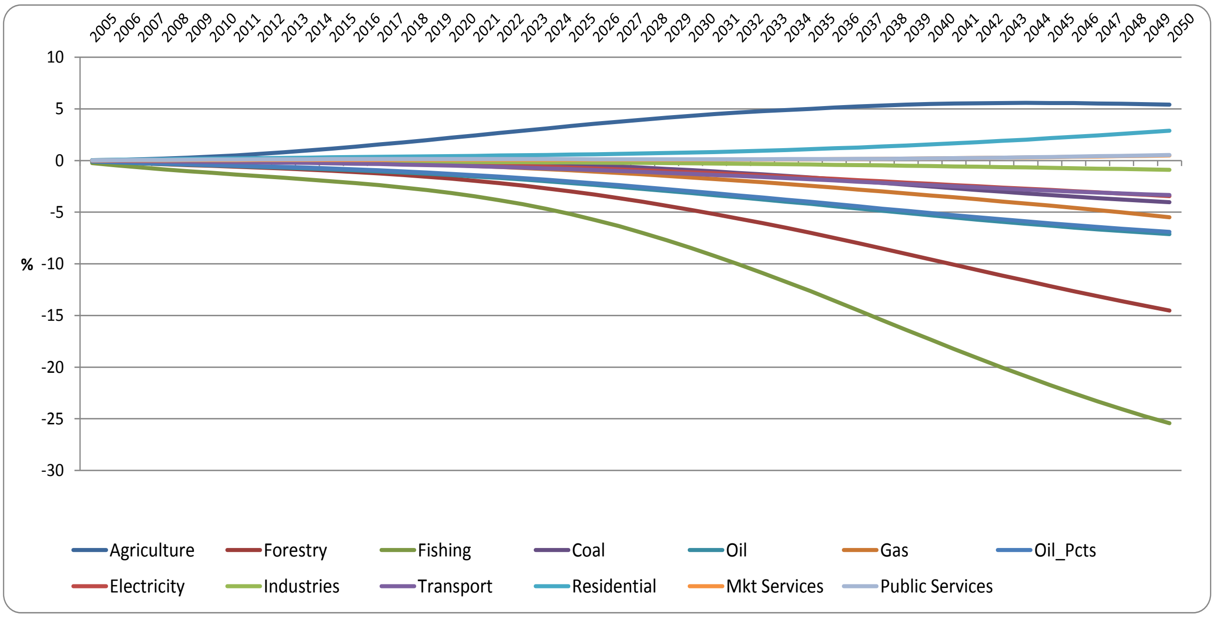


Figure 16: Terms of trade: % change wrt baseline - 2 °C temperature increase

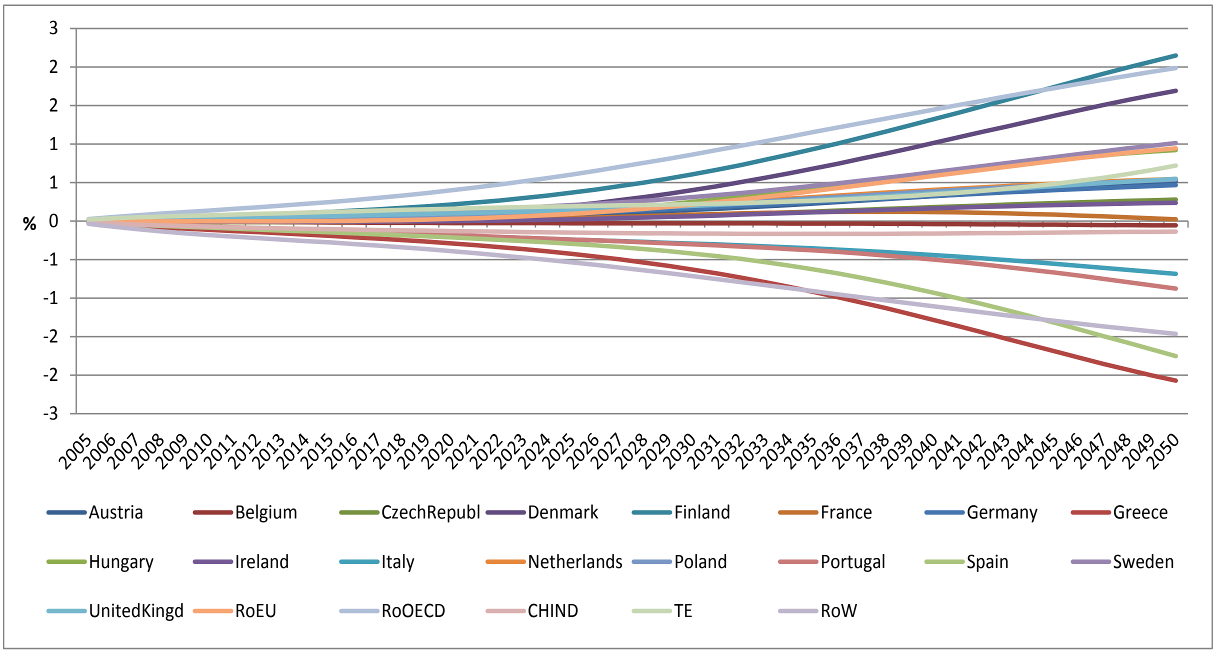
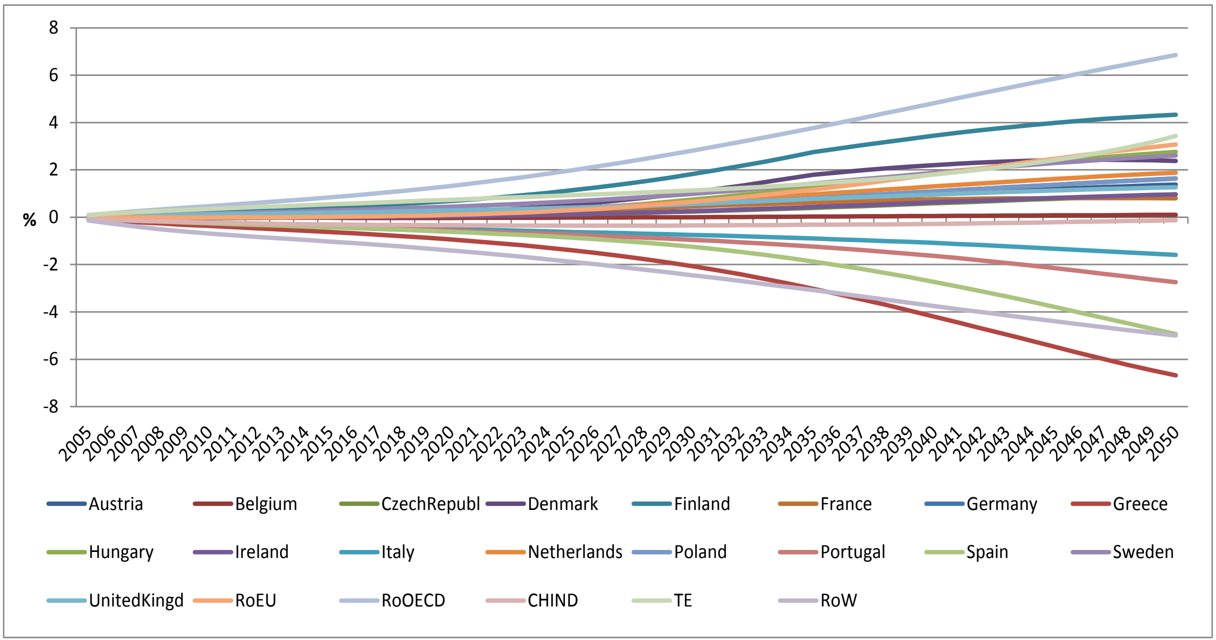


Figure 17: Terms of trade: % change wrt baseline - 4 °C temperature increase



3.1.7.2.3 Conclusions and caveats

To conclude the major caveats in interpreting the results presented in chapter 3.1.7.2.2 are discussed in the following:

Firstly, the impact list here considered, albeit wide, is still incomplete. Extreme events like droughts and more in general hydro-geological risk not only associated to river floods deserve a much better coverage and consideration.

Secondly, the treatment of non market ecosystem losses is highly speculative, very rough and uncertain. This is another field of research where economic assessment, especially conducted with a macro perspective is almost lacking.

Thirdly, high simplifications have been also adopted to extrapolate impacts of the 2°C case to the 4°C scenario which prevented the consideration of discontinuities which are typical of environmental phenomena. By the same token, simplifying assumptions have been adopted to match the geographical specification of the impact study source of the inputs for the CGE model and that of the CGE model itself.

Fourthly, a set of specific warnings relate to the specific economic investigation tool used: CGE models are based on a “Walrasian” view of the economic system, where all markets are in equilibrium and respond to the decision of optimising agents. Accordingly they cannot examine imperfect markets’ behaviour. In the specific case, this is particularly relevant for the analysis of labour market effects of climate change. Basically the current CGE model is not appropriate for that analysis if not to highlight just some potential "tensions" that in this market may originate. In CGE models the adjustment to equilibrium is instantaneous, thus they cannot represent frictions or transitions. CGE models are usually calibrated to some specific years, thus they can offer reliable information only if the economic context remains reasonably similar to the initial one, therefore they should be used only for short-term analyses. CGE models are usually static and, when dynamic, they usually allow for myopic expectations and systematic errors.

To conclude, CGE models are GDP oriented. Accordingly their assessment is more sensitive to shocks affecting flows and not stocks. This means that for instance stock losses like those affecting land or more generally property values are only indirectly and partially captured as long as they impair the ability of one country to produce goods and services. In this sense stock losses are underestimated by CGE models.

All this said, this exercise is, however, useful in highlighting at least some qualitative tendencies and the order of magnitude of the phenomena involved.

3.1.8 Balancing adaptation types and mitigation

3.1.8.1 Introduction

Given its predominantly local nature, research on the costs and benefits of adaptation has been mostly conducted through bottom-up studies (cf. Agrawala et al. (2011b) for a recent survey). Although such studies can provide valuable information about the economic performance, viability and side effects of specific adaptation measures, they are ill suited in providing strategic long-term and economy-wide indication on the optimal resource allocation across different climate change strategies, especially considering the interaction between mitigation and adaptation.

The following analysis belongs to the recent, but growing literature addressing these issues, using macroeconomic approaches (cf. e.g. Bosello et al. (2010a, b); Bahn et al. (2010); Hof et al. (2009); Agrawala et al. (2010a); de Bruin et al. (2009a, b)). Adaptation is typically modeled as an aggregate strategy, or strategy types, that are fostered by some form of planned spending and that directly reduce net climate change damages. Adaptation is then compared with mitigation and residual damages.

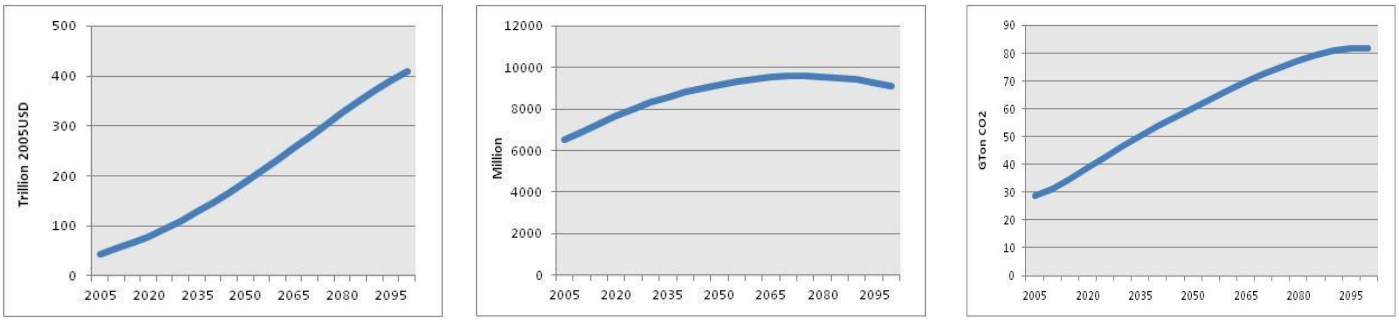
The following section analyses with a dynamic growth hard-linked integrated assessment model, AD-WITCH (for a detailed description of the model please cf. Annex 4), the interaction between different forms of adaptation, proactive, reactive, generic and specific adaptive capacity, and mitigation. A novel feature introduced in AD-WITCH is that generic adaptive capacity is endogenous as it depends positively on GDP, but negatively on population. The focus is on the EU, although results are also reported for the world as a whole.

3.1.8.2 Simulation of two scenarios with the AD-WITCH model

Two different scenarios are analysed with the AD-WITCH model. The first scenario examined refers to a medium climate change damage case where adaptation is the only pursued climate change strategy. It assumes that the public good nature of mitigation and the associated free riding incentive prevent the reaching of an international environmental agreement. This leaves countries only to implement those climate change policies whose benefits are fully appropriable; this is the case of adaptation. The first scenario thus refers to a non cooperative situation in which countries do not internalise the emission externality; accordingly mitigation, with its public good nature and the associated free riding incentive, is practically zero. Adaptation on the contrary, private good fully appropriable by implementers, is undertook optimally by individual regions which match its cost and benefits at the margin.

This scenario – named "Baseline Default" corresponds to the original AD-WITCH baseline presenting climate change damage very similar to that of the Nordhaus' RICE 99 model. Figure 18 reports its major macroeconomic assumptions.

Figure 18: BaU Default scenario. GDP Population and Fossil fuels emissions



In a second scenario, "Stab", adaptation in the Business as Usual (BaU) Default is backed by a mitigation policy aiming at stabilising CO_2 concentration at 550 ppm. In this case it is assumed that a world carbon market is fully efficient and operational allowing policy cost minimisation across world countries/regions through the equalisation of marginal abatement costs. The 550 ppm target is not consistent with the EU policy target of keeping temperature increase below the 2°C within the century. In fact it is consistent with a temperature increase of 2.5-3° C. Nonetheless we think is by far more realistic and still optimistic as it is consistent with a full implementation of the current Copenhagen Pledges whose fulfillment is far from granted. However, countries are still left with the choice on how much to invest in adaptation.

The questions this section tries to answer are thus the following:

- What forms could take an optimal adaptation mix?
- What is the scale of investment in the different types of adaptation?
- What their effectiveness in reducing climate change damages?

- Assuming that a mitigation policy is implemented, is there still room for adaptation?
- How will adaptation interact with mitigation?

In the following, section 3.1.8.2.1 describes the model simulation results for the EU27, section 3.1.8.2.2 drives major conclusions. Annex 4 introduces the AD-WITCH model used for the assessment, analyses in depth the implementation of the adaptation module of AD-WITCH and reports on world results.

3.1.8.2.1 Model simulation Results

Figure 19 reports the composition of total climate change costs in the EU27 in the Default BaU scenario. If uncontrolled, climate change damages can reach 3% of the EU GDP in 2100. Optimal adaptation can however cost-efficiently reduce this. In 2100 an expenditure of roughly 0.5% of GDP would halve the damage. Total climate change cost (that is, adding adaptation expenditure to residual damage) would drop to 2.3% of GDP. It is also interesting to note that adaptation remains negligible until 2035. This is a consolidated result from the top-down modelling literature on adaptation and depends upon the calibration procedure. Indeed according to the literature used as reference, still in 2050 adaptation expenditure is very low (cf. Annex 4).

Figure 19: Composition of climate change costs in EU: BaU Default.

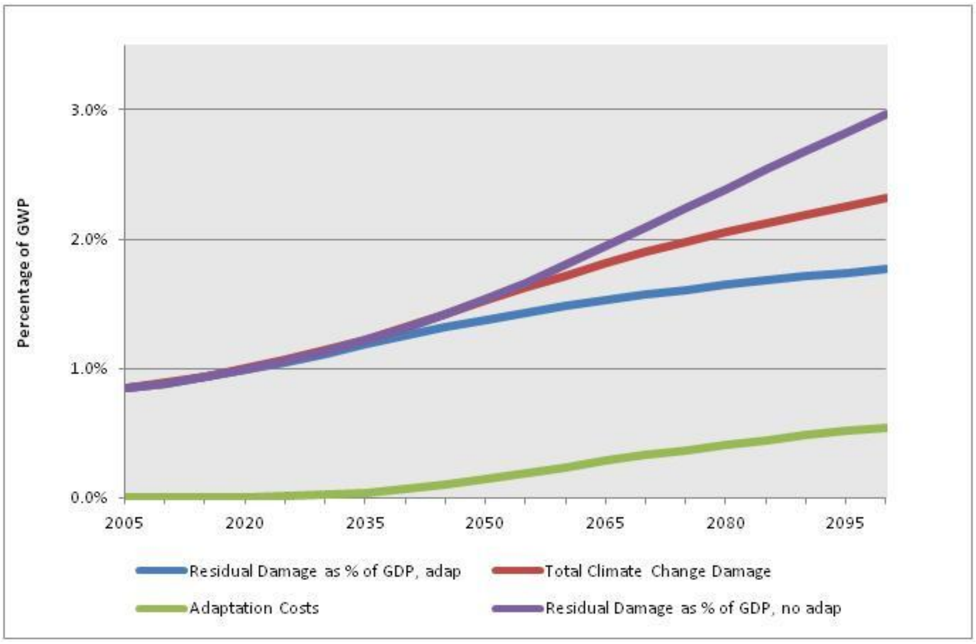


Figure 20 disentangles adaptation expenditure in the EU into adaptation measures and adaptive capacity building. The former is way higher than the second, building almost the total of adaptation expenditure. This is not surprising also considering that the EU belongs to those developed regions in which adaptive capacity is already developed and large adaptation gaps have not to be filled.

Figure 20: Composition of adaptation strategies in the EU (% of GDP) BaU Default. Capacity and adaptation activities

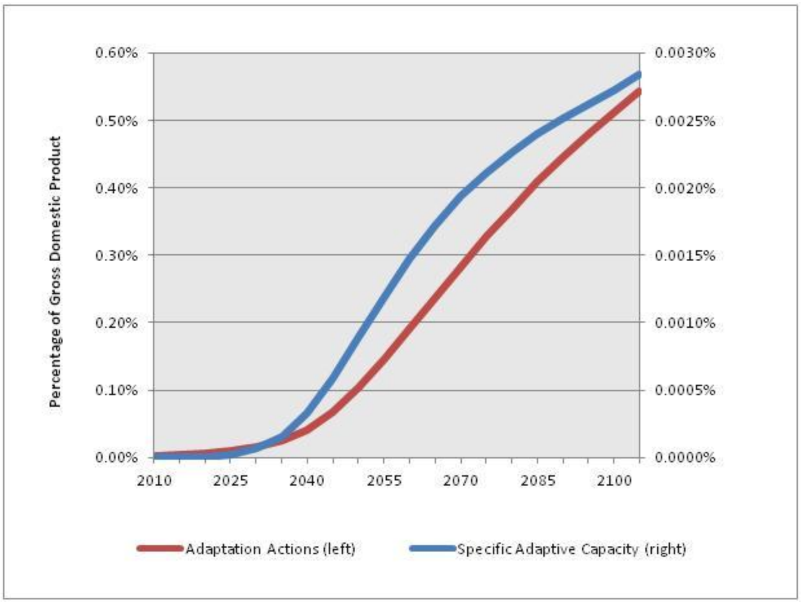
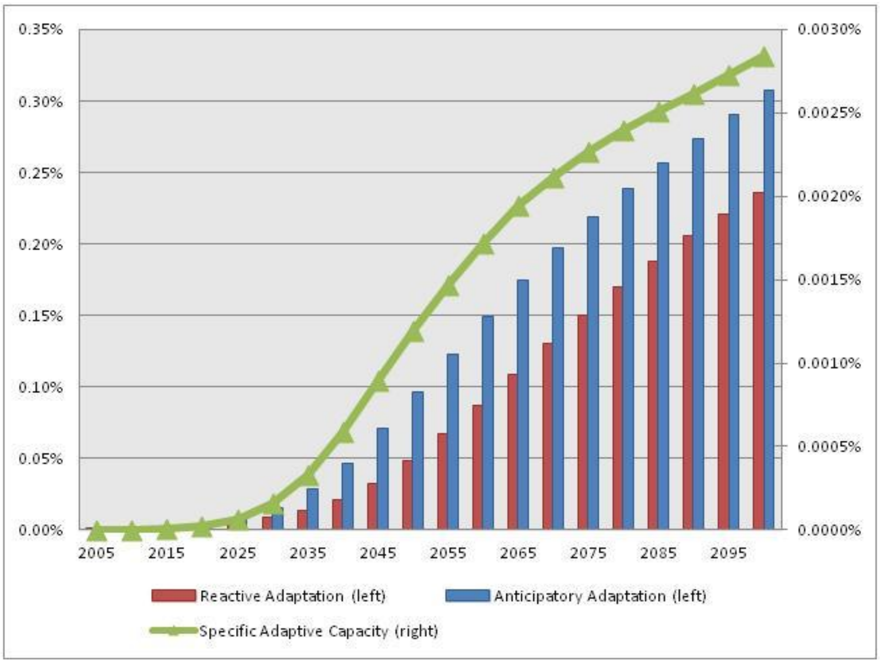


Figure 21 details the difference between anticipatory and reactive adaptation (for completeness also investment in adaptive capacity building is reported). Not surprisingly anticipatory adaptation starts before reactive adaptation. What is more interesting to note is that anticipatory adaptation is predominant, constituting roughly the 56% of the total adaptation bill. The model thus suggests that it would be optimal for the EU to devote more resources to anticipate the damages building a stock of pre-defensive capital rather than act in emergency or ex post. At the same time, not all the damages could be prevented, therefore a non negligible amount of resources should be anyway devoted to recovery measures.

Figure 21: Composition of adaptation strategies in the EU (% of GDP) BaU Default. Reactive and anticipatory adaptation to be read on the left axis, specific adaptive capacity building on the right axis.



To conclude, Table 14 reports the expenditure in various adaptation forms in the EU in absolute figures for the BaU Default scenario. In cumulated terms, the prevalence of anticipatory adaptation is even more evident.

Table 14: Composition of adaptation expenditure in the EU (2005 US$ Billion): BaU Default

	Anticipatory Adaptation	Reactive Adaptation	Specific Adaptive Capacity
2010	0.34	0.19	0.00
2030	4.54	2.45	0.05
2050	39.63	19.76	0.49
2100	203.43	156.22	1.88
2010-2100 Discount rate 3%	866.873	559.50	9.178

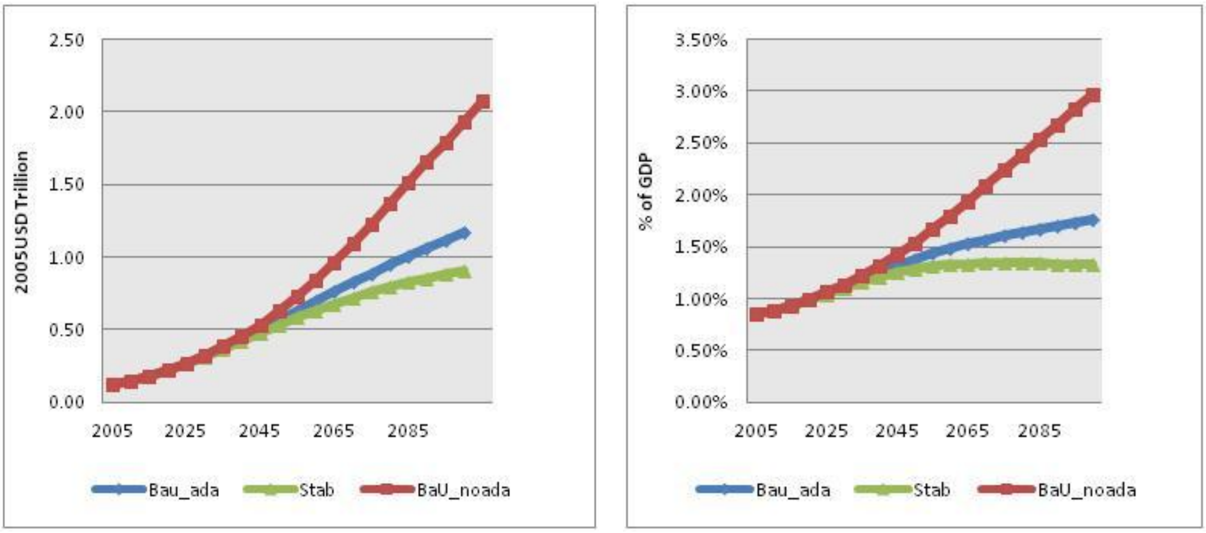
Let us now assume that a CO_2 concentration stabilization policy is put in place jointly with optimal adaptation. The intrinsic assumptions are that a global environmental agreement is enforced and that all participating countries have access to a fully operational global carbon market allowing to exploit at the maximum degree “where” flexibility. Total mitigation policy costs are thus minimised by allowing the equalisation of marginal abatement costs across all countries. This in turn implies that countries with the higher marginal abatement costs are called upon a lower mitigation effort. The interesting questions this “Stab” scenario can answer are:

- What is the role of adaptation in the presence of mitigation?
- How much the former is affected by the latter?

As shown in Figure 22, mitigation and adaptation jointly further reduce the damage potentially experienced by the EU. In 2100 residual damages are roughly 1.3% of GDP or US$ trillion 0.8 compared with the US$ trillion 1.2 accomplishable by adaptation alone. In addition, not only residual damages, but also total climate change costs, i.e. including mitigation and adaptation expenditures are lower when mitigation and adaptation are jointly implemented than in the adaptation only case. According to Table 15 the total climate change (mitigation and adaptation) policy costs amount to US$ 0.35 trillion to be added to the US$ 0.8 trillion represented by residual damage. When adaptation is the only policy implemented the total policy cost in 2100 amounts to more than US$ 0.36 trillion (Table 14) that need to be added to 1.2 of residual damage. Summarising, replicating a well known first-best efficiency principle, two instruments (mitigation and adaptation) can do no worse than one, in fact they are welfare improving. A final interesting indication is provided on the timing of mitigation and adaptation. As emphasised by Table 15, while adaptation starts to be appreciable in the mid century (even though some adaptation action starts in 2020), mitigation is aggressive since the beginning. This is because mitigation works against strong climatic inertia (from 50 to 80 years) and therefore should be implemented well in advance to produce some results. On the contrary, adaptation, also in its anticipatory form, works against a shorter economic inertia and can be implemented more closely in time to the expected damage occurrence[23]. All this boils down in confirming the strategic complementarity between mitigation and adaptation.

[23] Of course this is a modelling result which depends on model features. The general message thus should be taken with a grain of salt. For instance coastal defences are usually planned on very long time horizon.

Figure 22: Residual Damage in EU: Billion USD2005 (a) and % of GDP (b).



At the same time mitigation crowds out adaptation (Figure 23). The presence of the global mitigation strategy reduces climate change damages and accordingly the need to adapt. Adaptation expenditure in the EU results indeed almost halved, and postponed, albeit remaining important. Notwithstanding the presence of mitigation, there is a residual damage that cannot be eliminated and that can be optimally dealt with adaptation. It is worthwile to note that the decrease in adaptation expenditure is particularly relevant after the year 2030. Figure 24 shows finally that all the different forms of adaptation - investment in adaptive capacity building, reactive and proactive - are affected more or less uniformly. Accordingly, the presence of mitigation does not penalize particularly one form of adaptation with respect to another one.

Figure 23: Total adaptation expenditure in the EU without and with mitigation.

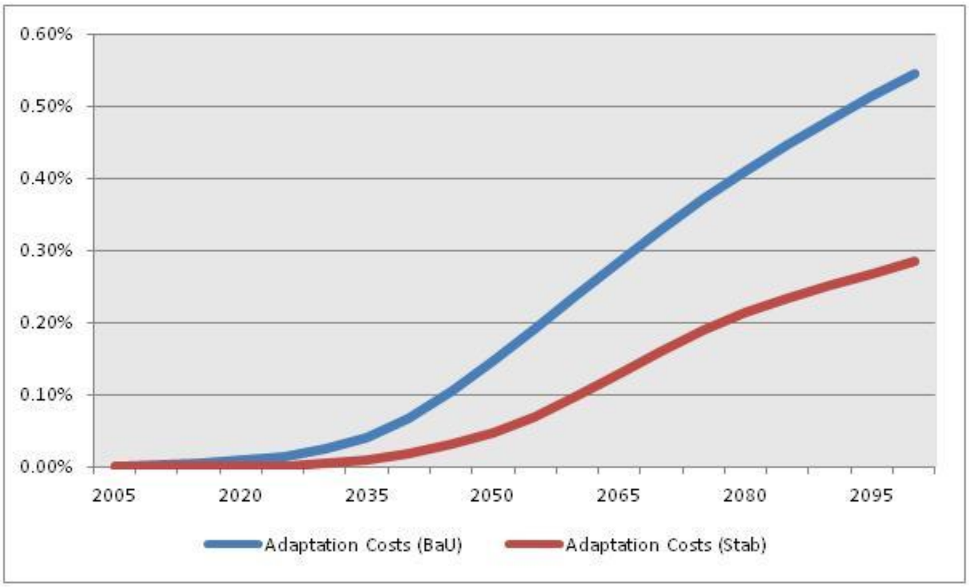
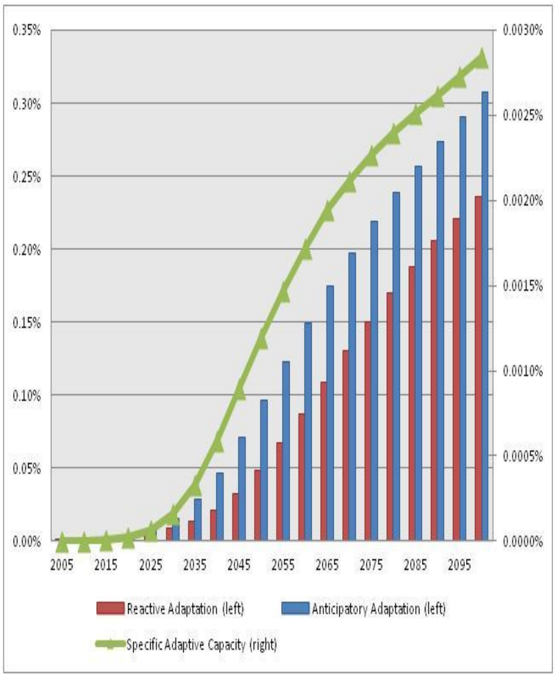


Figure 24: Adaptation expenditure by type in the EU without (left) and with (right) mitigation



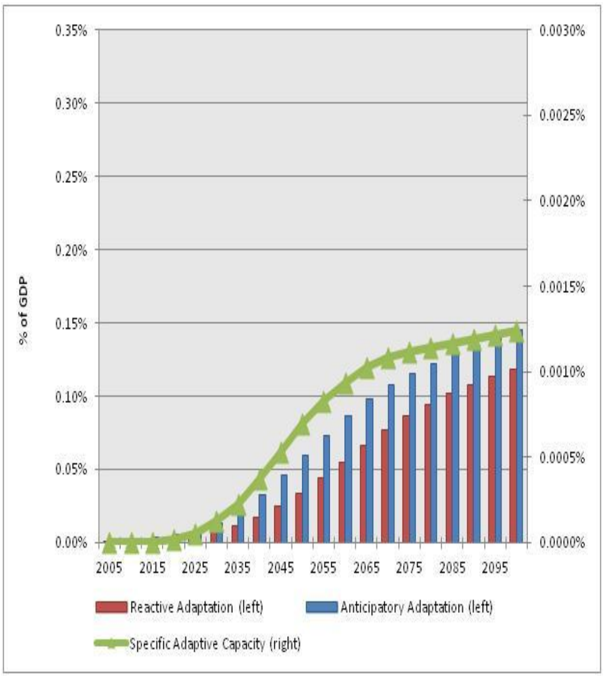


Table 15: Composition of climate change policy expenditure in the EU (2005 US$ Billion): Stab Scenario.

	Anticipatory Adaptation	Reactive Adaptation	Specific Adaptive Capacity	Mitigation Costs
2010	0.34	0.19	0.00	50.73
2050	24.74	13.87	0.29	109.70
2100	98.83	80.79	0.84	170.60
2010-2100 Discount rate 3%	493.35	341.00	4.89	2940.84

3.1.8.2.2 Conclusions

The major results referred to the EU27 can be summarised as follows:

If uncontrolled, climate change damages can reach 3% of the EU GDP in 2100. Optimal adaptation can however cost-efficiently reduce this. In 2100 an expenditure of roughly 0.5% of GDP would halve the damage. Total climate change cost (that is, adding adaptation expenditure to residual damage) would drop to 2.3% of GDP. Adaptation, although starting almost since the beginning of the simulation period, remains negligible until 2030. Indeed it is put in place only when the climatic damage reaches a detectable magnitude.

Analysing the optimal adaptation basket, proactive and reactive adaptation build almost the entirety of adaptation expenditure and the role of investment in adaptive capacity building is negligible. This is not surprising considering that the EU belongs to those developed regions in which adaptive capacity is already developed and large adaptation gaps do not have to be filled.

Anticipatory adaptation is predominant, constituting roughly the 56% of the total adaptation bill. The model thus suggests that it would be optimal for the EU to devote more resources to anticipate the damages building a stock of pre-defensive capital rather than act in emergency or ex post. At the same time, not all the damages could be prevented, therefore a non negligible amount of resources should be anyway devoted to recovery measures.

When the CO_2 concentration stabilisation policy is implemented together with adaptation the damage potentially experienced by the EU is reduced further. In 2100 residual damages are roughly 1.3% of GDP or US$ trillion 0.8 compared with the US$ trillion 1.2 accomplishable by adaptation alone. In addition, not only residual damages, but also total climate change costs, i.e. including mitigation and adaptation expenditures, are lower when mitigation and adaptation are jointly implemented than in the adaptation only case: they are US$ 1.15 trillion instead of US$ 1.56 trillion. Summarising, the joint use of mitigation and adaptation is welfare improving.

In terms of timing, while adaptation needs to take place large-scale in the mid century, mitigation is important immediately. This is because mitigation works against strong climatic inertia (from 50 to 80 years) and therefore should be implemented well in advance to produce some results. On the contrary, adaptation, also in its anticipatory form, works against a shorter economic inertia and can be implemented more closely in time to the expected damage occurrence. All this boils down in confirming the strategic complementarity between mitigation and adaptation.

At the same time mitigation crowds out adaptation. The presence of the global mitigation strategy reduces climate change damages and accordingly the need to adapt. Adaptation expenditure in the EU is reduced by half, and slightly postponed, albeit remaining important. Indeed, notwithstanding the presence of mitigation, there is a residual damage that cannot be eliminated and that can be optimally dealt with adaptation. All the different forms of adaptation - investment in adaptive capacity building, reactive and proactive - are affected more or less uniformly. Accordingly, the presence of mitigation does not penalize particularly one form of adaptation with respect to another one.

3.2 Who is affected, in what ways, and to what extent?

3.2.1 Climate impacts on economic sectors and systems

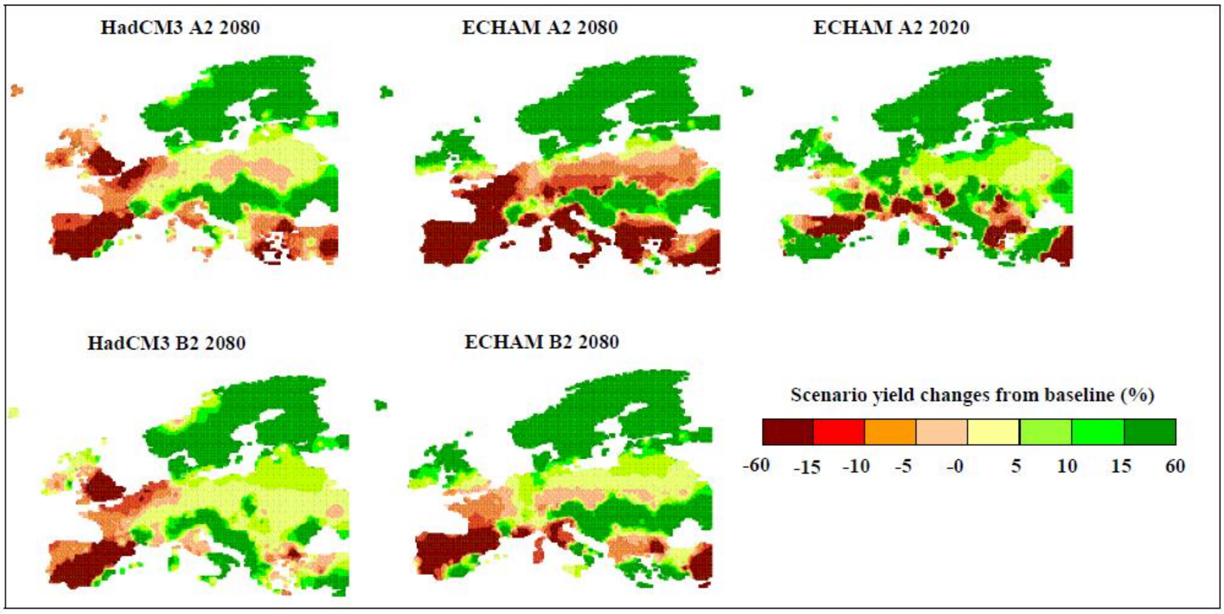
3.2.1.1 Agriculture

Early **scenarios** for European agriculture in a climate change context were developed in the context of the ATEAM project (e.g., Ewert, et al, 2005; Rounsevell, et al, 2006). The PESETA project addressed the potential impacts on crop yields in Europe on the basis of two GCMs and two SRES scenarios (A2 and B2, cf. Figure 25 for an example, Iglesias et al., 2009). The study also addresses adaptation options and adaptive capacity that would ameliorate the potential impacts. Other studies developed scenarios to determine the effects of future climates and socio-techno-economic developments for agricultural land use, combining models of crop growth and farm decision making to predict profitability over the whole of Europe (Audsley, et al, 2006; Berry, et al, 2006). They find that the main effects are expected in the agriculturally marginal areas of Europe, while the variations are much more determined by the economic scenarios than by climate change. Olesen et al. (2006) analyse a wide range of SRES scenarios and find that the variation in simulated results attributed to differences between the climate models were, in all cases, smaller than the variation attributed to either emission scenarios or local conditions, and that the methods used for applying the climate model outputs played a larger role than the choice of the GCM or RCM. Because of a longer growing season and higher CO_2 concentrations, Olesen et al. (2006) find an increased thermal suitability for grain maize cultivation and strong increases in net primary productivity in Northern Europe. Hermans et al. (2010) show that under a global market scenario agricultural productivity increases, while less agricultural land will be needed to supply the European demand for food. The results indicate a further concentration of economically and agriculturally strong areas, despite strong population pressures in some of these regions. The economic strength of the agricultural businesses gives them a strong competitive advantage in a global market. Regions which currently have a low competitiveness will have great difficulties in obtaining a stronger market position. This also shows that non climate drivers play an important role in the development of the European agriculture.

In general the scenario studies focus on changes in land use and productivity. Next to climatic drivers, important drivers for the development of agriculture are social and economic changes, such as changes in consumption, technology development, urbanisation and globalisation. The impact of weather extremes on farm systems and productivity are not included in most scenarios.

The Commission periodically publishes outlooks for EU agriculture and rural areas in which it is observed that climate change will remain to influence the market outlook, with unpredictable weather patterns leading to supply fluctuations (EC, 2010q). The Scenar 2020 studies for DG AGRI identified and analysed a number of long-term trends concerning the demographic developments in rural regions, the dynamics of rural areas and the future of the agricultural economy including the environmental dimension for the EU, in its planned and potential future geographical shape until 2020 (Nowicki, et al, 2006, 2009).

Figure 25: Crop yield changes under the HadCM3/HIRHAM A2 and B2 scenarios for the period 2071 - 2100 and for the ECHAM4/RCA3 A2 and B2 scenarios for the period 2011 – 2040 compared to baseline (Iglesias, et al, 2009)



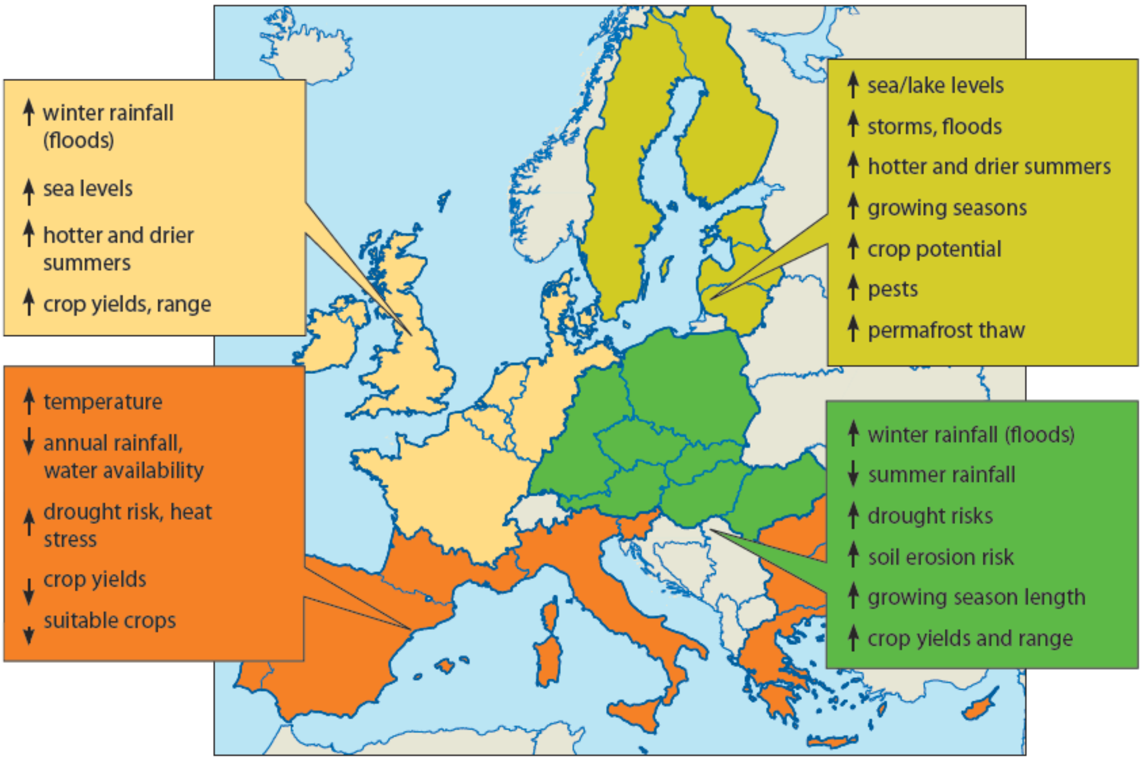
From the **literature** there is evidence that Europe is one of the world's largest and most productive suppliers of food, including both arable crops and animal products. In 2008 Europe accounted for 19% of global meat production and 20% of global cereal production (Olesen, et al, 2011). Due to the small proportion of total GDP and employment related to agriculture in Europe, the vulnerability of the overall European economy to changes in agricultural production is low. However, in areas which are strongly depending on agricultural production the effects may be substantial (Maracchi, et al, 2005).

Climatic conditions affect agriculture and the water resources needed to maintain stable production levels in many areas of Europe (Ciscar, et al, 2009). Various authors distinguish between direct and indirect effects of increased greenhouse gas emissions on the agro-ecosystem. Direct effects are primarily due to higher CO_2 levels and include increased biomass production and water use efficiencies. Indirect effects are related to climatic components such as temperature, precipitation, extreme events, radiation and humidity (Olesen & Bindi, 2004) which in turn influence crop growth and occurrence of weeds, pests and diseases (Olesen, et al, 2011) (cf. also chapter 3.2.2.3.3). Changes in temperature, radiation, precipitation and CO_2 concentration also impact plant water uptake (Supit, et al, 2010).

When studying the effects of climate change on agriculture in Europe, most literature makes a distinction between effects in Northern and Southern Europe. In Northern Europe, positive impacts of climate change on agriculture are expected. These are related to longer growing seasons, introduction of new crop species and varieties, higher crop production, and expansion of suitable areas for crop cultivation (Carter, 1998). Positive effects on agriculture in the whole of Europe include a potential increase in CO_2 fertilization of plants. In Southern

Europe however, the benefits of projected climate change will be limited, while the disadvantages will be prevalent. Disadvantages include increased water demand and periods of water deficit, extreme weather events (heat, drought, storms), loss of soil carbon content, erosion, lower harvestable yield and higher yield variability, increased pesticide requirements and crop damages, and reduction in suitable areas of traditional crops (Olesen & Bindi, 2004; EC, 2009a; Maracchi, et al, 2005). Rising sea levels may lead to a loss of farmland as a result of inundation and increasing salinity of soils and fresh water supplies, particularly in low-lying areas such as the Netherlands (Iglesias, et al, 2009; Falloon & Betts, 2010). Figure 26 gives an overview of the projected impacts of climate change in different European regions.

Figure 26: Projected impacts from climate change in different EU regions, Source: EC, DG Agriculture own elaboration based on literature.[24]



Socio-economic characteristics also influence the vulnerability and adaptive capacity of the European agriculture. Impacts of climate change and variability largely depend on farm characteristics (e.g. intensity, size, land use). Farm characteristics influence management types and adaptation. As different farm types adapt differently, a large diversity in farm types reduces impacts of climate variability at regional level. Certain farm types may remain vulnerable while others are resilient to climatic changes. These factors are often ignored in scenario studies (Reidsma, et al, 2010). Farm management and adaptation can largely reduce the impact of climate change on crop yields and farmers income (Reidsma, et al, 2010).

3.2.1.2 Forestry

Only limited broad scale knowledge is available regarding the prediction of impacts of climate change on European forests (EC, 2010f). This statement was confirmed two years later

[24] http://ec.europa.eu/agriculture/publi/fact/climate_change/leaflet_en.pdf

within an expert workshop carried out in the context of the development of the EU adaptation strategy by several experts[25].

Even if some progress has been made, only a patchy picture can be drawn and there is still a lack of EU wide impact studies. The following note summarises the main findings on how climate change might impact EU forest systems.

3.2.1.2.1 Change in species and forest patterns

Based on a **literature survey** the following picture can be drawn: Climate change is expected to have various complex effects on European forests, at least in the mid to long term (Lindner, et al, 2010). Forests and the way they are managed are particularly sensitive to climate change because the long lifespan of trees does not allow a rapid adaptation to environmental changes (EC, 2010f). Effects of climate change include increased risk of biotic (pests and diseases) and abiotic (droughts, storms and fires) disturbances to forest health. However, the exact effects of climate change on forests are complex and not yet well understood. The impacts of climate change will vary throughout the different geographic regions of Europe, with forest fires likely to dominate in Southern Europe and the limited diversity of tree species in boreal forests enhancing the risk of significant pest and disease impacts. Next to negative climate change impacts, especially in the long term, opportunities arise as well in the forestry sector. Evidence to date suggests that productivity in Northern and Central Europe has increased and is likely to continue to increase. Further, northward expansion of potential distribution of some tree species is expected and potentially more favourable conditions for summer recreation in mountainous regions will exist (Lindner, et al, 2010). However, with more drastic changes in climate towards the end of the 21th century, severe and wide ranging negative climate change impacts have to be expected in most European regions (Lindner, et al, 2008), with the Mediterranean region as the most vulnerable to climate change based on potential impact assessment and adaptive capacity (Lindner, et al, 2010).

Based on a literature survey (Turbe, et al, 2012) Table 16 summarises the impact of climate change on the distribution of tree species and impacts on abiotic factors considering the different forest types as follows.

[25] Cf. expert workshop" Climate change and the forestry sector" held 19.6.2012 (http://www.fresh-thoughts.eu/events.php?eventid=54&site=about and Background report to the IA, Part II). Also a recent large scale conference (see http://www.gip-ecofor.org/tours2012/) has clearly demonstrated this fact as most of the presentations are focusing on local/regional case studies or only a specific trees species.

Table 16: Impact of climate change on the distribution of tree species and impacts on abiotic factors

Forest type	Climate change expected	Change in tree species distribution due to climate change	Change in abiotic factors due to climate change
Boreal	4-5°C of temperature increase A 40% increase in yearly precipitation	Expansion of the broad leaves deciduous trees area northwards	Foreseen increase of damage by wind and storms
Atlantic	A 2°C of temperature increase	Decrease of conifers distribution area	More frequent extreme events like storms and flood in winter mainly
Continental	3-4.5°C of temperature increase and global decrease in precipitation with changes in inter-and intra-annual distribution	Decrease in the number of F. sylvatica	Increase of the vulnerability to water stress in some areas Increase of the vulnerability to frost for some tree species
Mediterranean	3-4°C of temperature increase A 20% decrease in yearly precipitation	Progressive extinction of the European Beech	Drought stress increasing Forest fires become a bigger threat Threat of desertification and soil loss
Mountainous	Rapid increase of the temperature compared to the other forest types	Predicted shifts in distribution of herbaceous, dwarf shrub alpine plants and even tree species	Forest fire threats in the Pyrenees and in temperate mountain range

In mountainous regions, a temperature-induced upward shift of the tree line will improve protection against natural hazards by stabilizing soils and erodible mass and reducing runoff peaks. For highly specialized alpine plant communities the upward shift of the tree line ecotone is a substantial threat. However, in managed forests where human interventions strongly affect the biodiversity, increased competitiveness of species-rich broadleaved forest communities can increase biodiversity.

Scenarios for forestry in Europe in a climate change perspective often focus on the effects of forest management strategies and/or climate change on carbon stocks and flows, such as analyses of the European Forest Institute. Based on three contrasting scenarios, the European Forest Sector Outlook Study (UNECE/FAO, 2005) presents long term trends for supply and demand of forest products and services and outlook to 2020 in Western and

Eastern Europe and also notes the potential for mitigation. Even taking into account the large uncertainties, for the forestry sector in Europe, climate change may offer opportunities for the forestry sector by higher productivity and northward shifts of tree species. Climate change on the other hand may reinforce damage by drought, fire, storm and insect calamities (Forest Europe, UNECE & FAO, 2011) Forestry is also linked to climate impacts and human health through forest fires affecting air quality (e.g. EEA, 2006).

In the European ECOCHANGE project[26], different modelling approaches have been used to better understand and evaluate the impacts of the climate change on ecosystem. To assess the impacts on forestry the CARAIB dynamic vegetation model (Dury, et al, 2011) under a A2 scenario was applied leading to the following results. Climate change might strongly modify around 60 % of the European vegetation resulting in a cover change. Around the Mediterranean Basin and the Black Sea, future landscape is likely characterized by more open vegetation. The warm temperate open woodland expands to the detriment of temperate broadleaved deciduous forests. The Mediterranean vegetation shifts northwards, towards Western and Central Europe. Temperate and boreal forests shift northwards and eastwards as well as upwards in the mountainous regions. As a consequence of this tree-line displacement, European tundras might disappear almost completely and might be replaced by boreal forests. The shift from mixed forest (deciduous and conifers trees) to deciduous forest is favoured under rising CO_2 conditions.

The FP7 project MOTIVE (MOdels for AdapTIVE forest management)[27] has recently produced a number of results documenting the impacts of climate change on Europe's forests. The project evaluates the consequences of the intensified competition for forest resources given climate and land use change. The project focuses on a wide range of European forest types under different intensities of forest management. In particular, MOTIVE examines impacts with respect to the disturbance regimes determining forest dynamics. Based on a multitude of Regional Circulation models the projects demonstrates that only early successional (pioneer) tree species, for example birch, may reach migration rates which are sufficiently large (ca. 1 km per year) to track recent rapid climate change. Late successional species e.g European beech or oaks), reveal very low migration rates which are considered to be insufficient to track on-going and accelerated climate change. For these tree species, therefore, major biome shifts under rapidly changing climatic conditions will only be possible with human intervention such as assisted migration (Vänttinen, 2012).

3.2.1.2.2 Changes in yields/productivity

The combination of rising CO_2 concentrations in the atmosphere and increasing temperatures result in changing productive patterns of forests and shifting distribution of forest biomes.

[26] http://www.ecochange-project.eu/
[27] http://motive-project.net

In Northwest Europe, where water supplies are not a limiting factor, growth rates are likely to be enhanced by a combination of rising CO_2 levels in the atmosphere, warmer winters and longer growing seasons, and increased nutrient availability as a result of atmospheric deposition and increased soil mineralisation (Lindner, et al, 2010). Maracchi et al. (2005) state that the climatic zone suitable for boreal forest can be enlarged by 150- 550 km due to rising (winter) temperatures. As a consequence, timber yields may increase in Northern Europe in the mid to long term with 8-22%, depending on climate scenario and species. Also, the accumulation of carbon in biomass will be enhanced (Lindner, et al, 2010). However, higher winter temperatures will shorten the period with frozen soils and snow cover. This results in a reduced availability to harvest timber due to inaccessibility of forest resources outside the frost period, which will pose a threat to the industry (Lindner, et al, 2008; Maracchi, et al, 2005). Projections of the development with the model EFISCEN, show that for all projected climate scenarios, climate change resulted in an increased forest growth, especially in Northern Europe. In Southern Europe increased precipitation in spring and increased water use efficiency of trees as a result of higher CO_2 concentrations compensate for increased summer droughts (Eggers, et al, 2008). Sarris et al. (2011) state that climate change will lead to more severe growth reduction, tree mortality and damage from forest fires on *Pinus Halepensis Miller* in the Mediterranean.

The latest result from the FP7 project MOTIVE (Reyer, et al, n.d.) which on one hand carried out a literature review and on the other hand simulated net primary production came to the following conclusion in relation to productivity:

- Most studies in Northern Europe zone show productivity increases and higher carbon stocks under global change scenarios.
- The response to global change is positive and negative in Central Europe.
- In the Mediterranean, the response depends strongly on CO_2. However, only a limited number of sub-regions and tree species are covered.
- The degree of acclimation to higher CO_2-levels is crucial.

3.2.1.2.3 Droughts

The increase in productivity in Northern Europe contrasts with Southern Europe as the positive effects of a rising temperature on tree growth could be counteracted by limited water availability. Despite the fact that CO_2 enrichment is likely to increase water use efficiency, more frequent and severe summer droughts may negatively influence forest stands. Droughts resulting from increased (summer) temperatures and (possible) reduced summer precipitation are likely to lead to reduced productivity (Lindner, et al, 2010; Maracchi, et al, 2005).

Increases in frequency, intensity and duration of drought and heat stress could fundamentally alter composition, structure and biogeography of forests in many regions. Of particular concern are potential increases in tree mortality associated with climate-induced physiological stress and interactions with other climate-mediated processes such as insect outbreaks and wildfire (Allen, et al, 2010).

3.2.1.2.4 Forest Fires

More extensive forest fires, especially in the already fire-prone Mediterranean areas, but also in the Temperate Continental and Boreal regions are expected (Lindner, et al, 2010; Maracchi, et al, 2005). While small to medium fires have little or no negative impacts, more severe fires can cause significant damage to forests stands and ecosystems (Lindner, et al, 2008). Ultimately, droughts can lead to desertification in some areas in Southern Europe. As extended droughts have much more drastic consequences on tree growth and survival than gradual changes in average climatic conditions, climate variability is of particular importance in this respect (Lindner, et al, 2010).

3.2.1.2.5 Storms

Wind throw and other storm damage is most relevant in Central, Western and Northern Europe. It is uncertain whether the frequency of Atlantic storms will increase in the future. However, local thunderstorms may be more intense and damage may be greater in combination with water saturated soils and decreased soil freezing which reduces stand stability. The economic impacts of wind damage are particularly severe in managed forests (cf. also Figure 27) because of the reduction in the yield of recoverable timber, the increased costs of unscheduled thinning and clear-cutting, and resulting problems in forestry planning (Maracchi, et al, 2005).

3.2.1.2.6 Pests and diseases

Changes in the patterns of disturbance by forest pests (insects, pathogens and other pests) are expected under a changing climate as a result of warmer temperatures, changes in precipitation, increased drought frequency and higher carbon dioxide concentrations. However there is evidence from an FAO desk review that climate change is having considerable and widespread impacts on forest health worldwide, and, as a result, on the forest sector (FAO, 2008). Climate change can affect forest pests and the damage they cause by: directly impacting their development, survival, reproduction, distribution and spread; altering host physiology and defences; and indirectly by impacting the relationships between pests, their environment and other species such as natural enemies, competitors and mutualists (ibid).

Estimates of the possible influence of climate change on insect infestation are uncertain due to complex interactions between forests, insects and climate (Maracchi, et al, 2005; FAO, 2008). However, studies show that a changing climate will have an impact on both temporal and spatial dynamics of pest species. Increasing temperatures and altered patterns of precipitation influence the frequency and intensity of forest pest and pathogens species as well as their spatial distribution, size and geographical range. This can result in serious damage to both protected forests and those used for timber production. Norway spruce and pine forests as well as forests stands of oaks are expected to be most affected by biotic disturbance agents. As these tree species are of high economic importance, a higher probability of damage might put European forests at risks (Lindner, et al, 2008). Wolf et al. (2008) studied the effects of background herbivory by insects on vegetation growth and production with the GUESS model framework. Temperature rise is likely to enhance the potential insects´ impact on vegetation. The impacts are strongest in eastern parts of Europe, where potential insect damage to *Betula pubescens* (Downy Birch) can increase by 4–5%.

Regions that represent northern or upper distributional limits, such as the Alps or the Boreal zone, will probably be most affected by an increase in stability and population density of certain pest species. Central and Northern European forests will be increasingly predisposed to fungal diseases that benefit from longer growing seasons associated with higher temperatures. In turn, the increased amounts of precipitation during summer as expected for Northern Europe can support the spread of fungal diseases. In Eastern Europe, more frequent occurrence of warm and dry years could promote pest and pathogen development. It is likely that the present distributional range in the southern part of Europe will become too warm for certain species, not only resulting in northward and upward shifts but also leading to a decrease in species. The probability of the establishment of exotic species will increase (Maracchi, et al, 2005).

Some pest might also turn forest from a carbon sink into a major carbon source, on its own accelerating global warming (e.g. large scale outbreaks of mountain pine beetle in British Columbia, Canada). The mountain pine beetle killed twenty million acres of trees between the mid 1990s and 2006 and was the largest outbreak of mountain pine beetle ever recorded. According to calculations, by 2020 the beetle outbreak will have released 270 megatonnes of carbon dioxide into the atmosphere (Kurz, et al, 2008).

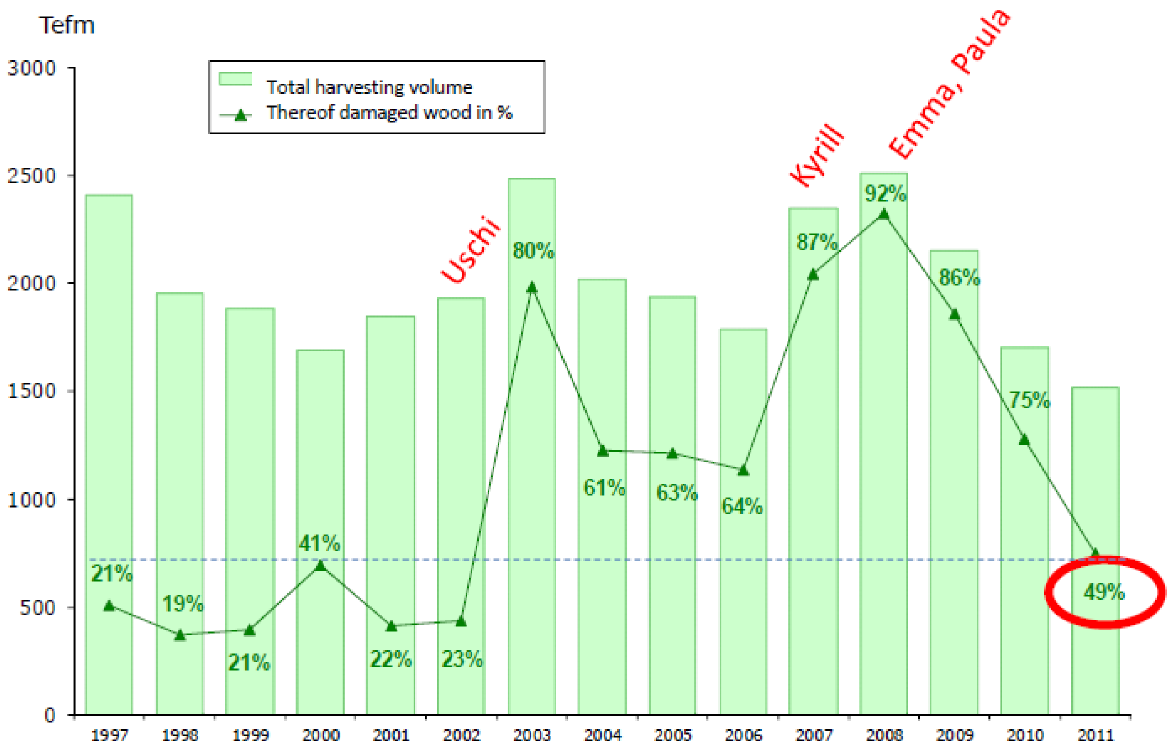
Due to climate change, previously inhospitable sites can become suitable for ‘alien' pests that are accidentally transported through international trade in wood products, seeds or nursery plants — as well as trade in other commodities packaged with wood materials. However according to new (alien or exotic) insect species that may present a future threat to woodland are more likely to be driven by global trade as by climate change (FAO, n.d.). Recognising the increasingly serious problem of invasive alien species in Europe, the Commission is currently working on a dedicated legislative instrument on Invasive Alien Species which is due to be adopted in 2012. In the context of preparing these legislative acts, the Commission has set up several working groups. The working Group on Risks recommends to include climate change in common framework for Invasive alien species risk assessment.

3.2.1.2.7 Potential costs of impacts

In Europe no detailed assessment has yet been made of the economic implications of climate change, nor of the potential costs of the various adaptation measures needed. In general, both the implications and the costs are affected by national and international forest (and energy) policy and global markets, in addition to the supply, demand and price of wood (Lauri, et al, 2011).

During the stakeholder meeting convened with forest experts in June 2012 it came clear that the overall damage due to natural catastrophes has increased massively over the last 10 years in several regions. Figure 27 shows an example from Austria (McCallum, et al, 2013).

Figure 27: Damaged Wood Development of Österreichische Bundesforste AG



Tol (2002) performed estimations for forestry. He based his calculations on a study of Perez-Garcia et al. (1996). He estimated that the impact of a 1°C global temperature rise and CO_2 fertilization is 134 million USD for OECD-Europe. For Central Europe and the former Soviet Union the impact is negative. The damage costs are 136 million USD.

3.2.1.3 Transport

We focus in the transport sector mainly on climatic pressures for the infrastructure and partly on transport equipment. The following four transport modes will be taken into account: a.) rail (railways); b.) road (roads in general and specific cases of coastal and mountain roads); c.) shipping (inland and ocean shipping, ports) and d.) aviation (airports). Furthermore, this document includes the issue of urban transport which might combine all four transport modes.

Consequences of climate change will be both negative and positive for transportation infrastructure (Vajda, et al, 2011). The infrastructure will experience impacts unique to each mode (e.g. scour on bridge supports), but many impacts, such as flooding and erosion, will be common across all modes. Furthermore, impacts will differ from region to region. In addition, the condition of the infrastructure itself will affect the impacts experienced.

Generally speaking, the frequency and intensity of weather and climate extremes are likely to continue to change in the future due to the projected climate change. Thus, adverse and extreme weather events, such as heavy rain (e.g. causing floods), heavy snowfall, strong winds, extreme heat and cold, drought and reduced visibility can enhance negative impacts on the transport infrastructure, causing injuries and damages as well as economic losses. But also some beneficial impacts on transport due to climate change can be expected, such as reduced snow fall for most European regions that improve traffic conditions.

The following tables (Table 17 to Table 21) provide a summary on future climatic pressures which may affect the rail infrastructure negatively. The summary is based on Altvater et al. (2011b) and has been further developed with additional information from literature.

Table 17: Climatic pressures on RAIL infrastructure

Climatic pressures	Risk	Time frame of expected impact	Area mainly affected
Summer heat	Rail buckling; material fatigue; increased instability of embankments; overheating of equipment (e.g. engine ventilation, climatization); increase wildfires can damage infrastructure	Medium negative (2025; 2080) to high negative (2080)	Southern Europe medium negative until 2025 and high negative until 2080; West, East and Central EU medium negative until 2080
Winter cold/ice	Ice on trains and catenary	Medium negative (2025; 2080)	Northern Europe, Central Europe
Extreme precipitation	Damage on infrastructure due to flooding and/or landslides; scour to structures; destabilization of embankment	Medium negative (2025) to high negative (2080)	European wide
Extreme storms	Damage on infrastructure such as signals, power cable etc. (e.g. due to falling trees, etc. In general: reduced safety; increased cost for reparation and maintenance; disruption of “just in time" delivery of goods and passengers	No information	No information

Table 18: Climatic pressures on ROAD infrastructure

Considered part	Climatic pressures	Risk	Time frame of expected impact	Area mainly affected
Roads **(including other infrastructure such as bridges, tunnels etc.**	Summer heat	Pavement deterioration and subsidence; melting tarmac; reduced life of asphalt road surfaces (e.g. surface cracks); increase wildfires can damage infrastructure; expansion/buckling of bridges	Medium negative (2025; 2080) to high negative (2080)	Southern Europe (2025), West, East and Central EU (2080)
	Extreme precipitation/ floods	Damage on infrastructure (e.g. pavements, road washout); road submersion; scour to structures; underpass flooding; overstrain drainage systems; risk of landslides; instability of embankments	Medium negative (2025) to high negative (2080)	European wide
	Extreme storm events	Damage on infrastructure; roadside trees/vegetation can block roads In general: speed reduction; road closure or road safety hazards; disruption of “just in time" delivery of goods; welfare losses; higher reparation and maintenance costs	No information	No information
Coastal roads	Sea level rise Extreme storm events Heavy precipitation events	Sea level rise, extreme storm events and heavy precipitation: Damage infrastructure due to flooding; coastal erosion; road closure	Medium negative (2080) No information Medium negative (2025) to high negative (2080)	European wide No information European wide
Mountain road	Permafrost degradation	Decrease of stability; rockfalls; landslides; road closure;	No information	No information
Sewerage system	Heavy precipitation events	Overloaded sewerage system can cause road flooding and water pollution	Medium negative (2025) to high negative (2080)	European wide

Table 19: Climatic pressures on AVIATION infrastructure

Considered part	Climatic pressures	Risk	Time frame of expected impact	Area mainly affected
Airports (including runways)	Summer heat	Greater need for ground cooling; degradation of runways and runways foundations; higher density altitudes causing reduced engine combustion efficiency; decrease airport lift and increased runway lengths	Medium negative (2025; 2080) to high negative (2080)	Southern Europe (2025), West, East and Central EU (2080)
	Heavy precipitation events	Flood damage to runways and other infrastructure; water runoff exceeds capacity of drainage system	Medium negative (2025) to high negative (2080)	European wide
	Extreme storms	Wind damage to terminals, navigation, equipment, signage	No information	No information
	Sea level rise	Flooding of runways, out-buildings and access roads In general: interruption and disruption to services supplied and to ground access; periodic airport closures; higher maintenance costs	Medium negative (2080)	European wide

Table 20: Climatic pressures on SHIPPING infrastructure

Considered part	Climatic pressures	Risk	Time frame of expected impact	Area mainly affected
Inland shipping	High river flow (e.g. extreme precipitation, snow melt)	Problems for the passage of bridges; speed limitations because of dike instability; some restrictions to the height of vessels	Medium negative (2080)	European wide
	Low river flow (e.g. drought)	Strong restrictions to the loading capacity; navigation problems, speed reduction	Medium negative (2025) to high negative (2080)	South, East and Central Europe; in 2080 also Western Europe
	Change in ice cover	In general shorter periods of ice cover can be expected; nevertheless warm and early winters, followed by a rapid decrease in air temperature, may result in thicker or rougher ice cover formation and thus, lead to ice jams, damage to navigation signs and infrastructure (e.g. locks) In general: disruption of "just in time" delivery of goods; stop of inland shipping; welfare losses	No information	No information
Maritime transport	Sea level rise	Navigability could be affected by changes in sedimentation rates and location of shoals (TRB, 2008); more frequent closure	Medium negative (2080)	European wide
	Change in sea conditions	More severe storms and extreme waves might affect ships (DNV 2009[28])	No information	No information

[28] http://www.dnv.com/press_area/press_releases/2009/designchangesneededforextremestormpredictions.asp

Considered part	Climatic pressures	Risk	Time frame of expected impact	Area mainly affected
	Less days below freezing	Reduce problems with ice accumulation on vessels, decks, riggings and docks; occurrence of dangerous ice fog (TRB, 2008)	Medium positive (2080)	European wide
	Reduced sea ice	Improved access; longer shipping seasons; new shipping routes (TRB, 2008)	Summer sea ice could completely disappear in the Arctic Ocean somewhere between 2013 and 2040[29]	No information
Ports	Extreme storm events	Storms, sea level rise and floods/landslide may cause: Devastation of infrastructure; interruptions and bottlenecks in the flow of products through ports	Storms: no information	No information
	Sea level rise		Sea level rise: medium negative (2080)	European wide
	Floods/landslide	In general: disruption of "just in time" delivery of goods; welfare losses; increased cost for reparation and maintenance	Floods/land-slide: medium negative (2025) to high negative (2080)	European wide

[29] WWF, Climate change: faster, stronger, sooner, A European Update of climate science, 20 October 2008.

Table 21: Climatic pressures on URBAN TRANSPORT

Type	Climatic pressures	Risk	Time frame of expected impact	Area mainly affected
Urban Transport (road infrastructure, bike lanes, walkways, rail infrastructure, waterways, public and private transport)	Temperature increase and heat waves	Increase of the heat island effect (e.g. melting asphalt, increased asphalt rutting due to material constraints, thermal expansion on bridge expansion joints and paved surfaces, and damage to bridge structure material)	Medium negative to extreme negative	2025: Southern, Eastern EU 2080: Northern, Southern, Eastern, Central EU
	Heavy precipitation events (extreme flash floods)	Damage to infrastructure due to flooding, property at risk due to location, heavy water run-off	Medium negative (2025;2080) to high negative (2080)	2025: Southern, Western 2080: Eastern, Southern, Northern, Western, Central EU
	Sea level rise and storm surge flooding	Risk of inundation of road infrastructure and flooding of underground tunnels, degradation of the road surface and base layers from salt penetration	Medium negative to extreme negative	2025: Southern, Western, Northern EU 2080: Southern, Western, Northern EU
	Extreme storms, strong winds	Damages, increase of maintenance cost	Small to medium impacts	European wide

Looking at the specific transport modes in detail, main threats of climate change to the **railways** are higher temperatures and extreme weather events like floods or storms. The effects of these events are increased risk of track buckling, instability of embankments or damage to infrastructure such as overhead wires. In addition, the capacity of railways can be impaired during heat waves. As the climate warms, milder winter conditions would likely improve the safety record for rails in some regions.

Less work has been done on assessing the future vulnerability of **road infrastructure**. Nevertheless, due to higher temperatures impacts on road pavement and subsidence as well as reduced life of asphalt road surfaces can be expected. Roads can be blocked by forest fires. Summer droughts might have critical impacts on road embankments and foundations. An increase of precipitation intensity will damage the infrastructure (e.g. pavements, road washout) and lead to road submersion, scour to structures as well as to overstrain drainage systems. Traffic jams are more likely to occur during rainfall. Warming winter temperatures will bring about reductions in snow and ice removal costs. Nevertheless, more freeze–thaw conditions may occur, creating frost heaves and potholes on road and bridge surfaces and resulting in load restrictions on certain roads to minimize the damage (Enei, et al, 2011).

In Europe, the most important **inland waterways** covered comprise the Rhine, the Danube, the Elbe and the Seine Nord Canal, representing the Rhine, the south-east, the east-west and the north-south inland waterway axes. Similarly to other modes of transport, inland waterway transport might be affected by climate change negatively, e.g. increasing occurrence of heavy rainfall, in particular in association with snow melt, may lead to floods resulting in suspension of navigation and causing damage to the inland waterway infrastructure. Negative impacts might also be expected in case of long periods of drought which may lead to low water levels and reduced discharge, thus requiring a decreasing load factors and increasing costs. In opposite, positive impacts of climate change could occur due to more balanced navigation conditions throughout the year as well as shorter ice periods reducing the duration of suspension of navigation (Schweighofer, 2010). **Maritime transport** will experience severe consequences from storms/hurricanes, followed by heavy rains, high wind speeds and, sometimes, hail, causing all kinds of damage, from infrastructure destruction to the impossibility of accessing the port (Enei, et al, 2011).

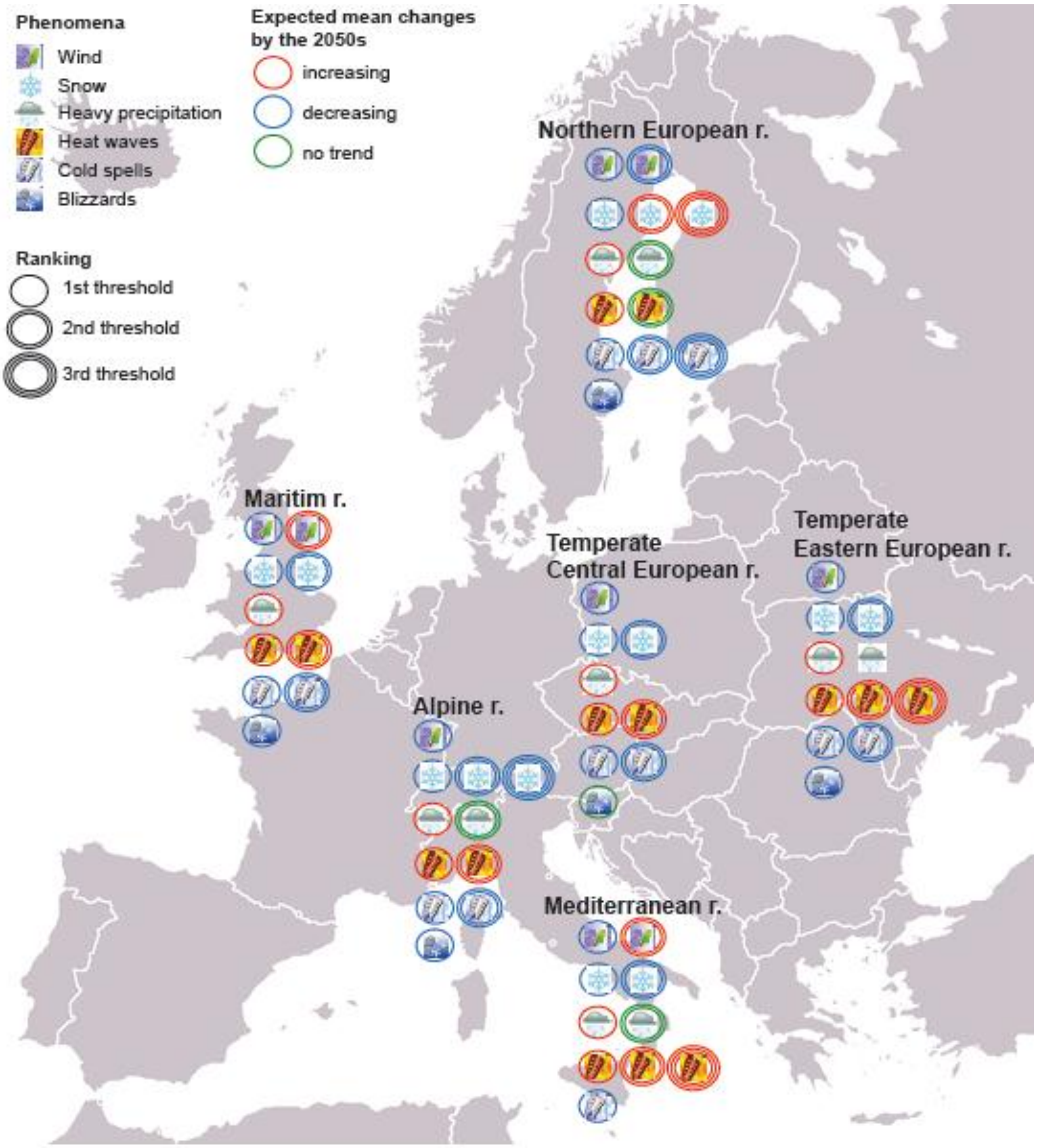
Aviation shows high weather dependence already today. Due to climate change it will acknowledge potential impacts which can be positive (e.g. less heavy snowfall, changed frost conditions, less need for de-icing) or negative or uncertain (e.g. more heavy rainfall/flooding, more storms or changed wind patterns). It can be expected that it will increasingly suffer from extreme weather events in the future. The reason for this is two-folded. On one hand, wind gusts will increase, especially in the southern part of Europe and on the other hand, free capacity, which is currently used to buffer weather events, will be occupied by additional flights (Enei, et al, 2011).

All four above mentioned transport modes might be of importance for **urban transport**. In the specific case of urban areas, transport infrastructure should be ensured to better cope with higher temperatures, low water availability and flooding.

European wide assessments of future vulnerabilities for various transport modes are ongoing under EU financed projects such as WEATHER, EWENT, ECCONET. The final results can be expected in summer/autumn 2012.

Nevertheless, first deliverables are available. A summary on possible changes in extreme weather events until 2050 has been prepared by the EWENT project (cf. Figure 28). They conclude that the future heat related problems are probably understated in many places, especially in the Mediterranean climate zone. Furthermore, snow and cold are in general a strongly declining phenomena in pace with the warming. Nevertheless, the extreme snowfalls are predicted to increase in Northern most parts of Europe. The projections are less coherent with regard to extremes in precipitation and wind, but an increase in extreme precipitation is likely in parts of Central Europe (Tuomenvirta & Vajda, 2012).

Figure 28: Summary of extreme weather trends for different thresholds (1st = consequences possible, 2nd= consequences likely, 3rd=consequences almost certain) (Tuomenvirta & Vajda, 2012)

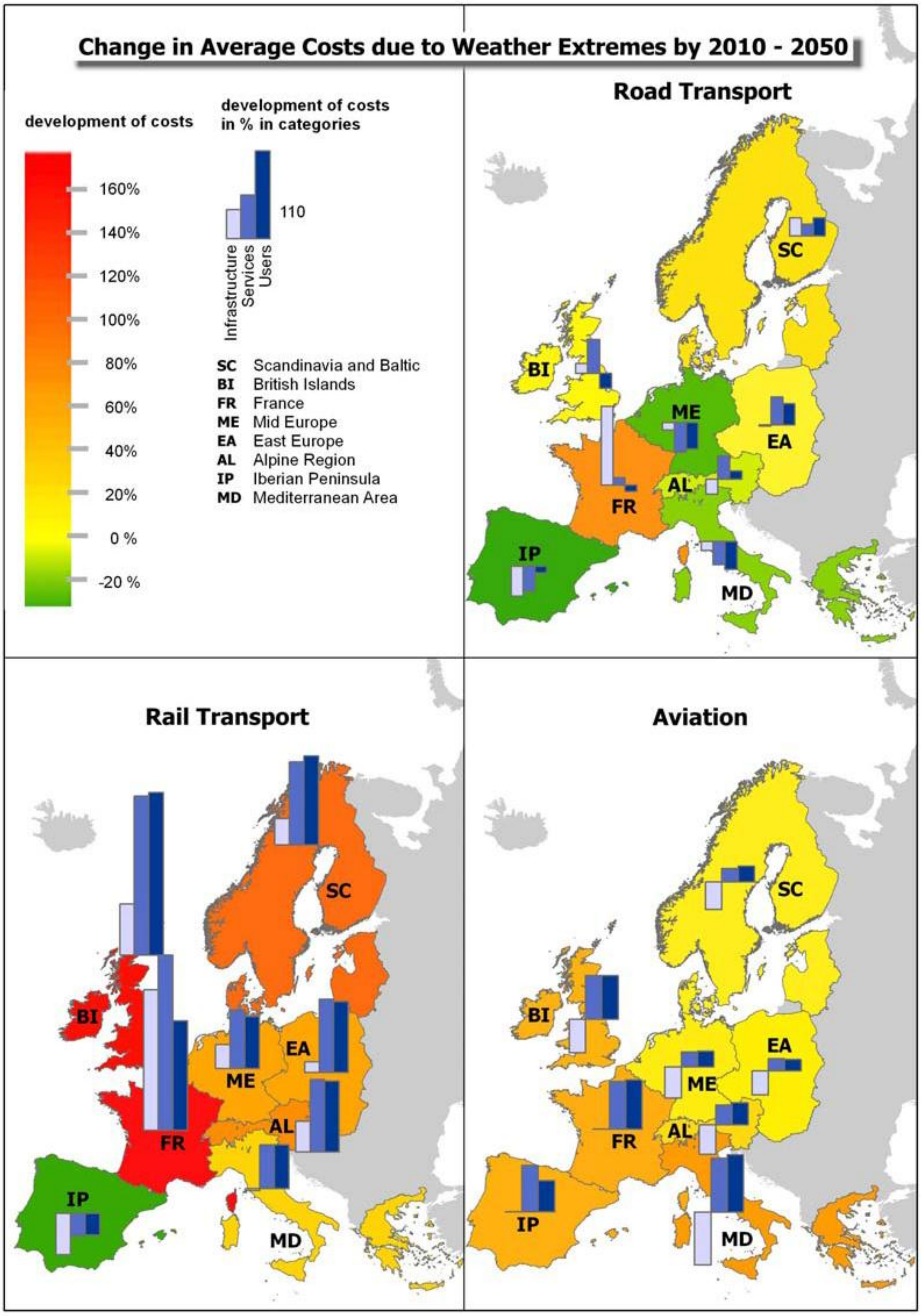


The Weather project calculated the costs of future climate change impacts. They conclude that from 2010 to 2050, that due to weather extremes rail transport will experience the most substantial increase in all cost categories (comprising direct costs to the transport sector and indirect costs to its users and to other sectors) (cf.Figure 29). Most hit are rail services in France and the UK, but also in Central Europe and Scandinavia (Fraunhofer ISI, in: Trinks, et al, 2012).

Regarding road transport an increase of infrastructure costs of approximately 80 % is predicted by the analysis. While in Scandinavia and Eastern Europe service and user costs may experience a modest. In contrast, a considerable decrease of more than 20 % in infrastructure, service and user costs in road transport related to extreme weather events is predicted for Germany, Spain and Italy (Fraunhofer ISI, in: Trinks, et al, 2012).

The impacts of weather extremes on aviation might be modest. Thus, total costs for aviation due to weather extremes will probably undergo no substantial changes in Central Europe, Scandinavia and Eastern Europe. However, the Mediterranean Area and again France will be confronted by increasing service and user costs (Fraunhofer ISI, in: Trinks, et al, 2012).

Figure 29: Change in average costs due to weather extremes by 2010-2050 (Fraunhofer ISI, in: Trinks, et al, 2012)



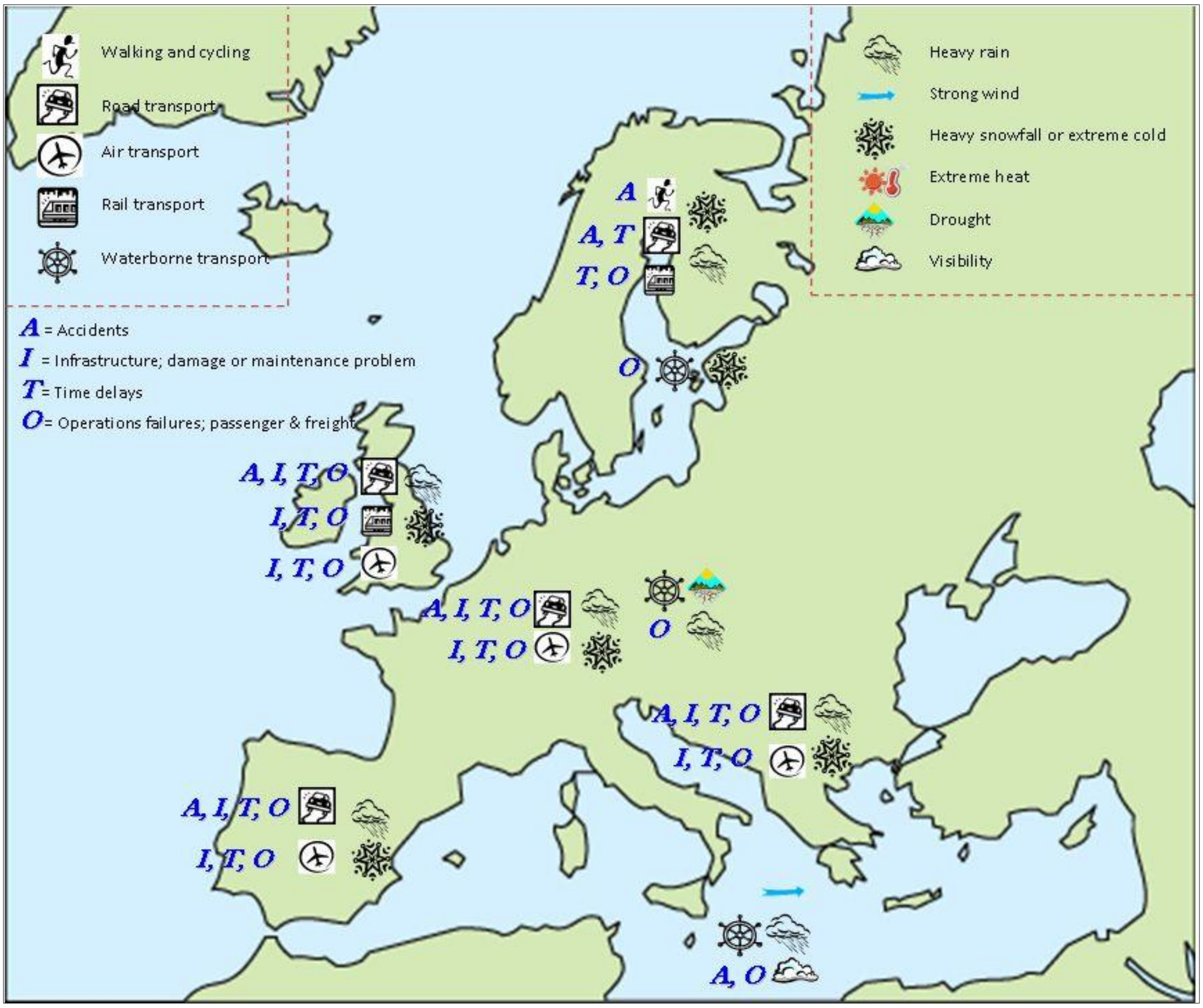
Results done by Greiving, 2011 show that regarding to sea level rise and a projected increase in river floods, remarkably high impacts on transport infrastructure can be expected in North-Western European coastal regions which border the Atlantic Ocean. For example, 34 European airports are expected to be at risk through sea level rise with impacts on runway capacity, ground transport access routes and global knock-on effects (Enei, et al, 2011).

Climate change affects not only road, rail, aviation and shipping infrastructure, but also the distribution of transportation and traffic flows, e.g. as a result of changing tourism patterns. Furthermore, the vulnerability of the transport sector is also influenced by human behaviour and societal changes: as different transport modes are differently affected by climate change, the kind of mobility chosen by individuals is influencing the vulnerability of the whole sector. For example, a strong shift from individual transport to public transport would decrease the vulnerability as public transport is better controllable and manageable. Individual mobility in turn is strongly influenced by other factors, such as the development of fuel costs.

The impacts of extreme weather events affect transport infrastructure already today. The EWENT project assessed past impacts and consequences of extreme weather events on transport system based on literature review, media mining and case studies. One result of the analyses is a simplified “extreme weather impact map” for Europe with the aim to visualize the most urgent problems in the past (Leviakangas, et al, 2011).

In the past, precipitation in its various forms caused the most damage to transport. This is true for all parts of Europe and all forms of transport. For example, heavy snowfall complicates road traffic, rail transport and airport operations regardless of where in Europe it occurs. The only differences are in how efficiently this problem can be resolved and how well unexpected weather conditions are prepared for with, for instance, sufficient availability of maintenance equipment. Heavy rain causes flash flooding, which disrupts transport connections, inhibits inland waterway traffic and damages earth structures such as road, bridge and rail embankments. Interestingly, extreme heat was not causing critical problems in the past (cf. Figure 30; Leviakangas, et al, 2011).

Figure 30: Sum-up of critical weather phenomena, their occurrence by region where effects are the most severe, with the most affected modes of transport and the consequences (Leviakangas, et al, 2011)

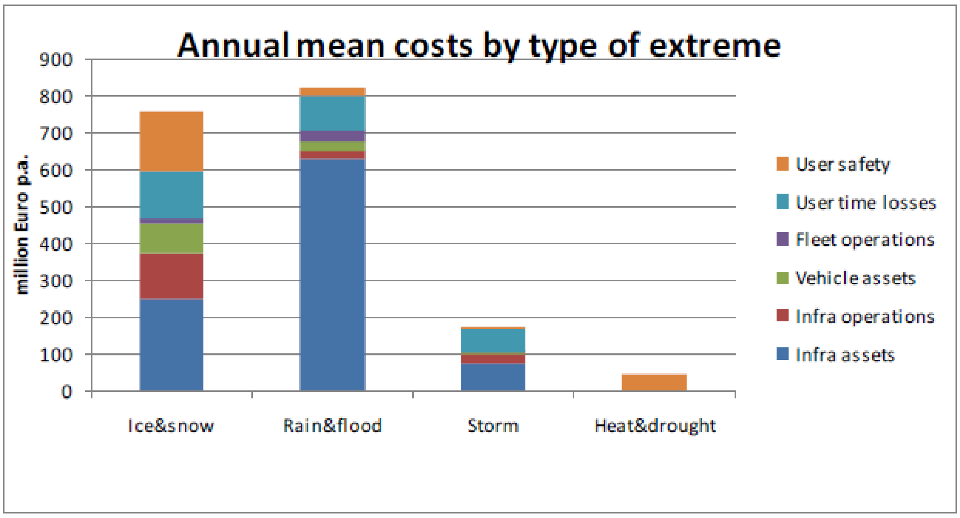


Furthermore, the EWENT project concluded that road transportation with its two traffic patterns, freight transport between major knots on corridors and passenger flows in large cities, is currently the most vulnerable transport mode. There are self-evident reasons for this. First, the traffic volumes are highest on roads and the capacity usually most limited in densely populated areas. The second reason is that road traffic is least controllable and manageable. Where air control or a railway traffic management centre can quickly decide on and execute adaptive and corrective measures, road traffic remains mostly a slow self-adaptive system that is geographically widespread and scattered (Leviakangas, et al, 2011).

The Weather project analyses the costs of past weather events on the transport sector and shows that the total costs amount to 2.5 billion Euro yearly (average year 2000 to 2010). The highest damage costs are found for road infrastructure (roughly 1.8 billion Euro annually). By far the most hit transport sector element are infrastructure assets (53% of total costs), followed by user time losses (16%) and safety implications (13%). Looking at both dimensions, rain and flood impacts on road infrastructure, accounting to 35% of total costs, dominate all other consequences of weather extremes (Enei, et al, 2011). This results stress the fact that the most relevant implications arising from climate change concern planning, design, construct, operate, and maintaining of transport infrastructure is likely (TRB, 2008).

Figure 31 shows the annual mean costs for roads structured along the types of extreme events (Enei, et al, 2011).

Figure 31: Roads: annual mean costs by type of extreme events (Enei, et al, 2011)



The total annual costs of extreme events for railways are roughly 0.3 billion Euro (while major floods cause 80 % of damages), for air transport system the costs are roughly 0.36 billion Euro annually. Minor costs are incurred to maritime transport (€ 20 million), inland waterways (€ 4 million) (Enei, et al, 2011).These damage costs are expected to increase in future due to climate change (Nordhaus & Boyer, 2000).

The project EWENT calculated that the European Union's 27 member states face each year at least 15 billion € cost resulted by extreme weather. This cautious estimate is about 0.1% of the EU-27 GDP (Nokkala, et al, 2012). This is significantly higher than the results taking from the Weather project due to the fact that EWENT used a wider definition of extreme events and non-motorised travel was taken into account (EEA, 2012a). Thus, it is important to mention that a careful interpretation of figures related to costs is required.

3.2.1.4 Construction and buildings

The impact of climate change is particularly pertinent to the construction industry given the life expectancy of buildings and the fact that there is a need to adapt the existing built environment, to deal with a climate that may be significantly different from that in which it evolved. Construction work needs to withstand a potentially very varied and uncertain climatic impact (Dlugolecki, et al, 2009).

Buildings and the whole construction sector can be vulnerable to climate change because of their design (low resistance to storms) or because of their location (e.g. in flood-prone areas, landslides, avalanches). Especially urban areas are affected by climate change due to higher sealing-rates related to construction and buildings (e.g. higher water run-off, heat island effect during summertime, and lack of fresh water during droughts).

The impacts of the changing climate on the built environment can be grouped into three broad categories (Gething, 2010; HM Government UK, 2012):

- those that affect comfort, health and energy performance – warmer winters may reduce the need for heating, but keeping cool in summer without increasing energy use and carbon emissions will present a challenge;
- those that affect construction – resistance to extreme conditions, detailing, and the behaviour of materials;
- managing water – both too much (flooding) and too little (shortages and soil movement).

Overheating is already a growing problem, in particular in cities. In London, for example, the number of days per year when temperatures rise above 26°C is projected to increase from the current average of 18 to between 27 and 121 by the 2080s (HM Government UK, 2012). 10% of the UK's commercial floor space was mechanically cooled in 1994. This proportion is expected to rise to 40% by 2020. Through overheating comfort and health of occupants can be affected by climate change (cf. chapter 3.2.2.3). At present the majority of buildings in Europe are naturally ventilated and do not use heating or cooling equipment (Jentsch, 2008).

Construction work needs to withstand and adapt to a potentially very varied and uncertain climatic impact, especially looking at the coming decades. The longer the use period the greater the climatic influence exerted. Much will centre on design flexibility, suitability of materials used and a skilled workforce during the construction phase. Thereafter sound standards of upkeep and maintenance must be observed. Construction-induced changes to drainage can be critical, for example, changing climatic conditions can quickly impose demands on drainage not anticipated when installed perhaps over a century ago (Dlugolecki, et al, 2009). Recent focus has been mostly on new homes but existing homes and other buildings will need to be adapted as well. There are few opportunities for intervention to influence the standards of existing stock, but sensible interventions may be possible, for example, at the time of resale or major refurbishment (Sir John Harman, chairman of the Environment Agency, UK).

Further, Carmin & Zhang (2009) call attention to the preservation of historic buildings, monuments, and archives in the historically very rich European cities, for example because building facades as well as statues and other monuments can deteriorate as a consequence of exposure to salts, pollutants, and changing weather patterns.

In the past, precipitation in its various forms caused the most damage to buildings and infrastructure. This is true for all parts of Europe and all forms of buildings and civil engineering works. For example, heavy snowfall caused building collapses, heavy rain and storm waters causing flash flooding lead to infiltration of water into buildings, damage or destruction. Additional salt water intrusion can cause deterioration of facades, statues and monuments. Heavy snowfall and landslides can seriously affect not only the day to day functioning of infrastructure (i.e. railways, roads) but also fast and efficient relieve activities.

With more intense extreme precipitation events expected, there is also a significant risk of drains and foul sewers flooding and failing to function. Recurring flooding and changes in ground water levels will require investment in flood resistance and resilience, while urban flash flooding must also be considered during extreme rainfall events (Gething, 2010).

In coastal areas, coastal protection (e.g. sea walls, barriers) might lead to increased maintenance costs and higher frequency of updating works (Dlugolecki, et al, 2009).

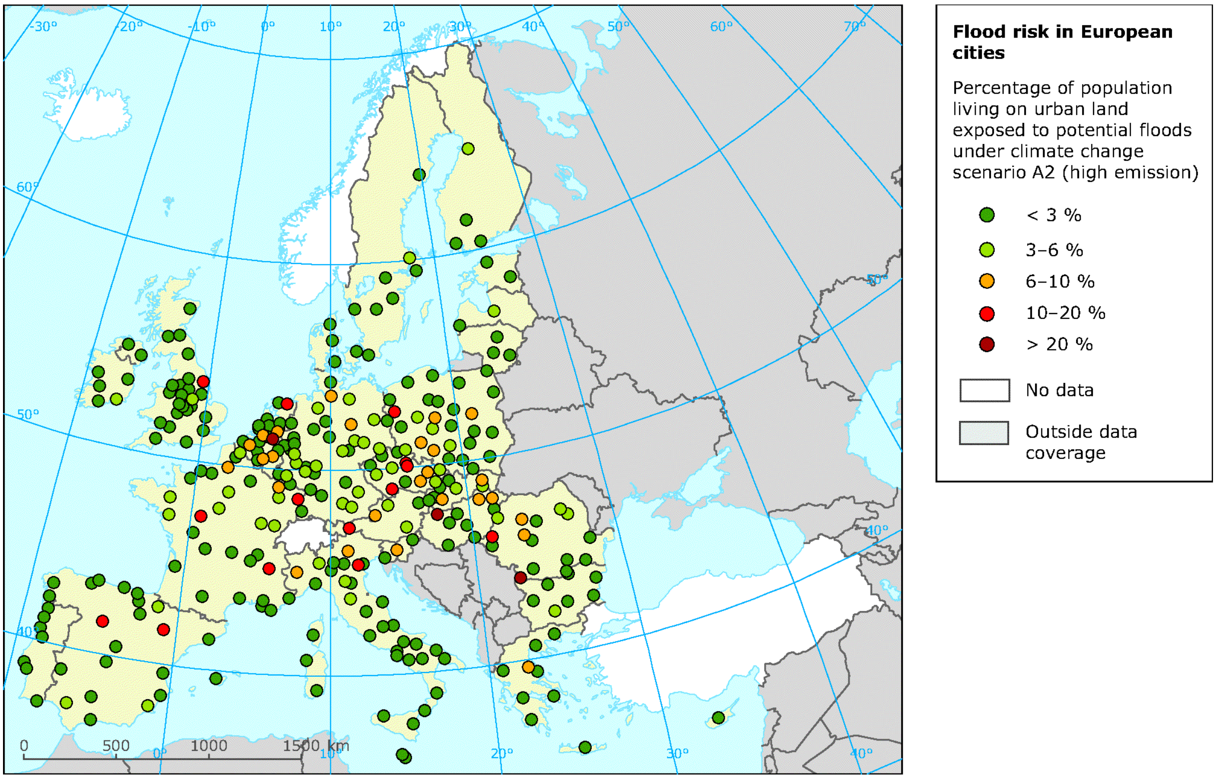
Flooding is (after earthquakes) one of the most costly kinds of disasters and this is mainly due to flooding events in built-up areas. For example, between May and June 2007, extreme rainfall led to widespread flooding in England and Wales, causing 13 deaths and £3.2 billion in damage.[30] Further, many European cities have been built on a river; and these rivers will respond to extreme rainfall or snowmelt events with extreme discharges; threatening the cities with floods. For example, Cologne was flooded by the river Rhine in 1995; Dresden was flooded by the Elbe in 2002, and Budapest was flooded by the Danube in 2009 (cf. also Figure 32). In July 2011, Copenhagen's worst flood in its recorded history ravaged residential and commercial infrastructure[31]. The flood, categorized as a one-in-1,000 year-event, cost the capital millions in economic damages. The Copenhagen flooding was estimated to cost reinsurers $800mn[32]. Even when the buildings themselves can withstand the water, the movable property at ground floor and lower is usually lost; to prevent such losses, new developments should either not be planned in flood-prone areas or should be built flood-proof. Water management in flood and drought must be adapted and the structural stability and weather resistance of current building materials must be investigated.

[30] http://www.parliament.uk/business/publications/research/key-issues-for-the-new-parliament/green-growth/reducing-flood-risk/

[31] http://www.unisdr.org/campaign/resilientcities/news/view/26871

[32] http://www.insuranceinsider.com/copenhagen-storms-set-to-cost-reinsurers-800mn

Figure 32: Exposure of population in European cities to flood risk under climate change (scenario A2 — high emissions; 100-years flood). Source: EEA, 2010g.



Due to a lack of space for settlements, flood plains are more and more used for housing and industry. The problem is how to maintain development within acceptable insurable risk parameters. Short term social, commercial, economic and political pressures may outweigh scientific caution and environmental concerns (Dlugolecki, et al, 2009). Research has shown that the increase in economic damage of the past decade is not merely caused by climate change but rather by an increase of economic assets in vulnerable places (Dlugolecki, et al, 2009; IPCC 2012b). A lack of information on future risks prevents local governments and citizens to make different choices. Insurance companies often look at history to define flood risks, and do not take climate change into account.

During the past ten years, Europe has seen a number of serious floods and heat waves. The flood incidents have been analysed by EEA (cf. Table 22) and although the flood damage costs show a growing trend, this cannot be ascribed to climate change yet. Instead, it is ascribed to an increase in valuable properties in areas with flood risk.

Table 22: Significant flood disasters in Europe (damage costs 500 million and more between 1998 and 2009, based on Wehrli & Jol, 2010)

Time	Place	Estimated damage costs in Euro (value of 2009)
May 1998	Turkey	2.5 billion
September 1998	Belgium and the Netherlands	600 million
May 1999	Germany and Switzerland	370 and 435 million
November 1999	France	570 million
October-November 2000	England and Wales	1.4 billion
October 2000	Italy, France and Switzerland	11.4 billion
July 2001	Poland	810 million
August 2002	Germany, Czech Republic, Austria	20.9 billion
September 2002	France	1.5 billion
February 2003	Greece	650 million
August 2003	Italy	510 million
December 2003	France	1.6 billion
August 2004	England	700 milion
April-May 2005	Romania, Serbia	565 million
July-August 2005	Romania	1.2 billion
August 2005	Switzerland, Austria, Germany	2.8 billion
March-May 2006	Hungary, Slovakia, Romania, Serbia. Czech Republic, Austria, Germany	590 and 210 million
June 2007	England and Wales	1.9 billion
July 2007	England and wales	1.9 billion

A DEFRA study (DEFRA, 2010) has analysed the costs of the 2007 floods in England in more detail. The damage to residential property, both buildings and contents, was the largest, amounting to an estimated 1.2 billion British pounds. Of this amount, the researchers ascribe 75 to the household inventories and 25% to building structures. The number of affected homes was estimated at 46.000-48.000 houses; a quick calculation shows that on average, a flooded house costs 15.000 pounds in structural damage and 45.000 pounds in movable property.

The year 2003 is a well known example with heat waves that cost 70.000 lives (Wehrli & Jol, 2010), and was a wakeup call for many governments. In 2006 and 2007 heat waves cost a total of 3000 lives (Wehrli & Jol, 2010).

Overall, the lack of knowledge on damage costs as well as costs of adaptation seems a bottleneck. In order to make sensible decisions one should be able to compare the investment costs for the measures with the damage costs they aim to avoid. Concrete and preferably quantitative assessments of consequences of climate change and associated costs for buildings or the construction sector are hardly available. It is difficult to distinguish impact costs on buildings from the literature. Often, terms such as 'infrastructure' or 'settlements' are used, which can include not only buildings but also roads, electricity networks, and (in the case of 'settlements'') moveable property. Impact costs are defined in different ways in the literature: damage costs without adaptation; or the costs of adaptation plus residual damage. Nordhaus & Boyer (2000) estimate the impact costs of climate change for settlements at 0,25% of GDP (repeated in Agrawala, 2010b; Bosello, et al, 2009).

Table 23: Cost estimates of climate change impact on the construction sector

	Estimates*	Regional coverage, time frame and/or climate scenario	Sources
Total impact on building and housing	0.25 %GDP	total Europe, +2°C	Nordhaus & Boyer (2000); Agrawala et al. (2010); Bosello et al. (2009)
Impact costs of flooding	currently totals around £1.2 billion per year –projected to rise to between £2.1 billion and £12 billion	Annual damage to England and Wales properties due to flooding from rivers and the sea by the 2080s.	HM Government UK (2012)
Costs of adapting vulnerable infrastructures	10-100 billion USD	Global; 5-20 % increase in investments in 2030	World Bank (2006)
Rising costs of flood damage	9.7 billion	A four-fold increase by 2080	ABI (2005)

* Units: %GDP = percentage of Gross Domestic Product; USD = United States Dollars.

More specific figures have been produced in the ClimateCost project for river flooding, as shown in Table 24. Assuming that these costs occur mainly in inhabited areas, they can be seen as an example of the damage costs-adaptation costs ratio (being more or less around 10:1). The ClimateCost project also puts the relation with mitigation efforts into the picture; it shows that, due to the slow reaction of the climate system, mitigation is especially relevant for the generations after 2050.

Table 24: Damage costs and adaptation costs for river flooding in billion Euros per year in the EU27

	Baseline 1961-1990	2020	2050	2080
Estimated Annual Damage costs high emission scenario A1B	5.5	20	46	98
Estimated Annual Damage costs low emission scenario E1	5.5	15	42	68
Adaptation cost (for achieving a 1-in-100 year protection level) high emission scenario A1B	0	1.7	3.4	7.9

3.2.1.5 Energy

The energy sector is of vital importance for Europe's economic performance. Climate change has far reaching consequences for the sector's stability, sustainability and resilience. Both mitigation and adaptation are policy responses which need to be taken on board.

While mitigation has been in the focus of the sector's climate action for decades, adaptation policies are rather new yet vital for an approach to cope with the effects of changing climatic parameters. Indeed, recent studies suggest important impacts of climate change on the energy sector and underpin the need for adaptation in the sector (cf. for example DG ENER study by Rademaekers, et al, 2011, Ebinger & Vergara 2011 and Williamson, et al, 2009). Impacts of climate change, such as an increased frequency of extreme weather events or changing water and air temperatures have effects on energy demand, supply and transmission. Adaptation should therefore be considered in the planning and operating of energy systems – and at all territorial levels, from local to European.

However, adaptation is not necessarily a further (separate) field for action, but more one that can be mainstreamed into existing energy policies on e.g. the internal energy market, TEN-E/CEF, the energy road map, energy efficiency policies and other strategies already set by the EU and the important players in the field (cf. SET plan and smart grid initiative). In addition, a great number of mitigation measures and policies already have the potential to include and mainstream adaptation action. This includes measures on the demand side of electricity consumption just as well as measures going along with the extension of renewable energy systems.

The energy 2050 roadmap (EC, 2011o) depicts the current *primary energy consumption* and shows the plausible ranges of five different decarbonisation scenarios in 2030 and 2050.

The analysis suggests the following shifts from current primary energy consumption to 2030 and 2050:

Table 25: Shifts from current primary energy consumption to 2030 and 2050

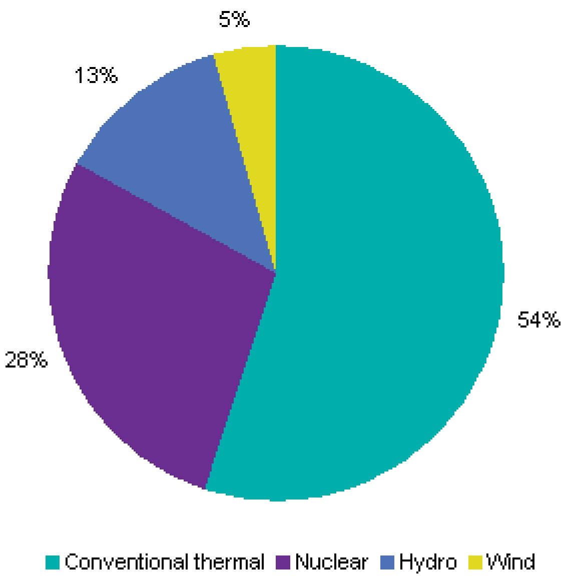
Primary energy source	current	2030	2050
Renewable energy	9%	~25%	~40-60%
Gas	24%	~25%	~20-25%
Oil	37%	~30%	~18%
Solid fuels	16%	~8-10%	~3-10%
Nuclear	14%	~10-14%	~5-15%

Three major trends are significant for energy sector adaptation:

1. The increasing share of renewable energy sources (water, wind, solar and biomass)
2. The decreasing importance of conventional thermal power generation. This excludes gas power plants, which will play a crucial role as backup capacity (since most flexible) for the decarbonisation/transition phase of the EU energy system.
3. The high uncertainty of nuclear power supply for the forthcoming decades.

The current EU *electricity production/supply mix* is roughly depicted in Figure 33 and shows a higher share of nuclear, wind and hydro power compared to the primary energy mix, which indicates that primary energy consumption is much more triggered by fossil fuels (due to their dominance in mobility/transport and heating):

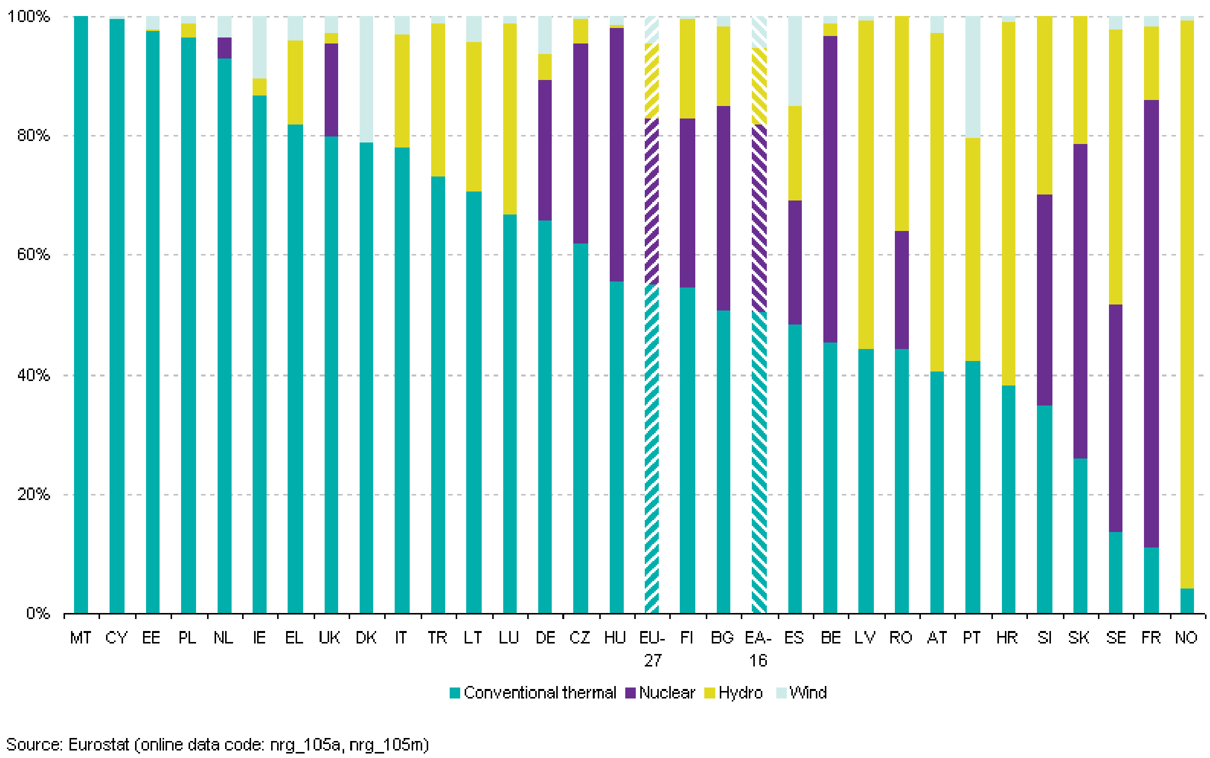
Figure 33: 2010 electricity production in EU-27. Online source of Eurostat:
http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Electricity_production_and_supply_statistics



A national breakdown for the electricity energy production (cf. Figure 34) shows a wide range of energy mixes among the EU-27 and thus very different energy supply vulnerabilities. This is due to i) different national energy policies (cf. nuclear policy) and ii) The different topography and geographic setting of the countries (cf. different potential for wind, solar and water power supply) and iii) The access to resources (primarily gas, oil and coal).

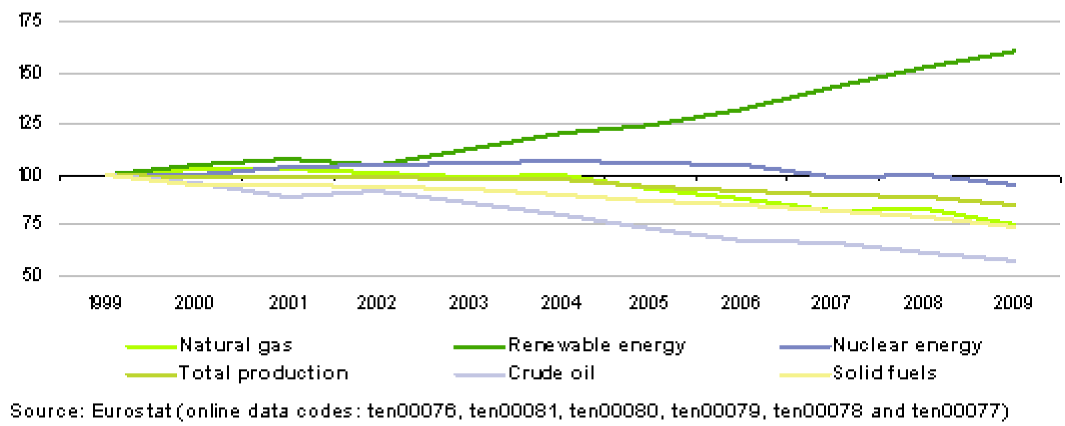
This is a first hint that adaptation efforts for energy supply remain more a national and energy company challenge than a responsibility for the EU.

Figure 34: 2010 electricity production country-wise for EU-27. Online source of Eurostat: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Electricity_production_and_supply_statistics



Over the last decade a substantial shift in the energy supply mix has already taken place (cf. Figure 35) and exhibits already a trend which underpins the scenarios.

Figure 35: Shift in the primary energy mix from 1999 to 2009. Online source of Eurostat: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Energy_production_and_imports



Note that the post-Fukushima shut-down of several (especially German) nuclear power stations has caused a (further) dip in nuclear energy supply which is not shown in this graph.

The energy sector is affected by climate-triggered threats in all three major parts of the system:

- Transmission and distribution of energy (mainly electricity) is challenged by new demand patterns as well as direct physical destruction due to extreme weather events;
- Supply/generation of electrical energy is affected by efficiency decreases due to climate change, the more complex vulnerability setting of renewable energy (as compared to fossil fuel based energy supply) to changing climate parameters; and
- Demand of energy is already triggered particularly by extreme periods (heat waves, floods/mass movements, droughts) causing demand-driven overstress of energy infrastructure, their direct destruction and consequent interruptions in energy supply.

3.2.1.5.1 Transmission and distribution

Important challenges related to the **transmission and distribution** of energy are:

- **Having climate-resilient transmission and distribution networks for electricity**: Transmission and distribution of energy is vulnerable to climate change since its security is undermined by direct climate threats (e.g. destruction of transmission and distribution lines caused by extreme weather events) as well as climate-induced changes in demand patterns (e.g. energy consumption peaks in hot summer). Overall, transmission and distribution networks for electricity are more vulnerable to interruptions caused by atmospheric conditions than the oil and gas transmission and distribution networks.
    - *Ensuring the resilience of electricity distribution networks*: The distribution infrastructure is most vulnerable in many regions as networks are often operated by smaller (e.g. regional/provincial) electricity companies. E.g. power pole constructions of the low voltage distribution system have much lower resilience towards wind, snow or ice loads since quite often wooden poles are used. Rural forested areas in which distribution infrastructures are highly exposed to wind fall (narrow aisles), mass movements, floods or ice/snow loads are thus highly vulnerable to black outs caused by climatic triggers i.e. extreme events (Martikainen, et al, 2007). While Martikainen (2007) argues that for Finland all high voltage (in Finland >45kV, in other countries >60 kV or >110kV) transmission infrastructure is sufficiently resilient towards climate change, the rural distribution infrastructure is regarded as vulnerable.
    - *Coping with changing energy demand patterns and peaks*: As a number of studies have shown, energy demand are subject to change under altered climatic conditions – namely to increase during summer (cf. Dolinar, et al, 2010; Mirasgedis, et al, 2007). The most crucial challenge is the potential coincidence of i) High demand during e.g. heat waves, ii) The

problems to meet this demand by supply as it is in parallel subject to shrinking cooling water supply and less efficiency of thermal power plants during heat waves as well as iii) the high loads of the transmission grid towards Southern Europe (e.g. Italy).

This includes the management of overloads and demand at European scale. As September 2003 black-outs in Italy have shown, cross-border and cross-European transmission is sensitive to threats caused by demand peaks which can't be met by domestic supply. Heavy overloads in the Swiss part of the Trans-European energy transmission is thought to be the reason why a flash over and a subsequent black-out happened.

An increase in maintenance and investments for redundancies in the north-western and southern grid networks and particularly into cross-border interconnectors was suggested by two UCTE[33] reports following the black out in Italy 2003 and Germany 2006 to help with the disconnection and reconnection of loads in case of interruptions and had already been addressed in TEN-E decision 1364/2006/EC (EC, 2006h) (cf. Annex I on priority axis) since then.

- **Making electricity transmission and distribution grid infrastructure fit for an increasing share of renewables**: Investments into the distribution grid infrastructure are necessary to connect new renewable energy production (often decentralised or remote energy supplies) to the grid. Significant investments are necessary to enable a true European grid that interconnects for example solar power production in Southern and Central Europe with Wind power in the North Sea and water power supplies in Norway or the Alps (including the pumped water storage systems). This is embraced by EU energy policies and initiatives already (cf. CEF, smart grid initiative etc.). However, new grid infrastructure should undergo an ex ante climate proofing, which should be incorporated into the pertinent EU policies.

- **Ensuring sufficient throughput capacities for gas** might cause problems, but since gas demand is lowest in summer season (when throughput capacity is constrained by high temperatures), the risk seems manageable

- **Protecting against storm surges/sea level rise** for oil refineries might cause problems in coastal areas, although most infrastructure should be resilient at least for non-abrupt climate change/sea level rise.

Interruptions in the transmission and (more often) distribution network (due to extreme weather events or demand-driven overloads in the network or coincidence of both) are the most important reason for electricity interruptions felt by all citizens.Since electricity can't be stored at private households (or just to a minor degree) and the number of electric devices

[33] Union for the co-ordination of transmission of energy

with important functions has increased, the dependence of citizen's on constant electricity supply has raised. This dependence (and the indirect economic effects of black outs) is due to further increase with e.g. more tele work offices and more electric mobility.

Most industrial production is dependent from external electricity production and does not produce own electric power (island facilities independent from the grid). Thus, cost assessments of electricity black outs usually come up with high values e.g. due to production and workflow interruptions[34].

The current national situation of electricity black-outs has improved significantly across Europe with about 100 average black-outs minutes per year becoming the EU average in 2008.

Yet, there is no clear evidence for a correlation between black-outs i.e. the performance of the Customer Average Interruption Duration Index *(CAIDI)* on the one hand and e.g. rising temperatures, droughts or increased frequency of extreme events on the other hand.

However, some important signals can be detected – all of which reveal that black-outs are not solely subject to 'force majeur', but triggered by climate change and weather extremes respectively to a significant degree:

- Black-out September 2003 in Italy, which was caused by a flash-over from trees to the heavily overloaded Lukmanier and San Bernardino highest voltage transmission lines storm events and heavy demand for cooling purposes.[35]
- Black-outs in Sweden in September 2003 and January 2005, when a series of rainstorms caused black-outs for 3,5 million resp. 400.000 people.
- Black-out in Germany in November 2005 where wet snow deposit caused a long-lasting black-out for around 250.000 people in the region of Münster. [36]

These plus numerous small-scale black-outs exhibit the vulnerability of the electricity grid to weather and climate extremes. Especially the large-scale 2003 event in Italy shows, how badly accelerated electricity demand due to the 2003 heat wave and severe weather may collude. In fact, this event should be (and has already been) taken as a warning sign for hot summer threats and vulnerabilities across Europe.

Special attention should be drawn to the fact that overloaded grid lines are more vulnerable to flash-overs from trees than normally loaded ones.

As a result, a correlation exists between economic losses due to weather and climate extremes[37] and the occurrence of black-outs (cf. CEER, 2008).

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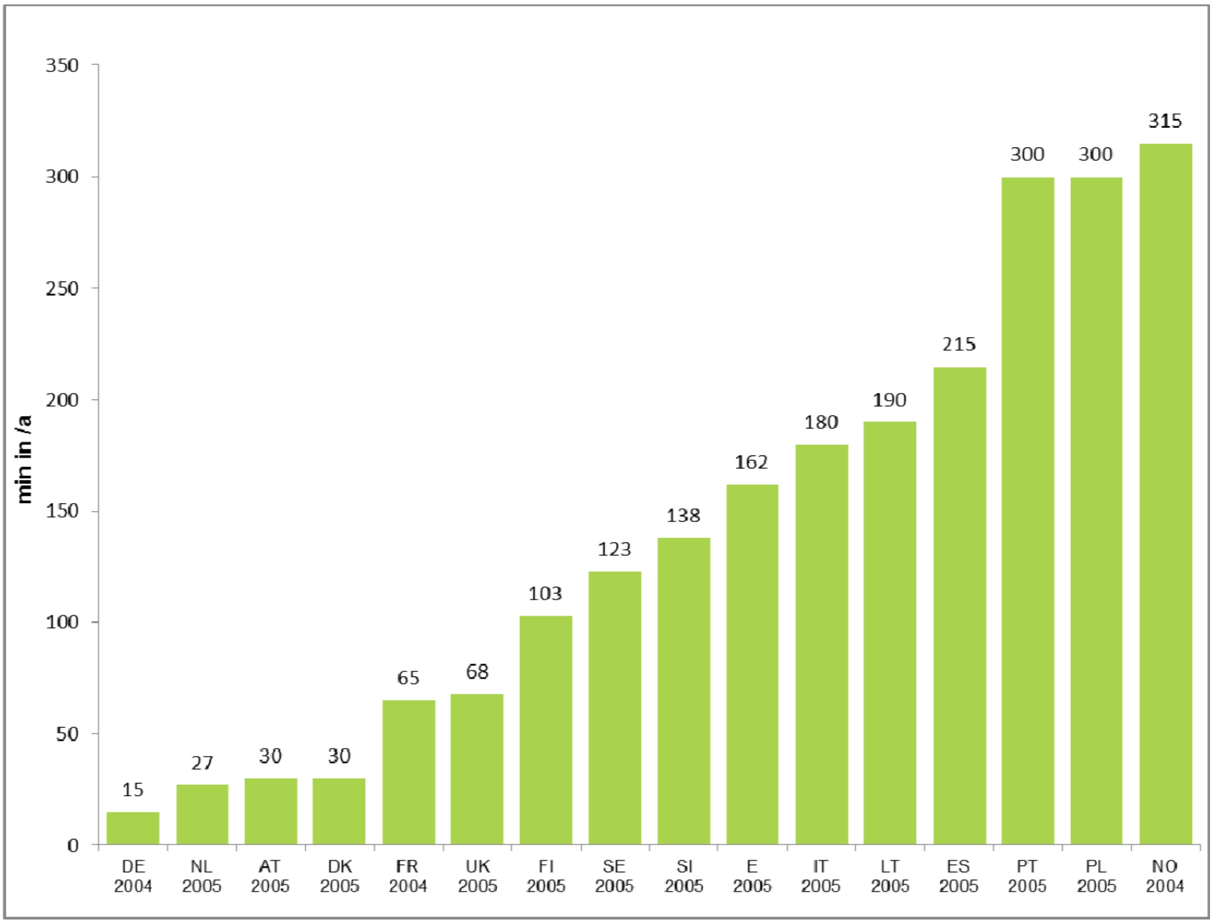
[34] Cf. for Austria: http://www.energyefficiency.at/web/projekte/blacko.html (German only)
[35] Cf. http://news.bbc.co.uk/2/hi/3146136.stm and SFOE (2003) for more details
[36] http://de.wikipedia.org/wiki/Liste_historischer_Stromausf%C3%A4lle and http://news.xinhuanet.com/english2010/world/2010-03/15/c_13211267.htm

It can be expected that in principle all European citizens might be affected by black out threats, particularly because of cascadal effects becoming relevant if ever black outs happen. In fact, some patterns for different vulnerability settings remain and become visible throughout Europe when comparing the average minutes without electricity per year and country as depicted in Figure 36.

Figure 36: Per capita average minutes without electricity. Source: CEER (2008). Note that more recent data has not been collected with a common method.



Disparities at regional level

Differences according regional vulnerabilities result from discrepancies between urban and rural and higher scale high-voltage transmission and distribution in (remote) regions.

According to oral information gathered, most cities across Europe use underground cabling up to a certain extent for the distribution infrastructure in their realm. This is why e.g.

[37] Cf. NatCat Service data from MunichRe at for example: http://www.munichre.com/app_pages/www/@res/pdf/NatCatService/great_natural_catastrophes/NatCatSERVICE_Great_1950_2011_losses_weather_de.pdf

Wienenergie (Vienna's main energy supplier and DSO) with its 83% share of underground cabling[38] can be regarded as climate resilient at least when focussing at the distribution infrastructure. However, substations and transformers are still exposed to extreme events and might fail as well as interconnection to and from the superior grid.

Distribution System Operators (DSO) would play an important role in the design of resilient grid structures and might be regarded as most vulnerable towards extreme events such as wind, snow and ice load. However, the big energy producers own a good share of the distribution network – sometimes via sub-companies, sometimes directly – too. From the energy production side, all electricity production companies depending on cooling and running water have an inherent vulnerability towards heat waves connected with droughts.

3.2.1.5.2 Supply/Generation

Important challenges related to the **supply (generation)** of energy are:

- **Ensuring cooling-water for thermal power generation**: For all thermal (including nuclear) power plants, effective air or water cooling is essential with respect to the CARNOT efficiency[39] as well as the security of e.g. nuclear power plants, which must be shut down, if no sufficient cooling can be guaranteed (cf. various Central and Western European nuclear power plants during heat summer 2003).

- **Considering changing climate conditions for renewable energy generation**: With respect to the 20-20-20 goals and the envisaged 20% share of renewable energy, PV, wind and small water power facilities will be further extended. All these facilities are directly dependant from (changing) climate parameters such as wind speed, radiation and water run-off (depending on the river run-off regimes precipitation, snow or ice melting). According to the EU 20-20-20 goals, an extension of renewable energy supply is crucial. While thermal (incl. nuclear) power plants' operation is only sensitive to temperature (i.e. mainly impacts on efficiency) and precipitation/run-off changes (i.e. mainly impacts on cooling water supply), electricity supply from renewable energy sources is directly exposed and sensitive to wind speed, water flow, solar radiation (cloudiness), and NPP[40] (biomass) (cf. recent DG ENER study by Rademaekers, et al, 2011).

- **Securing electricity generation during extreme weather events**: For certain (e.g. flood prone) power plants, more frequent extreme events might become a significant problem. As for efficient cooling, many thermal and nuclear power plants are located at rivers, lakes or at the coast. For the latter, storm floods (partly in conjunction with sea level rise) is a relevant climate threat.

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[38] www.wienenergie.at

[39] Also referred to as CARNOTransmission theorem and basically stating that the efficiency of thermal combustion is reciprocal to the ambient or cooling water temperature supplied to a power plant.

[40] Net Primary Production (allows an assessment of how much biomass extraction is sustainable)

- **Overcoming lack of regional and local electricity storage:** Despite on-going efforts in electrical battery and other energy storage technology development, electricity cannot yet be stored like oil and gas at least not at relevant scale (e.g. households, cities, regions or companies). So there is no possibility to build electricity storage reservoirs as it can be done for energy based on burning fuels. This leads to the fact – although dependency from electricity rises – that no suitable emergency, contingency or substitution plans could have been elaborated so far.

A DG ENER study of Rademaekers et al. (2011) shows the impact of certain climate parameters on the different energy production technologies as follows (cf. Figure 37). The classification and the assessment are based on stakeholder consultation, expert judgement and literature review.

Figure 37: Impacts of changing climate parameters on different energy supplies. Source: Rademaekers et al. (2011)

Technology	Δ air temp.	Δ water temp.	Δ precip.	Δ wind speeds	Δ sea level	Flood	Heat waves	Storms
Nuclear	1	2		-	-	3	1	-
Hydro	-	-	2	-		3	-	1
Wind (onshore)	-	-	-	1	-	-	-	1
Wind (offshore)	-	-	-	1	3	-	-	1
Biomass	1	2	-	-	-	3	1	-
PV	-	-	-	-	-		1	1
CSP	-	-	-	-	-	1	-	1
Geothermal	-	-	-	-	-	1	-	-
Natural gas	1	2	-	-	-	3	1	-
Coal	1	2	-	-	-	3	1	-
Oil	1	2	-	-	-	3	1	-
Grids	3	-	-	-		1	1	3

Note: 3 = Severe impact, 2 = Medium impact, 1 = Small impact, - = No Significant impact;

The results give some important hints on the players that are most affected in the energy sector by impacts of climate change:

1. TSOs, since the grid is – due to its linear and exposed structure – most vulnerable. For the 'grids' referred to in the table, a distinction between the (usually) less robust distribution grid and the (usually) physically more robust transmission grid should be incorporated (cf. Martikainen, et al, 2007).

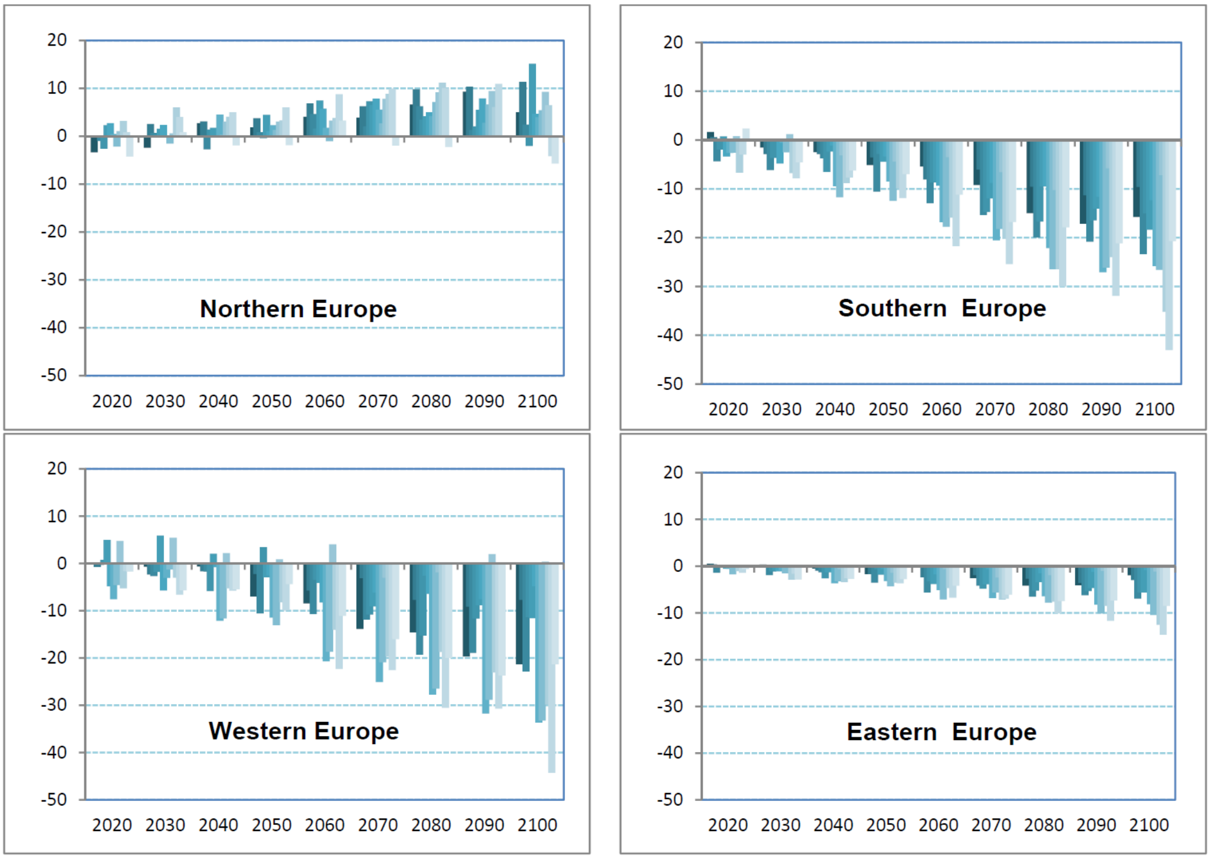
2. Energy companies with a large share of thermal and hydro power in their energy production mix (i.e. almost all conventional energy companies).

In general, all energy production that is (more or less) 'water- and temperature-independent' (i.e. onshore wind and solar power – at least dry-cooled Collective Solar Power and

Photovoltaic power) might be regarded as much better 'climate-proofed'. ('Yield declines' of PV due to temperature increase of 2°C might just be around 1%). Companies with these energy mixes could thus have advantages in future.

Mima et al. (2011) have modelled the impacts for hydropower across four major regions in Europe until 2100 and found out most adverse impacts in Southern and Western Europe, while Northern Europe might gain surplus hydropower potential (cf.Figure 38).

Figure 38: Hydropower generation in TWh modelled for A1B emission scenario using different GCMs. Source: Mima et al. (2011)



3.2.1.5.3 Demand

Important challenges related to the **demand** of energy are:

- **Cooling demand is supposed to increase further:** Electricity demand is driven by ambient temperatures and by getting indoor temperatures comfortable. This is the case for private housing, office buildings and the service sector (for example shops and malls). A significant cooling demand is also given by food and pharmacy storage as well as for certain production processes. Temperature raise and extended heat periods in summer become more and more relevant for energy demand pattern throughout the year, since peak demands already occur in southern countries during heat waves in the summer season. In conjunction with reduced cooling water supply for power plants during summer heat/drought waves and overload capacities of electricity transmission towards the import-dependent southern countries, increased demand becomes a very relevant challenge for supply and transmission. For the Mediterranean part of Europe, the additional (electrical) energy for air conditioning might even outweigh the decrease of primary energy consumption for less heating energy in winter.[41]

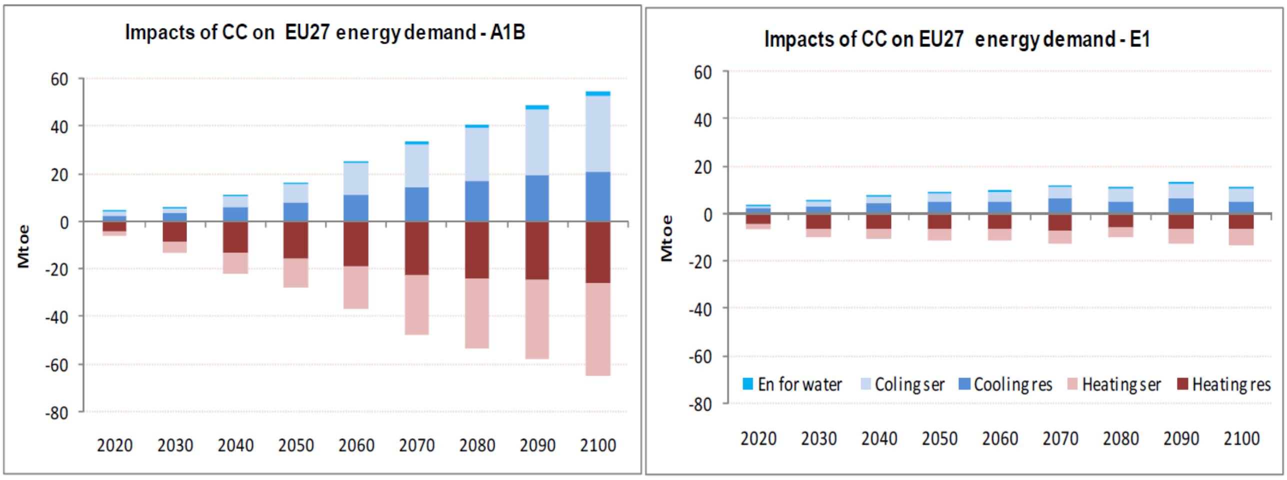
- **Demand for irrigation during drought periods is supposed to increase:** With longer droughts and dry season especially around the Mediterranean, irrigation of agriculture land is expected to be extended significantly challenging supply and transmission of electric energy accordingly to the threats posed to energy supply by cooling water (and air) shortages. Furthermore, many irrigation/pumping devices are powered by petrol or diesel generators and thus increase demands on direct fossil fuel consumption.

From EU citizens' perspective, energy demand is met by fossil fuels (oil/gasoline yet for mobility, gas, oil and coal for heating), sometimes biomass and biogas (primarily for heating) and electricity (for heating, cooling, cooking, running electrical devices of various types (including office equipment) and recently emerging electrical mobility).

Less heating demand has positive effects on the residential sector, while more cooling demand is cost-intensive. In fact, 1K cooling is much more cost-intensive than 1K heating. This is why the saved costs for heating and the additional costs for cooling are balanced across EU-27 (cf. Figure 39), but indeed there are significant disparities among EU citizens with Northern European citizens benefiting and Southern European citizens having a higher 'energy bill'.

[41] A further challenge for electrical energy supply is that cooling (air conditioning) is supplied by electrical energy, whereas (reduced) heating is mostly met by other energy sources (with France being an exception).

Figure 39: Comparison of additional cooling demand and saved heating demand for A1B and E1 emission scenarios. En for water stands for surplus energy needs for water treatment, ser stands for service sector, res for residential sector. Source: POLES model, LEPII-EDDEN, ClimateCosts after Mima et al. (2011).



Taking into account all three system compartments, it becomes obvious that Southern Europe is most affected:

- The transmission of electricity towards Southern Europe has most striking bottlenecks
- On the supply side, energy efficiency for thermal and nuclear power plants and hydropower potential show most adverse effects in Southern Europe
- The demand patterns are triggered by surplus cooling further enforcing the transmission problems and accelerating energy cost increases for Southern European citizens and companies

3.2.1.5.4 Megatrends affecting the energy system

Energy security is already the core objective of all relevant energy strategies at Member States' and EU level (EC, 2006i; EC 2008i). This implies primary energy sources as well as electricity production and the policy on critical infrastructures (cf. EPCIP and EC, 2008l).

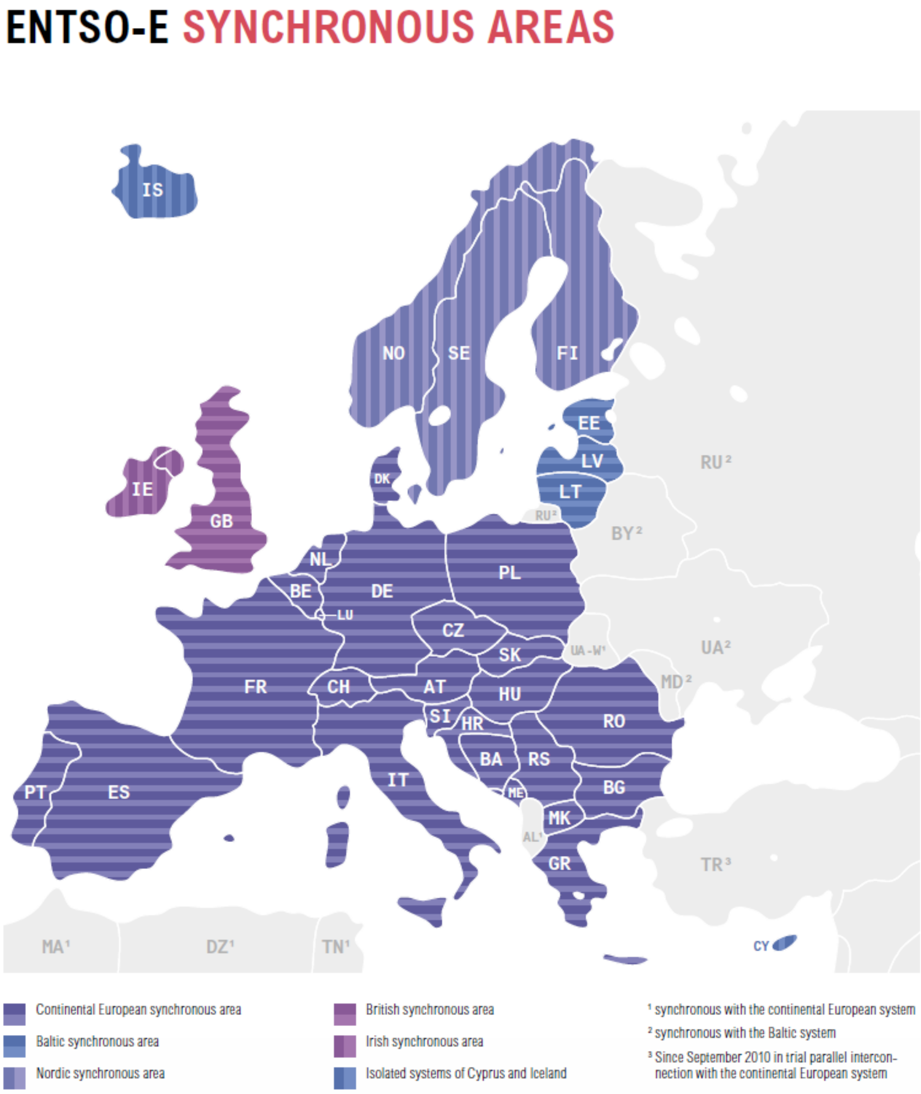
All three compartments of the energy system, Transmission/Distribution, Supply and Demand, are driven by megatrends and political developments driving the vulnerability patterns of the European energy sector.

The multi-stress environment of the energy sector has been described by AEA (2009a) with the following bullet points for **Transmission**:

- Development of the EU internal energy market, but still facing many monopolies which are hampering urgently needed investments in energy infrastructure (e.g. new transmission and distribution);

- The increasingly interconnected and complex EU energy system (cf. Figure 40);

Figure 40: The six synchronous areas in the European grid. Each of them aims at high integration towards interoperability and common standards. Source: ENTSO-E (2011).



- Management of intermittent distributed generation on the electricity grid;

- The integration of the grid (transmission and distribution of electricity) in the frame of the internal energy market and further developments of smart grids and smart metering have already led to a certain level of ICT dependence (and will lead to more in future), which raises the vulnerability towards IT system failures and cyber attacks, which have to be taken into account (IT security)[42].

- A trend towards energy production in (as seen from a grid perspective) remote areas (e.g. offshore wind parks) in many parts of the EU leading to a need for more distribution and transmission infrastructure that is vulnerable to direct impacts from e.g. extreme events and indirect climate impacts by certain (mostly temperature triggered) demand peaks;
- Urbanisation and the need to supply growing agglomerations with energy that is often produced quite far from end-user location;
- Ageing energy infrastructure urgently requiring significant investments;
- The expansion of the EU energy market beyond the EU borders via the Energy Community;

On Supply and Demand:

- Increasing global energy demand and prices;
- The expansion of renewable energy sources;
- Geopolitical and terror risks;
- Some Member States facing very high import dependencies and the EU as a whole facing import dependencies for oil and gas

A summary of future climatic pressures which may affect the energy system negatively (based on Altvater, et al, 2011a) is provided in Annex 5.

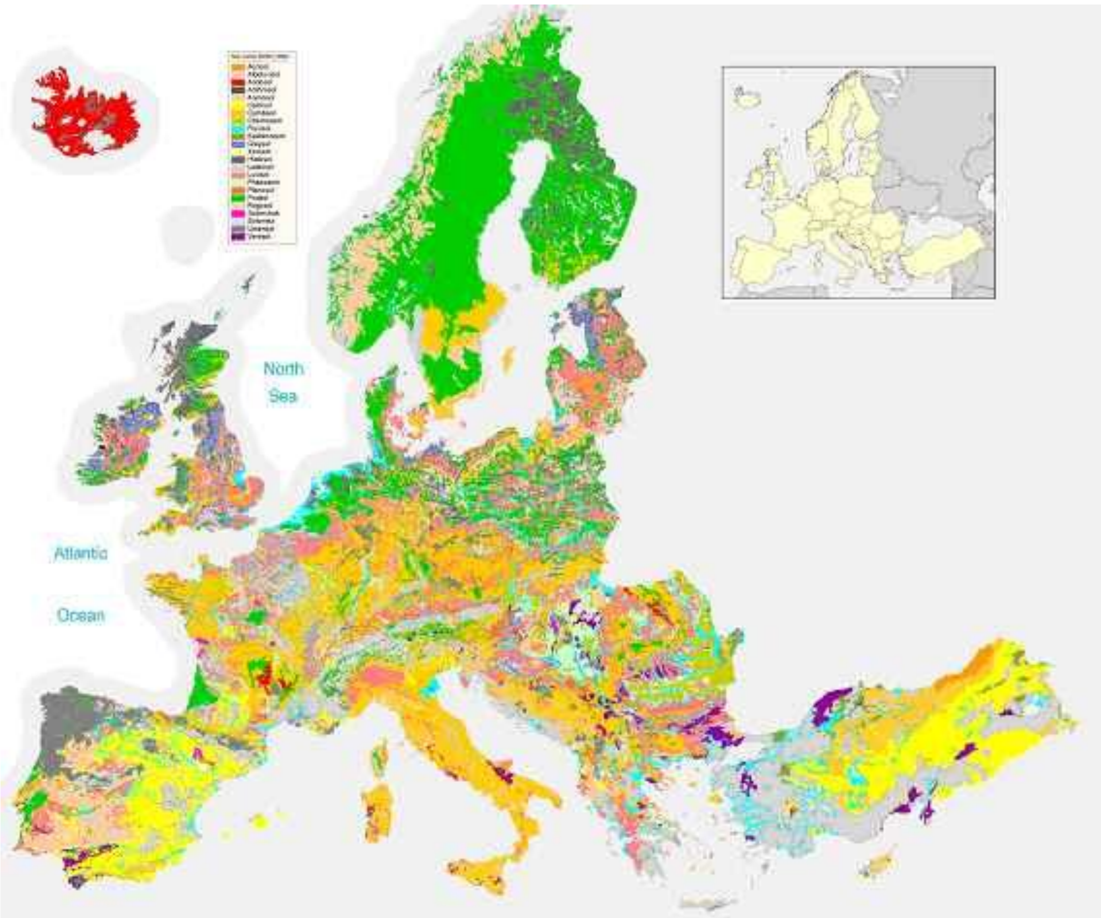
[42] The AEA (2009a) report commissioned by DG Justice, Freedom and Security focuses on risks for the energy sector caused by ICT dependencies and points out that an increase in connectivity, wireless networks, IP based network communications, cloud computing system complexity and smart grids, their dynamics and regulatory requirements thereof result in increased risks from ICT system failures or cyber attacks. This has to be taken into account when claiming smart grids, smart metering and other ICT-based technologies to support adaptation e.g. by helping to cut off demand peaks, smart distribution of energy or steering of supply (power plants) in a ‘smarter than today’ grid. There is no direct reference to climate change in the AEA study though. Smart grids remain the key for mitigation but also for adaptation efforts as they are able to match demand and supply in an optimum way. A regionally more volatile base load due to more renewable energy resources supply is only possible with a stronger physical as well as smart-driven grid (transmission and distribution). This implies chances for adaptation: smart-metering for demand steering, cut-offs from the grid for electricity consumption of critical infrastructure that are self-sustaining due to own PV or other electricity production (‘islands’), smart steering of power plants to avoid surplus energy that is not demanded and so on. But, with a higher integration there comes a higher risk of knock-on effects if a part of the system collapses – be it either due to physical transmission interruption by an extreme event, by cyber attacks or supply failures.

3.2.2 Climate impacts on environmental and human systems

3.2.2.1 Soil

A large range of soil types exists across the European Union (for a soil map of the EU, cf. Figure 41). Soils are an important natural resource both for nature and for agriculture.

Figure 41: Soil classification map; this is an example from the Soil Atlas (http://eusoils.jrc.ec.europa.eu/projects/soil_atlas/Atlas_Contents.html)



The relation between climate and soil is complex; three important categories of relations can be identified:

- Direct adaptation issues: Climate change can have an impact on soil processes (for example, prolonged droughts influence soil moisture).
- Indirect adaptation issues: Autonomous soil degradation processes may aggravate climate impacts (for example, soil sealing is an important factor in the urban heat island effect).
- Mitigation issues: Loss of soil carbon (for example, because of oxidation of peat soil) can increase the greenhouse effect; at the same time, carbon sequestration can

mitigate climate change (for example, in new forests). Loss of soil organic matter is also an adaptation issue because it reduces soil fertility and changes soil moisture characteristics.

In the following, the focus lies on the first two categories, while shortly addressing the third issue as well.

Climate change possesses a variety of threats to various soil types in Europe. In its 2002 Communication 'Towards a Thematic Strategy on Soil Protection', the European Commission identified eight main threats to soils in Europe: erosion, decline in organic matter, contamination, salinization, compaction, soil biodiversity loss, soil sealing, landslides, and flooding. The Thematic Strategy stated that 'there is no conclusive evidence on the effects of climate change on soil, but it appears likely that it will increase the potential of the threats. This in turn suggests that soil protection will be of increasing importance in the future' (EC, 2002a). From the eight threats mentioned in this note, we consider three as human-induced drivers unrelated to climate change (contamination, compaction, and soil sealing). The other five are, or may be aggravated by climate change (erosion, decline in organic matter, salinization, soil biodiversity loss, landslides, and flooding).

According to a conference on the interactions between climate change and soil, the main impacts of climate change concern soil degradation through erosion, loss of soil organic matter and progressive desertification (EC, 2008p). Desertification is caused by prolonged drought, but also by declining soil organic matter (EC, 2008p).

Based on the current state of the art the potential impacts from climate change on soils are described below for soil carbon storage, erosion, salinization, landslides, soil biodiversity loss, and desertification. Soil cracking is a horizontal issue that relates to biodiversity loss, erosion and desertification. Flooding is dealt with under the headings of erosion and salinization. Soil sealing will be addressed shortly under the paragraphs on drivers and underlying causes below.

Soil carbon storage

Soil carbon is a mixture of organic compounds with turnover times ranging from days to millennia. The overall change in soil carbon is determined by the balance between carbon inputs from photosynthesis and carbon losses through decomposition and hydrological processes, including erosion. The effect of climate change on soil carbon storage can be related to changing atmospheric CO_2 concentrations, increased temperatures and changing precipitation patterns.

The evidence of changes in soil carbon content as a result of increased atmospheric CO_2 concentrations is limited. However, a meta-analysis concludes that if results of various experiments are combined, a net increase in soil carbon of about 6% would be observed as a result of the climate change over the next 50 – 100 years, indicating an overall positive effect of elevated CO_2 on soil carbon input to soils (Schils, et al, 2008).

Elevated temperatures have been shown in experimental studies to generally increase the rate of soil respiration and thereby the loss of soil carbon content due to increased decomposition rates. It is expected that the effects of increasing temperatures on decomposition have a higher and more sustained impact on soil carbon than the effects of temperature on plant production, due to the fact that soil respiration is more sensitive to changes in temperature than photosynthesis and plant respiration. Increase in decomposition rates ranges from 15 to 45% in different studies across a range of habitats. The loss is thought to be greatest in northern latitudes as current decomposition processes are presently limited by low temperatures and permafrost. The consequence of loss of soil carbon will be a positive feedback to the climate system in the long term.

A more extreme hydrological cycle as a result of climate change will result in more extreme and frequent periods of soil moisture deficit. This will decrease the rate of decomposition in many systems but increase decomposition in waterlogged system such as peat lands, where much carbon is stored. Long term effects of repeated summer droughts vary; in a range of European shrub lands, droughts were observed to either stimulate soil respiration rates by 40% or depress the rates by 30%, depending on initial hydrological conditions. The largest emissions of CO_2 from soils are caused by land use change and especially drainage of organic (peat) soils. It amounts to 20-40 tonnes of CO_2 per hectare per year (Schils et al, 2008).

On average, soils in Europe will most likely accumulate carbon on a net basis with a sink for carbon in soils under grassland and forest (from 0 – 100 billion tonnes of carbon per year) and a smaller source for carbon from soils under arable land (from 10 - 40 billion tonnes of carbon per year). Soil carbon losses occur when grasslands, managed forest lands or native ecosystems are converted to croplands. When cropland is converted to forest or nature, carbon stocks increase, albeit it slower (Schils, et al, 2008). Changes in land use and land cover are also behind major changes in terrestrial emissions of other greenhouse gases, especially methane (through altered surface hydrology and elimination of forest cover) and nitrous oxide (through agriculture).

Droughts in combination with higher temperatures could exacerbate the loss of carbon by erosion. As a result, Mediterranean countries have a relatively high risk of desertification. In the mountainous areas of Central Europe, expected changes in rain storm frequency and intensity may increase soil erosion. Flood events will partly remove eroded carbon from soils but they will also redistribute the carbon across the landscape.

Erosion

Erosion is the displacement of soil particles due to heavy rainfall, wind and ice melt, and is often speeded up by human land use activities. Erosion has a negative impact on soil productivity because of removal of the most fertile topsoil. Also, it leads to increased vulnerability to drought, because the organic matter present in top soil has an important function in soil water retention. In areas with a shallow top layer erosion may lead to an irreversible loss of natural farmland (Bakker, et al, 2007). Several types of soil erosion can increase as a result of climate change. In a ‘business as usual’ scenario, the European

Environmental Agency (EEA) expects an increase in erosion risks of 80% in agricultural areas in Europe, especially in places where erosion is already severe. Extreme precipitation events, melting of snow, high river discharges and increased droughts are all climate related events which influence soil degradation. Accelerated erosion by running water has been identified as the most severe threat to soil in Europe (Kirkby, et al, 2004). However, this climate related phenomenon is often not the only driver of erosion: erosion risks depend also on the types of land use, vegetative cover, slopes and land management. Land use, vegetative cover and land management contribute to a large extent to soil degradation (EEA, 2007b). Although the Mediterranean region is historically most severely affected by erosion there is growing evidence of significant erosion occurring in other parts of Europe as well (e.g. Austria, Czech Republic and the loess belt of Northern France and Belgium).

In more than one third of the total land area of the Mediterranean basin, average yearly soil losses exceed 15 tons/ha (EC, 2002a). In this region, where droughts are expected to occur more often due to a changing climate, water and wind erosion can lead to increased land degradation. While the abandonment of agricultural land and subsequent reversal of permanent vegetation may have contributed to reduced erosion rates, a lack of maintenance of terraces in mountain areas may have actually led to increased erosion (EEA, 2007b). In mountainous areas of Central Europe, expected changes in the frequency and intensity of precipitation events may increase soil erosion (Schils, et al, 2008).

Salinization

Saline soils are expected to increase in coastal areas as a result of salt water intrusion from the sea side, because of rising sea levels and (periodically) low river discharges. A higher sea level increases the pressure on the groundwater along the coastline and the salty water will displace the freshwater to a certain extent. An occasional flooding with sea water will also leave behind a saline soil which may need several years of rain before it is again usable as arable land. Salinization alters soil quality and reduces crop yields, thereby reducing an area's capacity to produce food, which in turn has severe socio-economic implications (EEA 2007b).

Salinization can also take place after inappropriate irrigation practices, use of salt-rich irrigation water and poor drainage conditions. This type of salinization affects approximately 3.8 million hectares in Europe (Jones, et al, 2012). Artificial salinization occurs in Portugal, Spain (Ebro valley), Italy (Sicily), France, Greece, Hungary, Slovakia and Romania.

Landslides

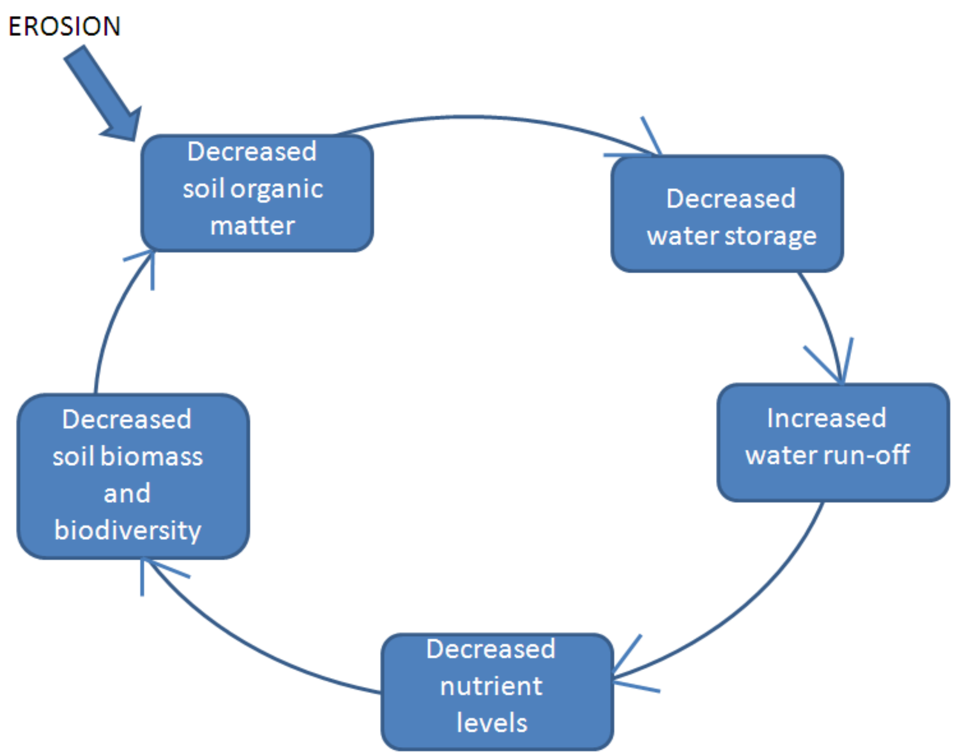
Although there are multiple causes of landslides, landslides in Europe are most often the result of soil saturation with water from heavy rainfall events and snow melt. Landslides mainly have a local effect, and it is therefore difficult to make general statements about landslides on a European scale. Landslides result in soil loss in the case of shallow landslides, or soil transfer in other cases. Particular physical soil properties such as structure, bulk density, water permeability and retention capacity can be affected. This can subsequently result in loss of soil functions and an increased vulnerability of the soil to other threats, such as erosion and compaction (Eckelmann, et al, 2006). Landslides are also caused by human activities such as cultivation, removal of vegetation (including deforestation), construction activities and changes in the shape of a slope (Jones, et al, 2012).

Loss of soil biodiversity

Living organisms in the soil form a web of biological activity (Jones, et al, 2012). This system delivers key ecosystem services such as processing of nutrients and influencing of water retention characteristics. Soil biodiversity is already under threat because of soil contamination, soil sealing (urbanisation), mining, deforestation and other human-induced impacts. There is little information available on impacts of climate change on soil biodiversity, also because the majority of soil organisms are still unknown (e.g., nematodes, fungi, microorganisms). Soil biodiversity is related to all other aspects of soil degradation (e.g. loss of organic matter, erosion, desertification); cf. Figure 42 for an example.

Stokes & Slade (1994) pose an additional impact of climate change, namely soil cracking. It can play a role in heavy clay soils during a drought period. Soil cracks in these environments can be used by small animals such as rodents and reptiles to protect themselves against the daily heat. These aspects have been reported for the US Great Plains and in Queensland, Australia; it is yet unknown if it is also relevant in Europe. If climate change has an impact on this phenomenon this can be considered as an aspect of the impact of climate change on soil biodiversity but will also have an impact on infrastructure such as electricity lines and pipe systems.

Figure 42: example of interrelated aspects of soil degradation (EC, 2010e)



Desertification

Desertification is a form of land degradation in arid and semi-arid areas, caused by climatic variations and human activities (EC, 2010e). Desertification often results from the overexploitation of vegetation cover leading to topsoil erosion and hence reduced productivity, or improper water use resulting in salinization. This affects crops, nature and soil biodiversity. As climate change can lead to more extreme drought, this may take the land in arid countries closer to the tipping point. In Europe, Bulgaria, Cyprus, Greece, Hungary, Latvia, Italy, Malta, Portugal, Romania, Slovakia, Slovenia, and Spain are already affected by desertification.

The agricultural and forestry sector is closely connected with soil and is affected by soil degradation through soil carbon loss, erosion and salinization. Coastal areas and irrigated agricultural land are sensitive to salinization. Biodiversity may be reduced due to soil degradation. At the same time, European cities are expected to increase their sensitivity for floods and the urban heat island effect by increasing the percentages of sealed soils.

The northern latitudes are most affected by the loss of CO_2 through decomposition of organic matter in soil. Currently decomposition processes are limited by low temperatures and permafrost. Peat lands are sensitive to increased decomposition if they are exposed to more extreme and frequent periods of soil moisture deficit.

Droughts in combination with higher temperatures could exacerbate the loss of carbon by erosion. Mediterranean countries have a relatively high risk of desertification as a result. As climate change can lead to more extreme drought, this may take the land in arid countries closer to the tipping point.

Soil sealing

Soil sealing (permanent covering of soil with layers that are impermeable for water, such as buildings, asphalt and concrete) affects the vulnerability and resilience of European cities and areas to climate change. The driving force behind soil sealing is the need for new housing, business locations and infrastructure. Soil sealing interrupts the exchange of water, biochemical compounds and energy between the soil compartment and the biosphere, hydrosphere and atmosphere. All processes in the water cycle, the biochemical cycles and energy transfers are affected (Prokop, et al, 2011). Soil sealing is an important factor in the urban heat island effect. Soil sealing can be described through the DPSIR model as a driver leading to the following climate related impacts (Prokop, et al, 2011):

- Reduced soil functions
- Loss of water retention and increase of flood risk
- Less soil sequestration and carbon storage
- Landscape fragmentation leading to increased vulnerability of ecosystems
- Higher surface temperatures and increase of the risks of the urban heat island effect
- Unsustainable living patterns such as increased traffic and air emissions
- A lack of productive soils for food and other biomass production. It may also lead to less availability of fertile soils for future generations

3.2.2.2 Biodiversity

The main pressures driving biodiversity loss include land use change and management (agriculture), the expansion of commercial forestry, infrastructure development, human encroachment and fragmentation of natural habitats, as well as pollution and climate change. However, climate change is projected to become the fastest growing driver of biodiversity loss to 2050, followed by commercial forestry and bioenergy croplands (OECD, 2012).

There is clear evidence collated by the Intergovernmental Panel on Climate Change (IPCC) to show that biodiversity is already responding to climate change and will continue to do so as impacts become more severe in the years and decades to come (IPCC, 2007a).

Species respond individualistically to climate change, with direct impacts including changes in phenology, species abundance and distribution, community composition, habitat structure and ecosystem processes (Mitchell et al., 2007; Hodgson et al., 2009a).

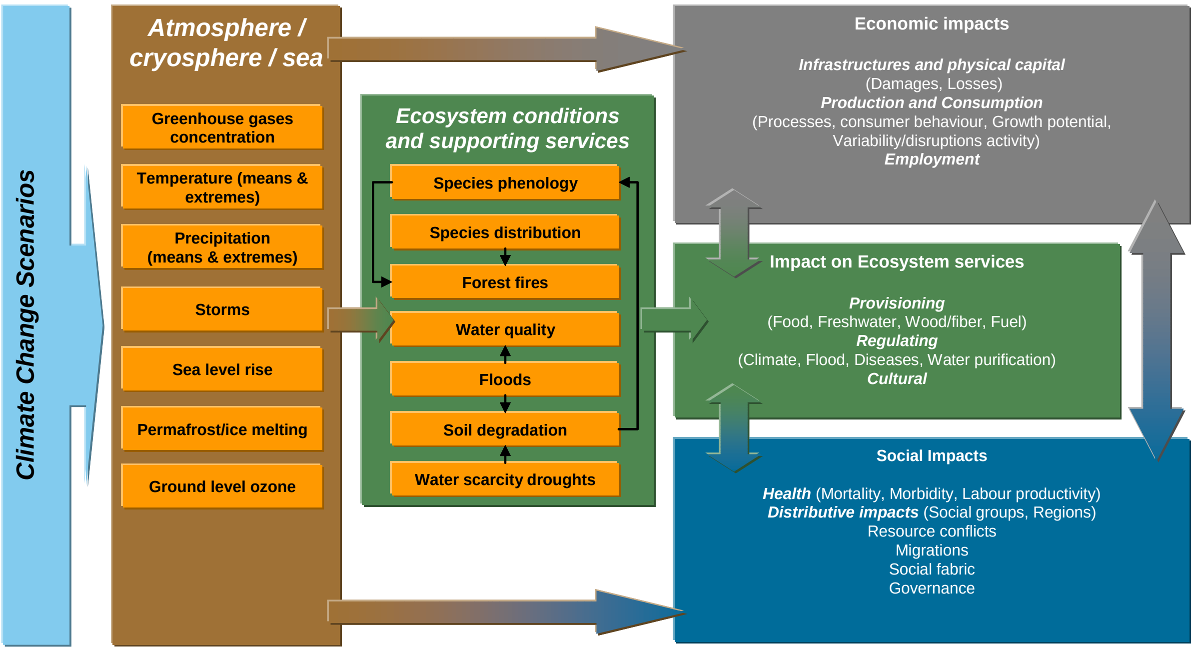
Many studies and reports have shed light on some of the consequences of climate change for Europe's species and habitats. In the DG ENV study Impacts of climate change and selected renewable energy infrastructures on EU biodiversity and the Natura 2000 network, Hodgson et al. (2009a) cited evidence and modelled projections for the following key impacts on biodiversity and the physical environment:

- Phenological changes
- Decoupling of events
- Climate-related stress and changes to disturbance regimes
- Range contraction and expansion
- Species and habitat composition changes.

Similarly, a series of reports from the EEA (EEA, 2010a; EEA 2010b; EEA 2010c; EEA 2010d) provide observational evidence for changes in habitat composition and shifts in species distributions in response to climate change. The reports anticipate more severe impacts in the future due, for example, to an increase in heavy rainfall events and flooding in Northern Europe and to drought and desertification in Southern Europe. Climate change also interacts with, and often exacerbates, other threats to biodiversity.

Ecosystems play a vital role in climate regulation (EC, 2009a). Changes in ecosystem structure, function and composition have important implications for the interactions between the biosphere and the climate system. Oceans, forests, grasslands, wetlands and, in particular, peatlands are essential in mitigating climate change (terrestrial and marine ecosystems currently absorb around 50% of anthropogenic CO_2 emissions). However, climate change and the degradation and destruction of these ecosystems are weakening their capacity to sequester and store carbon, and can lead to significant releases of greenhouse gases. For example, degraded peatlands account for around 10% of anthropogenic emissions, and deforestation and degradation around 23%. Climate change can also have significant impacts on other ecosystems and the services that they provide (cf. Figure 43).

Figure 43: Potential impacts of climate change on natural systems, their services and human benefits. Source: EC (2009b).



Hodgson et al. (2009a) undertook a systematic review, synthesis and analysis of published reports, information and data relating to the observed and projected impacts of climate change in Europe, with a particular focus on the species and habitats in the EU 27 Member States. Information on the observed and projected implications of climate change for the EU's nine biogeographic regions – Alpine, Atlantic, Black Sea, Boreal, Continental, Macronesian, Mediterranean, Pannonian, Steppic – is provided in Annex 5, Table 73 (Hodgson, et al, 2009a).

Climate change will also lead to indirect impacts on biodiversity through changes in socio-economic drivers, working practices, cultural values, and policies. These have potential to exacerbate many of the main pressures driving biodiversity loss. These include habitat fragmentation and loss due to land use change, over-exploitation and unsustainable use of natural resources, pollution of air, water and soil and, increasingly, invasive alien species (EEA, 2010a, b, c, d). Further, human consumption and production patterns are causing ecosystems to degrade and depriving them of their capacity to withstand climate change and deliver essential services, such as crop pollination, clean air and water, and control of floods or erosion (RUBICODE project, 2006–2009[43]). Due to their scale, scope and speed many could be more damaging than direct impacts (Smithers, et al, 2008), with knock-on implications for ecosystem services on which our society and economy rely.

[43] http://www.rubicode.net/rubicode/index.html

The DG ENV study *Impacts of climate change and selected renewable energy infrastructures on EU biodiversity and the Natura 2000 network* and complementary work for the EEA included the development of vulnerability assessments for species and habitats (Sajwaj, et al, 2009; Harley, et al, 2010). In addition to estimating potential impacts (i.e. the combined effects of exposure and sensitivity), the methodologies consider the adaptive capacity of species (either individually or as proxies for assessing habitat vulnerability). The results of the species assessments (Sajwaj, et al, 2009) suggest that the majority of species from the four exemplar taxonomic groups studied are likely to be vulnerable to some extent. Of the 212 species assessed, the vulnerability of 135 (64%) was ranked as high, very high, critical or extremely critical under at least one future climate change scenario. The assessment also shows that vulnerability primarily arises where species are constrained in their ability to move to and colonise new areas with suitable climate. This complements the findings of other vulnerability assessments, which have typically focused on particular species or groups of species within Member States or regions.

The vulnerability of habitats to climate change is also likely to be a problem for species, particularly those that are habitat specialists and are already constrained by habitat availability and/or condition. Climate change is likely to exacerbate such threats, rather than create new opportunities (Harley, et al, 2010).

The results of vulnerability assessments should, however, be treated with some caution. This is due to the large number of caveats and assumptions associated with attempts to understand the implications of climate change for biodiversity, including the uncertainties and limitations inherent in the use of climate models in impact projections and the reliance on expert judgements in determining constraints on adaptive capacity.

3.2.2.3 Health

Climate and weather have a powerful impact on **human, animal and plant health**. A variety of impacts are projected for European countries. The most important health effects from future climate change are projected to include (Watkiss, et al, 2009; D`Amato, et al, 2007):

- Increases in summer heat related mortality (deaths) and morbidity (illness);
- Decreases in winter cold related mortality (deaths) and morbidity (illness);
- Increases in the risk of accidents and wider well-being from extreme weather events (floods, fires and storms);
- Changes in the disease burden e.g. from vector-, rodent-, water- or food-borne disease;
- Changes in the seasonal distribution of some allergenic pollen species, range of virus, pest and disease distribution.

Climate changes can effect human, animal and plant health directly by thermal stress (heat waves) and casualties and injuries of extreme events (floods and storms), and indirect by changes in distribution of vector-borne diseases, rodent-borne diseases, water-borne diseases, food-borne diseases and air quality, ozone, air allergens and ultraviolet radiation. The IPCC 4th Assessment Report (AR4) concluded with a very high degree of confidence, that climate change is contributing to the global burden of disease and causing premature deaths, and that while currently these effects are small, they are "projected to progressively increase in all countries and regions" (Confalonieri, et al, 2007).

3.2.2.3.1 Human Health

As stated in the OECD Environmental Outlook to 2050 – The consequences of inaction, climate change affects human health adversely through extremes in temperature, weather disasters, photochemical air pollutants, vector-borne and rodent-borne diseases, and food-related and water-borne infections (OECD, 2012). Also the WHO Report on protecting health form climate change: connecting science, policy and people (WHO, 2009b) highlights the effects on human health in a similar way. Especially the CEHAPIS WP2 report: "The effects of climate change in the European Union: evidence for action" (CEHAPIS, 2012, DRAFT) highlights the consequences of climate change on human health.

All people are affected, but potential health effects depend largely on populations' vulnerability and their ability to adapt, and may be modified by ecological, social, economic and cultural factors, including education, access to health care, etc. (EEA, 2010g).

Temperature increase

There is a direct relationship between human mortality and **temperature** (thermal stress due to extreme high temperature events, heat waves) that differs by climatic zone and geographical area. High ambient temperature is associated with mortality from heat stroke, and also illnesses (e.g. cardiovascular diseases). However, rising temperatures will also reduce winter excess deaths. At present cold and extreme cold temperatures (cold spells) lead to more deaths than warm/hot temperatures in Europe (WHO, 2010c).

A warmer climate will have particular benefits in northern latitudes of Europe (Watkiss, et al, 2009). Nevertheless the IPCC AR4 chapter 12, which focuses on Europe[44], reported that heat waves are very likely to become more common and severe over the next century. The 2003 heat wave was the most dramatic in recent history, but there have been a number of fatal heat waves in Central and Southeastern Europe over the last ten years. Heat waves in Central and Southeastern Europe between 2005 and 2007 caused at least 839 heat wave related morbidities in Romania, Slovakia and Bulgaria (EM-DAT, World Bank 2009).

The number of climate-related extreme events in Europe increased by 65% between 1998 and 2007, with overall economic losses doubling to almost €14 billion from the previous decade. About 40 million people have required help with their health and basic survival needs, such as safe shelter, medical assistance, safe water supply and sanitation, in the past

[44] http://www.ipcc-wg2.gov/AR4/website/12.pdf

20 years. This is a growth of about 400% compared to the 8 million people affected in the previous two decades[45] (WHO Europe, Information for the media, 2011)[46].

As reported to EM-DAT/CRED[47] (The International Disaster Database - Centre for Research on Epidemiology of Disasters-CRED), the highest health impact, in terms of numbers of people killed, was linked to extreme temperatures (especially heat waves) in most regions of Europe, particularly in the south and west. Floods and wet mass movements were linked with the highest death rates in Southern and Eastern Europe, droughts and wildfires in Southern Europe, while for storms higher death rates were reported in Northern and Western Europe. Between 1980 and 2011, the number of reported climate related extreme events in Europe increased (EEA, 2012b).

Between 1900 and 2012, 38 drought events occurred in Europe, killing 1.2 Million people (31.579 average per event) (directly related to **thermal stress** from **heat waves**), affecting 15.4 Million (407.447 per event) and causing a damage of US$ 21 billion (US$ 564.771 per event) (EM-DAT, 2012)[48]. The most serious drought in the Iberian Peninsula in the last 60 years occurred in 2005 (e.g. in many parts of Portugal, January 2005 was the driest January in more than 100 years)[49], reducing overall EU cereal yields by an estimated 10%. The drought also triggered forest fires (27.000 fires occurred, 400 fires a day)[50], killing 15 people and destroying 180.000 ha of forest and farmland in Portugal alone (UNEP, 2006). However, there is no evidence that river flow droughts have become more severe or frequent over Europe in general in recent decades (Hisdal et al. 2001)[51], nor is there conclusive proof of a general increase in summer dryness in Europe over the past 50 years due to reduced summer moisture availability (van der Schrier, et al, 2006).

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[45] According to data from the Centre for Research on the Epidemiology of Disasters (CRED) International Disaster Database (EM-DAT), 2009

[46] http://www.euro.who.int/en/what-we-publish/information-for-the-media/sections/latest-press-releases/extreme-weather-events-threaten-safe-drinking-water-and-sanitation

[47] http://www.cred.be/ and http://www.emdat.be/

[48] http://www.emdat.be/result-disaster-profiles?disgroup=natural&period=1900%242012&dis_type=Drought&Submit=Display+Disaster+Profile#summtable

[49] http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=14717

[50] http://wwf.panda.org/who_we_are/wwf_offices/spain/news/?22801/WWF-urges-Portugal-to-fight-root-causes-of-forest-fires

[51] http://onlinelibrary.wiley.com/doi/10.1002/joc.619/pdf

Extreme weather events

Climate change comprises changes in weather patterns and an increase in **extreme weather events**, such as heavy rainfall with subsequent floods, which are the most immediate and obvious health risks. Projections indicate that these events will become more intense and frequent (Work Bank, 2009). **Floods** (e.g. a consequence of heavy storms, sea level rise as well as increased glacial melt (EEA, 2009a)) **and storms** are the most common natural disasters causing loss of life and economic damage in Europe. In the past 20 years, 953 disasters killed nearly 88.671 people in Europe, affected more than 29 million others and caused a total of US$ 269 billion economic losses. Compared to the rest of the world, economic loss per capita is high in Europe, partly because it is very densely populated (United Nations International Strategy for Disaster Reduction Secretariat (UNISDR, 2009c) and the economic wealth by capita is high.

Adverse health impacts associated with flooding include direct physical effects (drowning and injuries), but also wider effects on well being (e.g. mental illnesses from the effect of flooding and displacement) (Watkiss, et al, 2009). Most importantly, the disruption and stress of a flood event have negative effects on mental health for a long time after the event (Ahern, et al, 2005).

Additional floods and storms can lead to indirect effects, e.g. contamination of e.g. soil, fresh water, and groundwater with persistent organic pollutants (POPs) and heavy metals. This can cause problems, like long-range chronicle contamination of water bodies, ground water and food chain. Several climate-related factors combined (e.g. excessive heat or greater cold, overcrowding and disease spread associated with population migration) will aggravate the effects of POPs on humans. Other determinants of health (e.g. socio-economic status, education, adequacy of shelter, general health status) will also combine the adversely affecting human responses to POPs and climate change (UNEP/AMAP Expert Group report – Climate Change and POPs: Predicting the Impacts)[52].

Vector-, rodent-, water- and food-borne diseases

Climate is important in determining the geographical range of vectors carrying a range of **vector-borne diseases** (Semenza & Menne, 2009). Climate and other changes (e.g. demographic, socio-economic, migration, trade and travel) are likely to affect the distribution of the vectors of infectious diseases and pest species in Europe in the future. There is good evidence that the distribution of vectors and pathogens has already changed in Europe due to anthropogenic warming.

There is a continuing risk of Chikungunya and Dengue fever importation into Europe due to international air travel. The presence of a competent vector and a conducive climate, particularly in the Mediterranean area calls for heightened surveillance of potential outbreaks. There have been increases in incidence of tick-borne encephalitis and Lyme disease,

[52] http://chm.pops.int/Implementation/GlobalMonitoringPlan/ClimateChangeandPOPsPredictingtheImpacts/tabid/1580/language/en-US/Default.aspx

particularly in Northern/Central and Leishmaniasis in Southern Europe over recent decades, though there are many additional factors associated with these increases (e.g. the influence of increased travel, changes in leisure activity affecting exposure, levels of reporting) (Semenza & Menne, 2009). Tick-borne diseases and the associated Lyme borreliosis disease and tick-borne encephalitis are moving into higher altitudes and latitudes (Semenza & Menne, 2009). Changes in the geographical distribution of the sandfly vector (which is a competent vector for Sicilian, Naples, Toscana phlebovirus and other related viruses) are occurring in several European countries (high confidence), e.g. Cypress, Italy, Spain and Portugal (Depaquit, 2010). For leishmania parasite, temperature influences the biting activity rates of the vector, diapauses, and maturation of the protozoen parasite in the vector and there is a risk of expansion of human Leishmania[53] cases further north. The two tick-borne diseases - Crimean-Congo haemorrhagic fever (CCHF) and Rickettsia - may be influenced by climate change, but the evidence is currently rather limited. Potential reasons for the emergence or re-emergence of CCHF (e.g. in 2009 six confirmed cases in Bulgaria and two in Germany, ECDC, 2011) include climate changes, which may have a significant impact on the reproduction rate of the vector Hyalomma ticks, as well as anthropogenic factors (e.g. changes in agricultural and hunting activities). There are models that show the probability of CCHF extending to other countries around the Mediterranean basin, suggesting that vector, veterinarian and human surveillance should be enhanced (Maltezau & Papa 2011).

The Asian tiger mosquito (Aedes albopictus), a transmitter of a number of viruses (e.g. Arboviral Encephalitides[54], Dengue Fever, West Nile Virus, Yellow Fever, Chikungunya[55] Fewer), has extended its geographical range in Europe[56] (preliminary in Italy, Southern France and the Adriatic Coast) substantially over the past 20 years and is projected to extend even further[57] (ENHanCE team Animation – The Asian Tiger Mosquito: climate controls in Europe[58]) and to larger parts in Europe, which are climatically suitable for Aedes albopictus, meaning that additional expansion of the vector is highly probable (Caminade, et al, 2012).

Projected temperature increases in the United Kingdom could increase the risk of local malaria transmission only by 8 to 15%; in Portugal a significant increase in the number of days suitable for the survival of malaria vectors is projected. However, the risk of localised malaria transmission is low (Semenza & Menne, 2009). The malaria vectors (Anopheles

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[53] Asiatic and African parasite transmitted by local Phlebotomine sandflies highlights the risk of introduction diseases potentially transmitted by European Phlebotomine sandflies.

[54] Arthropod-borne viruses are maintained in nature through biological transmission between susceptible vertebrate hosts by blood feeding arthropods (mosquitoes, psychodids, ceratopogonids, and ticks). Vertebrate infection occurs when the infected arthropod takes a blood meal. http://www.cdc.gov/ncidod/dvbid/arbor/arbdet.htm

[55] Chikungunya is a viral disease that is spread by mosquitoes. It causes fever and severe joint pain. Other symptoms include muscle pain, headache, nausea, fatigue and rash. http://www.who.int/mediacentre/factsheets/fs327/en/

[56] http://ecdc.europa.eu/en/activities/diseaseprogrammes/emerging_and_vector_borne_diseases/Pages/VBORNET_maps.aspx

[57] http://ecdc.europa.eu/en/healthtopics/aedes_albopictus/Pages/index.aspx

[58] http://www.liv.ac.uk/enhance/news/index.htm

mosquitos) are present in much of Europe. In the past decade, a few cases of autochthonous transmission occur in continental Europe (for example, Florescu, et al, 2011 and Danis, et al, 2011). Rodent populations are affected by weather conditions and landscape features. Under climate change scenarios, rodent populations could be anticipated to increase in temperate zones, resulting in greater interaction between human beings and rodents and a higher risk of disease transmission (**rodent-borne diseases**, e.g. hantavirus[59]), especially in peri-urban and urban areas (Semenza & Menne, 2009). In some European countries, breakdown in sanitation and inadequate hygiene are contributing to serious rat infestations (ECDC)[60],

In Europe, the incidence of salmonellosis and campylobacteriosis has decreases or stayed constant over the last years but is strongly seasonal where elenated temperatures influence the transmission (Semenza, et al, 2012b) (**food- and water-borne disease**).

There has been a linear increase in reported cases of some food-borne diseases for each degree increase in weekly or monthly temperature over a certain location-specific threshold (medium confidence). Thousands of cases of salmonella will continue to occur, particularly in countries where food safety standards are poor. Higher temperatures favour the growth of bacteria in food (Semenza, et al, 2012b). Infections with Salmonella spp. rise by 5–10% for each 1°C increase in weekly temperature, at ambient temperatures above 5°C (Semenza, et al, 2012b). The annual costs of food-borne salmonella in the EU reach up to € 2.8 billion per year (CEHAPIS, 2012, DRAFT). In the Mediterranean, additional public health issues from recreational water use due to microbiological water contamination are projected, which would require proper monitoring and surveillance (Semenza & Menne, 2009).

Changing frequency and intensity of precipitation events (and temperature) from climate change may result in outbreaks of water-borne diseases (high confidence) and could mobilise pathogens. Increased temperature will generally have a eutrophication-like effect (e.g. Schindler, 2001), with enhanced phytoplankton blooms (e.g. Wilhelm & Adrian, 2008), and increased dominance of cyanobacteria (blue-green algae) in phytoplankton communities, resulting in increased threat of harmful cyanobacteria and enhanced health risks in water bodies used for public water supply and bathing. As an example, one category of algal blooms, cyanobacteria, in the Baltic, has been present for decades, but have recently increased in duration, frequency, and biomass. Resulting toxins trigger gastrointestinal illnesses and liver damage in cases of persistent exposure, and ingesting contaminated water has killed cattle and pets (World Bank, 2009). *Vibrio* bacteria (including *V. vulnificus* and *V. cholerae*), native to the North and the Baltic Sea, proliferate in warmer water temperatures during unusually hot summers (Semenza & Menne, 2009). They can infect open wounds that can necrotise and cause septicaemia.

A recent study conducted by the European Centre for Disease Prevention and Control, Mapping Climate Change Vulnerabilities to Infectious Diseases in Europe (Semenza, 2012a),

[59] Humans may be infected with hantaviruses through rodent bites, urine, saliva or contact with rodent waste products. Some hantaviruses cause potentially fatal diseases in humans, hemorrhagic fever with renal syndrome (HFRS) and hantavirus pulmonary syndrome (HPS).

[60] http://www.ecdc.europa.eu/en/healthtopics/climate_change/health_effects/Pages/rodent_borne_diseases.aspx

assessed incidence, outbreak frequencies and distribution of many infectious diseases in relationship to climate change. In 2007 and 2009/2010 national infectious disease experts from Europe were surveyed and peer-reviewed literature was evaluated. A large majority of respondents agreed that climate change would affect vector-borne (86% of country representatives), food-borne (70%), water-borne (68%), and rodent-borne (68%) diseases in their countries. Based on this assessment seven diseases call for changes in the surveillance system (Lindgren, 2012). Imported cases of chikungunya fever (CF) dengue fever (DF), and Rift Valley fever (RVF) are currently reported to ECDC, either voluntarily (CF) or legally (DF, RVVF); however, autochthonous transmission demands heightened surveillance. Lyme disease, tick-borne encephalitis (TBE), Vibrio spp. (except V. cholera O1 and O139) and visceral leishmaniasis.

The ECDC Technical Report - Assessing the potential impacts of climate change on food- and water-borne diseases in Europe (ECDC, 2012) needs to be seen as a starting point in this field. Nevertheless, it was concluded that the risk of campylobacteriosis[61] is associated with mean weekly temperatures, although this link is shown more strongly in the literature relating to salmonellosis. Irregular and severe rain events are associated with Cryptosporidium[62] spp. outbreaks, while non-cholera Vibrio sp. displays increased growth rates in coastal waters during hot summers. In contrast, Norovirus and Listeria spp. show only a relatively weak association with climatic variables, but a much stronger one with food determinants.

Ozone and fine particulate matter

There is growing evidence that the effects of heat wave days on mortality are greater on days with high levels of **ozone** and **fine particulate matter** (PM10). This affects the elderly (75–84 years) in particular and the total daily number of deaths in this age group increased by 16.2% on heat wave days with high ozone levels and by 14.3% on days with high PM10 levels, respectively, compared to an increase of 10.6% and 10.5% on days with low levels of ozone and PM10 (WHO, 2007).

In 2005, 40 European Member States faced a total of 500.000 premature deaths per year from particulate matter (PM) air pollution. Changes in wind patterns, increased desertification and fires boost the long-range transport of air pollutants. The projected increase in heat waves in Europe is expected to result in more frequent ozone episodes. During heat waves mortality is higher when PM and ozone pollution are high (CEHAPIS, 2012, DRAFT).

As ozone is potentially threatening human and animal health, this could have very serious consequences such as eduction in lung function, aggravation of preexisting respiratory disease (such as asthma), increases in daily hospital admission and emergency department

[61] Campylobacteriosis is an infection by the Campylobacter bacterium. It is among the most common bacterial infections of humans, often a food-borne illness. It produces an inflammatory, sometimes bloody, diarrhea or dysentery syndrome, mostly including cramps, fever and pain.

[62] Cryptosporidium cause gastro-intestinal illness with diarrhea in humans. Treatment is symptomatic, with fluid rehydration, electrolyte correction and management of any pain.

visits for respiratory causes, and excess mortality (WHO, 2003). In addition to an estimated 20.000 premature death associated with ozone exceeding the threshold of 70 µg/m^3 (maximum daily 8-hour average), excessive exposure to ozone is linked with 14.000 respiratory hospital admissions every year in EU25, and more than 100 million person-days with minor activity restrictions, respiratory medication use, cough or lower respiratory symptoms (WHO, 2008a).

Climate change may increase summer episodes of photochemical smog due to increased temperatures, and decreased episodes of poor air quality associated with winter stagnation. Stratospheric ozone depletion and warmer summers influence human exposure to ultraviolet radiation and therefore increase the risk of skin cancer (IPCC, 2007a). In the past, climate change has contributed to an increase in ozone concentration in Central and South-western Europe, and the climate-induced increase in ozone levels might be hampering current ozone abatement efforts. Nevertheless, detailed projections for the future effects of climate change on air quality are largely missing (EC, 2009b).

Allergenic disorder

There is also the potential for an increase in the seasonality and duration of **allergic disorders**, with implications for direct costs – roughly estimated at €40 billion per year in the EU-15[63] – in terms of care and medicines. Indirect costs are also considerable and include opportunity costs associated with non-optimal performance of market and household activities, for example, the sizeable loss of school and working days/hours, the negative impact on school performance and on social and sport activities for the individual patients. The IPCC AR4 (IPCC, 2007a) reported with high confidence that climate change altered the seasonal distribution of some allergenic pollen species. There may be other indirect health effects due to climate change acting on other health determinants, such as on indoor and outdoor air quality (accumulation of pollutants), the level of air pollution and the nature, severity and timing of air allergens, such as pollen or mould (EC, 2009b). Also Blando et al. (2012) argues, the evidence that links climate change to the exacerbation and the development of allergic disease is increasing and appears to be linked to changes in pollen seasons (duration, onset and intensity) and changes in allergen content of plants and their pollen as it relates to increased sensitization, allergenicity and exacerbations of allergic airway disease. Also synergistic effects such as increase of potent allergen plants and also animals related to a changing climate occur (Blando, et al, 2012).

The introduction of new invasive species with highly allergenic pollen, in particular ragweed (Ambrosia artemisiifolia), presents important health risks. Several laboratory studies show that increasing CO_2 concentrations and temperatures increase ragweed pollen production and prolong the ragweed pollen season and increase some plant metabolites that can affect human health (BMU & UBA, 2010).

[63] http://www.allergie.wur.nl/UK/Research/

The IPCC AR4 (IPCC, 2007a) reported that there may be other indirect health effects due to climate change acting on other health determinants, such as on indoor and outdoor air quality (accumulation of pollutants), the level of air pollution and the nature, severity and timing of air allergens, such as pollen or mould (EC, 2009b). Climate Change and air pollution is directly impacting indoor air quality, taking into account that people spend about 90% of their time indoor. Especially indoor air quality can be improved in order to raise health benefits like identified in the Report of DG Health and Consumers (Jantunen, et al, 2011) Promoting actions for healthy indoor air (IAIAQ).

In general, the quality of health care is high in Europe, but quite different depending on the region (CEHAPIS, 2012, DRAFT). The WHO Regional Office for Europe concludes that health services play an important role in identifying impacts as well as raising awareness about and adapting to climate change (in Altvater, et al, 2011a).

Furthermore, the short- to medium-term impacts of climate change on health are mainly expected to be exacerbations of existing effects. In this case, it can be concluded that much of the expected increased burden could be avoided through scaling up existing cost-effective interventions (Hutton, 2011) or prevented by introducing new instruments (e.g. heat health action plans in order to prevent, react upon and contain heat-related risks to health).

3.2.2.3.2 Animal Health

With regard to impacts on animal health, climate is an important factor in determining the geographical range of vectors (for instance mosquitos) that carry a range of diseases. There are vector-borne animal diseases including some of zoonotic character for which an increased geographical distribution has been observed in recent decades. Many factors influence the emergence and spread of infectious diseases such as trade in live animals and animal products, international tourism, migration, food preferences, political and economic stability, and increased contact to wildlife by growing urbanisation, constructing in previous animal habitats or increase in outdoor activities. However, the expansion of the distribution of bluetongue disease and its emergence during 2006/07 in Northern Europe outside of its previously known geographical range is one of the most prominent examples for the potential impact of climate change on animal health.

Non-statutory diseases

Non-statutory diseases are animal diseases for which no EU harmonised veterinary legislation is laid down as it is the case for some epidemic and highly contagious diseases. Their appearance does not influence the official animal health status of a country in particular with a view to possible cross border spread, but they may also be important for the farmer's income.

As stated in the accompanying documents[64] of the White paper on adaptation (EC, 2009a) climate change has an impact on **non-statutory diseases**, affecting the animals' living

[64] http://ec.europa.eu/health/ph_threats/climate/docs/com_2009-147_en.pdf

conditions and conducive to pathologies such as parasitic diseases (e.g. infestation/affection by nematodes and taenia), nutritional disorders, sunstroke or dehydration.

Statutory diseases

Statutory diseases are mainly serious transmissible infectious animal diseases, which are subject to international and EU veterinary legislation and which are relevant in determining the animal health status of a country. Some of them can be considered to respond to climatic changes especially vector-transmitted diseases dependent on specific weather conditions and those transmitted by wildlife. This includes a number of **vector-borne diseases** such as Rift Valley Fever, African Horse Sickness, African swine fever and West Nile Fever and **most importantly Bluetongue** (effects ruminants) with its emergence in the summer of 2006 in the Netherlands, Belgium, Germany, France, Luxemburg and spread up to Sweden, which is much further north outside the previously known range (Southern Europe) of virus distribution. Climate change is likely to have facilitated the expansion of Bluetongue in Europe (e.g. Takken & Knols, 2007).

Bluetongue emergence in Europe is thought to be linked to increased temperatures, which allows the insects that carry the virus to spread to new regions and transmit the virus more effectively (Guis, et al, 2011).

Using these future projections, researchers found that in Northern Europe there could be a 17% increase in incidence of the bluetongue virus, compared to 7% in southern regions, where it is already much warmer.

It is also a relevant example the discovery of >150 cases of Chikungunya in Italy (Takken & Knols, 2007).

The recently discovered (November 2011) Schmallenberg virus fits into the wider pattern of animal diseases and their vectors moving northwards. The virus belongs to a group of viruses (Bunyaviridae) that are spread by insect vectors.

Temperature increase

Heat waves provoke stress in animals, but provided they have a shelter place, adequate ventilation and fresh water, livestock animals are rather resistant to heat. Also livestock animals are quite resistant to cold, but are more vulnerable in adverse weather condition (e.g. humidity, wind) (Gobin, et al, 2008).

Non vector disease

The dynamics of **non vector-borne diseases** such as infections with avian influenza may also be influenced by changes to migratory routes of wild waterfowl. The EU has already experienced during early 2006 that very cold weather in some areas causing feed scarcity and unusual freezing of open waters forced wild waterfowl to change their flyways, which has led to the introduction of highly pathogenic avian influenza of the H5N1 subtype into the EU. Some wild bird species have already decreased their range of migration, which could also contribute to the spread of certain infectious fish diseases to new areas. Virus persistence in the environment including in water may also be influenced by changes in temperature.

Highly pathogenic avian influenza of the H5N1 subtype has caused an international crisis affecting more than 60 countries in Asia, Africa and Europe leading to important economic losses and social disruption. As regards human health more than 607 confirmed cases and 358 deaths have been reported to the WHO[65]. The disease remains a reason for concern due to its unprecedented involvement of wild birds in long distance virus spread and the endemicity of the infection in domestic poultry in Egypt, Indonesia and some other Asian countries, which seems not to be eradicated in the short term.

The dynamics of non vector-borne diseases such as avian influenza may also be influenced by changes to migratory routes of wild waterfowl.

Wildlife plays an important role in transmission of animal diseases such as avian influenza, rabies, classical swine fever and tuberculosis. Reduced water availability will lead to increased congregation of animals and be conducive to conditions for the persistent circulation of pathogens.

In the light of the global repercussions of transboundary animal diseases on animal health and trade, and on human health, awareness, early detection, diagnosis and response efforts must be fast, well coordinated and strategically planned to help stop diseases before they spread. The capacity and performance of the veterinary services are crucial in this context.

3.2.2.3.3 Plant Health

Changes in climate impact on the susceptibility of plants to pests and diseases. In addition, warmer summers and shorter winters will in general result in increasing populations of harmful organisms and extension of their geographic range, and will enable new ones to become established in the EU. The crops selected for cultivation will also change in response to climate change, bringing fresh opportunities for pests and diseases.

The timing of seasonal events in plants and animals is changing across Europe. Between 1971 and 2000, phenological events in spring and summer have advanced on average between 2.5 and 4 days per decade. The pollen season today starts on average 10 days earlier and is longer than it was 50 years ago. Climate change is regarded as the main cause of these changes (EEA, 2012d).

Impacts of climate change on plant health as stated in the accompanying documents[66] of the White paper on adaptation (EC, 2009a) are, inter alia, effects on cropping system, plant breeding, natural vegetation, forest, meadows, woodland.

Several European plant species have shifted their distribution northward and uphill. These changes have been linked to observed climate change, in particular to milder winters. The

[65] http://www.who.int/influenza/human_animal_interface/H5N1_cumulative_table_archives/en/index.html
[66] http://ec.europa.eu/health/ph_threats/climate/docs/com_2009-147_en.pdf

rate of climate change is expected to exceed the ability of many plant species to migrate, especially as landscape fragmentation may restrict movement (EEA, 2012d).

While a fair amount of information is already available concerning the impacts of climate change on the world's species and ecosystems, from the perspective of forests, considerably more information is needed on the impacts on forests, forest pests and the complex relationships relating to climate change.

Emerging pests and diseases

Direct consequences are related to emerging pests (e.g. spruce bark beetle as a result of increased temperature and precipitation reduction) (Marini, et al, 2012) and disease as well as indirect risks to agricultural productivity and trade. Additional, breeding seasons are lengthening, allowing extra generations of thermophilic insects such as butterflies, dragonflies (Hassall, et al, 2007), bark beetles and others to be produced during the year (EEA, 2012a).

Changes in plant phenology have shown to be good bio-indicators (e.g. Estella, et al, 2009; Gordo & Sanz, 2006) for climate change impacts, which already occur, like earlier start of the growing season, onset of bud break reported for numerous species in the northern hemisphere (Walther, 2003). Especially in mountain areas, the continent-wide response of vegetation to climate change is a fact and it is shown that ongoing climate change gradually transforms mountain plant communities. The more cold-adapted species decline and the more warm-adapted species increase, a process described as thermophilization (Gottfried, et al, 2012).

With increasing global trade, new challenges emerge due to the increased risk and frequency of trade-driven international pest movement (Evans, 2008). When **pests** expand into new territories without the checks and balances provided by natural enemies, or encounter either a new host species or a large expanse of their natural host species, opportunities may be created for significant outbreak episodes, resulting in reductions in forest growth and tree mortality. Gradual shifts in climatic suitability in previously unsuitable regions of the world provide new opportunities for forest pests to establish in new locations.

Disturbances

Disturbances such as fire, drought, landslides, species invasions, insect and disease outbreaks, and storms such as windstorms and ice storms influence the composition, structure and function of forests (Dale, et al, 2001).

All of these impacts related to increased temperature and changes in precipitation patterns on trees and forests will inevitably have widespread impacts on the forest sector. Changes in the structure and functioning of natural ecosystems and planted forests (due to temperature changes and rainfall regimes) and extreme events and disasters (droughts, fires and pests) will have negative impacts on the productive function of forest ecosystems, which in turn will affect local economies (FAO, 2005).

Changes in the patterns of disturbance by forest pests (insects, pathogens and other pests) are expected under a changing climate as a result of warmer temperatures, changes in precipitation, increased drought frequency and higher carbon dioxide concentrations. These changes will play a major role in shaping the world's forests and forest sector.

Insects and pathogens

Insects and pathogens have been noted to respond to warming in all the expected ways, from changes in phenology and distribution to influencing community dynamics and composition. While some impacts of climate change may be beneficial in terms of protecting forest health (e.g. increase winter mortality of some insect pests due to thin snow cover; slower larval development and increased mortality during droughts), many impacts will be quite detrimental (e.g. accelerated insect development rate; range expansions of pests).

Climate change can affect forest pests and the damage they cause by directly impacting their development, survival, reproduction, distribution and spread; altering host physiology and defences; impacting the relationships between pests, their environment and other species such as natural enemies, competitors and mutualists.

Different forest insect pests, diseases and other pests have already impacted or are predicted to have impacts on forests due to climate change. For example, Agrilus pannonicus (=A. Biguttatus (Fabricius)) has recently been associated with a European oak decline throughout its natural range and has increased in incidence in several countries including France, Germany, Hungary, Poland and the Netherlands, and the UK where it is believed to be contributing to oak decline (Gibbs & Greig, 1997; Ciesla, 2003). Infestations can result in extensive tree mortality which, combined with other factors involved in the decline, can drastically alter the species composition of oak forests.

With short generation times and low developmental threshold temperatures, aphids can be expected to be strongly influenced by environmental and climatic changes. In general, it has been predicted that aphids will appear at least eight days earlier in the spring within 50 years, though the rate of advance will vary depending on location and species (Harrington, et al, 2007). This could potentially result in greater damage to host plants depending on the phenology of host plants and natural enemies.

Zhou et al. (1995), for example, investigated the timing of migration in Great Britain for five aphid species (Brachycaudus helichrysi, Elatobium abietinum, Metopolophium dirhodum, Myzus persicae, Sitobion avenae) over a period of almost 30 years and concluded that temperature, especially winter temperature, is the dominant factor affecting aphid phenology for all species. They found that a one degree Celsius increase in average winter temperature advanced the migration phenology by 4 to 19 days depending on species.

The green spruce aphid (Elatobium abietinum) is also believed likely to benefit from the increase in winter survival, leading to more intense and frequent defoliation of host spruce trees (Picea spp.). Infestations in the UK have resulted in large losses of spruce foliage and height both during the active infestation and in subsequent years. Westgarth-Smith et al.

(2007) showed that warm weather associated with a positive North Atlantic Oscillation (NAO) index caused spring migration of E. abietinum to start earlier, last longer and contain more aphids.

Native to Central and Southern Europe, Thaumetopoea processionea is a major defoliating pest of oak. Since the late 20th century it has been expanding its range northwards and is now firmly established in Belgium, Denmark, Northern France, and the Netherlands and has been reported from Southern Sweden and the UK. It is believed that the northward progression of the oak processionary moth is due to improved synchrony of egg hatch and reduction of late frosts as a result of warmer temperatures (Evans, 2008).

The larch bud moth, Zeiraphera diniana, is a European pest that has been defoliating large areas of larch forests in the Alps every 8 to 10 years for centuries (Battisti, 2004). It has an annual life cycle, overwintering as an egg on the larch branches and feeding on the needles as soon as the bud breaks. As such synchrony between egg hatch and bud burst is critical.

Increased temperatures associated with climate change have affected this relationship leading to asynchrony and reduced incidences of the moth in Switzerland (Evans, 2008). It has been reported that abnormally high temperatures result in unusually high egg mortality (Battisti, 2004).

Increases in ground-level ozone are likely in some regions due to **warmer temperatures**, which would cause a decrease in forest health and growth, which in turn has critical implications for forest distributions and future rates of carbon sequestration (Matyssek, et al, 2012 in: EEA, 2012d).

Climatic conditions affect agriculture and the water resources needed to maintain stable production levels in many areas of Europe (Ciscar, et al, 2009). Various authors distinguish between direct and indirect effects of increased greenhouse gas emissions on the agro-ecosystem. Direct effects are primarily due to higher CO_2 levels and include increased biomass production and water use efficiencies. Indirect effects are related to climatic components such as temperature, precipitation, extreme events, radiation and humidity (Olesen & Bindi, 2004), which in turn influence crop growth and occurrence of weeds, pests and diseases (Olesen, et al, 2011).

3.2.2.3.4 Invasive species

Invasive species (IS) are treated separately, since they are not a sub-challenge of human or animal health, but instead they are a chapter for invasive species affecting human, animal and plant health and biodiversity problems.

Invasive Species like the Asian tiger mosquito, which is increasingly present in Europe and is a vector for at least 22 arboviruses (including dengue, Chikungunya, Ross River, and West Nile), was introduced via trade in used tyres. Climate change is likely to foster its spread further north (EC, 2008b).

The main identified costs related to Invasive species in Europe comprise eradication and control costs and damage to agriculture, forestry, commercial fisheries, infrastructure and human health. While it may appear that there are either impact costs or eradication costs, in fact partial eradication and control programmes are undertaken in parallel, on an ongoing basis in order to try and limit the impact. In 2008, an initial estimate assessed annual Invasive Species-related costs in Europe at between €9.600 million and €12.700 million per year (Kettunen, et al, 2008). This figure is undoubtedly an underestimate, as it is based on current expenditure to eradicate and control Invasive Species plus the documented cost of the economic impact. Given that many countries are only now starting to document and record costs and effects, the real figures for the financial costs involved will be considerably higher (EC, 2008b).

3.2.2.3.5 Climatic drivers affecting human health

Temperature increase

According to the Impact Assessment accompanying the White paper “Adapting to climate change: towards a European framework for action” (EC, 2009a), the WHO (WHO, 2010b) and the IPCC (IPCC, 2007a) the primary concern in Europe with regard to climate change is the mortality and morbidity related to heat waves. Heat waves are very likely to become more common and severe (IPCC 2007a). People become more sensitive to heat waves, if the duration is longer. The sensitivity is country specific and is a result of differences in physiological and social conditions. The IPCC concludes that elderly, disabled, children, women, ethnic minorities and those on low incomes are more vulnerable and need specific consideration (IPCC 2007a).

The EEA report “Urban adaptation to climate change in Europe” (EEA, 2012c) highlights that thermal stress, increases cardiac output and redirection of blood flow to the skin (Hajat, et al, 2010). Diminished or delayed physiological responses cause people to be extra sensitive to heat exposure. In particular the elderly, young children and those using certain medication are sensitive to heat (Kovats & Hajat, 2008) as well as pregnant women (EEA, 2012c).

The impacts of climate change on human health in the 2080s without acclimatization were analysed in the Peseta Study (Watkiss, et al, 2009). The estimated range of increase in annual heat-related mortalities is between 60.000 and 165.000, while the range of diminution of cold-related mortalities is between 60.000 and 250.000. Acclimatisation to warmer climate in summer would reduce the projected mortality changes by a factor of five, but heatwaves have not been considered in the project (Watkiss, et al, 2009).

In addition, people living in cities are specifically vulnerable for heat stress as a result of the urban heat island effect. According to the EuroHEAT[67] project, the increase in mortality during heat wave days (study period 1990-2002 and 2004), ranged from +7.6% in Munich to +33.6% in Milan. The increase was up to three times greater during episodes of long duration and high intensity. Pooled results showed a greater impact in Mediterranean (+21.8% for

[67] http://www.euro.who.int/__data/assets/pdf_file/0010/95914/E92474.pdf

total mortality) than in North Continental (+12.4%) cities. The highest effect was observed for respiratory diseases and among women aged 75-84 years (D'Ippoliti, 2010) [68].

A ten-year analysis in 15 European cities, carried out by the PHEWE (Assessment and Prevention of acute Health Effects of Weather conditions in Europe)[69] project, estimated a 2% increase in mortality in northern cities and a 3% in southern cities for every 1°C increase in apparent temperature above the city threshold level.

A European heat wave occurred during the summer of 2003 causing health problems for between 22.000 and 35.000 mainly elderly people, of which 14.802 died within 20 days. The associated costs of this heat wave were estimated at € 13 billion (Kovats & Hajat, 2008 and van Aalst, 2006, in: Altvater et al. 2011a). Related to a study by (LoVecchio, et al, 2005)[70] in the United States, during 1979–2002, 6% of the 4.780 deaths classified as heat-related occurred in children (Ebi & Meehl, 2007).

According to the EEA Report No 4/2008 (EEA, 2008c) increasing temperatures are likely to increase the number of heat-related deaths. Mortality risk increases by between 0.2% and 5.5% for every 1°C increase in temperature above a location-specific threshold. Heat-wave events can have detrimental effects on human health. More than 70.000 excess deaths were reported from 12 European countries in the hot summer of 2003 (June to September). Long heat waves (more than 5 days) have an impact 1.5 to 5 times greater than shorter events. 86.000 net extra deaths per year are projected for the EU Member States for a high-emissions scenario with a global mean temperature increase of 3°C in 2071–2100 relative to 1961–1990. Heatwaves can compromise public health, reduce the ability to work and result in lower productivity thus shortening or delaying the delivery of products and services to clients (EEA, 2012a).

Heat exposure and heat stress have a major effect on a person's ability to carry out physical activity, whether it is a part of general daily activities (such as carrying things to and from the household) or part of daily work. Heavy labour is most affected as such jobs generate heat in the body. If the body cannot be cooled down sufficiently by sweating or other cooling mechanisms (radiation, conduction or convection), the only way to avoid heat stroke is to slow down and reduce work output, affecting worker productivity or "work ability". Using the common heat stress index WBGT (Wet Bulb Globe Temperature), the reduction of "work ability" due to increasing heat exposure is based on international guidelines like ISO, 1989 (WHO, 2009c). The WHO report 2009 highlights that for e.g. Delhi at the peak heat exposure of WBGT at 28°C, the loss of work ability is almost 50% and the losses in a heavy labouring job (500W, e.g. construction worker) become extreme, and in fact during the middle of the day no work of this type can be carried out. For a person working with less physical demand (200W) the work ability losses are less, but still almost 100% in the middle of the day. As an

[68] http://www.ehjournal.net/content/9/1/37
[69] http://cordis.europa.eu/projects/rcn/70003_en.html
[70] http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5425a2.htm

example, Athens has been analysed showcasing that the lowest work ability outdoors in the hottest month, July is at around 7% (500W) and 30% (200W).

Extreme weather events

The life of thousands of people may be threatened by more frequent extreme weather events in the future. The value of excess deaths is estimated at € 50 billion annually (when valuing each excess death) and € 120 billion (when valuing the loss of a year of life) for 2080, from heat alone. The greatest impact is in Central Southern Europe. These impacts are, however, likely to be balanced out by reduced cold-related deaths, with the greatest gains in Northern Europe and the British Isles (CEHAPIS, 2012, DRAFT).

The intensity of heavy rain events has increased in the past 50 years. Up to 20% of the European population lives in river basins that are likely to be affected by increased flood hazards, direct by e.g. drowning or injury or indirect by e.g. allergy to moulds of infectious diseases (EEA, 2012e). For example, intense precipitation events have been associated with large water-borne disease outbreaks, through contamination of water treatment and distribution systems with cryptosporidium (Semenza & Nichols, 2007). The number of winter floods is projected to rise in north-western countries, and of flash floods throughout the region. Between 2000 and 2009 death incidents from flooding were highest in Central and Eastern Europe. Particular risks were from fast flowing water, hidden hazards, water of unknown depth, driving and walking through flood water and infectious disease outbreaks (Semenza & Menne, 2009). Sea level rise and storm surage cause coastal flooding, which is likely to threaten an additional 1.6 million people and their health every year in the European Union (WHO, 2008b), especially in the Northern Mediterranean, Northern and Western Europe might experience coastal flooding by 2018 (Nicholls, 2004), compared to past data. According to CEHAPIS (2012, DRAFT), the areas potentially most affected by coastal floods are the British Isles, the Central Europe North and Southern Europe regions. PESETA (2009) estimated that the number of people affected by coastal flooding in the EU in 1995 (reference year) is estimated to be 36.000. Without any adaptation measures, the number of people and people's health annually affected by coastal flooding in the EU is approximately between 775.000 and 5.5 million, depending on the scenario. The impacts on public health (including school education) accounted for about 9% (£287 million) of economic costs. £260 million of this comprises the mental health cost associated with flooding based on estimates of people's willingness to pay to avoid exposure to the distress caused by flooding (CEHAPIS, 2012, DRAFT).

Vector-borne diseases

Climate change is likely to affect the geographical distribution, seasonality, and incidence of many of the vector-borne diseases that are endemic in Europe or neighbouring regions (Semenza & Menne, 2009). Today's interconnectedness with rapid travel and trade increase the risk of introduction of new pathogens, vectors, and hosts into new places[71]. Tick-borne

[71] http://edinburgh.academia.edu/JonathanSuk/Papers/1032512/Future_infectious_disease_threats_to_Europe

diseases, Lyme disease and Crimean Congo fever are likely to further change their distribution; a northern spread of Leishmania is expected; mosquito-borne diseases may further spread in parts of Europe and create localized outbreaks including dengue fever, Chikungunya and West Nile Fever. An empirical model estimated that, in the 2080s, an additional 1.5-2.5 billion people (two fifths of the world's population) would be at risk of dengue as a result of climate change and population increase (CEHAPIS, 2012, DRAFT).

Water-borne diseases

By the 2020s, the average annual number of temperature-related cases of salmonella may have increased by a total of almost 20.000 as a result of climate change in Europe (on top of any increases expected from population changes). For the 2080s, the climate change induced increase in temperature-related cases of salmonella could be around 40.000 annually, on average for the whole of Europe. A number of other food-borne diseases could follow similar trends, although salmonella is the most common form of food-related illness in Europe (Watkiss, et al, 2009). The damage costs of increased Salmonella cases in the EU due to higher average temperatures has also been estimated, with an annual damage cost of between €70-139 million until 2040, based on the average medical treatment cost per case of €3.500 (Watkiss, et al, 2009).

Invasive species and allergenic pollen

The introduction of new invasive species with highly allergenic pollen, in particular ragweed (Ambrosia artemisiifolia), presents important health risks. Several laboratory studies show that increasing CO_2 concentrations and temperatures increase ragweed pollen production and prolong the ragweed pollen season and increase some plant metabolites that can affect human health (BMU & UBA, 2010).

Ozone and fine particular matter

Air quality may also attribute to the additional deaths during heat waves; this is due to a combination of factors, such as high temperature and radiation, stagnation of air masses and weak dry deposition, which favour the accumulation of ozone precursors and the build-up of ozone (Tressol, et al, 2008). In the Netherlands Fischer et al. (2004) suggest that a significant proportion of the deaths now being attributed to the hot summer weather of 2003 can reasonably be expected to have been caused by air pollution. There is a potential that populations will slowly acclimatize to higher temperatures. Dessai (2003) assumes that it takes three decades to acclimatize to 1°C temperature rise (in Altvater, et al, 2011a). The combined effect of heat-waves and of peaks of ozone or PM10 (particulate matter with a diameter under 10 µm) air pollution increases mortality, particularly among elderly people (those aged 75–84 years) (WHO Regional office for Europe, n.d.b).

3.2.2.3.6 Climatic drivers affecting animal health

Diseases

One potential consequence of significant and permanent changes to our climate is altered patterns of disease in humans and animals. Such may include 1) the emergence of new disease syndromes and 2) a change in the prevalence of existing disease, particularly those spread by biting insects. A wider geographic distribution of known vectors and/or the recruitment of new strains to the vector pool could result in infections spreading to more and potentially new host species. Some of the diseases impacted by climate change may be endemic some show an epidemic pattern. In general, warmer temperatures can result in higher virus titres within vectors, increased vector survival from season to season and higher vector biting frequency. The *Culicoides* midges, which disseminate Bluetongue virus have shown to invade new territories finding a virgin host population and finally involving indigenous insects in the gradual development of the disease.

Climate change does not only refer to incremental changes of long-term means over time, but also to changes in variability and increases in frequency and intensity of extreme events. Rift Valley Fever strongly depends on rainfall patterns. Extreme weather events might then create the necessary conditions for that disease to expand its geographical range northwards (Martin, et al, 2008).

For example, the highly pathogenic avian influenza remains an unparalleled international crisis. Other animal diseases also present cause for alarm. Prevalent in many areas of the world, African swine fever, foot-and-mouth disease, Rift Valley fever and other transboundary animal diseases are often not recognized in time.

Swift to spread from herds to markets and beyond, some of these diseases are also transmissible to humans and can move to cities, countries and regions if left unchecked.

In light of the global repercussions of transboundary animal diseases on animal health and trade, and on human health, response efforts must be fast, well coordinated and strategically planned to help stop diseases before they spread.

Food safety

Climate change will additionally impact livestock production systems across Europe and thus affect food safety. In some areas, farmers will need to adapt their practices to combat, for example, new animal diseases and detrimental impacts to pasture land. Direct and indirect impacts of climate change on animal health and boosting weather-related deaths and diseases will also be crucial factors for the reduction of livestock productivity and management, and certainly the location of production. The integration and intensification of systems of monitoring and surveillance of animal diseases ensure early detection of outbreaks and better adaptation (copa*cogeca, European farmers and European agri-cooparatives)[72]. Cf. also chapter 3.2.3.2 and 3.5.3.2).

3.2.2.3.7 Climatic drivers affecting plant health

Changes in climate impact on the susceptibility of plants to pests and diseases. In addition, warmer summers and shorter winters will in general result in increasing populations of harmful organisms and extension of their geographic range, and will enable new ones to become established in the EU. The crops selected for cultivation will also change in response to climate change, bringing fresh opportunities for pests and diseases.

Climate change affects plant health in diverse ways and thus impacts different kinds of utilisation of land like forestry and agriculture.

Pests

A considerable effect on pathways of exotic pest introduction in new geographic regions is anticipated: as climatic conditions become more favourable, new or migrant plant pests may become established and more widespread in areas that were previously considered being pestfree. An example is that of pine wood nematode Bursaphelenchus xylophilus currently causing great damage in Portugal. The nematode is a considerable threat for the northern areas in the EU and it has been estimated that if the average temperature increases above 20ºC during July or August, a mortality of 50-90% of conifers should be expected.

Indigenous plants will be subjected to greater environmental stress and will become more vulnerable to pests and diseases. In principle, fungal and bacterial pathogen outbreaks are expected to increase both in number and in terms of the severity of outbreaks in areas with increased rainfall[73]. However, warmer summers may also favour certain thermophilic fungi.

It would be reasonable to assume that most insect pests have the potential to become more damaging due to global warming. It is also likely that the pests' natural enemies may increase, making the overall effect less predictable. This is because in many cases there is a fine balance between pests/diseases, their natural enemies and their host plants.

Regarding plant health, it is recognised that the recent rapid increase in agriculture (e.g. Western corn rootworm Diabrotica virgifera virgifera), forestry and public green sites (e.g. Pinewood nematode Bursaphelenchus xylophilus, Pitch canker Gibberella circinata and Red palm weevil Rhynchophorus ferrugineus) pest incursions, into the EU necessitates the establishment of closer links between plant health and environmental policy.

[72] http://www.copa-cogeca.be/img/user/file/Climate/5659%20version%20E.pdf
[73] http://www.foresight.gov.uk/Infectious%20Diseases/t7_2a.pdf

The European Food Safety Authority (EFSA)[74] focussed in it last Scientific Colloquium on emerging risks in plant health (EFSA, 2011) inter alia on climate change as a driver of emerging plant health risks and potential impacts of climate change on emerging pests, e.g.:

- Pest range changes: leading to pest overwinter survival, longer growing season, change in reproductive cycle, extreme climatic events
- Host range changes: host overwinter survival, changed cropping patterns (crops and cultivars)
- Host-pest synchrony changes: temperature change impacts on phenological development
- Increased pest virulence: increased generations, increased fecundity, increased multiplication, increased host susceptibility
- Increased pest entry: atmospherically transported pests, pest entry with new biofuel crops and exotic horticulture plants

Forests and the way they are managed are particularly sensitive to climate change, because the long lifespan of trees does not allow a rapid adaptation to environmental changes (Lindner, et al, 2008). Effects of climate change include increased risk of biotic (pests and diseases) and abiotic (droughts, storms and fires) disturbances to forest health. However, the exact effects of climate change on forests are complex and not yet well understood. The impacts of climate change will vary throughout the different geographic regions of Europe, with forest fires likely to dominate in Southern Europe and the limited diversity of tree species in boreal forests enhancing the risk of significant pest and disease impacts.

In the field of forest health, the most commonly studied insects belong to the orders Lepidoptera and Hemiptera, while there is only limited information on coleopterans. There is also scant information available on the effect of climate change on symbionts and host dynamics. Further detailed studies of important forest pests would allow for the development of pest management strategies for the future and assist forest managers and policy-makers to better prepare for the challenge of dealing with climate change and provide insights into future pest adaptations to climate change.

Opportunities

Next to negative climate change impacts, especially in the long term, opportunities arise as well in the forestry sector. Evidence to date suggests that productivity in Northern and Central Europe has increased and is likely to continue to increase. Further, northward expansion of potential distribution of some tree species is expected and potentially more favourable conditions for summer recreation in mountainous regions will exist (Lindner, et al, 2010). However, with more drastic changes in climate towards the end of the 21th century,

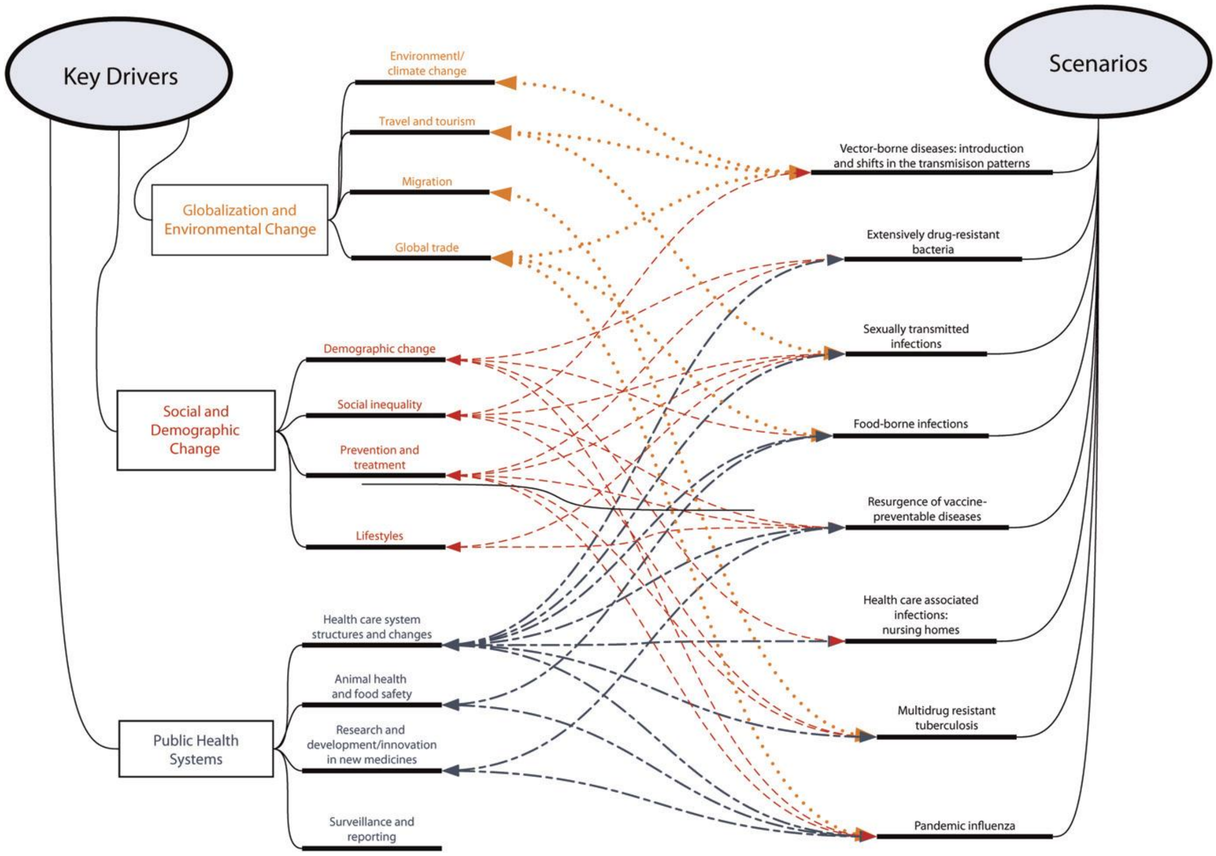
[74] http://www.efsa.europa.eu/en/panels/plh.htm

severe and wide ranging negative climate change impacts have to be expected in most European regions (Lindner, et al, 2008), with the Mediterranean region as the most vulnerable to climate change based on potential impact assessment and adaptive capacity (Lindner, et al, 2010).

The relation between human health and climate change are complex and interact with several other factors. Important factors are the population health status, population demographics and the health infrastructure. Vulnerable groups among are children, elderly, pregnant women, low income groups and people with health issues (WHO, 2010a). In many parts of Europe population is aging. The figure below shows the relationship between climate change, its drivers, effects on systems and socioeconomic development, health, mitigation and adaptation (WHO, 2010b).

Communicable diseases continue to emerge in Europe and elsewhere, and it is by now widely understood that myriad social and environmental risk factors influence their emergence. Major drivers of emerging infectious diseases that could threaten control efforts in Europe include globalization and environmental change (including climate change, travel, migration, global trade); social and demographic drivers (including population ageing, social inequality, lifestyles); and public health system drivers (including antimicrobial resistance, health care capacity, animal health, food safety). These factors, alongside many others, interact in dynamic and stochastic ways to drive the emergence and re-emergence of new diseases. Yet, individually, such factors are not easily addressed by medical and public health communities alone, woven as they are into the fabric of our societies. This, however, does not obviate medical and public health communities of the responsibility to assess, communicate and address the potential risks from communicable diseases that society faces. In an increasingly complex world, it is ever more important to anticipate and prepare for the unexpected. ECDC has completed an infectious disease threat assessment with international experts (Suk & Semenza, 2011). In the threat assessment numerous key disease drivers were identified to explore how they might interact to create new risks or exacerbate current ones. They are shown in Figure 44.

Figure 44: Interaction between disease drivers and scenarios: European Union[75]



The global spread of disease vectors is facilitated by global trade and travel patterns (Suk & Semenza, 2011). Three developments are concerning for 2020. First, the introduction of new disease vectors, which creates new opportunities for disease transmission, such as has happened with the introduction of Aedes albopictus into Europe through global trade and then transmitted an outbreak of Chikungunya in Italy in 2007, when the virus was introduced by a traveller. A second possibility is that vectors currently exist in Europe prove to have a previously unknown capacity for disease transmission, such as has happened with the spread of Bluetongue, as well as with a mutation in the Chikungunya virus that made it easier to be transmitted by Aedes albopictus. The third development is the shift in the transmission range of a disease, the host and its vector such as Tick-Borne Encephalitis, which had a marked increase in incidence in the Baltic region that has been linked to socio-economic change as well as a northerly expansion of the vector in Nordic countries linked to climate change. Consequently, vector-borne diseases may be an increasing problem across the EU by 2020 (ECDC, 2012).

[75] http://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.2011.300181

Changes in animal phenology have shown to be good bio-indicators (e.g. Estella, et al, 2009; Gordo & Sanz, 2006) for climate change impacts, which already occur like composition of fish fauna, spread of invasive species, statutory disease spread (e.g. Bluetongue).

Figure 45: Climate change and health: pathway from driving forces, through exposures to potential health impacts (CEHAPIS, 2012, DRAFT)

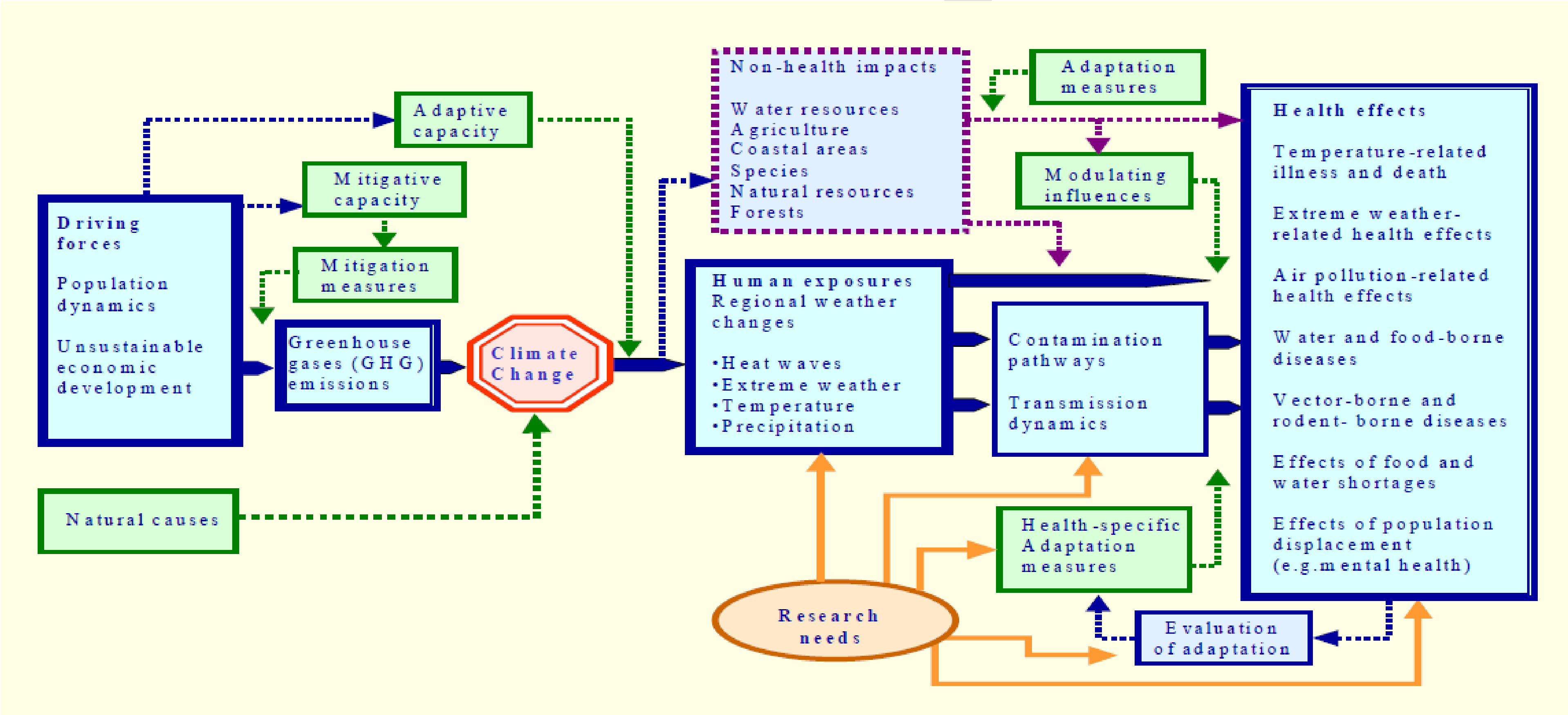


Figure 45 can be accordingly interpreted for animal and plant health.

3.2.2.4 Inland Water

The recently completed **ClimWatAdapt** project[76] has investigated the future water situation and developments in the water sector in Europe until 2050 in terms of “vulnerability to water scarcity”, “vulnerability to droughts”, and “vulnerability to floods”. **ClimWatAdapt** has been used as the main source for this chapter, but has been accomplished by additional information. Water quantity and water quality aspects were addressed, with water quality issues mainly addressed by literature review because of gaps in research, data collection, and observation. The sectoral level of detail involves the agricultural, energy, industrial, and tourism sectors, as well as navigation and aquatic ecosystems (environmental flows). Overall, one emission scenario (SRES A1B) using a multi-model ensemble of 11 GCM-RCM combinations and two socio-economic scenarios, particularly “Economy First” (EcF) and “Sustainability First” (SuE), were analysed in this report.

The ClimWatAdapt project concludes that changes in future water scarcity are mainly driven by changes in water withdrawals. Under the EcF scenario, the percentage of area under severe water stress is expected to increase in all regions until 2050, with major changes in particular in Eastern, Western, and Southern Europe. Increasing water withdrawals are the main cause in Eastern and Western Europe. In Southern Europe a decrease in water availability due to climate change exacerbate the situation. No water stress occurs in Northern Europe. In river basins under severe water stress, there will be strong competition for scarce water resources between households, industry, agriculture, and nature. Overall, this situation is most severe during summer when river flows are low and are becoming lower due to climate change. Additionally, the water demands are highest during the summer due irrigation demands and tourism water use.

Under the SuE scenario, the water withdrawals are significantly reduced and as a result, the percentage of area under severe water stress is expected to decrease in all regions by 2050 and almost diminishes on an annual basis. Southern Europe and parts of Western Europe are still likely to suffer from water scarcity during summer, primarily caused by agricultural water use together with decreasing water availability because of climate change. The vulnerability of hydropower, navigation, and environmental flows is less affected by the water use scenarios since climate change is the dominant driver; however, water abstractions need to be considered to avoid further depletion and maintain the ecological function of the rivers.

In Western Europe, the energy sector in particular is extremely vulnerable to water scarcity and droughts under the EcF scenario conditions because of increased electricity production. This would lead on the one hand to cooling water stress during the low flow period, i.e. when cooling water requirements cannot be fulfilled, and on the other hand, to thermal pollution when water temperature is high and there is reduced cooling water intake. Alternative energy sources like hydropower are also at risk due to reduced river discharges, and growing biofuel crops may result in increasing diffuse source loadings. Hence, depending on the location, the

[76] This text is mainly taken from: Flörke et al. (2011).

expansion of hydropower might be critical. Irrigation water stress only occurs occasionally during the summer season, and maize yields are likely to decrease under rainfed conditions. Environmental flows are at risk or severe risk in the future and the same may be the case for the navigation sector.

Considering 100-year flood events, Western Europe is likely to be hit but these larger and richer EU countries can afford the rather high absolute costs. With respect to water scarcity and droughts, measures should preferably address the thermoelectric power sector. A shift in cooling systems reduces water stress as shown by the SuE scenario but increases water consumption, and therefore, a reduction in thermal electricity production as such or changing consumption patterns should be preferred. A special role is given to the navigation sector, which has to adapt to climate change impacts regardless of the water use scenario. Temperature increases and reduced snow cover will influence winter tourism in the Alps. In Western Europe, the different upstream and downstream-related vulnerabilities of transboundary river basins need to be carefully analysed to avoid negative side effects of adaptation measures. Most of the transboundary river basins have been subject to water quality and flood problems so far, but in the future, they need to be better prepared to avoid, e.g., losses in the thermoelectric power sector due to water shortages during low flow periods or even droughts. This is obvious for the Rhine where the navigation sector will be affected, too.

For Eastern Europe, the results of the vulnerability assessment are not as clear as for Western or Southern Europe. Although the percentage of area under severe water stress is anticipated to increase due to higher water withdrawals no individual sector is particularly affected. Rather, the occurring water stress is caused by the cumulative water stress of the all sectors. An exception is the thermoelectric energy sector during low flow conditions when cooling water requirements are probably not met. The minimum flow for maintaining aquatic ecosystems is depleted under the EcF scenario and the navigation sector is affected in the lower Danube. In this area, the occurrence of severe droughts is rather likely. Extreme flood events are expected to increase in Eastern Europe, leading to higher flood damages. For example, among the European countries, Hungary is likely to suffer from the highest costs in percent of GDP due to direct impacts of flooding. Flooding damages might decrease the Hungarian GDP by 0.09% in 2050. In Eastern Europe, measures addressing floods and droughts should have highest priority; water scarcity seems not to be a major problem. However, the latter seems to be the case in the lower Danube where minimum environmental flows as well as navigation are expected to be at risk. This is an important result since the Danube, as a transboundary river basin, has to deal with a range of vulnerabilities affecting different sectors.

In Southern Europe, agriculture is the major water use sector and will remain so in the future. Irrigation water stress occurs throughout the year and especially during the summer. In some river basins much more water is consumed by crops than is available. Seasonal water shortage may be overcome by water stored in reservoirs. However, there is also a risk that the “water gap,” the imbalance between demand and supply, will be closed by over-exploitation of groundwater resources. Most prone to an increase in drought hazard is

Southern Europe, which already suffers most from water scarcity. Due to reduced river discharge, aquatic ecosystems and transitional waters will be threatened. Saltwater intrusion along the coastline is most likely, polluting aquifers that are used for domestic water supply. Additional pressure is caused by the tourism sector, which increases demand during summer. With respect to the energy sector, losses in hydropower electricity production are most likely for run-of-the-river plants and for reservoir stations. In some river basins, thermoelectric power plants will also be at risk during the low flow season. Changes in flood hazards are expected to increase in parts of Southern Europe with a strong increase in Italy. Concerning adaptation measures, Southern Europe is mainly affected by water scarcity and droughts but also by (flash)floods. The imbalance between water supply and water demand is caused by increasing water withdrawals and decreasing water availability. For instance, a large portion of the agricultural land is intensively irrigated causing water stress and competition with other water users. A large decrease is necessary on the demand side to reduce water stress as could be shown with the SuE scenario. This cannot be reached only through technical measures addressing water use efficiencies. Instead, non-technical measures/actions that lead to a change in demand and water use are very important. Transboundary issues are mainly related to water scarcity and droughts and this will remain so in the future. However, in order to solve the problems between upstream and downstream user needs, integrated management is of high importance as well as cuts in agricultural sector water use by e.g., reducing the irrigated area or changing crop patterns. It is rather likely that downstream areas have to struggle with saltwater intrusion due to reduced freshwater intake but also sea level rise destructing wetland areas and reducing biodiversity.

In Northern Europe, no water stress occurs and only (locally) the thermoelectric sector may be at risk during low flow periods. The main water user in Central & Eastern Europe in 2000 was the electricity production sector. However, average annual precipitation and temperature are expected to increase, leading to changes in snow cover during winter. This can lead to a shorter snow season and reduced snowmelt-induced flood peaks in the spring. Nevertheless, some areas are affected by an increase in flood hazards. Due to increased use of water in the agricultural sector, water quality problems may occur and resulting in an increase in diffuse source loadings. Results from WATCH recommend the relationship between air and water temperatures and river flow levels should be included to improve estimates of river temperatures, especially during dry, warm spells.

The drought atlases delivered by the WATCH project provide spatial-temporal evolution of droughts (and high flows) for the past and future across Europe in a single diagram. These atlases provide an objective means to assess the duration and spatial extent of droughts using a regional deficiency index. Using this approach a multi-model assessment to evaluate extremes (drought & floods) for the future across Europe suggests for temperate regions of Europe the number of large scale drought events is projected to increase by the end of the 21st Century.

With respect to water quality, less information is available on the European scale; however, some findings from SCENES are presented. The EU-FP7 project ClimateWater addresses water quality issues as well (but no modelling) and concludes with the urgent need for the development of a broad range of catchment models that are calibrated and verified against time series from catchment monitoring stations. Combining such models with long-term field monitoring allows the assessment of relationships between, e.g., diffuse pollution and its impacts. Hence, clear recommendations are given for the improved control of pollution with the increasing impact of climate change. Current management practices are inefficient in eradicating all pollution, the relative merits of which remain a contentious issue, therefore requiring the development of inter-disciplinary research.

However, water quality will deteriorate as a consequence of climate change, e.g. reduced runoff leading to lower dilution rates and higher runoff causing higher nutrient loads. It turns out that climate change-induced diffuse source pollution loadings would have a major impact on Europe’s water resources. According to ClimateWater, only general advice in terms of adaptation strategies is available so far. This statement is contradicted by the fact that diffuse source pollution is expected to grow to high levels due to catastrophic flooding and wash-off events after heavy rainfall. Finally, it becomes more important to consider both, the development of future water quantity and water quality to identify regions or sectors that are vulnerable to climate change.

All the above mentioned issues will clearly impact Europe’s drinkning water supply. An ongoing study[77] is review existing knowledge on the potential effects of climate change on drinking water resources across the EU. The preliminary findings show that climate change will also affect drinking water supply from ground and surface water. In particular changes in groundwater recharge and low flow conditions are the main issues. Most vulnerable areas are:

- Coastal aquifers, because of the combined effects of increasing sea levels, reduced recharge and often high abstraction pressures. Mediterranean – whilst there is still considerable climate uncertainty, Spain, southern Italy and Greece appear to be at risk of decreased groundwater recharge. Further supply reservoirs located in these areas will face a higher risk from sea flooding and increase wave heights.
- A number of studies suggest decreased groundwater resources in parts of Germany, Belgium, UK.
- Mountainous, permafrost and boreal areas, where increasing temperatures lead to changes in snow accumulation and melting, with resultant impacts on groundwater recharge and discharge
- Most small islands are especially vulnerable to future changes and distribution of rainfall because they have a limited water supply, and water resources.

[77] Cf. second interim report to the study: “Literature review on the potential climate change effects on drinking water resources across the EU and the identification of priorities among different types of drinking water supplies – ADWICE project” contract DG ENV 070326/SER/2011/610284/D1

- In the case of increasing frequency of flood events, combined with associated increased pollutant peaks (combined sewer overflows, pesticide runoff etc) all drinking water resources along rivers could be impacted as well as systems that use bank filtration

However it should be noted that additional pressure will arise from socio-economic pressures due to increased urbanisation, growing water demand in other sectors (in particular agriculture) and further loss of ecosystems.

3.2.2.5 Marine and coastal zones

In the literature, climate change risks and impacts relevant for marine areas and coastal zones include, among others, changes in sea surface temperature, sea level rise, ocean current and the direction and power of waves, coastal erosion, algae blooms impacts on aquatic species, changes in biodiversity and ecosystems and ocean acidification. To date, however, studies and report dedicated to climate change adaptation in coastal zones focus primarily on sea level rise.

3.2.2.5.1 Sea Surface Temperature

Increased sea surface temperature (SST), coupled with changes in precipitation, wind and salinity, influence sea ice coverage as well as the diversity and number of marine species (EEA, 2008c). Increases in SST have been greatest in the Baltic Sea and the North Sea, with lower rates identified in the Black Sea and the Mediterranean Sea. In the North Sea and the Baltic Sea values are over 0.06-0.07 °C/year (ibid). The fourth IPCC assessment report reports global scale SST increase in the A1B scenario, including deep ocean temperatures. Under both the A2 and the B2 scenarios, the mean annual surface temperature can be expected to increase by 2-3°C during the 21st Century, with larger increases up to 3-4 °C expected during the spring and summer months (Meier, 2006 *in* MacKenzie, et al, 2007). The warming trend is expected to be greater in the upper 100m of the ocean, but also the lower reaches will be affected in the latter half of the century (IPCC, 2007a). Current ocean-climate models are limited in their spatial resolution and are not able to project changes in SST for different geographic regions across Europe (EEA, 2008c).

Over the past 60 years, the extent of Arctic sea ice at the end of summer melt has declined at a rate of -7.8%/decade; the last 20 years have seen a trend of -9.1%/decade (Stroeve, et al, 2007). Current projections indicate that summer ice is very likely to continue to shrink in extent and thickness, although winter sea ice will continue to cover large areas in winter. New models, however, indicate that ice-free summers could start to occur sooner than previous estimations under all IPCC models (IPCC AR4), which projected this phenomena by the end of the century, as actually observed melting has been faster than the average expected trends (ibid). Taking into account forced change by greenhouse gas loading, Stroeve et al. (2007), estimate that between 47-57% of sea ice melting can be attributed to GHGs (from 1979-2006), which is a much more considerable contribution than what the IPCC AR4 models take into account. As such, observed trends show that sea ice melt in the summer is approximately 30 years ahead of the mean model forecast under IPCC AR4 simulations (ibid).

In this context, an important phenomenon is the ice-albedo feedback loop. The albedo - the amount of energy reflected by a surface – of snow and ice is .8 or .9[78], i.e. very little solar radiation is absorbed. In the Arctic, the melting and cracking of ice sheets exposes darker ice as well as sea water, which have a much lower albedo compared to ice. As a result, more solar energy is absorbed, which causes more ice to melt, which further lowers the albedo and more ice to melt. Although this is a normal seasonal process that occurs during the summer, the increase in the melting of ice associated with climate change will aggravate this feedback loop: as ice melts earlier in the year due to increased temperatures, more ocean water is exposed. Conversely, as ice forms later in the year due to increased temperatures, the ocean remains exposed longer.

3.2.2.5.2 Sea Level Rise

Trends and Projections

Global sea level has been rising since the late 19th century and over the 20th century this rate was 1.7 ± 0.5 mm/year, with slightly higher rate for the period 1961 to 2003 of 1.8 ± 0.5 mm/year (Solomon, et al, 2007). A modelling exercise by Marzeion et al. (2012), indicates that the world's glaciers have already lost mass equalling .114 ± .005 m sea-level equivalent (SLE) between 1902 and 2009. Shepherd et al. (2012) confirms the results, finding that the melting of the Antarctic and Greenland ice sheets has contributed .0111 m to global sea levels since 1992.

Tide gauge and satellite studies show that regional sea level rise can deviate from global projections. Figure 46 shows the rates of change in sea level since 1992 for the European region. From 1900-2010, sea level rose around 2mm/year in the North Sea, with the southern-most part experiencing greater change. Similarly, the Baltic Sea has undergone sea level rise of between around 2mm/year and 5mm/year [79]. On the other hand, parts of the English Channel and the Bay of Biscay show a small decrease in mean sea level. The Mediterranean Sea has experienced both increases and decreases depending on the region in the range of -4mm to +6mm/year. Trends in the Black Sea from 1900-2010 point towards an increase between zero and around 5mm/year.

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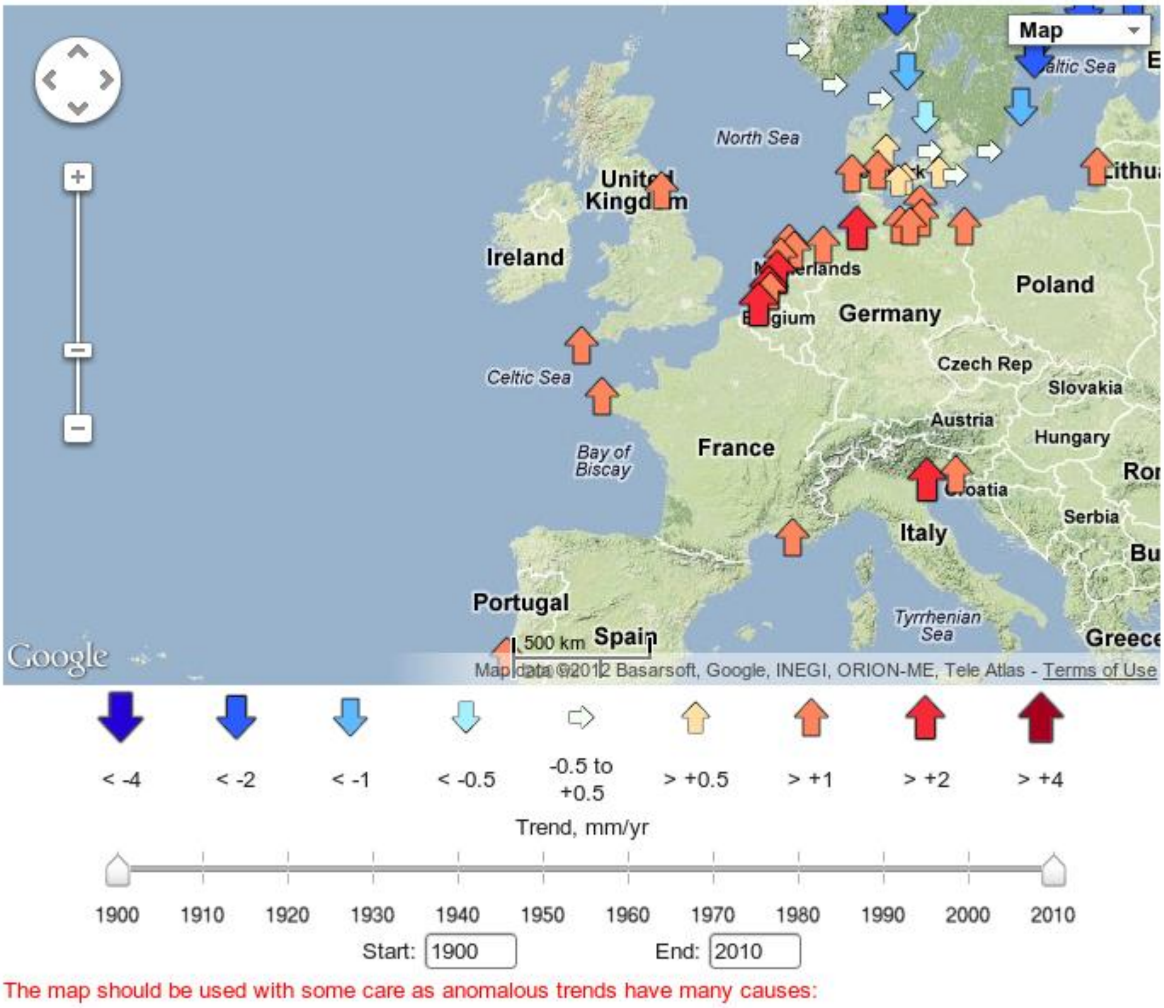
[78] Albedo is calculated on a scale from 0 to 1 where zero is no reflecting power of a perfectly black surface and 1 represents perfect reflection of a white surface.

[79] In the Baltic Sea sea level rise trends differ depending on the region. In Stockholm, sea level has been decreasing at a rate of -3.81 to -.32 mm/year during the period 1890-2010. North of Stockholm in the Gulf of Bothnia (covering Sweden and Norway) relative sea level decreased around -2 to over -4mm/year from 1970-2010. South of Stockholm, sea level has remained steady or experiend a -.5 to 1mm/year trend from 1970-2010. In Denmark, Germany, Lithuania and Poland, sea level has been increasing between 1 to over 4mm/year for the period 1970-2010.

Figure 46: Annual sea-level trend at selected European tide-gauge stations (Source: Permanent Service for Mean Sea Level (PSMSL)[80]



In its Fourth Assessment Report (AR4), the IPCC projected global average sea-levels to rise between 0.18 m and 0.59 m for the end of the 21st century, depending on greenhouse-gas emissions scenarios and climate change sensitivity (IPCC, 2007a). According to the IPCC AR4, sea-level rise estimates are based on models for thermal expansion of sea water, melting of glaciers and small ice caps, the mass balance of the Greenland and West Antarctic ice sheet, and a term to represent the observed dynamic acceleration of the major ice sheets (ibid). The main driver for sea-level rise is thermal expansion (0.10 to 0.41 m), followed by melting of glaciers and ice caps (0.07 to 0.17 m) and Greenland Ice sheet (0.01 to 0.12 m) (IPCC; 2007c). In addition, the North Atlantic Oscillation (NAO) influences sea-surface height and the geographic distribution of sea-level rise in the Atlantic coasts and shelf seas (Parry, et al, 2007).

[80] http://www.psmsl.org/products/trends/

For the European seas adjacent to the Atlantic Ocean, such as Baltic and North seas, IPCC the UKCP 09 projections[81] for the sea level rise change at the end of the 21st century in the Atlantic Ocean around the UK range from 0.13 – 0.76 m. This regional projection added one very low-probability high impact scenario that accounts for massive input from melting ice sheets in the range of 0.93m - 2 m by 2100.

For the Mediterranean and Black seas, global averages are moderated by the two narrow straits, Gibraltar and Bosporus respectively. These straits determine the distinct current behaviour of the Mediterranean and Black seas - while at some parts the Mediterranean sea level even slightly decreases, the Black sea level rises much faster than the global average. The reasons for this are different salinities and evaporation/precipitation and river run-off ratios for these seas. In the Mediterranean, evaporation greatly exceeds precipitation and river runoff and therefore increases the salinity (e.g. Tsimplis, et al, 2006). This increased salinity is one of the physical parameters that together with evaporation/precipitation and reduced river flows may lead to a partial drop in sea level in the Mediterranean because saltier water is denser than freshwater. In contrast to the Mediterranean Sea, the Black Sea has relatively low salinity, because of very high flux of freshwater (3 × 102 km^3 per year) from its catchment area that is about five times larger than the sea (Stanev, 2005).

Regional projections for the Mediterranean sea for the end of 21st century made within the CIRCE project[82] suggest that climate change might induce a 2021-2050 mean steric[83] sea-level rise between 0.07m and 0.12m with respect to the reference period (1961-1990 with ranges between -0.0007 and 0.002m/year). These trends are in accordance with the previous projections, made with Global Climate Models (Marcos & Tsimplis, 2008; Vellinga, et al, 2010), which indicate the possibility of higher upper end of the range of 0.76 m. However, this follows the upper range of Atlantic sea level rise at the other side of Gibraltar strait, as projected by UKCP' 09. There are no climate projections for the Black Sea yet.

More recent studies have shown that sea-level rise could be more considerable than the previous IPCC AR4 estimates, although this is largely due to ice sheet dynamics, knowledge of which is still hindered by reliable models. Recent studies using statistical models as opposed to physical models project considerably larger sea-level rise estimations up to 2m (e.g. Rahmstorf, 2007; Vermeer & Rahmstorf, 2009). Table 26 and Figure 47 highlight the differences in global and regional seal-level rise projections from different studies and/or different models. Marzeion et al. (2012)[84] have found that during the 21st century glaciers will

[81] http://ukclimateprojections.defra.gov.uk/

[82] http://www.circeproject.eu/index.php?option=com_frontpage&Itemid=1

[83] i.e. global changes in sea level due to thermal expansion and salinity variations

[84] Taking into account projected temperature and precipitation anomalies from 15 coupled general circulation models from the Coupled Model Intercomparison Project phase 5 (CMIP5) ensemble. CMIP5 provides a framework for coordinated climate change experiments from 2008-2013 and includes simulations for assessment in the AR5. CMIP5 provides a multi-model context for 1) assessing the mechanisms responsible for model differences in poorly understood feedbacks associated with the carbon cycle and with clouds, 2) examining climate "predictability" and exploring the ability of models to predict climate on decadal time scales, and, more generally, 3) determining why similarly forced models produce a range of responses.

lose additional mass under various GHG emission scenarios ranging from 148 ± 35mm SLE (scenario RCP26), .166 ± .042m SLE (scenario RCP45), .175 ± .040m SLE (scenario RCP60), or .217 ± .047m SLE (scenario RCP85). Moreover, Shepherd et al (2012)[85], has found that the combined rate of ice sheet melting of Greenland and Antarctica has increased over time. According to their research[86], Greenland and Antarctica are now losing more than three times as much ice (equivalent to 0.95mm SLR/year) as they were in the 1990s (equivalent to 0.27mm SLR/year). These results negate the previous assumption in IPCC AR4 that the ice accumulation in Antarctica would balance ice loss from Greenland.

Table 26: Comparison of different studies providing sea-level rise projections

Study and Model approach	Geographic scope	Projection	Time Frame
IPCC AR4 (IPCC, 2007a)	Global	Between 0.18 m and 0.59 m	By 2100
UKCP 09 based on the HadCM3 model using perturbed physics ensembles[87] and results of IPCC climate models	Atlantic Ocean	Between 0.13 m – 0.76 m	By 2095
Lowe et al. (2009) based on IPCC AR4 (IPCC, 2007a)	UK	Between 0.12 m to 0.76m	By 2095
Katsman et al. (2011) based a high-end scenario[88] taking into account various climate models and expert judgment	Netherlands, North Sea	Between 0.40 m to 1.05m in the 21st century	By 2100
CIRCE project (FP6) based on A1B and A2	Mediterranean	Between 0.07m and 0.12m	By 2050

[85] The study combines observations from 10 different satellite missions to measure polar ice sheet changes and comparing previous ice sheet studies.

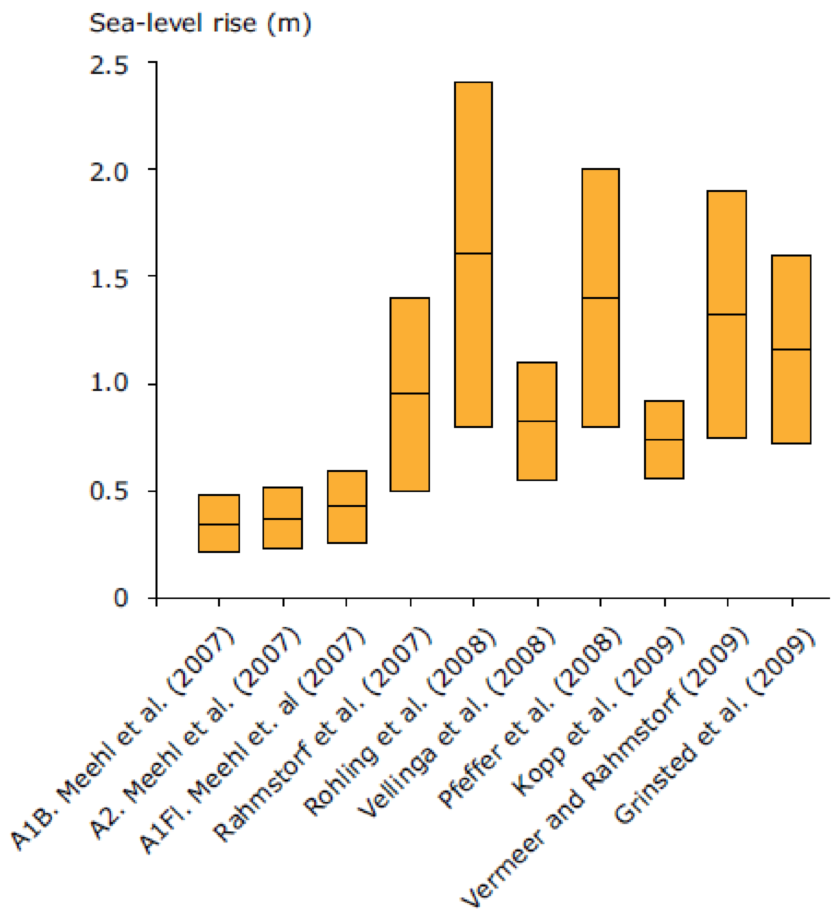
[86] Ice2sea FP7 Research Project.

[87] A perturbed physics ensemble (PPE) is generated by varying the values of parameters in a given climate model, thus creating different variants of that model, and making simulations using each variant. The production of PPEs in UKCP09 takes into account parameter errors, which arise as a result of incomplete or imprecise knowledge of the actual values of the climate model parameters that are used to represent processes within the climate model. By perturbing (varying) climate model physical parameters within plausible ranges to create different variants, and making a projection of climate change for each variant, it is possible to quantify the impact of this source of uncertainty in resultant climate projections.

[88] For the high-end scenario, Katsman et al. (2011) estimated high-end contributions from global mean thermal expansion of the ocean, mass changes of small continental glaciers and ice cape; mass changes of the Antarctic Ice Sheet and mass change of the Greenland Ice Sheet. This was coupled with climate models (Meehl, et al, 2007), simple scaling models (van de Wal & Wild, 2001; Rahmstorf, 2007; Katsman, et al, 2008) and expert judgement.

Study and Model approach	Geographic scope	Projection	Time Frame
Marcos & Tismplis 2008 based on SRES A1B and A2	Mediterranean	Between -0.22 m to +0.31m	By 2099
Rahmstorf (2007); Vermeer & Rahmstorf (2009) based on statistical modelling	Global	Up to 2m	By 2100

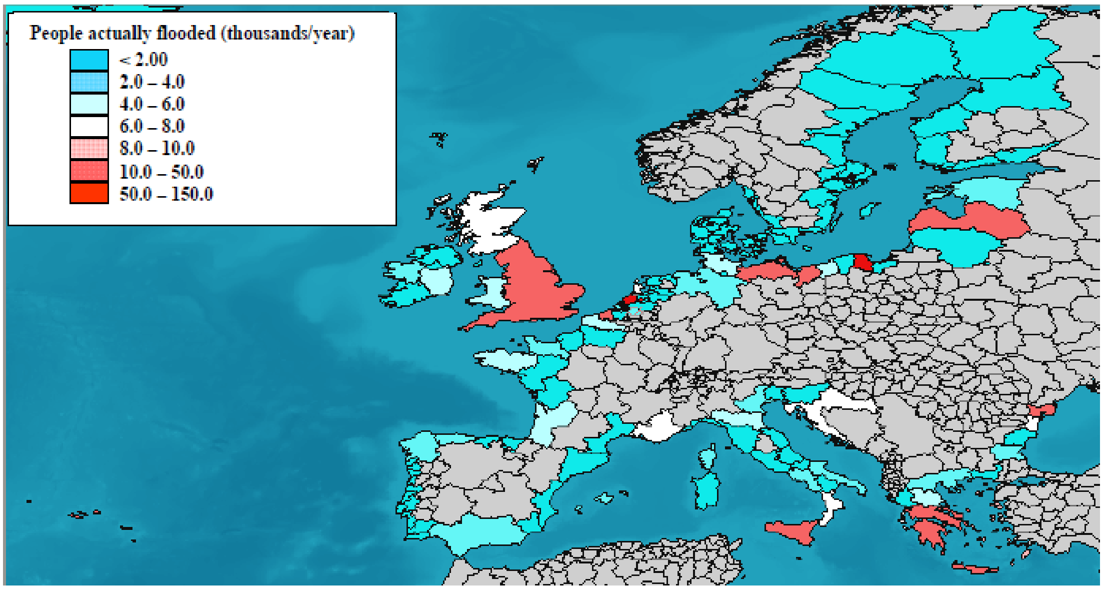
Figure 47: Range of high-end global sea-level rise (metre per century) estimates according to post-IPCC Fourth Assessment research (assembled by Nicholls, et al, 2011 in: EEA, 2012d)



Impacts from Sea-level Rise on coastal areas

Using the DIVA model[89], the PESETA project[90] (analysed coastal flooding impacts (i.e. on the area, people, and costs) for the set of A2 and B2 climate and sea level rise scenarios reported in IPCC's 3rd Assessment report (Richards & Nicholls, 2009); cf. Figure 48 for example. These results, together with other literature and country reports, formed the core of a broader economic analysis of coastal zone expenditures (PRC, 2009, summary in: EC, 2009a), which covered flooding, erosion, loss of eco-systems and freshwater shortage and took into account an accelerated climate change according to the IPCC AR4 report (IPCC, 2007a). The study diversifies its findings to include the Baltic Sea, the North Sea, the Atlantic, the Mediterranean, the Black sea and the outermost regions.

Figure 48: People actually flooded (thousands/year) across Europe, for the A2 scenario, 2080s (ECHAM4), without adaptation (Richards & Nicholls, 2009)



As noted in Hinkel et al. (2010), the IPCC AR4 (Working Group II) gives a conservative range and also notes that no reasonable upper bound of sea-level rise can be determined as we are unsure how rapidly the major ice sheets (Greenland and Antarctica) could collapse in a warming world. Several post-AR4 papers support the view that a 1 m+ rise in sea level over the next century cannot be discounted at present. These new insights about which no scientific consensus exists affect the estimates of the long-term risks for Europe's coasts.

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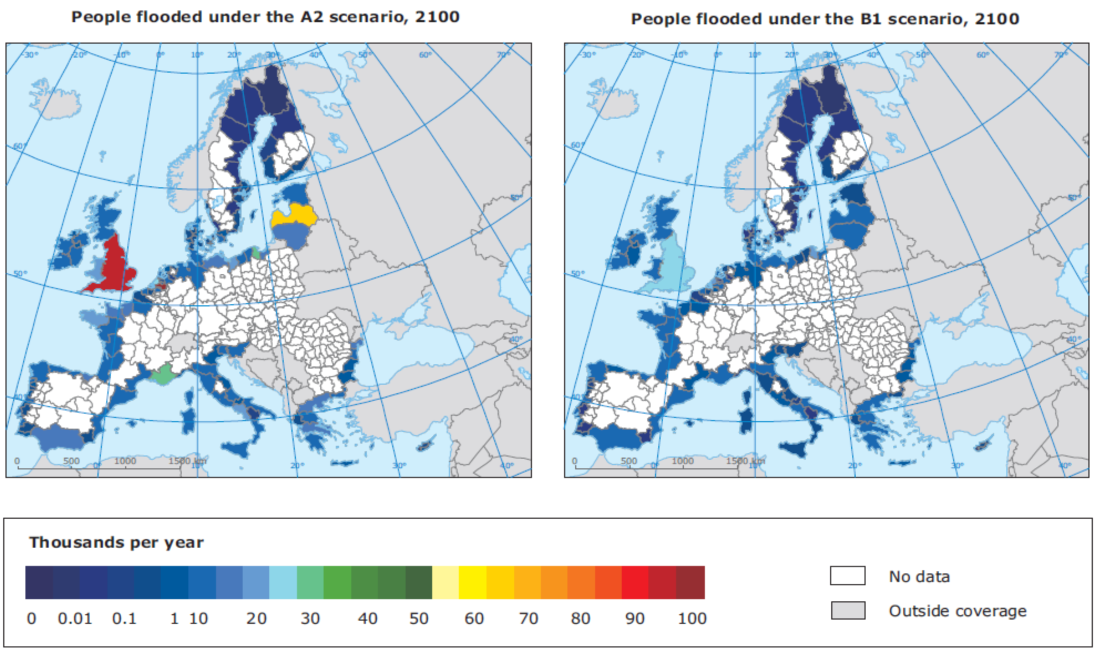
[89] The DIVA model is an integrated, global model of coastal systems that assesses biophysical and socio-economic consequences of sea-level rise and socio-economic development taking into account coastal erosion (both direct and indirect), coastal flooding (including rivers), wetland change and salinity intrusion into deltas and estuaries as well as adaptation in terms of raising dikes and nourishing beaches.

[90] http://peseta.jrc.ec.europa.eu/index.html

Based on modelling using the A2 and B1 scenarios for 22 EU coastal Member States, Hinkel et al. (2009, 2010) suggest that the UK, the southern part of the Baltic coast and the north-western Mediterranean coast are highly vulnerable to sea level rise flooding, especially in the extreme A2 climate scenario (cf. Figure 49).

Figure 49: People at risk of flooding without adaptation in 2100 scenario according to the A2 and B1 IPCC SRES scenarios. Source: Hinkel et al. (2009, 2010).



Sea level rise is not the sole threat for the coastal areas; severe storm surges, resulting from the combination of winds, atmospheric pressure on sea level and high waves could also cause hazardous impacts. Clearly defining past trends in storm surges and being able to develop future storm projections for the entire European coastline is difficult because of differences on local topographical features on the storms (EEA, 2012d). This is coupled by too few studies available for the Mediterranean and Baltic seas. Although this situation is starting to improve there are still considerable uncertainties surrounding future projections of storm surges (ibid). Current projections do not point to significant increase of storminess due to climate change for the major part of European seas (e.g. Grabemann & Weisse, 2008; Debernard & Roed, 2008; Lowe, et al, 2009; Lionello, et al, 2010). In general there are also uncertainties due to large natural variability that makes it difficult to detect changes in the rate of change in water level extremes (EEA, 2012d). This issue has been highlighted in various global and regional studies (Woodworth & Blackman, 2004; Menendez & Woodworth, 2010; Haigh, et al, 2010; Araujo & Pugh, 2008; Marcos, et al, 2011; Suursaar, et al, 2010), which makes it currently difficult to link climate change and increases in storm surges. Continued research in this area will help to reduce the knowledge gaps.

Salt water intrusion, often associated with the overexploitation of groundwater resources, could be exacerbated by sea level rise combined with periods of low river flow, causing salt water intrusion to reach farther points in the river than in the times with normal river flow. Transitional waters are expected to be threatened mostly. Salt-water intrusion can threaten freshwater supply, which not only impacts the drinking water supply but also water for irrigation purposes, and ecosystems in coastal areas. Current information on ecological impacts is lacking on the European scale (EEA, 2012d). Estuaries of Southern European rivers are particularly endangered, and the situation becomes even more severe in summer when river discharge is even lower. During the low flow season, Europe's biggest rivers are affected, e.g. Danube, Rhine, Elbe, Tagus and Loire. The risk in a shift in freshwater-seawater balance is highest in summer and lowest in winter, which increases the potential for saltwater intrusion into fresh groundwater in coastal aquifers. Highly urbanised coastal areas rely in particular upon aquifers sensitive to saline intrusion for domestic water supply, and are thus highly vulnerable. This is also an effect of sea level rise, which is expected to steadily increase due to climate change. The combined effects of human development and reduced river flow will also degrade water quality conditions, negatively affecting fisheries and human health through such changes as increased presence of harmful algal blooms and accumulation of contaminants in animals and plants.

3.2.2.5.3 Ocean Currents

Ocean currents are driven by wind and the thermohaline[91] circulation. Ocean currents are important for maintaining sea temperatures, especially in Western Europe which relies in the Gulf Stream to ensure warmer ocean temperatures than the continent's latitude would normally allow. Currents are not only important for maintaining warm water flow and aiding in aquatic migration. They are also important for navigation, as shipping companies rely on their knowledge of current to reduce fuel consumption and therefore costs. The Gulf Stream is governed by the thermohaline circulations, which is driven by density differences caused by variations in salinity and temperature. In light of climate change, researchers are concerned that thermohaline circulation could be affected by a reduced rate of water and heat transport, leading to cooling in the Northern European oceans near Scandinavia and the UK and at the same time affecting the process of dense water formation in the Mediterranean (Weaver, et al, 2012). According to Velling & Wood (2006), if thermohaline circulation is shut down, the Northern Hemisphere could potentially cool by -1.7°C, which could significantly increase frost and snow cover; sea ice cover would not be affected because of increased temperatures due to GHG emissions. The probability that the thermohaline circulation is significantly affected by climate change is low, but due the potentially high impacts of such an event more research should be carried out.

[91] There are three main processes that make the oceans circulate: tidal forces, wind stress, and density differences. The density of sea water is controlled by its temperature (*thermo*) and its salinity (*haline*), and the circulation driven by density differences is thus called the thermohaline circulation (Osborn & Kleinen, 2008).

According to the IPCC AR4 report, the potential impacts of a rapid shut down of the thermohaline circulation in Europe include: reduction in runoff and water availability in Southern Europe; a major increase in snowmelt flooding in Western Europe; increased sea-level rise in both Western European and Mediterranean coasts; changes in sea temperatures affecting marine and terrestrial ecosystems; and disruption in winter shipping routes (IPCC, 2007a). However, modelling has indicated that an abrupt shut-down of thermohaline circulation in the Atlantic is unlikely to occur before 2100. Moreover, several studies have found that potential impacts on European temperatures of any slowing in circulation before then are likely to be mitigated by increasing temperatures due to increased GHG emissions (cf. for example Arnell, et al, 2005; Vellinga & Wood, 2006). Nevertheless, studies found that significant socio-economic impacts could occur due to a shut-down; therefore, mitigation and adaptation policies should account for such impacts as a precaution. Climate variability in Europe is also affected by the North Atlantic Oscillation (NAO) (Hurrell, et al, 2003, 2004 in: Parry, et al, 2007).

3.2.2.5.4 Coastal Erosion

Coastal erosion is largely governed by sediment transport, which is greatly influenced by the damming of rivers and the replacement of soft natural coastlines with harder man-made structures.

Coastal erosion occurs during periods of strong winds, high waves and high tides and therein sea level rise. The EUROSION Project estimated that about twenty thousand kilometres of coasts faced serious impacts in 2004 and most of the impact zones (15,100 km) are actively retreating, some of them in spite of coastal protection work (2,900 km). Within Europe, the Mediterranean and North seas present the highest risks to erosion (EUROSION, 2004). Coastal erosion in Europe causes significant economic loss in the order of millions of Euros through property losses and damage to infrastructure and beaches (EEA, 2012d).

So far climate change has not been identified as a major factor in coastal erosion. However, coastal erosion could increase due to climate change despite amelioration efforts already being taken. Potential drivers for climate change induced coastal erosion are sea-level rise, increased storminess, higher waves and changes in prevalent wind and waves directions (Marchand, 2010 in EEA, 2012d). The impact of storm surges on coastal erosion is regionally dependent. Research in Estonia indicates increased beach erosion due to increased storminess in the eastern Baltic Sea (Kont, et al, 2008 in: IPCC, 2012), while in France the picture varies according to region, for example the Atlantic region is considered resilient to rising sea levels due to extensive dune systems but the Mediterranean coast is considered more vulnerable because of its narrow dune systems (Vincho, et al, 2009 in: IPCC 2012).

3.2.2.5.5 Eutrophication

Nutrient run-off, mainly from agricultural land, causes significant eutrophication problems in coastal zones as substances such as nitrogen and phosphorus compounds are transported to the sea via rivers. Households and industry, as well as aquaculture are major sources of phosphorous. Ferreira et al. (2011) define eutrophication as "a process driven by enrichment of water nutrients, especially nitrogen and/or phosphorus compounds, leading to: increased growth, primary production and biomass of algae; changes in the balance of organisms; and water quality degradation". Eutrophication affects all major seas in Europe, especially the Baltic Sea.

An overload of nitrogen and phosphorus can cause an excessive growth of algae which can lead to reduced oxygen content of waters. Oxygen depletion impacts aquatic communities and their structures. Harmful algal blooms can affect water colour, cause death of benthic fauna and poisonous shellfish making them unsuitable for consumption. Oxygen deficiency is not only a result of eutrophication, it can also be caused by decreases in the ventilation of deep water caused by climate change (Ferreira, et al, 2011).

Although in recent years nutrient concentrations have been decreasing in some areas, the increase in other MS coastal waters justify the need to take further action in this areas. EEA (2001) indicates an increase in nutrients in transitional, coastal and marine waters in parts of the Baltic (Denmark, Finland), the North Eastern Atlantic (Ireland) and the Mediterranean (Croatia).

This picture is confirmed by the work under the OSPAR Commission[92]. According to OSPAR (2010), eutrophication due to nitrogen and atmospheric nitrogen is still a problem in the Greater North Sea, the Celtic Seas, the Bay of Biscay and the Iberian Coast.

Climate Change is likely to increase atmospheric nitrogen deposition into oceans through increasing precipitation. The growth of atmospheric nitrogen deposition in the Baltic Sea has been estimated between 0-20% for the period from 1961-1990 to 2071-2100 (Hole & Engardt, 2008 in: Helcom, 2009). Moreover, an increase of the mean annual temperature by 3ºC to 5ºC, coupled with an increase in precipitation, would probably lead to increased nutrient loads from the drainage area to the Baltic Sea (Helcom, 2009).

OSPAR (2010) suggests that climate change could indirectly increase eutrophication problems in coastal waters. Through increased rainfall and its associated flooding, surface run-off from land could increase, thus loading rivers that discharge into coastal areas. While climate change will not directly affect the source of the problem (nutrient loads originating from household discharges and fertiliser use in agriculture), it can indirectly affect the discharge processes and therefore nutrient runoff could increase. Recent observations of the decline in sugar kelp along the southern coast of Norway indicate possible interactions between climate change and eutrophication (ibid).

Given the indirect pathway climate change affects eutrophication problems, more research is needed to assess the potential impacts of climate change on the availability of nutrients

[92] Governed by the Convention for the Protection of the marine Environment of the North-East Atlantic covering 15 European countries (Belgium, Denmark, the European Community, Finland, France, Germany, Iceland, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden and the United Kingdom of Great Britain and Northern Ireland, Luxembourg and Switzerland).

including transportation (e.g. from new circulation patterns, changes in coastal processes that might lead to new or enhanced sources, etc.), and transformation of nutrients and organic matter, as indicated by the MSFD guidance task group (Ferreira, et al, 2011).

3.2.2.5.6 Aquatic Species

Predictions of the consequences of climate change on marine fish populations are complex. Fish populations are influenced by a host of environmental factors such as temperature and salinity but also the abundance of food and predator-prey relationships (Mackenzie, et al, 2007). Climate change influences the marine ecosystems by altering temperatures, changing wind patterns and altering precipitation rates and thus salinity. These changes can both positively and negatively affect fish populations and their geographical distribution, depending on the species, geographical area and distribution. Changes in temperature have the potential to change a fish species distribution and abundances. Such changes can be direct: for example, in Scotland catch records point to a considerable increase in warm water species, such as sardines and Ocean Barbe, since 1995, species which were previously quite uncommon in Northern Europe (Beare, et al, 2004).

In this context, it is important to distinguish between the expansion of the range of a native species and the invasion of alien species; the latter is a sub-category of non-native species which have demonstrated their potential to spread elsewhere and cause significant harm to biological diversity and ecosystem functions (Olenin, 2010). Alien species often compete with native species for food and habitat, leading to reductions in fish stocks. Whereas the expansion of a native fish species' range happen as a result of environmental factors (whether nature or human-induced), most often alien species have been deliberately or accidentally introduced anthropogenically. Both types of species, however, can negatively impact marine ecosystems and their food webs.

Generally speaking, increases in sea temperature in the North Sea have caused an increase in the abundance of warm-water species and at the same time cold-water species have decreased (Beaugrand, 2004). Changes in SST can also indirectly impact fish species by altering the balance of the food chain.

Research results of cod, herring, and sole populations in the Baltic sea by Mackenzie, et al., highlight the differing impacts: while warmer temperatures will improve the reproductive success of herring, sprat and Kattegat sole near their northern limits of distribution, these higher water temperatures will reduce the size of cod spawning areas due to increased oxygen consumption in the lower reaches of the ocean. However, the positive effects increased water temperatures may have on Baltic herring may be counteracted by decreased salinity. According to Mackenzie, et al., increasing precipitation rates coupled with changes in wind patterns will decrease the salinity in the already low saline Baltic Sea. A further reduction in salinity – decreases are expected by between 7-47% (Meier, 2006) - will restrict spawning habitats both for the herring and the cod.

Changes in fish population distribution are difficult to pinpoint, as food abundance and the ratio between predator-prey also affects this. Predators of cod eggs, for example herring and sprat, may benefit more from climate change than cod, and an increase in cod predators will also suppress the cod population (ibid). It is suggested that the reproductive biology of cod will suffer considerable under future climate change and cod could collapse completely (ibid). Despite the uncertainties and differing effects of how climate change affects different fish species in the Baltic region, Mackenzie, et al, make two general predictions: 1) warmer, fresher conditions will lead to relative changes in the existing species composition and their distribution – ranges are expected to contract and habitats of cold-adapted species, such as salmon, are expected to shrink; and 2) the decrease in salinity will inhibit the invasion by new species because only few are able to reproduce successfully in low salinity. Overall, they estimate that there will be an overall decrease in species richness and biodiversity in the Baltic (ibid).

Research data from three independent sources confirm that sea surface temperature in the North Sea affects the timing of mackerel spawning and migration (Jansen & Gislason, 2011). The researchers found that warmer temperatures were associated with earlier migration to spawning areas as well as greater egg production. Their research indicates a strong, positive relationship between SST in the North Sea and the timing of spawning and post-spawning migration. Marine organisms in European seas appearing earlier in their seasonal cycles could have negative consequences for marine ecosystems and food-webs. For example, the decline in North Sea cod stocks (due to overfishing and climate change) has contributed to changing other fish populations like sand-eels that are essential for seabird populations (EEA, 2008c). In addition, the number and diversity of cold water species have declined in the North and Baltic Sea and warm water species from the south are moving northwards. This will have an impact on the distribution of fish in the region and may affect the management of fisheries. The overall change in the appearance of certain species has led a decoupling of species relationships and has led to changes in food-web structures (Edwards & Richardson, 2004 in: EEA, 2008c).

Research analysing fishery records off the coast of Sweden and the English Channel from the last 100 years confirms that climate variations clearly govern periods of abundance in herring and sardines. In both countries, herring only plays a significant role in their fisheries in decades where there is strong ice cover off Iceland, when there are severe winters in Western Europe and when there is a reduction of westerly wind caused by negative anomalies in the North Atlantic Oscillation (Alheit & Hagen, 1997). On the other hand, in decades where the climate conditions are the reverse – less ice cover, less severe winters and western winds – sardines play a much stronger role in fishery catches. Therefore, Alheit & Hagen (1997) found that the different herring and sardine periods appear to be related to sea surface and air temperatures, ice cover and wind, parameters that change drastically with climate change.

Sea warming not only affects native aquatic species by limiting and/or expanding their range, it also enables non-native species to expand into regions where they previously could not survive (Walther, et al, 2009). According to the literature, the effect of climate change and invasive species have been implicated in the decline and even collapse of several marine ecosystems (Harris & Tyrel, 2001; Stachowicz, et al, 2002; Frank, et al, 2005; all in: Occhipinti-Ambrogi, 2007). However, the literature varies on the extent of current impact. Some examples of non-native species can be linked to climate change, whereas many more are linked to maritime transport and aquaculture.

Following the sequential stages of an invasion (i.e. introduction, establishment, expansion and adjustment), Walther et al. (2009) investigated how climate change influence biological invasions. The principle pathways of introduction are through ships, canals (e.g. Suez Canal), non-native aquaculture, and the purposeful introduction of non-native species to support fisheries (Minchin, et al, 2009). The opening of new summer shipping trading routes – for example through glacier melt in the Arctic – is likely to result in exchanges of cold water species. The basic theory is that once a few species are introduced, more favourable climatic conditions through warming could prolong the duration of introduction as well as their frequency, which more likely results in their establishment, expansion and invasion (Walther, et al, 2009).

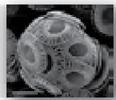
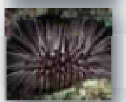
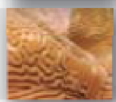
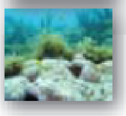
Alien species are more likely to survive if they are introduced into areas with similar climatic conditions – especially temperature - to their native habitats. With increases in temperatures, alien species from warmer regions may more easily survive in their new habitats. For example, in the northern Mediterranean Sea, higher water temperatures have enabled a former sterile fish species (Ornate Wrasse) to become fertile and reproduce (Vacci, et al, 2001 in: Walther, et al, 2009). Fish species normally found in the southern coast of Ireland or France are now being found off the northern coast of Ireland towards the North Sea (Boelens, et al, 2005). Climate change has been suggested as one of the principle drivers for the establishment of alien plant species in the Mediterranean (Gritti, et al, 2006 in: Occhipinti-Ambrogi, 2007) as well as for the expansion of the biogeographical range of benthic and nektobenthic marine species (Francour, et al, 1994; Vacchi, et al, 1999; Bianchi & Morri, 2000; Laubier, et al, 2004; all in: Occhipinti-Ambrogi, 2007). The introduction of alien species does not just impact native species. It also causes ‘ecosystem cascading effects’. For example, the invasion of the American carnivorous comb jelly in the Black and Caspain Seas resulted in significant declines in zooplankton and anchovy populations (Occhipinti-Ambrogi, 2007).

3.2.2.5.7 Ocean acidification

48% of the carbon emitted to the atmosphere is absorbed by the ocean. The carbon chemistry of seawater acts as a buffer, enabling the oceans to hold 50 times more CO_2 than the atmosphere can. However, CO_2 absorption by seawater decreases the pH of oceans, leading to acidification, as well as carbonate ion (CO_3^{2-}) levels. The uptake of CO_2 by oceans in the past 200 years has led to a reduction of the pH of surface seawater of 0.1 units, which is equivalent to a 30% increase in the concentration of hydrogen ions (Royal Society, 2005). The business-as-usual model of the IPCC estimates that atmospheric CO_2 levels could approach 800 ppm by the end of the century; this will result in a drop in surface water pH from a pre-industrial value of about 8.2 to about 7.8 in the IPCC A2 scenario by the end of this century, increasing the ocean's acidity by about 150% relative to the beginning of the industrial era (Feely, et al, 2009). Models have predicted that by 2020 aragonite unsaturation will occur in the Arctic Ocean in the A2 business-as-usual scenario and by 2095 all of the Arctic will be under-saturated with respect to aragonite (ibid).

One of the most likely consequences of less aragonite (*i.e*. a soluble form of calcium carbonate) will be slower growth of organisms with calcareous skeletons. As CO_2 concentrations increase in seawater, the CO_2 gas reacts with water to form carbonic acid. CO_2 dissolution in the ocean increases hydrogen (H^+), and thus decreases pH and carbonate ion concentrations. The decrease in carbonate ions reduces the saturation state of calcium carbonate, which directly affects the ability of some calcium carbonate-secreting organisms, such as planktonic coccolithophores and pteropods, and invertebrates such as mollusks and corals, to produce their shells or skeletons (Feely, et al, 2009). Reductions in these species may also impact the fish that feed on them. Ocean acidification may influence the structure and productivity of primary and secondary benthic and planktonic production, which in turn may affect the productivity of fish communities and higher trophic levels. For example, salmon yearlings prey mainly on pteropods, which may be among the first organisms to be affected by ocean acidification (ESF, 2009). The impact of increased CO_2 concentrations on different species is outlined in Figure 50.

Figure 50: Impacts of ocean acidification on marine species[93], Source: Doney, et al, 2009a.

PHYSIOLOGICAL RESPONSE	MAJOR GROUP	# SPECIES STUDIED	RESPONSE TO INCREASING CO_2 a	b	c	d
CALCIFICATION						
	Coccolithophores	4	2	1	1	1
	Planktonic Foraminifera	2	2	–	–	–
	Molluscs	6	5	–	1	–
	Echinoderms	3	2	1	–	–
	Tropical Corals	11	11	–	–	–
	Coralline Red Algae	1	1	1	–	–

However, the response of calcifying organisms to ocean acidification may be more varied than first thought, as indicated in recent experiments showing elevated calcification rates for some taxa under higher CO_2 (Doney, et al, 2009).

The effects of reduced pH levels are still poorly understood. Some research has indicated that ocean acidification reduces the absorption of low-frequency sound. Brewer & Hester (2009) found that a decline in pH of only 0.3 causes a 40% decrease in absorption. The impact increase “noise” may have on whales and marine mammals is still largely unknown (Doney, et al, 2009a, b). Another aspect is light prorogation: According to Doney et al. (2009), fewer calcium carbonate particles could reduce light scatter and result in deeper euphotic zones.

Acidification also decreases the ability of the ocean to absorb additional atmospheric CO_2 (ESF, 2009). Schuster & Watson (2007) analysed sea surface pCO_2 and air-to-sea flux from the mid-1990s to the early 2000s. Their results indicate that the uptake of atmospheric CO_2 in the North Atlantic Ocean, which is the most intense sink for atmospheric CO_2, slowed down dramatically between the mid-nineties and the early 2000s. Reasons for the decrease

[93] The response curves indicate : a) linear negative, b) linear positive, c) level and d) non-linear.

in uptake point to a couple of factors including rates of wintertime ocean mixing[94] and winds but also the changing buffer capacity of the ocean as the carbon content increases.

3.2.2.5.8 Economic costs of climate change impacts on coastal zones

Sea level rise has the potential to negatively impact economic growth by affecting the classical 'production factors' or 'production capitals' associated with GDP, namely natural capital, physical capital, human, and social capital (Hallegatte, 2012). Permanent losses of natural capital include, for example, the combination of the net loss of coastal land plus the gain of bringing infrastructure closer inland or loss of natural habitats and associated ecosystem services. Permanent loss of physical capital occurs through loss of infrastructure like housing and roads. Additionally, human life (i.e. human capital) may be lost through extreme flood events, and there can be a permanent loss of social capital through political and social tensions associated with migration from coastal zones (ibid). In addition, sea level rise will increase expenditures associated with coastal protection, i.e. adaptation measures. Hallegatte (2012) defines the costs of adaptation as the sum of all investments and maintenance costs necessary to protect human settlements in flood risk areas.

Estimates of the economic costs of climate change impacts on coastal zones are still in the early stages of development. Such estimations need to be considered as preliminary findings as a) future sea-level rise is uncertain and b) data on coastal vulnerability to sea-level rise at European scale is very patchy. Impacts from sea-level rise and rising costs of combating coastal erosion are not always clearly linked. Nevertheless, the information below presents an indication of the types of costs that may incur in facing of climate changes.

Sea level rise (in combination with storm surges) will have many impacts on the coast and transitional waters: permanent inundation, flooding due to storm surges, coastal erosion, salt water intrusion to groundwater resources and to rivers/deltas and estuaries. The economic impacts and associated costs of these impacts depend on the IPCC scenario used in modelling. A summary of the outcomes of various economic studies is presented in Table 27.

Table 27: Annual economic impacts of climate change under different IPCC scenarios (Source: adapted from Brown et al. (2011a) and Richards & Nichols (2009))

Study	IPCC Scenario Used	Impact	Year	People affected	Annual economic impact €million	
PESETA	A2	sea floods sea floods	2020 2080		1,100.0 12,000.0	optimal adaptation

[94] Ocean mixing refers to the processes that involve rates of advection, upwelling/downwelling, and eddy diffusion and that determine, for example, how rapidly excess atmospheric carbon dioxide can be taken up by the oceans.

Study	IPCC Scenario Used	Impact	Year	People affected	Annual economic impact €million	
		salt intrusion	2020		607.0	
		salt intrusion	2080		10,500.0	
		migration	2020		0.2	
		migration	2080		20.1	
PESETA	B2	sea floods	2020		6,020.0	
		sea floods	2080		18,200.0	
		salt intrusion	2020		607.0	
		salt intrusion	2080		1,500.0	
		migration	2020		182,400.0	
		migration	2080		252,400.0	
ClimateCost	A1B	flooding	2050	55,000	11,000.0	undiscounted
		flooding	2050		2,400.0	marginal effects
		flooding	2050		1,500.0	adaptation
		flooding	2080	250,000	25,000.0	undiscounted
		flooding	2080		18,000.0	marginal effects
		flooding	2080		1,600.0	adaptation
ClimateCost	E1	flooding	2080	45-145.000	17,000.0	
Hinkel et al.	A1	flooding	2100	780,000		
	B2	flooding	2100	200,000		

The adaptation costs in these scenarios are 1.013 billion €/year and net benefit of adaptation 3.89 billion€/year in 2020 (Richards & Nichols, 2009). The adaptation costs in 2080 are 2.6 billion€/year, while the net benefit of adaptation is 39.75 billion€/year (ibid).

Using the A2 and a B1 scenario, Hinkel et al. (2009, 2010) calculated the contribution of each of these impacts to total damages due to climate change. Damage is slightly higher under B1 because it assumes exposure grows faster — the higher sea-level rise under A2 is compensated for by lower GDP growth, reducing the cost of damage in 2100.

The PESETA coastal report (Richards & Nichols, 2009) uses the DIVA model to assess European coastal vulnerability to sea-level rise. The projections of PESETA suggest that by 2085 between 775,000 and 5.5 million people in the coastal zone could be flooded annually without adaptation (for the reference year 1995 this number is 36,000). The land loss due to annually flooded areas and erosion as a percentage of the region total without adaptation is between 0.2% (for Northern Europe) and 1.5% (for the British Isles), or about 0.6% as European average for the A2 scenario.

The ClimateCost project[95] assessed the potential economic impact of climate change in Europe's coastal zones using the DIVA model as well. Projections under a medium to high emission scenario (A1B) give a 0.37 m sea level rise for Europe in the 2080s, under an E1 emissions scenario, which is broadly consistent with a 2 °C temperature rise scenario, a 0.27 m sea level rise for Europe is projected.

Taking into account an ice-melt related uncertainty range, in the A1B scenario the 5-95 % uncertainty range would be between about 120,000 to more than 400,000 additional people at risk by the 2080s. Under a high sea level rise scenario (1.2 m), the marginal climate effects could rise to almost 150 billion€/year in the 2080s. The analysis also shows also a huge impact on the European wetlands, which has not been valued in economic terms. Estimates suggest that by 2080 over 35% of the European wetlands might be lost, unless protected measures are taken (Brown, et al, 2011a); the impacts of climate change are not taken into account in this estimation. The uncertainties for this type of estimations are high: for example, the annual undiscounted damage costs associated with a higher 1.2 meter sea level rise are 156 million€ for Europe (Brown et al, 2011a). It should also be noted that the estimated damages only consider direct effects of coastal flooding and not secondary, indirect economic costs. Protection levels at the national level can be higher (e.g., in The Netherlands) or lower (e.g., Black Sea countries) than assumed in the model. Additionally, there is uncertainty of how emission rates and temperature influences sea-level response, so the economic estimates in the ClimateCost project[96] show a significant range (e.g. annual

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[95] The ClimateCost project took into account damage and adaptation costs. Damage costs include: total annual damage costs (2005 price), including the number of people forced to move due to erosion and submergence (assuming the cost for people that move is 3x the value of their per-capita GDP; land-loss costs (land below the 1-in1 year flood level) taking into account dikes and direct erosion ignoring nourishment, salinisation costs and the expected costs of sea and river floods. Adaptation costs include the sum of sea dikes, river dikes and beach nourishment.

[96] In general, the results of the ClimateCost project should be viewed with caution: only one temperature profile was used for projections but a multi-profile could change estimates regarding sea-level rise. Other sources of uncertainty in the coastal model include socio-economic projections (e.g. changes to population, population density and gross national product) and economics (e.g. exchange rates, discount rates).

damage costs due to ice melt response between €19 billion to €37 billion (Brown, et al, 2011a)).
The ClimateCost project also assessed the costs and benefits of adaptation for sea level rise, considering beach nourishment and dikes. Adaptation greatly reduces the overall cost of flood damage. The uncertainties are high and depend strongly on the level of future climate change, the level of accepted protection and the framework of analyses (Brown, et al, 2011a).

Hinkel et al. (2010) assessed the impact of sea level rise under an A1 and B2 scenario. In 2100 assuming no adaptation, 780,000 people (A2) or 200,000 (B1) people are estimated to be affected by coastal flooding. Under both scenarios the associated costs are roughly 17 billion USD.

3.2.2.5.9 Impacts on economic sectors

Fisheries

All of the above mentioned climate change impacts on fish species could greatly affect the fisheries and aquaculture sectors in Europe. Precise information is still not available: while some species will increase in population, while others will decrease or even die out. The impacts on the income of fisheries are not completely clear. Impacts will be different depending on the marine region and the species involved.

An analysis of the impacts of climate change on fisheries by Brander (2005), points to the decline of different fish species due the decline of their main food sources due to the warming of ocean temperatures. For example, the reduction in *Calanus finmarchicus* has affected cod populations in the North Sea and resulted in their progressive decline. Herring in the Baltic have also had their food source affected by climate change induced decreases in salinity (ibid). In addition, size and weight of fish can be affected by changes in water temperature. Minimum size limits for fish catches means that smaller fish could affect fisheries (Moth-Poulsen, n.d.).

Fluctuations in fish stocks can have serious economic consequences. One implication is an increase in aquaculture production: it has increased by nearly 50% between 1997 and 2003 while capture production decreased by nearly 5% during that time. For Europe, this is a bit contradictory, as projections estimate between a 25-45% increase in fish catches in Scandinavia from 2005 to 2055 (Cheung, et al, 2010 in: Perry, 2010). What these projections ignore, however, is that although catches may increase due to increased diversity of fish due to migration of fish from southern region, such future changes will result in the disappearance of some traditional fishery stocks (Perry, 2010). In general, it can be said that research is not in agreement on the impacts climate change can have on fisheries. Potential economic impacts highlights this uncertainty: World Bank estimates on the impacts of a 2°C warmer world by 2050 on catch values varies between a loss of US$1 billion to a slight gain in Europe (ibid). Another issue is alien fish species. Economic impacts have not been well documented but the European Commission puts the damage costs for fisheries and aquaculture at €162 million/year (Kettunen, et al, in: EC, 2008).

Aquaculture

Climate change will also have significant effects on European aquaculture through changes to water temperature, ocean currents, weather patterns and frequency of extreme weather. Sea-cages hold over 1 million tons of fish and there are hundreds of thousands of tons of mussels, oysters and clams grown in coastal aquaculture in Europe (FAO, 2006). A potential concern for aquaculture is sea level rise and associated erosion, as this could eliminate sites for aquaculture farms and require relocation (de Silva & Soto, 2009). Using the projections of IPCC AR4 (Working Group II), de Silva & Soto (2009) highlight that sea-level rises and increases in temperature will affect deltaic regions. With respect to changes in salinity and temperatures, significant changes in brackish water habitats could affect aquaculture production if such changes as not conducive to the fish species used in aquaculture. As a result of sea-level rise and the influx of brackish water, farms could be relocated or different species may be farmed (ibid).

Overall, according to de Silva & Soto (2009), it is likely that aquaculture, in view of its resilience and adaptability and its cultivation of a wide array of species/species groups will be able to respond positively to climate change impacts.

Tourism

The tourism industry is an important sector in the European economy. In 2006 alone tourism represented more than 4% of the EU GDP employing around 8 million people, 3 million of which are found in coastal and marine areas (EC, 2006c, 2008a).

Within the tourism sector, coastal tourism is by far the most significant in terms of tourist numbers and generation of income (EC, 2008b). Coastal tourism is the largest single maritime economic activity, which could be threatened by climate change such as sea-level rise and/or changing weather conditions (Ecorys, 2012). According to EC (2012c) currently about 2.36 million people are employed (1.1% total EU employment) in the coastal tourism sector and around 51% of bed capacity in hotels across Europe is concentrated in regions with a sea border. Different economic activities such as yachting, boating and cruising are important to coastal and maritime tourism. Cruise tourism alone represents a distinct segment generating direct turnover of € 14.5 billion and nearly 150,000 jobs (2011).

Some climate change effects have already impacted coastal resorts: the increased frequency of intense storms has increased beach erosion and warmer sea temperatures have led to recurrent algal blooms and infestation by jellyfish (EC, 2008b).

Table 28: Climate Change impacts and implications for tourism destinations (Source: UNWTO, 2008)

Impact	Implications for tourism
Warmer temperatures	Altered seasonality, heat stress for tourists, cooling costs, changes in plant-wildlife-insect populations and distribution
Increasing frequency and intensity of extreme storms	Risk for tourism facilities, increased insurance costs/loss of insurability, business interruption costs
Reduced precipitation and increased evaporation in some regions	Water shortages, competition over water between tourism and other sectors, desertification, increased wildfires threatening infrastructure and affecting demand
Increased frequency of heavy precipitation in some regions	Flooding damage to historic architectural and cultural assets, damage to tourism infrastructure, altered seasonality
Sea level rise	Coastal erosion, loss of beach area, higher costs to protection and maintain waterfronts
Change in terrestrial and marine biodiversity	Loss of natural attractions and species

Climate plays a major role in the popularity and success of tourist destinations and therefore tourism income. Tourism spending could shift further north away from traditional holiday destinations (e.g. Mediterranean) due to climate effects. Accordingly, climate change is expected to “reshape” the tourism industry and will impact the geographical and seasonal distribution of tourists (EC, 2008b). These shifts on tourism climate suitability patterns have been projected for Europe towards the end of the 21st century (Amelung & Viner, 2006 in: UNWTO, 2008). This was also confirmed by a more bottom up study where over 800 international Austrian vacation travellers were asked how climate change impacts would change their travel behaviour. The results clearly showed that with a succession of several extremely hot summers with unattractive conditions at the Mediterranean makes approximately 30% of the Austrian beach/bath holiday-makers no more Mediterranean vacation would use but the domestic seas for one bath vacation. Further each sixth beach holiday-maker would undertake something else, e. g. one walking/mountain vacation instead of one bath vacation in the future (Fleischhacker, et al, 2009).

In the Mediterranean, tourism is projected to shift away from the summer and become more attractive in the spring and autumn. In Northern Europe, the situation is expected to improve all around (UNWTO, 2008).

A recent EU-wide modelling study on the link between climate and tourism confirms that although currently climatic conditions in Southern Europe are most conducive for tourism, a change in climate is projected to shift favourable tourism conditions northwards (Perch-Nielsen, et al, 2010 in: EEA, 2012d). The CIRCE project (Climate Change and Impact

Research: the Mediterranean Environment (FP6)) further suggests a shift in tourism flows away from north-south and increasingly south-north (EEA, 2012d).

Adaptation efforts in some regions are already under way to explore alternative tourism products in order to maintain tourist interest and secure important income sources. Such efforts have taken place with regional development policies such as structural and cohesion funds and Interreg (EC, 2008b).

Energy production

Energy production located in coastal areas may be threatened by climate change induced storm surges, sea-level rise and flooding. With respect to electricity production, climate change can impact the sector through increased disaster risks. Storms, heavy precipitation and sea-level rise could damage power plants located along the coast, and therefore the siting of future plants must take into account climate scenarios (Urban and Mitchell, 2011). In the UK, for example, 12 of 19 nuclear power plants – including 8 proposed stations - are at risk due to rising sea levels and coastal erosion; 9 of plants assessed by UK Department for Environment, Food and Rural Affairs (Defra) are already considered vulnerable, while 3 more plants are in danger from rising sea levels and storms in the future[97].

Water stress and drought conditions may also affect energy production, as well as high temperatures, which reduce the thermal generation efficiency and decrease power output. In 2003, 2006 and 2009 the heat waves in France greatly limited its electricity production from nuclear power, which was impacted by low river flows and droughts, as 17 reactors had to limit output or shut down (Urban and Mitchell, 2011). As a result, electricity had to be imported from neighbouring countries, leading to increased production costs. Similar problems have been recorded in Germany and the Netherlands. (for more impacts on the energy system cf. chapter 3.2.1.5)

Agriculture

Agriculture land use in coastal areas may decrease considerably in the future. The EU Clue Scanner Land use model[98] assessing the spatial impact of policy options in coastal zones analysed the impact of two different scenarios on the agriculture sector from 2000-2050[99]. According to these results in coastal zones between 2000 and 2050 land use changes could

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[97] http://www.guardian.co.uk/environment/2012/mar/07/uk-nuclear-risk-flooding

[98] The EUClueScanner allows the exploration of future policies and impact assessments of alternative scenarios compared through a set of indicators. The EUCS model uses the dynamic probabilistic allocation based on econometric estimation of suitability and process knowledge (e.g. growth processes) to “translate driving factors and policy specifications into spatially explicit assessments of land use dynamics at high spatial and temporal resolution.” The two scenarios are: (1) uncontrolled development assuming continued urban growth with additional measures to encourage natural areas and (2) sustainable planning and environmental friendly assuming constraint on urban growth by increasing measures to protect vulnerable and natural areas.

[99] Lavalle, C., R, Rocha Gomes, C., Baranzelli, C., and Batista e Silva, F. (2011): Coastal Zones: Policy alternatives impacts on European Coastal Zones 2000-2050. JRC: Italy

result in decrease in agriculture areas by 20% (EU-wide average) and a stabilization of pasture area in both scenarios, mainly due to the abandonment of arable land and increase in built-up land. Climate change has the potential to increase flooding and inundation of fields, destroying crops or making some parcels unusable. In addition, saltwater intrusion of groundwater aquifers could negatively impact sources for irrigation and therefore crop yield could be indirectly affected if suitable alternatives are not available.

3.2.3 Social issues

3.2.3.1 Jobs/Employment

The direct physical effects of climate change on employment have not yet been studied systematically. However, it is very probable that the phenomena induced – changes in temperatures and precipitation levels, rising sea levels and changes to the frequency of extreme climatic events – will have implications for economic activity and employment in Europe (GHK, 2009a).

Climate change is expected to cause a mix of positive and negative impacts on economic activity and employment, with substantial disparities among regions in Europe. In general, modest changes in climatic conditions are expected to have a relatively minor impact at macro level in Europe due to redistribution effects (between economic sectors, as well as between countries/regions) and adaptation capability. However and even under optimistic scenarios, climate change could have significant adverse impacts at local level in terms of economic activity and employment. Communities relying on primary sectors, such as agriculture, forestry, and fisheries are likely the most vulnerable to the effects of climate change. Further, impacts on employment for local economies relying on tourism could be significant (ETUC, 2007).

Essentially most economic sectors (cf. chapter 3.2.1) will be affected by climate change, although some sectors are more weather sensitive than others and will have more impact on people’s lives and income possibilities. The most extensive amount of work with regard to implications on jobs has been focused on agriculture, forestry and fisheries due to its climate sensitivity.

ETUC (2007) has analysed the likely effects of climate change on economic activity and jobs in different sectors (agriculture, forestry, fisheries, tourism, finance/insurance, health, infrastructure and energy). For the agricultural sector the study found negative employment impacts in Southern Europe and balanced or slightly positive effects on agriculture due to potential gains in arable land and new types of crops in the Nordic countries. Forestry might suffer from forest fires and storms (cf. chapter 3.2.1.2) with decreasing revenues and employment. Tourism is another major sector affected by climate change, either due to worsening conditions for winter tourism in the lower mountainous regions or from less demand for vacations in warmer regions due to excess heat (GHK, 2009). Thus, the attraction of tourist destinations will change with the variation of tourist flows affecting regional economies. However, the macroeconomic effects might be fairly neutral (Berrittella, et al, 2006).

The ETUC (2007) study further highlights that the likelihood of extreme weather events becoming more frequent and intense will affect the insurance industry, which will be forced to pass on the rising cost of damages to other economic sectors. Structural changes can thus be expected to which small companies will be particularly vulnerable (cf. also chaper 3.6).

Fankhauser et al. (2008) discuss employment effects from short-, medium- and long term point of view. In short term jobs are lost in directly affected sectors and new ones are created in replacement industries. In medium-term, impacts of climate change policy ripples through the economy. Jobs are created and lost due to higher order economic linkages, further up- and downstream of the value/production chains. In long-term, innovation and the development of new technologies create opportunities for investment and growth.

The climate change policies may substitute, transform, create new or eliminate (without replacement) existing jobs (UNEP/ILO/IOE/ITUC, 2008). Initially, high-skilled workers may benefit more from the implementation of advanced technology (EC, 2012b) whereas the long-life learning should enable lower-skilled workers to access to these jobs after adequate training.

Climate change adaptation has the potential to alleviate part of the adverse impacts of human-induced climate change and avoid to some extent economic and social disruptions. Adaptation to climate change is seldom undertaken in a stand-alone fashion, far more common as a part of comprehensive economic and development transformations. Climate change adaptation is an instrument for maintaining the EU's macro-economic stability and growth. It contributes to preserving existing jobs through maintaining viability and resilience of existing businesses. Many climate adaptation measures will require one-time investments which temporarily stimulate demand for labour. However, long-term indirect and induced effects on employment on labour patterns and markets are difficult to demonstrate (Harsdorff, et al, 2011). Responding to a changing climate also presents a growing market, with expected business opportunities for European firms on the EU and global markets. The next ten years should provide additional insights on how European firms will feature on this growing market.

Up to date, most studies have focussed on employment generated by climate mitigation policies whereas the employment effects of climate adaptation are examined qualitatively or within a larger context of policies stimulating 'green' growth. The few studies that address the relationships between climate change adaptation and jobs, propose three different perspectives of analysis:

- The first analyses the amount of jobs exposed to climate change risk and then tries to assess the potential of adaptation to prevent, smooth or eliminate that risk, with the associated job saving potential. It either conducts an analysis at the sectoral level, or tries to compare the expected negative GDP effect of climate change (e.g. from the -

4% to the -20% of world GDP as proposed by the 2006 Stern Review) with that of other crisis (e.g. the last financial crisis) to then make a parallelism between observed and expected job losses (Rosenberg, 2010);

- The second thread of studies analyses the skills (new and old) that are, and will be increasingly required to develop appropriate climate change adaptation strategies. All economic sectors are expected to undertake some adaptive adjustments to climate change, but the most concerned appear to be agriculture, forestry, building and infrastructures. Technologies and therefore skills to develop good adaptation practices will be required (cf. e.g. Strietska-Ilina et al., 2011);

- Finally the third thread, drawing almost entirely qualitative conclusions, recognises that the development of adaptation technologies and the implementation of adaptation measures, like large irrigation programs, building insulation, landscape re-planning against hydro geological risk, land recovering after floods or drought may create additional jobs (Harsdorff, et al, 2011).

In addition to the lack of quantitative studies, it is important to consider that: (a) the studies by a large address developing countries; (b) job creation potential of adaptation, if one excludes the technology-induced one, is likely to be short to medium term (i.e. it can be experienced mainly as long as specific adaptation measures are being implemented) and many climate adaptation measures will require one-time investments which temporarily stimulate demand for labour; and (c) the investment needed to implement adaptation measures or to develop adaptation technologies will probably crowd out other kind of investments, therefore draining resources from other economic sectors or activities. In the light of this the job creation potential of adaptation can be reduced.

Climate change impacts and adaptation needs are rooted in site-specific patterns of resource availability and use, sensibility to climate risk, and ability to resist to, and cope with climate extremes. Moreover, it is difficult to disentangle climate adaptation activities from development and economic transformation driven by other factors. Climate adaptation is about preserving employment in sectors struggling with the impacts of the climate change, as well as about exploiting opportunities of shift in markets or new product markets (e.g. climate proofing materials and building designs) (Sussman & Randall Freed, 2008).

Case studies

For this study, the observable and expected effects of climate change and adaptation policies on enterprises and employment is explored on a set of ad-hoc chosen case studies that draw on ongoing research in Po river basin. The analysis is completed by literature review of comparable studies conducted elsewhere and can be found in Annex 6.

The case studies focus on the expected transformation of water intensive sectors in the Po river basin, the largest and arguably most important river basin district in Italy. The Po basin area is home to 17 million inhabitants (~28% of the state population). More than one third of country's industries producing 40% of the national GDP are located in the basin area.

Climate change induced alteration of rainfall pattern (form, intensity and timing of rainfall) will have significant effects on water availability and frequency of extreme events such as droughts. According to the recent IPCC projections employing a GCM model ensemble (Solomon, et al, 2007) the temperature may raise by some 0.2°C every ten years atmospheric circulation. A less pronounced warming will occur even in case the concentration of greenhouse gases (GHG) is stabilised at the levels in 2000. The IPCC 4th Assessment Report (AR4) includes the Po valley among the European continental zones affected by a shift of rainfall regime and amplified extreme events (Naldi et al., 2008). The knock-on effects of these changes will affect almost all communities throughout Europe, and most economic sectors.

The case studies focus on expected effects of climate adaptation policies on employment and the medium-to long term economic transformation of the analysed sectors, which include agriculture, water supply and sanitation, and the energy sector (cf. Table 29).

Table 29: Adaptation policies and measures explored in the case studies

Sector	Adaptation measure/policy	Employment effects
Agriculture	Improved application and conveyance efficiency	On farm employment Construction industry
Domestic water use	Water efficient domestic appliances, increased conveyance efficiency (reduction of pipeline losses)	Water industry, development of products, techniques and services that promote the efficient use of water
Energy generation	Alternative sources of water for cooling purposes	Construction industry, labour demand for operation and maintenance

The case studies provide interesting insights summarised as follows:

- The employment trend experienced by the analysed sectors is driven by a host of factors other than climate change. Europe has seen a constant decline in agriculture labour demand, as the farms become more specialised and larger, and professional farms drive out the family held farms. The adaptation efforts only marginally affect the prevailing trend, as show in the first case study. The investment-driven new jobs are created predominately in construction industry and the on-farm labour demand after implementing the adaptation measures – here a more efficient irrigation system – increases only slightly.

- In the water supply and sanitation sector, the investments needed to replace and modernise the existing infrastructure by far outweigh the investment needed to adapt to the expected impacts of climate change. Moreover, efficient adaptation based on water demand management strategies may actually reduce the base-line demand for new infrastructure. Thus adaptation pursuing greater water efficiency in the second case study may slightly reduce, rather than increase the investment in water infrastructure. This does not hold true for water technology that is not addressed in the case study.

- The third case study – the transformation of thermo-electrical plants to less 'thirsty' cooling alternatives – is capital and labour-intensive but delay transformation to renewable energy sources and in medium to long-term may not be the best investment.

3.2.3.2 Food security

According to the Rome Declaration in 1996 food security exists – at the individual, family, national and global levels – when all people at all times have physical and economic access to enough safe and nutritious food in order to cover their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996).

The problem of food security is more complex than agriculture in a general point of view. Food security is highly correlated with agriculture for two main reasons: The food people eat is mainly produced by agriculture, and this sector of activity provides the primary livelihood of 36% of the world work force. The European Commission (EC, 2009g) understands that the concept of food security is based in four pillars, namely:

- **The physical availability of food for everyone**. This involves offering enough foodstuffs to meet everyone's needs through national farm production, distribution and imports, as well as adequate local and national policies in these sectors;

- **Economic and physical access (e.g. affordability, transport possibilities) to food, basic needs (health, education, etc.) and adequate resources**. This involves stable markets, affordable prices for local populations, decent incomes and adequate purchasing power, thus enabling households to cover their food needs.

- **The utilisation of food and of related resources (drinking water, drainage, healthcare)**. This involves supplying an adequate and balanced diet in a way that satisfies the physiological needs (nutrition) of populations and enables people to lead healthy and active lives.

- **The stability of food supply over time (short/medium/long term)**. This should guarantee that access to food is safe from either the emergence of sudden shocks (economic or climate crisis) or cyclical events (seasonal food insecurity).

To analyse the potential impacts of climate change the FAO developed a conceptual framework on climate change and food security interactions. The climate change and food security (CCFS) framework shows how climate change affects food security outcomes for the four components of food security – food availability, food accessibility, food utilization and food system stability – in various direct and indirect ways. The framework illustrates, as set out in Table 30, how adaptive adjustments to food system activities will be needed all along the food chain to cope with the impacts of climate change.

Table 30: Potential impacts of climate change on food systems and food security, and possible adaptive responses

Potential impacts of climate change on food systems and food security, and possible adaptive responses

A. CO2 fertilization effects				
Impact on food system assets	**Impact on food system activities**	**Impact on food security outcomes**	**Impact on other human well-being outcomes**	**Possible adaptive responses**
Production assets: ▪ Increase in availability of atmospheric carbon dioxide for plant growth	***Producing food:*** ▪ More luxuriant biomass ▪ Higher yields of food and cash crops, mainly in temperate regions	***Food availability (production, distribution, exchange):*** ▪ Increased food production in major exporting countries would contribute to global food supply but diversion of land from food to more economically attractive cash crops could negate this benefit ***Food accessibility (allocation, affordability, preference):*** ▪ Increases in food production would limit price increases on world markets, but diversion of productive assets to other cash crops could cause food prices to rise	***Livelihoods:*** ▪ Increased income from improved food and cash crop performance would benefit commercial farmers in developed countries but not in developing countries	***Policies and regulations:*** ▪ Avoidance of subsidies or other monetary or non-monetary incentives for diversion of food production assets to other uses

B. Increase in global mean temperatures				
Impact on food system assets	**Impact on food system activities**	**Impact on food security outcomes**	**Impact on other human well-being outcomes**	**Possible adaptive responses**
Production assets: ▪ Trend changes in suitability of land for crop and livestock production ▪ Gradual loss of biodiversity ▪ Trend changes in vectors and natural habitats of plant and animal pests and diseases ***Storage, transport and marketing infrastructure:*** ▪ Strain on electricity grids, air conditioning and cold storage capacity	***Producing food:*** ▪ Immediate crop and livestock losses due to heat and water stress ▪ Lower yields from dairy animals ▪ Reduced labour productivity due to heat stress ▪ Trend impacts uncertain, conditional on location, availability of water and adoption of new cropping patterns by farmers ***Storing and processing of food:*** ▪ Upgrade in cooling and storage facilities required to maintain food quality at higher temperatures ▪ Increasing energy requirements for cooling ***Consuming food:*** ▪ Higher intake of liquids ▪ Lower intake of cooked food ▪ Perishable products have shorter shelf life ▪ More need for refrigeration ▪ Heat stress may negatively affect people's ability to access food (no energy to shop or do productive work)	***Food availability (production, distribution, exchange):*** ▪ Reduced production of food crops and livestock products in affected areas ▪ Local losses could have temporary effect on local markets, ▪ Reduction in global supplies likely to cause market prices to rise ***Food accessibility (allocation, affordability, preference):*** ▪ Impacts on incomes, prices and affordability uncertain ▪ Changes in preference uncertain ***Food utilization (nutritional value, social value, food safety):*** ▪ Risk of dehydration ▪ Risk of ill health from eating food that is spoiled ▪ Ability of body to process food reduced due to heat stress or diseases ***Food system stability:*** ▪ Higher cost for storing grain and perishable products	***Livelihoods:*** ▪ Trend changes in vectors and natural habitats of pests and diseases that affect human health and productivity ***Social values and behaviours:*** ▪ Acceptance of a greater degree of risk and uncertainty as a natural condition of life ***National and global economies:*** ▪ Reorientation of public and private sector investments towards mitigating and adapting to climate change	***Policies and regulations*** ▪ Greater reliance on weather-related insurance ▪ Development of risk management frameworks ***Farming, forestry and fishery practices*** ▪ Trend changes in cropping patterns ▪ Development and dissemination of more heat-tolerant varieties and species ***Food processing, distribution and marketing practices*** ▪ Greater use of alternative fuels for generating electricity ***Food preparation practices*** ▪ Greater use of alternative fuels for home cooking

C.1. Gradual changes in precipitation (increase in the frequency, duration and intensity of dry spells and droughts)				
Impact on food system assets	**Impact on food system activities**	**Impact on food security outcomes**	**Impact on other human well-being outcomes**	**Possible adaptive responses**
Production assets ▪ Loss of perennial crops and vegetative cover for grazing and fuel wood due to water stress and increasing fire hazard ▪ Loss of livestock due to water stress and lack of feed ▪ Loss of productive assets due to hardship sales ▪ Loss of buildings, equipment and vehicles and other productive assets due to fire ▪ Changes in rates of soil moisture retention and aquifer recharge ▪ Trend changes in suitability of land for crop and livestock production ▪ Gradual loss of biodiversity ▪ Trend changes in vectors and natural habitats of plant and animal pests and diseases ***Food preparation assets*** ▪ Lack of water for cooking ▪ Lack of vegetation for fuel	***Producing food:*** ▪ Immediate crop and livestock losses due to water stress ▪ Trend declines in yields ▪ Change in irrigation requirements ***Storing/processing of food:*** ▪ Less need for chemicals to preserve stored grain ▪ Scarcity of water for food processing ***Distributing food:*** ▪ Easier movement of vehicles on dry land ***Consuming food:*** ▪ May not be possible to continue growing preferred foods ▪ May be necessary to purchase a larger proportion of foods consumed ▪ Diet may become less varied and / or less nutritious	***Food availability (production, distribution, exchange):*** ▪ Declines in production ▪ Wild foods less available ▪ Pressure on grain reserves ▪ Decrease in food exports / increase in food imports ▪ Increased need for food aid ***Food accessibility (allocation, affordability, preference):*** ▪ Local increase in food prices in drought-affected areas ▪ Loss of farm income and non-farm employment ▪ Preferred foods not available or too costly ***Food utilization:*** ▪ Risk of dehydration ▪ Ability of body to process food reduced due to diseases ▪ Dietary adjustments with different nutritional content ***Food system stability:*** ▪ Greater instability of food supply, food prices and agriculturally-based incomes	***Livelihoods:*** ▪ Decline in expenditure for other basic needs, e.g., clothing, shelter, health, education ▪ Trend changes in vectors and natural habitats of pests and diseases that affect human health and productivity ***Social values and behaviours:*** ▪ Food scarcity strains ability to meet reciprocal food-sharing obligations ***National and global economies:*** ▪ Strain on national budgets and aid resources due to increased need for food safety nets	***Policies and regulations:*** ▪ Greater reliance on weather-related insurance ▪ Development of risk management frameworks ***Infrastructure investments*** ▪ New investment in irrigation for intensive agriculture where water resources permit ***Farming, forestry and fishery practices*** ▪ Trend changes in cropping patterns ▪ Development and dissemination of more drought-tolerant varieties and species ▪ Use of moisture-retaining land management practices ▪ Use of recycled wastewater for irrigation ***Food processing practices:*** ▪ Use of recycled wastewater ▪ Use of dry processing and packaging methods ***Food preparation practices*** ▪ Use of dry cooking methods

C.2. Gradual changes in precipitation (changes in timing, location and amounts of rain and snowfall)				
Impact on food system assets	**Impact on food system activities**	**Impact on food security outcomes**	**Impact on other human well-being outcomes**	**Possible adaptive responses**
Production assets ▪ Changes in rates of soil moisture retention and aquifer recharge ▪ Increase in proportion of global population exposed to water scarcities ▪ Changes in locations where investment in irrigation is economically feasible ▪ Trend changes in suitability of land for crop and livestock production ▪ Trend changes in vectors and natural habitats of plant and animal pests and diseases	***Producing food:*** ▪ Trend impacts on yields uncertain, conditional on location, availability of water and adoption of new cropping patterns by farmers ***Consuming food:*** ▪ Changes in consumption patterns may occur, in response to changes in relative prices	***Food availability (production, distribution, exchange):*** ▪ Some local losses virtually certain, but their likely geographic distribution is not known ▪ Likely impact on global supplies, trade and world market prices is not known ***Food accessibility (allocation, affordability, preference):*** ▪ Full-cost pricing for water may cause food prices to rise ***Food system stability:*** ▪ Greater instability of food supply, food prices and agriculturally-based incomes is likely	***Livelihoods:*** ▪ Changes in geographic distribution of vulnerability ***Social values and behaviours:*** ▪ Acceptance of a greater degree of risk and uncertainty as a natural condition of life ***National and global economies:*** ▪ Reorientation of public and private sector investments towards mitigating and adapting to climate change	***Policies and regulations:*** ▪ More aggressive support for efficient water management policies and water use regulations ▪ Full-cost pricing for water ***Infrastructure investments:*** ▪ New investment in irrigation for expanding intensive agriculture where available water resources permit ***Farming, forestry and fishery practices*** ▪ Use of moisture-retaining land management practices ▪ Use of recycled wastewater for irrigation ***Food processing practices:*** ▪ Use of recycled wastewater for plant hygiene ***Food safety and preventive healthcare practices:*** ▪ Use of recycled wastewater for home hygiene

D. Impacts of increase in the frequency and intensity of extreme weather events (increase in annual occurrence of high winds, heavy rains, storm surges, flash floods and rising water levels associated with tornados, tropical storms, and prolonged heavy rains)				
Impact on food system assets	**Impact on food system activities**	**Impact on food security outcomes**	**Impact on other human well-being outcomes**	**Possible adaptive options**
Production assets: ▪ Damage to standing crops ▪ Animals stranded ▪ Increase in water-borne livestock diseases ▪ Damage to buildings and equipment ▪ Loss of stored crops ***Storage, transport and marketing infrastructure:*** ▪ Damage to roads, bridges, storage structures, processing plants and electricity grids ***Non-farm livelihood assets:*** ▪ Damage to trade goods ***Food preparation assets:*** ▪ Loss of household food supplies	***Producing food:*** ▪ Possibility of lower yields in flooded agricultural areas ▪ Increased soil erosion reducing future yields ***Processing food:*** ▪ Pollution of water supply used in processing food ***Distributing food:*** ▪ Disruptions in food supply chains and increase in marketing and distribution costs ***Consuming food:*** ▪ Reliance on emergency rations ▪ Possibility that preferred foods will be less available in emergency situations and food variety will decrease ▪ Increased health risks from water-borne diseases may negatively affect people's ability to access food (no energy to shop or do productive work)	***Food availability (production, distribution, exchange):*** ▪ Possible decrease in surplus production in flooded agricultural areas ▪ Increased need for emergency distribution of food rations ***Food accessibility (allocation, affordability, preference):*** ▪ Possible increase in food prices ▪ Possible loss of farm income and non-farm employment, depending on extent of asset loss ***Food utilization (nutritional value, social value, food safety):*** ▪ Food safety is compromised by water pollution and damage to stored food ▪ Ability of body to process food reduced due to diseases	***Livelihoods:*** ▪ Decline in expenditure for other basic needs, e.g., clothing, shelter, health, education ▪ Trend changes in vectors and natural habitats of pests and diseases that affect human health and productivity ▪ Changes in geographic distribution of vulnerability ***Social values and behaviours:*** ▪ Acceptance of a greater degree of risk and uncertainty as a natural condition of life ***National and global economies:*** ▪ Reorientation of public and private sector investments towards mitigating and adapting to climate change	***Policies and regulations:*** ▪ Development of weather-related insurance schemes for storms and floods ▪ Development of risk management frameworks ▪ Support for resettlement schemes in low-risk areas ***Infrastructure investments:*** ▪ New investment in flood embankments ▪ Use of wind resistant technologies on new and existing structures ▪ Establishment of emergency shelters on high ground ***Farming, forestry and fishery practices*** ▪ Use of practices that create more dense root mass to hold soil in place ▪ Development and dissemination of more flood-tolerant varieties and species ***Food safety and preventive healthcare practices*** ▪ Provision for emergency water supplies

E. Impacts of greater weather variability				
Impact on food system assets	**Impact on food system activities**	**Impact on food security Outcomes**	**Impact on other human well-being outcomes**	**Possible adaptive options**
Production assets: ▪ Change in frequency and extent of pests and diseases	***Producing food:*** ▪ Increasing uncertainty ▪ Changing yields ▪ Changing land use patterns ▪ Viability of production systems may be undermined	***Food availability:*** ▪ Some local losses virtually certain, but their likely geographic distribution is not known ▪ Likely impact on global supplies, trade and world market prices is not known ***Food accessibility:*** ▪ Reduced yields may lead to loss of farm income, but this depends on market conditions ***Food system stability:*** ▪ Greater instability of food supply, food prices and agriculturally-based incomes is likely	***Livelihoods:*** ▪ Decline in expenditure for other basic needs, e.g., clothing, shelter, health, education ▪ Trend changes in vectors and natural habitats of pests and diseases that affect human health and productivity ▪ Changes in geographic distribution of vulnerability ***Social values and behaviours:*** ▪ Acceptance of a greater degree of risk and uncertainty as a natural condition of life ***National and global economies:*** ▪ Reorientation of public and private sector investments towards mitigating and adapting to climate change	***Policies and regulations*** ▪ Greater reliance on weather-related insurance ▪ Development of risk management frameworks ***Farming, forestry and fishery practices*** ▪ Trend changes in cropping patterns ▪ Changes in water management regimes

Source: FAO/IDWG on Climate Change. Table produced for this report.

As shown in Table 30 climate change variables influence biophysical factors, such as plant and animal growth, water cycles, biodiversity and nutrient cycling, and the ways in which these are managed through agricultural practices and land use. They also have an impact on physical/human capital – such as roads, storage and marketing infrastructure, houses, productive assets, electricity grids, and human health – which indirectly changes the economic and socio-political factors that govern food access and utilization and can threaten the stability of food systems.

3.2.3.3 Other social issues

Social issues cover a wide range of aspects ranging from education, to gender, disadvantaged population groups and migration. In the context of the European Adaptation strategy only those aspects are highlighted which fall within EU competence and seem particularly relevant with regard to climate change impacts and adaptation.

These issues are:

- Migration,
- Gender,
- Ageing population, and
- Social protection (including disadvantaged population groups).

These priority policy areas have been chosen in particular due to their potential for contributing to higher social climate resilience in Europe, building on existing initiatives and policy actions. Annex 10 and Annex 11 provide a much broader summary of the specific risks and opportunities associated with impacts of the social realities going beyond EU policies.

Climate change impacts might affect people’s daily lives in terms of employment, housing, health, water and energy access as well as the implementation of gender equality and other human rights. Thus, including the social dimension of climate change within future climate change adaptation efforts is of central importance and reflects one of the key challenges at EU and Member State level.

Recent evidence and predictions show that climate change impacts are accelerating and will result in changes to the characteristics of climate risks in terms of frequency, magnitude, timing, duration, and distribution over space, sectors, and society groups.

While not all climate change impacts will be negative, it is broadly accepted that the most vulnerable communities will bear a disproportionate share of the hardships associated with climate change (UNICEF, 2007; Adger, et al, 2003; Mearns & Norton 2009; Verner, 2011; World Bank, 2012). Negative impacts of climate change will especially affect *disadvantaged population groups* (especially those living in poverty) in least developed countries, but also within the EU Member States. Often people living in poverty depend highly on the very natural resources affected by climate change and have less capacity to protect themselves, adapt or recuperate losses (UN, 2011b).

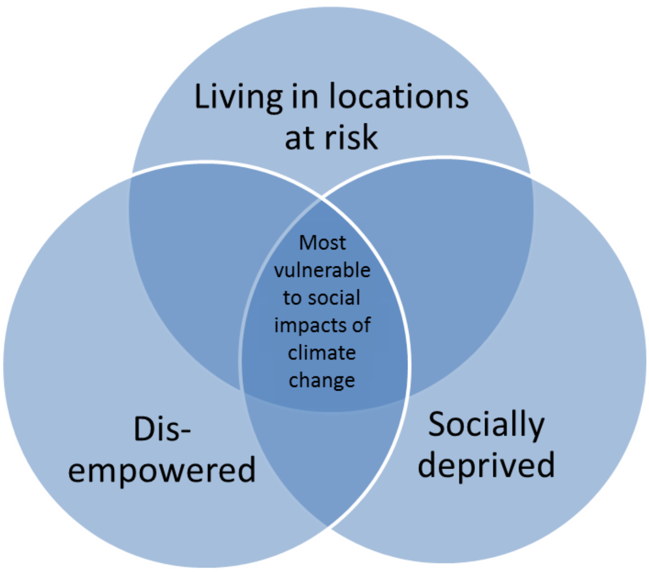
Several sources (IPCC, 2007a; CAG Consultants, 2009; UN, 2011b), including the White Paper on adaptation (EC, 2009a) identify that “those who have fewer resources are more vulnerable to climate change effects” with “certain sections of society (the elderly, disabled, low-income households) expected to suffer more”. The Impact Assessment of the White Paper (EC, 2009c) details that impacts of climate change will be felt the heaviest by those who spend higher proportions of their disposable income on basic needs, as well as migrants. Moreover, often the socially disadvantaged groups are also the ones more exposed to biophysical impacts of climate change (e.g., living in flood-prone areas or low quality housing in cities vulnerable to heat waves) (EC, 2009c; CAG Consultants, 2009; UN, 2011b).

Adger et al. (2003) furthermore highlight that 'societal vulnerability to the risks associated with climate change may exacerbate on-going social and economic challenges, particularly for those parts of societies which are dependent on resources that are sensitive to changes in climate.' Thus, climate change acts as a multiplier of existing vulnerabilities.

On a more abstract level research leads to the conclusion that the people most vulnerable to social impacts of climate change will be those (CAG Consultants, 2009):

- living in places at risk,
- already socially deprived (e.g. by poor health, low income, inadequate housing, lack of mobility);
- disempowered (by lack of awareness, adaptive capacity, support services and exclusion from decision-making).

Figure 51: Identification of the most vulnerable to social impacts of climate change (Adapted from CAG Consultants, 2009)



People matching all three vulnerability characteristics are likely to be most vulnerable to social impacts of climate change. However, matching only one of the characteristics can also make people highly vulnerable to climate change impacts. For example, a household, living in a flood prone area albeit not socially deprived nor disempowered is vulnerable to climate change impacts, but to a much lesser degree than a low-income household living in the same area, which in turn is less vulnerable than socially excluded immigrant household having low income and living in the same flood-prone area. This can be explained by the fact that the later the least alternatives to move out of the flood risk area.

Adaptive capacity, exposure and sensitivity to climate change are shaped by many non-climatic, socioeconomic factors, such as access to and control over economic, social and institutional resources. These resources comprise (UN, 2011b; Blaikie, et al, 2003):

- Human capital, such as good health, skills, knowledge and education;
- Social capital, including the power to influence decision-making, voting rights, and social connectedness;
- Physical capital, such as housing, but also community infrastructure (energy, water supply, transport) and health care facilities;
- Natural resources, including clean air, land and water; and
- Access to choice and quality of food products
- Financial capital, such as income, savings or credit.

Socioeconomic factors not only influence adaptive capacity, but also exposure and sensitivity to climate-related hazards. Exposure itself is being shaped through a range of political, socioeconomic and demographic processes. Changes in the number and spatial distribution of people, through population growth or decline and through processes like seasonal or international migration and urbanization, can significantly change the exposure of populations.

Availability and access to human, social and financial resources, as well as policies that support and plan for mobility, or those that attempt to restrict them or fail to plan ahead for coming population change, are key determinants of where people live. High dependence on natural resources, a key indicator of sensitivity, is linked to and shaped by economic and social structures. Policies on agriculture, land tenure, urban planning and many others can enhance or limit peoples' ability to change to livelihoods that are less sensitive to climate change (UN, 2011b).

Assumptions and uncertainties

When it comes to social issues there are lots of uncertainties. In general uncertainty is not only the result of the projections about climate change can be made, but also:

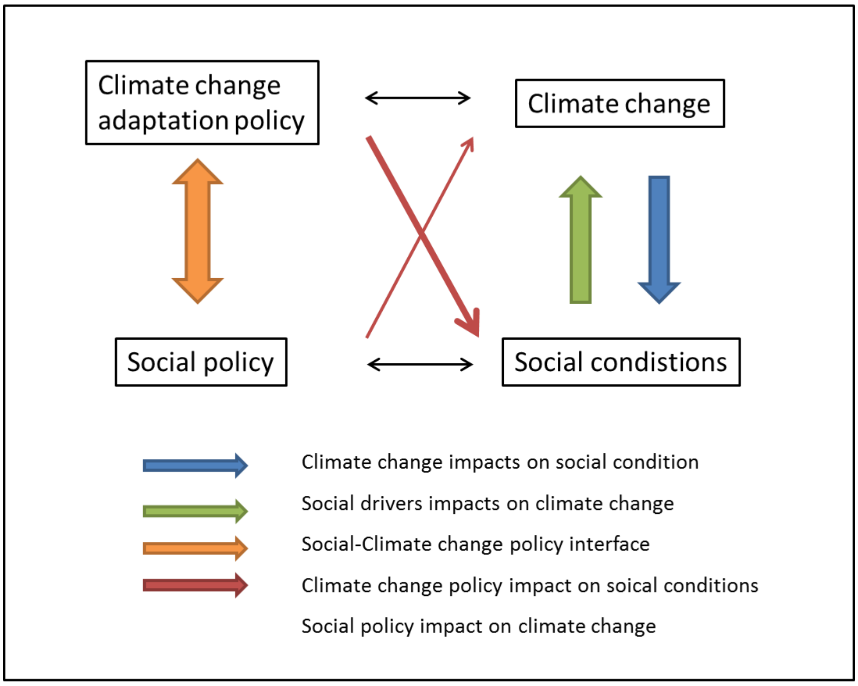
- The role of assets and institutions in both the production and communication of knowledge about uncertainty, and what influence this has on the vulnerabilities of particular groups of people;
- Behavioural/cultural practices that deal with uncertainty and variability developed over time;
- changes due to the expected demographic shifts.

In relation to the four issues mainly discussed below, the uncertainties are:

- **Migration**: There are some uncertainty about the extent to which (in terms of scale, location and timing) decisions to migrate are affected by climate change, climate-induced events and environmental disruptions. In addition, uncertainty about the pace and extent of climate change (and also broader environmental changes in specific geographical areas) and other processes like urbanisation make it difficult to pinpoint clearly the role played by the environment and climate change in individuals' decision to migrate (IPCC, 2007a).
- **Gender**: As set out in EIGE (2012a) it is important to acknowledge that gender is not just a binary concept (women and men) but entails a whole range of factors such as age, marital status, affluence or poverty, ethnicity, sexuality, caste, culture, etc. For this reason, it is essential to recognise that women and men are not homogenous groups. They represent a vast range of different identities, needs, capacities and experiences. While the contributions of women and men to climate change and their attitudes towards its impacts and possible solutions may differ, it is not simply a case of men being involved in one way and women another. Instead, complex interactions between identity and impact take place which can never fully be understood or predicted. In the future climate change adaptation may lead to different roles and responsibilities of man and women in the future, which need to be taken into account.
- **Ageing population**: The detailed economic effects of such a profound and rapid change in social structure are not well understood. In particular the relation between an aging population, labour supply and the use of public social protection systems are not known (IPCC, 2000). There is also a huge uncertainty in relation to the health status of an elder population, which influence the adaptive capacity
- **Social protection**: Social protection is clearly linked in many cases to state budgets. Due to the economic crises there is some uncertainty

Uncertainties also result from a lack of understanding the interdependencies between the different components defining our social system and how they will develop and interact under a climate change scenario (cf. also Figure 52).

Figure 52: Connection between social policy and climate change adaptation (based on Pye, et al, 2008)



Further the Intergovernmental Panel on Climate Change (IPCC) recognizes that vulnerability and the potential impacts of climate change are determined by the exposure, sensitivity and adaptive capacity of people and societies. In its fourth assessment report in 2007, the IPCC noted shortcomings in its definition of vulnerability, particularly in its lack of consideration of 'social vulnerability', the need to address the determinants of adaptive capacity, and the need to consider human development as an essential mediator of climate vulnerability (IPCC, 2007a).

The following chapters provide an overview of the main potential impacts on social issues that are most relevant for the EU level.

3.2.3.3.1 Migration

There are clear indications that climate change and environmental degradation play an increasingly determinative role in shaping human mobility. Climate change is understood to heighten the intensity and frequency of natural disasters and accelerate environmental degradation, which may induce people to migrate because of threats to their lives or livelihoods.

Environmental migration, however, is essentially a complex, multi-causal phenomenon, driven by a variety of factors and compounded by social, economic and political forces. In this context, it is important to note that environmental migration is not necessarily a problem and does not necessarily carry negative effects for migrants and countries of origin, transit and destination. Indeed, migration has been a traditional coping mechanism, widely used by populations around the world to adapt to a changing environment. If properly managed, migration can therefore also be a solution to cope with climate change.

According to the International Organization for Migration (IOM)[100] climate change could affect the movement of people in the following ways:

- Greater frequency and intensity of sudden and slow-onset weather-related natural disasters entail a higher risk of humanitarian emergencies and related population movements;
- The adverse consequences of increased warming, climate variability and other effects of climate change for livelihoods, public health, food security and water availability can exacerbate pre-existing vulnerabilities and contribute to migration;
- Rising sea levels may make coastal areas and low-lying islands uninhabitable;
- Competition over shrinking natural resources (e.g. water) may lead to tensions and potentially to conflict and, in turn, to forced migration.

Environmental migration may take place internally, regionally or internationally. The type of environmentally induced migration – whether long or short distance, long or short term – will vary with the type of environmental event or process and its severity. In cases of irreversible environmental degradation (for instance due to rises in sea level), resulting migration can require relocation of affected populations either internally or between countries and may become permanent. Most empirical research, however, tends to suggest that internal migration, such as rural-urban migration, or movement across immediate borders between neighbouring countries, is likely to be predominant.

Migration can be classified as forced in cases of imminent or acute natural disaster, while migration is more likely to be voluntary at early and intermediate stages of environmental degradation. For the latter it can be argued that migration is used by the affected populations as a normal or near normal adaptation strategy to environmental and climate change. However, the decision to move has to be analysed in the context of viable alternatives, which depend, inter alia, on individual, social and even cultural ability to cope with and adapt to climate shocks and stresses (IOM website[100]).

[100] IOM website http://www.iom.int/jahia/Jahia/complex-nexus, accessed July 2012.

Migration inside the EU

One of the fundamental principles of the European Union is the free movement of people and intra-EU migration is therefore promoted and encouraged. The European data on internal migration reveal that in 2009 one million EU citizens migrated to another EU country (EUROSTAT, 2011a). Climate change is also projected to trigger migration. This subsequently may induce various social risks both among the migrants and within the host communities.

Empiric evidence backs the conclusion that 75% of environmental migration occurs internally without crossing international borders (Foresight, 2011). This is also the case for Europe (Findlay, 2011). The already existing and protected internal mobility in EU (migration between MS) in combination with intra-European economic contrasts are likely to result in significant migration flows over the next 50 years (Findlay, 2011).

An important aspect of environmental migration is the tendency to migrate to urban areas, which amplify urbanisation, pressures on infrastructure, jobs and services in cities, further deepening city vulnerability to climate change and enlarging the proportion of poor population, which is an especially vulnerable group (Foresight, 2011). Although these processes will be experienced the most in the cities of developing countries, European cities likewise need to be prepared to accommodate increasing populations.

The number of urban dwellers in Europe is projected to increase from 75% to 80% until 2020 (EEA, 2009b). As cities grow, people are increasingly likely to inhabit areas exposed to climate change risks, most likely the urban poor being driven to settle in the most vulnerable locations. Increased size and density of population may also lead to increasing social tensions and pressures on resources and infrastructure. In most of the EU poverty is rather an urban than rural problem with severe material deprivation occurring more in densely populated areas; and cities also experience higher crime levels (EUROSTAT, 2011b).

Furthermore, the quality of life in cities is also directly impacted by climate change impacts. For example, many EU Member States are experiencing difficulties ensuring good air quality levels, compliant with the legally binding EU limits and targets (EEA, 2011b) or secure sufficient water supply (e.g. Barcelona was forced to import emergency water in 2008[101]).

To conclude, the aspects of climate change driven internal EU migration that need to be taken into account in the European context of policy-making and adaptation planning are:

1) Changes in agricultural productivity and location of the productivity, as well as adjustments of job markets in various economic sectors;

2) Rural-urban migration patterns and growing pressures on cities;

[101] http://www.guardian.co.uk/world/2008/may/14/spain.water

3) The risk of people moving to exposed locations due to economic reasons and the risk of “trapped populations”.

Migration from outside the EU

Findlay (2011) argues that there are three regions in the world that could potentially be sources of climate change induced immigration in Europe and are often determined by former colonial ties: North Africa and the Sahel, South Asia and Small Island States. In the case of North Africa and the Sahel, the drought and desertification that is aggravated by climate change and the resulting crop failures might further stimulate the already historically existing migration to Southern Europe (Italy, Spain and France, Malta) driven by other determinants.

The High Representative and the European Commission stated in the paper Climate Change and International Security that “Europe must expect substantially increased [environmentally-induced] migratory pressure” (EC, 2008g). However, predicted numbers related to climate change-induced migration should be treated with some caution.

There may be some powerful images of migration phenomena which are rather driven from the security community and environmental NGOs than from the scientific field of migration and refugee studies[102]. In particular already existing migration streams cause political challenges in host countries by providing an inflow of people who are poorly matched to job market needs (Findlay, 2011; Bilgic, 2011).

Migrants as a vulnerable group

At the beginning of 2010 there were 32.5 million non-nationals living in EU countries comprising 6.5% of all EU population, one third of them being citizens of another EU country (EUROSTAT, 2011a). In six Member States the share of non-nationals living in their territory is higher than 10% (EUROSTAT, 2011a). The average naturalization rate in EU is roughly 2.5 persons among every 100 non-nationals acquiring citizenship and the trend is slightly increasing (EUROSTAT, 2011a).

Migrants are one of the most vulnerable groups having limited resources and more difficult access to real estate have a tendency to settle in poor, densely populated areas exposed to climate risks. Migrants are at risk of poverty, social marginalization and deprivation, especially so if effective integration policies and measures are missing. This is equally the case both for intra-EU migrants and external immigrants. The issue of external migration and climate change has been further mentioned in the Communication on the Global Approach to Migration and Mobility (GAMM) (EC, 2011w). In addition a staff working paper on climate change and migration is being prepared by the European Commission. Research to date shows that due to complex interplay between drivers of migration and the difficulty of isolating climate change as such as a driver it is difficult to evaluate the scale and patterns of

[102] http://w3.cost.eu/fileadmin/domain_files/ISCH/Action_IS1101/mou/IS1101-e.pdf

environmentally induced migration. Most studies to date have not been able to demonstrate any high probability of large international movements as a result of climate change. They show that most of the persons affected would remain in their countries and regions of origin. Moreover, in certain cases, migration and displacement can be seen as a climate change adaptation strategy and an opportunity for migrants, their families and countries of origin. To maximise this positive impact, appropriate tools and strategies will be required that could be developed alongside those already existing in the area of migration and development.

3.2.3.3.2 Gender

Women and men are affected in different way by the impacts of climate change. Gender-differentiated roles and responsibilities in families and households as well as gender segregated labour market and income gap cause differentiated vulnerabilities of women and men to the effects of climate change. Economic disparities lead to differences in adaptive capacity. In more detail the following dimensions need to be taken into account (EIGE, 2011 and EIGE, 2012a,b):

- **Socio-psychological**: Gender identities are rooted in cultural understandings of what it means to be masculine or feminine, whereas gender roles are based on societal expectations of being a man or a woman. Both can be translated into different consumption patterns, potentially resulting in more or less energy-intense lifestyles, and in differentiated attitudes and perceptions, based on different values (e.g. fairness and ethics v cost-performance-ratio);

- **Socio-economic**: The gender division of labour, in paid and unpaid work, leads to differences in the effects of climate change. For example, time-use studies show that even in the Nordic countries, and when both partners have full-time jobs, women spend more time on household and family work than men. Economic disparities lead to differences in the capacity to cope with climate change. On average, women's salaries and assets are lower. Thus, women (in particular single mothers and elderly women) are disadvantaged if expensive adaptation measures are required;

- **Socio-cultural**: It is not only the household in which social roles play out: other areas of social life also exhibit and entrench cultural patterns, such as the use of public services (e.g. parks, transportation systems) or the radius within which women and men move. In some cases more men fall victims in disasters than women because of expected masculinity roles of rescuing (IUCN, n.y.);

- **Legal**: Although legal rights in EU Member States are gender-neutral, this does not necessarily mean that gender equality is implemented and all forms of discrimination removed. Indices for inequality which might influence gendered impacts of climate change policies are, for example, gender income gaps and gendered access to loans;

- **Political**: Several social sectors which have the greatest influence in climate-related decision-making are male-dominated. This is a detrimental shortcoming, as women and men show great differences in their perceptions of, and attitudes towards, climate change-related problems and display different risk perspectives;

- **Physical, biological**: There are indications that the health impacts of climate change can differ between women and men for biological reasons, in addition to the social reasons of health impacts such as being cared for by partners or suffering exposure to chemicals.

Gender differences of the vulnerability to the impact of climate change are relatively well documented and acknowledged in particular for developing countries and, to a lesser extent, for industrialised countries. So far research data highlight the following gender differences related to climate change impacts:

- Among women, there are more casualties in cases of extreme weather events (EIGE, 2011, 2012b; IUCN, n.y.) For example during the heat wave that affected Europe in 2003 in France most deaths were among elderly women There are also specific health-related vulnerabilities of pregnant women, who are more susceptible to vector- and water-borne diseases (IPCC, 2007a); In some cases, gender differences also increase men's mortality in disaster situations. Many men are exposed to risky situations and even die because they believe that by being the "stronger sex" they need not take precautions and because society expects them to take heroic rescue action (IUCN, n.y.);

- Furthermore climate change is likely to increase the burden of (most often unpaid) care work, which is mostly carried out by females, when females already experience higher workloads of paid and unpaid work (including caring for family and housework and similar) (EIGE, 2011). More than 30% of European women work over 70 hours per week, compared to less than 15% of males (EIGE, 2011). This also correlates with women spending less time than men on leisure activities and physical exercise (EUROSTAT, 2008), thus being more deprived of the health and social benefits of such activities;

- There are economic disparities between men and women, leading to different levels of adaptive capacity. While young female graduates are less likely to be employed in adequate jobs (EUROSTAT, 2012a), which results in less income and therefore less availability of resources for adaptation, even though females consistently outnumber males in the attainment of university education (EUROSTAT, 2012a)[103];

[103] The gender inequality in terms of income is significant in Europe with females on average having 17% lower wages (EUROSTAT, 2010b). Among full-time low-wage earners the majority are female and this wage gap widens with age (EUROSTAT, 2010b). The income inequality is evident not only across professions, but also when females and males hold same or similar positions. In 2002 a female manager in EU on average earned 29% less than a male manager (EUROSTAT, 2008).

- There is evidence that perceptions and attitudes towards climate change and climate policy options vary substantially between women and men. Women are, on average, more concerned about climate change. They feel a greater need for action to tackle climate change, and are more likely to be willing to change their behaviour. Men generally have more trust in technological solutions (EIGE, 2012b);

- There is a proven link between women's participation in the negotiations and the prominence of gender issues within these negotiations. In cases where women started to enter the international climate negotiations, gender issues gradually gained more attention. There have been a growing number of gender references in the negotiation papers, including cases where gender issues are seen as an integral component in the development of actions to adapt to and mitigate climate change (EIGE, 2012b).

3.2.3.3.3 Ageing population

Added to climate change the European Union needs to contend with demographical changes, especially changes in populations' age structure. These changes will affect the environmental behavior and perceptions toward climate change, and furthermore, will have impact on particular requirements of the ageing population (e.g. sensitivity of older people to extreme heat). As a consequence, the demographical development of the EU will also affect the planning and implementation of climate change adaptation measures.

The IPCC recognises the elderly as a group of greater vulnerability, which is mainly due to people of older age being more sensitive to health impacts (IPCC, 2007a), especially caused by heat, as well as to stress associated with losses and physical damage during extreme weather events (CAG Consultants, 2009). They are also more likely to have reduced mobility and therefore reduced access to essential services. Additionally, older people are less likely to be willing to relocate away from exposed areas due to general reluctance to migrate, which rises sharply with age (Huber & Nowotny, 2008).

The demographic trends of population ageing in Europe are significantly increasing a group of population especially vulnerable to climate change impacts. The median age in EU has risen by 26% between 1960 and 2010, from 31.5 to 39.1, with the projected trend of increased median age by 50% by 2060 (1960 base year) (EUROSTAT, 2011c). This will be an unprecedented situation in the history of human populations, when there may be more than two elderly persons per one young person (EUROSTAT, 2011c).

3.2.3.3.4 Social protection

Social protection describes all initiatives that aim to reduce poverty, and protect, promote and transform livelihoods and social relations, including income or assets transferences to the poor, protection against livelihood risks, enhancing the social status and rights of disadvantaged population groups. In the European context social protection deals with reduction of poverty and social exclusion, access to healthcare, pensions, long-term care, social security, employment and training services, social housing, child care and social assistance. Furthermore, social protection strategies can include options that cope with damages related to weather-dependent livelihoods.

The areas of social protection are facing climate change related negative impacts and at the same time directly influence the capacity of societies to adapt to all types of climate change impacts (Davies & Leavy, 2009).

The problem as regards climate change impacts and social protection largely stems from the lack of mutual considerations and policy coordination between adaptation and social protection policy fields. This shortfall currently inhibits the unlocking of the highly beneficial synergies that such coordination can mutually provide, taking into account that successful achievement of social protection aims increase adaptive capacity and increased adaptive capacity in turn is beneficial to all areas addressed by social protection. In order to overcome this problem a close linkage between adaptation and social protection policies is necessary, which in itself raises policy-making challenges (Davies & Leavy, 2009).

Low income households / poverty

Low income households are considered as vulnerable group which is particularly susceptible to negative impacts of climate change (IPCC, 2007b). Poor people lack the access to resources that is required to take adaptive action, they are also less likely to cope and recover from impacts of natural hazards due to low rates of savings and alternative income sources. They are furthermore increasingly likely to be living in areas vulnerable to climate change impacts.

Even slight changes in food prices can mean decreased levels of nutrition for poor people, who are typically net food buyers. In situations of high food prices, poor households typically reduce expenditure on health and education and shift away from nutrient rich foods, as well as sell assets, borrow or engage in new economic activities (FAO, 2011a). Thus the food price has far reaching effects on the social wellbeing of vulnerable populations.

Currently[104] one in every 6 European citizens or 80 million people live at risk of poverty in European Union with slightly higher average at risk of poverty rates in the new Member States and more than 20% of people at risk in Lithuania, Greece, Bulgaria, Romania and Latvia (EUROSTAT, 2010a). Furthermore, the Gini coefficient illustrating income inequality in EU ranges between 23% (in Slovenia) to 38% (in Latvia), with the EU-wide average being 31% (EUROSTAT, 2010a) and the countries having highest at-risk-of-poverty rates also have the highest income inequalities. Although Europe 2020 Agenda aims to “lift at least 20 million people out of risk of poverty and social exclusion” (EC, 2010d), which would reduce poverty in Europe by 4% (EUROSTAT, 2010a), in fact in recent years the share of people at risk of poverty has increased (EUROSTAT, 2010a).

[104] 2007 data.

Old age can coincide with being at risk of poverty. In the early 2000s approximately 13 million, or one in six of elderly persons were at risk of poverty (Zaidi, et al, 2006). In 14 Member States the risk of poverty was higher for older people than for working age individuals. Moreover, poverty risk was higher for elder females than males (Zaidi, et al, 2006)

Access to healthcare

The projected climate change impacts in the form of heat, fires, floods, storms, coastal erosion, sea level rise and the associated disruption to energy supply, telecommunications and transportation lead to further limitations in access to healthcare services (UN, 2011b). As climate change is expected to increase the frequency of these weather extremes in Europe, due effort needs to be given to climate proofing health care infrastructure, as well as energy, communication and transport networks. Research confirms that distance and time taken to reach healthcare facilities (Nicholl, et al, 2007) as well as hospital overcrowding (Sprivulis, et al, 2006) are directly correlated to increase in mortality rates.

Consequently access to healthcare in EU as a social good and adaptation of health care system to future conditions needs to be addressed in the light of both pre-existing inequalities of access and the projected disruptive impacts of changing climate with special regard to the most deprived populations.

Although EU Member States have committed to providing universal access to healthcare services, inequalities within and between European countries still exist. In five Member States of the EU more than 30% of the population have difficulty accessing primary health care (EUROSTAT, 2011b). Sienkiewicz (2010) quotes social affairs ministers of Europe: “There is a social gradient in health status, where people with lower education, a lower occupational class or lower income tend to die at younger age and to have a higher prevalence of most types of health problems”. These inequalities are driven by socioeconomic status, place of residence, ethnic group and gender and are characterised by legal, financial, cultural and geographical barriers to access, including lack of insurance coverage, inability to bear the financial costs of healthcare, lack of mobility, lack of knowledge of local language and no access to information and time constraints (Sienkiewicz, 2010). The most vulnerable groups to climate change impacts facing barriers to health care access are the disabled, people suffering from chronic diseases and mental disorders, the unemployed, people with poor working conditions, the homeless, legal and illegal immigrants, refugees and asylum seekers, the elderly, women and minority groups (especially Roma people) (Sienkiewicz, 2010). Additionally, population groups located in remote areas further away from health care facilities and mostly depending on public transport systems are more vulnerable to disruptions due to catastrophic events.

Access to education

Level of education is an important determinant of individual’s adaptive capacity and promotes social and economic integration as discussed above. The rates of participation in education in EU starting from pre-primary to compulsory to post-compulsory education levels are increasing. In 2009 almost 90% of all 17-year olds were attending school and the number of people achieving tertiary education increased by 20% between 2000 and 2009. Nevertheless, there are still inequalities in access to education particularly disadvantaging immigrants and exhibiting varying opportunities of life-long learning in the different Member States (EUROSTAT, 2012a).

Homeless people

Arguably the poorest of the poor and the most socially deprived population group in Europe are the homeless people, who are more likely to be exposed to climatic impacts such as heat, cold and extreme weather and also lack access to resources and information. The homeless are routinely omitted from poverty assessment surveys (EUROSTAT, 2010b). According to the ‘European Federation of national organisations working with the homeless’ up to now there are no comparable data available for EU-wide assessment of the levels of homelessness (FEANSTA, 2008), however, the 2011 censuses data should prove first insights, as homelessness indicators have been included for the first time (EC, 2010c).

The Disabled

The disabled and those suffering from poor health is a population group extra sensitive to climate change impacts on health, and also having less mobility, lower income and having hardships attaining education, finding employment and participating in social life (EUROSTAT, 2001). 30% of adults in the EU report having long-standing illness or health problem and 24% report a disability limiting their daily activities[105] (OECD, 2010b). The ones disadvantaged by disability and poor health are furthermore likely to be more dependent on help and spend larger proportion of income on their essential needs, and thus have significantly reduced adaptive capacity.

[105] 2008 data.

3.3 Adaptation Efforts

Adaptation, as defined by the IPCC (2007a), is any adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Adaptation can involve both building adaptive capacity thereby increasing the ability of individuals, groups or organisations to adapt to changes, and implementing adaptation decisions, i.e. transforming that capacity into action. Both dimensions of adaptation can be implemented in preparation for or in response to impacts generated by a changing climate. Hence adaptation is a continuous stream of research, activities, actions, decisions and attitudes that informs decisions about all aspects of life, and that reflects existing social norms and processes (Adger, et al, 2005).

However, adaptation to environmental change is not a new phenomenon. Both traditional and industrialised societies have adapted their environments to smooth risks associated with climate variability throughout human history (Adger, et al, 2003; Brooks, 2006). Hence, it is to be expected that some adaptation by economies and societies will already have begun and continue to take place even without any policy intervention. Autonomous responses to a changing environment are mostly triggered by individuals, groups or organisations being directly affected. It can thus be expected that autonomous adaption will take place, when people or assets are at risk and/or any action provides economic and societal benefits.

While some economists suggest that much adaptation will occur spontaneously through marginal adjustments in markets and individual behaviour, there are good reasons for public policy intervention. The Stern Review (Stern, 2006) suggests that market forces are unlikely to lead to efficient adaptation because of a certain degree of uncertainty in the climate projections and lack of financial resources. Hence the major objectives of public policy in this area are: (1) to protect those least able to cope by addressing the causes of vulnerability; (2) to provide information for planning and stimulating adaptation by non-state actors; and (3) to protect important public goods such as ecosystem services, public resources, land use coastal defence and early warnings of extreme events.

There have been significant changes in Europe in responses to climate change over the last decade both in policy development and adaptation action (planned and autonomous) across various governance levels and in most affected sectors. Achievements so far at EU, Member States, transnational, regional and local level as well as for the private sector and ecosystem-based adaptation are briefly summarized in the following.

3.3.1 EU level efforts

The EU has adopted a Green Paper on Adaptation (EC, 2007l) followed by a White Paper (EC, 2009a). The Adaptation White Paper supports the preparation of a comprehensive EU Adaptation Strategy in Phase 1, 2009–2012, which then shall be implemented as of 2013 in Phase 2.

The White Paper is framed to complement and ensure synergies with actions by Member States and focuses on four pillars to reduce the EU's vulnerability and improve its resilience:

- Pillar 1: develop and improve the knowledge base at regional level on climate change impacts, vulnerabilities mapping, costs and benefits of adaptation measures to inform policies at all levels of decision-making;
- Pillar 2: integrate adaptation into EU policies (mainstreaming);
- Pillar 3: use a combination of policy instruments – market-based instruments, guidelines, and public-private partnerships – to ensure effective delivery of adaptation;
- Pillar 4: work in partnership with the Member States and strengthen international co-operation on adaptation by mainstreaming adaptation into the EU's external policies.

Several actions are mentioned for all pillars that have been in the focus until 2012 and build the basis for preparing a comprehensive EU Adaptation Strategy. The following paragraphs aim to highlight major achievements while not going into detail on progress made on single actions under all 4 pillars.

Referring to pillar 1, on developing and improving the knowledge base, the White Paper noted that information (including research results) already exists, but is not shared across Member States. Further, the White Paper and various assessment reports including the EEA/JRC/WHO report on climate change impacts in Europe (EEA, 2008c), underlined that information on climate change impacts and vulnerability and on the costs and benefits of adaptation measures in Europe remained scarce and fragmented and that more spatially detailed information was needed to develop adequate adaptation policies. Thus, the White Paper called for a European Climate Change Impacts, Vulnerability and Adaptation Clearinghouse to be established by 2012. Substantial efforts have been undertaken to establish this Clearinghouse, now called 'European Climate Adaptation Platform (Climate-ADAPT[106])' that has been launched on 23 March 2012. The EC and EEA are jointly responsible for managing and maintaining the platform.

Climate-ADAPT is aimed to be a tool with added value compared to national adaptation knowledge platforms in place or being developed in various countries across Europe. It aims

[106] http://climate-adapt.eea.europa.eu/

to support cooperation across countries and regions (transnational, with neighbouring countries and/or interregional in areas with similar characteristics, e.g. mountainous regions). Climate-ADAPT can also help to identify gaps in available information, and thus support potential improvements by countries and/or at EU level (e.g. through research).

To assist the implementation of pillar 1 the EC further established a Working Group on Knowledge Base on Climate Change Impacts, Vulnerability and Adaptation (WG-KB). This group was meant to contribute in particular to:

- Science-policy interaction, by providing opportunities to exchange information on on-going activities and available knowledge sources and to synthesize the needs of adaptation policy makers in terms of knowledge base;

- Methodological guidance to adaptation practitioners, on the basis of the information available. A specific focus should be given to support the development of adaptation activities in less advanced countries or sectors.

The main role of WG-KB was to provide technical assistance and expert advice on the development of Climate-ADAPT.

Mainstreaming climate change adaptation in EU policies has been particularly active under pillar 2 in terms of implementing the EC 2009 Adaptation White Paper. Climate-ADAPT provides an up-to-date overview and state-of-play of initiatives and main policy developments to integrate adaptation into EU sector policies[107]. The key policy initiatives concentrate on 9 particularly vulnerable sectors: water management, marine and fisheries, coastal areas, agriculture and forestry, biodiversity, infrastructure, financial, disaster risk reduction and health. These initiatives consider in turn the most vulnerable areas in Europe (e.g. mountains, coastal areas, river flood prone areas, the Mediterranean, and the Arctic) (EEA, 2013, DRAFT).

The EU´s Seventh Framework Programme for Research and Technological Development (FP7) as well as several EC service contracts are contributing to better inform the development of the EU Adaptation Strategy in the areas of mainstreaming and potential policy instruments. In addition, sectoral guidelines for several EU policy areas highlighted in the White Paper have been or are currently developed.

One major achievement for future mainstreaming is laid down in the next Multi-annual Financial Framework (MFF). The Commission has committed that climate related expenditures will represent at least 20% of the overall EU budget and will be tracked according to a specific methodology.

The various legal proposals for sectoral instruments adopted for the MFF emphasize the mainstreaming of climate action into the next budget, in particular in the field of cohesion

[107] http://climate-adapt.eea.europa.eu/web/guest/eu-sector-policy/general

policy, agriculture, energy and transport infrastructures, research, innovation and competitiveness, external policies. Furthermore, the proposal for a dedicated LIFE instrument includes a specific sub-programme on climate action benefiting from substantial budget increase.

In particular, the MFF includes proposals for major funding policies and financial instruments, such as Structural Funds, the Cohesion Fund, the CAP (Common Agricultural Policy), TEN-T (Trans-European Transport Networks) and TEN-E (Trans-European Energy Networks), Interreg, LIFE+, HORIZON 2020 (the future research policy) and the legislative and non-legislative developments related to those.

With regard to pillar 3, the EC has launched several studies to identify policy instruments suited for adaptation purposes and to develop specific guidelines (e.g. for CAP and Cohesion under the next financing period). Further, stakeholder involvement has been taken place with the private sector on specific issues, such as standards and insurance.

Both for engaging with the private sector and working in partnerships with the Member States (pillar 4) an Adaptation Steering Group (ASG) was created in September 2010 to assist the Commission in developing its approach to dealing with adaptation. The Steering Group brings together Member States and a diverse range of stakeholders, including business organisations and NGOs. The Group met 6 times between September 2010 and June 2012.

For strengthening the international co-operation on adaptation, the proposed review of the EU Environment Integration Strategy presents a good opportunity to emphasise the need for integrating adaptation needs, as will the Mid-Term Review of EC cooperation strategies. Further, emphasis is put on early warning systems and integrating climate change into existing tools such as conflict prevention mechanisms and security sector reform. Adaptation is also being brought into the dialogue with European Neighbourhood Policy (ENP) partner countries and the regular "Energy, Transport, Environment" sub-committees offer a forum for structured dialogue. Under the UNFCCC the EU is taking an active role in the negotiations to ensure adaptation issues are adequately dealt with in a post 2012 agreement.

3.3.2 Member States´ efforts

3.3.2.1 Member States with a National Adaptation Strategy adopted (Status: January 2013)

15 EU Member States have adopted a national adaptation policy (strategy and/or plan) so far. Overall, the National Adaptation Strategies (NAS) that currently exist for European Member States are comprehensive and well-established. Some set out concrete action plans, namely Austria, Denmark, Finland, France, Germany, Malta and Spain. The Belgian, Portuguese, Irish and Lithuanian NAS are comprehensive but do not include action plans. The Netherlands NAS, while comprehensive, states that it is a preliminary document setting out the first steps towards an agenda for a climate-resilient Netherlands. All NAS appear to

be intended as evolving documents which will be reviewed and updated to take account of advancing climate change science, research and technology.

A brief analysis of the existing NAS is given in the following:

Legal framework; mandatory and voluntary actions

Each of the National Adaptation Strategies (NAS) has been directed by government; therefore it is considered that the Member State is committed to delivering all actions outlined in the NAS. However to provide further detail on the types of actions, mandatory actions are defined as those which have a specific legal requirement or policy commitment (e.g. relating to the Water Framework Directive). Voluntary actions are those without a specific policy commitment (e.g. general awareness raising activities). However, this is not always made explicit.

Action plans

8 of the NAS in place have action plans of varying levels of detail. The Finnish NAS assigns timeframes and owners to the adaptation actions, which are categorised by sector. The German NAS is accompanied by an action plan which commits to concrete steps in its further development and implementation. It follows an integrated approach which takes account of the interactions between sectoral and regional activities and strives to anchor consideration of the possible impacts of climate change in all relevant policies. The Austrian NAS is accompanied by an action plan. It focusses on the implementation of the recommendations for action of the 14 fields of activity in the strategy. In some cases the NAS provides a framework for developing a National Adaptation Plan (NAP), e.g. Belgium, Portugal, Ireland and Lithuania. The Dutch NAS recognises that a framework for assessing adaptation actions is the ‘missing link’, but the Delta Programme has been commissioned to fill this gap.

Transboundary and international issues

Only two of the NAS in place consider transboundary issues, i.e. those issues affecting neighbouring countries: Belgium and Ireland. The Belgian NAS mentions the cross-border SCALDWIN project (2009-2012) which aims to identify the best measures available for an improvement of the ecological status of surface water and groundwater, and a promotion of biodiversity in the Scheldt basin. The TIDE project (2010-2013) focuses on a better knowledge of the ecosystem functioning and a coherent management of the estuaries including the Scheldt (BE/NL). The AMICE project (2009-2012) is a transnational project about the adaptation of the Meuse and its catchments to the impact of flooding and low waters due to climate change. The Future Cities - project (2009-2012) aims at making city regions in Northwest Europe fit to cope with the predicted climate change impacts.

The north and south of the island of Ireland already work together on cross-border issues including river basin management plans under the Water Framework Directive, marine and coastal management. Existing cooperation is identified as an opportunity to develop a trans-boundary approach to implementing adaptation actions.

While the Maltese NAS does not make significant reference to transboundary issues, it highlights that the Environmental Impact Assessment regulations can address the transboundary effects of a development project and sets out the procedures to be followed when a project is likely to have a transboundary impact. Lithuania's strategy recognises that the Baltic Sea Region is the most at risk from climate change and prioritises the importance of the implementation of adaptation actions in this area which is also shared with other Member States. It's involvement as a partner in the project "Baltadapt" (2007-2013) also shows working in a transboundary capacity.

In contrast 10 of the NAS consider international issues: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Malta, Netherlands and the United Kingdom. For example, the international focus is very important for the ARK programme in the Netherlands, both in terms of the development of knowledge and policy. Knowledge will be developed in a manner consistent with international programmes and initiatives such as Climate Impact Research Coordination for a Larger Europe (CIRCLE), Biodiversity Requires Adaptation in Northwest Europe under a Changing Climate (BRANCHE) and European Spatial Planning: Adaptation to Climate Events (ESPACE). The projects of the EU's Sixth Framework Programme will also be involved. The Finnish NAS contains a chapter on the need to adapt to changes taking place in other parts of the world, including the adaptive capacity in different countries; the interrelationship between the global impacts and adaptation to climate change in Finland; financial measures and mechanisms and connections between adaptation and reduction of emissions. The NAS recognises that climate change will bring challenges in the planning of Finland's development cooperation. International supply issues, for example concerning food and water, by contrast are only mentioned in two NAS (Finland and Belgium). Ireland's NAS identifies Irish Aid and the support programmes it funds for developing countries to build adaptive capacity.

Governance structure for implementation

14 NAS have been directed by government. This explains why they are being implemented (or will be implemented) by government / inter-ministerial committees or working groups, e.g. Austria, Finland, Germany, Ireland, Netherlands, Portugal and Spain. The objective of these working groups is to create a forum for cross-department working, as well as to reach out to businesses and citizens at the national, regional and local levels. In the Netherlands, the State wishes for all parties, including government bodies, the business community, scientists, and civil-society organisations, to share in the responsibility for implementing the NAS. In Belgium, it is foreseen that the future NAP will be based on a bottom-up approach, building on the plans already developed by the regions of Walloon, Flanders and Brussels. A number of regional committees are already bringing together the sectors. This will result in the federal government working closely with regional government to ensure effective implementation and follow-up (monitoring and evaluation). This approach confirms an acceptance of adaptation as something that must be implemented by stakeholders at all levels and in all

areas of society, and not something to be pursued in isolation of other policy objectives, programmes and services. Adaptation is an emerging policy area and it is important for government (national or regional) to facilitate dialogue with the relevant stakeholders and to be seen to be leading by example until adaptation becomes firmly embedded. In Denmark, the central government plays less of a role and NAS development and implementation is driven by the municipalities. The Lithuanian strategy sets deadlines and defines responsible authorities as part of its integrated adaptation and mitigation management policy and associated implementation.

Integration and mainstreaming

Each of the NAS has been developed with sectoral focus, reflecting the need for Cross-Government Adaptation Working Groups to drive implementation. Integration and mainstreaming adaptation with existing national programmes and policies is central to each of the NAS. For example, the objective of the Spanish NAS is to mainstream adaptation to climate change in the planning processes of all the relevant sectors or systems. To achieve this, it is important that the development of the Plan becomes a major collective project with the participation of all institutions and key players. In Finland, some government departments have already developed adaptation plans of their own, e.g. Ministry of Agriculture and Forestry, to assist with integrating and mainstreaming adaptation in other policy areas. The French NAS outlines a number of cross-sectoral initiatives, e.g. Club ViTeCC connects local policy makers with scientists involved in adaptation, thus addressing the need for information on the local climate impacts and for funding innovative projects; indeed ‘cross-cutting actions’ is one of the 20 thematic areas outlined in the NAS. The German NAS follows an integrated approach which takes account of the interactions between sectoral and regional activities and strives to anchor consideration of the possible impacts of climate change in all relevant policies. The German NAS is intended to supplement and support other cross-sectoral strategies such as the National Strategy for Biological Diversity. In other Member States, integration and mainstreaming of adaptation is a key pillar of the NAS, including in Austria, Denmark, Norway and the Netherlands. The Lithuanian NAS takes an integrated approach at the regional level to optimise inter-sectoral interaction.

Communication and awareness raising

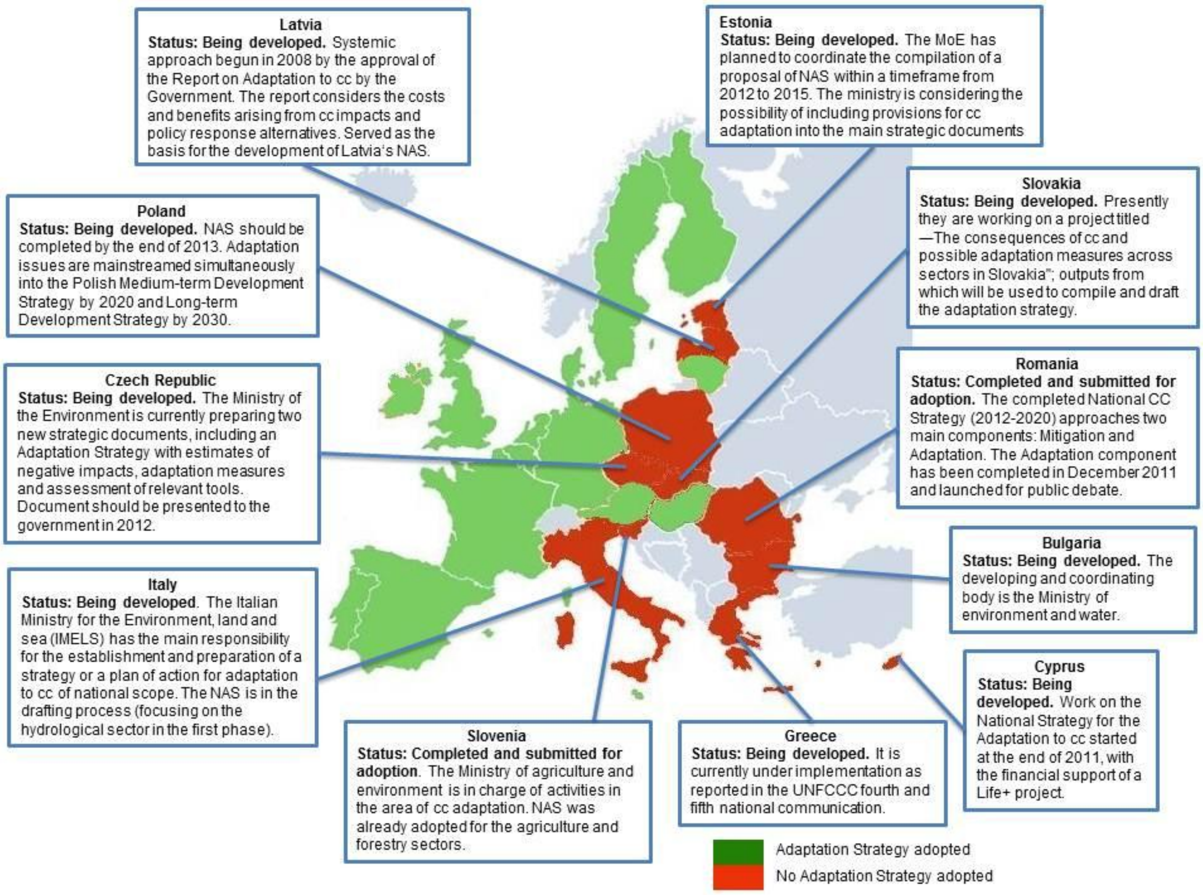
As with integrating and mainstreaming adaptation, communication and awareness raising is another key principle of each of the NAS. Member States acknowledge that without effective communication and awareness raising, the NAS will not be successful. For example, the Spanish NAS states “*the NAP will not be effective unless its existence, progress and results are disseminated and communicated to stakeholders*”. In Portugal, awareness raising and knowledge dissemination are one of four objectives; in Norway, communication is one of three key principles. The Dutch NAS centres on three work packages, all of which depend on awareness raising and communication. During the preparation of the Austrian NAS a key focus was on the participation process with all relevant key stakeholders on the national, regional and partly local level in order to ensure awareness and ownership of the stakeholders responsible for implementation at a later stage.

Communication is also inherent in many of the actions outlined in the NAS. In France, four thematic groups explicitly addressing communication have been created. These are: information, education and training, research and governance. The success of other actions depends on effective communication, e.g. the National Flash Flood Plan. Finally the Cross-Government Working Groups which have been created will also facilitate communication and awareness raising. Ireland's NAS includes the development of a Climate Information Platform which will develop a website that will raise awareness as well as provide tools and guidance to support implementation. Lithuania will also develop its Web portal on adaptation in accordance with it's Action plan for the period of 2013-2020.

3.3.2.2 Member States with a National Adaptation Strategy under preparation (Status: January 2013)

Most of the Member States with currently no National Adaptation Strategy adopted are in the course of developing one. Figure 53 provides an overview of efforts undertaken.

Figure 53: Member States´efforts in developing a NAS (EAA, February 2013)



Bulgaria is preparing a NAS. The developing and coordinating body is going to be the Ministry of environment and water.

In **Cyprus**, work on the National Strategy for the Adaptation to Climate Change started at the end of 2011, with the financial support of a Life+ project. A report on the observed changes and responses to climate change in Cyprus will be concluded in 2012, while the impact, vulnerability and adaptation assessment report for the case of Cyprus is under development. More specifically, detailed research is being carried out for this report at sectoral level (Water resources, Biodiversity, Coastal areas, Agriculture, Forestry, Fisheries and aquaculture, Tourism, Public Health, Energy and Infrastructure.)

In the **Czech Republic**, the National Programme to Abate the Climate Change Impacts (hereinafter, the National Programme) presents the climate protection strategy of the Czech Republic and contains greenhouse gas emission reduction goals, mitigation and adaptation measures. The Ministry of the Environment, together with other relevant ministries, is currently preparing two new strategic documents, including an Adaptation Strategy with estimates of negative impacts, adaptation measures and assessment of relevant tools. This document should be presented to the government in 2012. Priority sectors defined in the National Programme were water management, agriculture, forestry and health. These four areas remain the most important ones with regard to the adaptation action in the Czech Republic.

In **Estonia**, there is no comprehensive strategy for adaptation in place. However, a process for drawing up a NAS (NAS) has started and is coordinated by the Climate and Radiation Department in the Ministry of the Environment (MoE). Within a timeframe from 2012 to 2015, the MoE has planned to coordinate the compilation of a proposal of NAS including the collecting, analysing and prioritising of relevant data of climate change impacts and future scenarios in different sectors, sector-specific vulnerability analysis with proposing possible adaptation measures.

Italy does not have a NAS and/or a National Adaptation Plan (NAP) to date; it is in the process of drafting a first phase of its NAS (starting with what has already been done and focusing on the hydrological sector in the first phase). The Italian Ministry for the Environment, land and sea (IMELS) has the main responsibility for the establishment and preparation of a strategy or a plan of action for adaptation to climate change of national scope. The IMELS focuses on the integration (mainstreaming) of adaptation into sectoral policies, while Regional Governments are entrusted with the implementation of local plan of action for adaptation.

In **Poland**, the Council of Ministers decided in July 2009 on the development of the National Strategy for Adaptation to Climate Change (SAP), including vulnerability of sectors and the public to climate change and an analysis of the costs and benefits of the possible adaptation measures. According to this decision, adaptation strategy is now under elaboration and should be completed by the end of 2013. Adaptation issues are mainstreamed simultaneously into the Polish Medium-term Development Strategy by 2020 and In Long-term Development Strategy by 2030. The Government will adopt these two Strategies, probably in 2012.

In **Slovenia**, the Government Office of Climate Change (GOCC) prepared a draft Climate Change Act (CCA), which aims to establish inter alia the so-far missing legal basis for adaptation to climate change. It can thus be considered as equivalent to a NAS. Moreover, a NAS was already adopted for the agriculture and forestry sectors.

3.3.2.3 Member States for which the adoption of a National Adaptation Strategy remains uncertain (Status: December 2012)

In **Greece**, no NAS has been adopted as yet; however it is currently under implementation as reported in the UNFCCC fourth and fifth national communication. No further information is available at present.

In **Romania**, there is no NAS per se. Yet, in response to the EU “Green Paper- Adapting to climate change in Europe - options for EU action”, in 2008 the Ministry of Environment and Forests developed the Guide on the adaptation to the climate change effects. At present, the almost completed National Climate Change Strategy (2012-2020) will approach two main components: Mitigation and Adaptation. The Adaptation component has been completed at the end of December 2011 and launched for public debate. The Adaptation component from the National Climate Change Strategy (2012-2020) aims to provide an action framework and guidelines in order to enable each sector to develop an individual action plan in line with the national strategic principles. It proposes objectives which future actions should be designed to reach.

In **Latvia**, a systemic approach begun in 2008 by the approval of the Report on Adaptation to Climate Change by the Latvian Government. This advisory report identifies risks related to climate change (e.g. more often and powerful storms, floods, dryness, human health problems, loss or movement of animals and plants etc.) as well as advantages of climate change (e.g. a longer vegetation period and an increasing volume of precipitation which will allow to achieve higher and a more stable power generation from own hydro power plants). The report considers the costs and benefits arising from climate change impacts and policy response alternatives. It should have served as the basis for the development of Latvia’s NAS. Yet, due to a lack of institutional capacity and financial resources for relevant researches, the work is currently stopped.

In the latest national communication to the UNFCCC (5^{th}), **Luxembourg** disclosed that a strategy would be published, and adopted by the government by the end of 2011. It stated that: “it would capitalise on the various measures already in place, but are not yet complied and linked in an effective action plan.” [108] However, no official details of a NAS are available at present.

[108] http://unfccc.int/resource/docs/natc/lux_nc5.pdf

The **Slovak Republic** currently does not have a comprehensive NAS in place; however it is an on-going task for the Ministry of Environment. Presently they are working on a project titled “The consequences of climate change and possible adaptation measures across sectors in Slovakia"; outputs from which will be used to compile and draft the adaptation strategy.

3.3.3 Transnational, regional and local adaptation efforts

Many transnational cooperation projects on adaptation have been initiated over the last years. They are typically partially financed by EU-funds such as the Life+ and INTERREG programmes. INTERREG activities have been initiated in all regions in Europe. However most focus on North-West Europe and the Alps while less adaptation projects address the Mediterranean and Eastern Europe. An overview of on-going and finalized projects can be found on Climate-ADAPT[109].

INTERREG projects differ in scope and focus, nevertheless they share the advantage to deal with regional specifics and develop appropriate adaptation responses. They all very much focus on involving stakeholders on regional and local level aiming at gathering knowledge and specific needs from the regional and local communities and develop jointly feasible adaptation responses. Many of these transnational projects are set up with case study regions within the greater transnational cooperation area, where project results can be tested and discussed with regional and local stakeholders towards their practical applicability.

Results of INTERREG projects often also inform sub-national and national strategic initiatives and programmes or are even being integrated in legislation. UN Conventions as e.g. the Alpine and Carpathian Conventions are highly engaged with INTERREG projects and make use of their outcomes in a political context (e.g. Climate Action Plan under the Alpine Convention).

On local efforts, some information has been provided by Member States towards the countries webpages on Climate-ADAPT[110] on a voluntarily base end of 2011. Most of the local actions reported seem to be triggered by research programmes, either on national or EU level. Many EU Member States also established databases on their national climate change website that collect and present regional and local adaptation good practices. On the policy level, Denmark is particularly focusing its adaptation efforts on municipalities with all of them having to prepare climate change adaptation plans within the next 2 years.

A significant share of local adaptation activities takes place at city level. There are many examples of cities in Europe that have adopted adaptation strategies or action plans or are in the process of developing them. A number of cities or city regions have initiated specific

[109] http://climate-adapt.eea.europa.eu/web/guest/transnational-regions
[110] http://climate-adapt.eea.europa.eu/web/guest/countries

measures. It is also common to include adaptation measures in existing climate strategies or to develop strategies that cover both mitigation and adaptation. For example, Dublin's climate change strategy includes adaptation objectives that initiate, modify and improve existing policies, and in Finland several municipalities and regions have climate strategies that cover mainly mitigation but address also to some extent adaptation (EEA, 2013, DRAFT).

Several countries (for example CH, ES, FR, HU, NO, RO) have cities that form collaborative networks of climate change mitigation and adaptation activities with other cities. An example from Norway is a six-year collaborative programme between the government and 13 largest cities, "The Cities of the Future"[111]. In Spain, a network of cities for Climate (RECC)[112] has produced e.g. guidance for local authorities to identify vulnerabilities to climate change impacts and to promote adaptation. The purpose of these networks is to share experiences between cities and provide them with practical guidance on how to reduce their greenhouse gas emissions and how to adapt better to the impacts of climate change. Some of these networks have been created as a result of international projects, while some are initiated by national government bodies. In addition to local governments, networks can involve also researchers or NGOs as partners. In France, Club ViTeCC networks local policymakers with scientists and it is initiated by CDC Climate Research, ONERC and Météo France. The aim of the network is to make the results of academic and applied research on the economics of climate change usable and comprehensible to local decision-makers and their service providers (EEA, 2013, DRAFT).

City level adaptation has been addressed in detail in the EEA 2012 report ‘Urban adaptation to climate change in Europe’ (EEA, 2012a), which provides a wide range of examples of local adaptation action in various European countries.

3.3.4 Private sector engagement

Climate change will present businesses with a range of risks, which may significantly affect their business operations, their competitiveness, and their profits. Given that businesses face and are increasingly aware of these risks, the rational self-interest of businesses is most likely a major driver of adaptation actions.

Businesses are increasingly aware of the need to respond to climate change, both in operational and strategic terms. Climate change will have a range of impacts on businesses, including disrupting business operations, increasing costs of maintenance and materials, and raising insurance prices. In other cases, climate change may also offer new business opportunities for products and services that would help people to adapt, including e.g. water management technologies, healthcare, agricultural products, heat-resistant materials, building designs. Pressure for private sector engagement also comes from increasing

[111] http://www.regjeringen.no/en/sub/framtidensbyer/cities-of-the-future-2.html?id=551422
[112] http://www.redciudadesclima.es/index.php/

consumer demand for environmentally friendly products and governmental attempts to regulate environmental externalities. In the case of adaptation to climate change this could call for developing and propagating new products suited to future climatic conditions (e.g. cleaning products that require less water). In this context, preparing for the effects of climate change will become increasingly important as companies seek to maintain their current operations and competitive advantage. While understanding the current and potential role of the private sector in adapting to climate change is important, it is also crucial to identify the tools and policies that can be used to encourage their engagement (Agrawala, et al, 2011a).

Although private actions in response to climate change are primarily motivated by rational self-interest, they can also make significant contributions to societal resilience. On a basic level, private sector adaptation actions contribute to broader societal resilience (and reduce the need for the public sector to invest in adaptation measures).

The OECD hosted a Policy Forum on Adaptation to Climate Change in OECD Countries in May 2012, which brought together over 100 participants over two days with the second day addressing the challenge of engaging the private sector in adaptation. Discussions highlighted that while the traditional response to climate change has been to focus on the additional risks it poses, the private sector is increasingly interested in the new commercial opportunities arising due to climate change, such as new shipping possibilities due to reduced sea ice and increased agricultural production in areas that were previously not economically viable (Although this new economic activity does have to be balanced against the large expected losses due to climate change). The presentations also illustrated the range of new adaptation market opportunities which are arising. It was commented that companies are already starting to realise new commercial opportunities for products and services to help people and companies adapt to its impacts, including agricultural products, water management technologies, healthcare, logistics and transport, industry and manufacturing, and financial and consultation services.

The discussion at the OECD policy forum also covered multiple opportunities for the private and public sectors to collaborate to increase resilience and assist adaptation efforts. These include working together on: economic models and recommendations; technological responses to climate change; forecasting systems and climate models; early warning systems; new building codes and land use regulations; new standards for equipment and products; behavioural recommendations; making supply chains climate resilient; knowledge networks and information-sharing regimes; and design specifications for resilient infrastructure. Discussion highlighted some particular benefits and challenges for some public-private collaboration opportunities. While knowledge-sharing can be a “win-win” that benefits both the public and private sectors, it was stressed that frameworks are needed to encourage and enable such activities. Additionally, participants commented that commercial sensitivities around vulnerabilities and opportunities limit the private sector´s incentives to share information. Attendees also noted that businesses can use their experience in marketing and product development to steer consumer behaviour and encourage the use of products suited to future climate conditions (such as cleaning products that require less water). Additionally, businesses can use their procurement power to require that their supply chain is resilient and environmentally and economically sustainable, and that in turn this gives rise to new commercial opportunities for industries and suppliers to develop operations in climate-resilient locations.

3.3.5 Ecosystem-based adaptation

Ecosystem-based approaches to climate change adaptation use biodiversity and ecosystems as the central underpin to the development of adaptation strategies. Such strategies seek to sustainably manage, conserve and restore ecosystems to reduce their vulnerability and build their resilience to climate change impacts, so that they continue to function and provide the services that allow people to adapt to climate change. Ecosystem-based adaptation also contributes to climate change mitigation by conserving and enhancing carbon stocks, and reducing emissions caused by ecosystem degradation and loss.

Ecosystem-based adaptation can be implemented in programmes and projects at regional, national and local levels to bring multiple social, economic, and environmental benefits. The approach engages people and contributes to building responsibility and partnerships, and allows the integration and maintenance of traditional and local knowledge and cultural values. A recent study for DG ENV assessed the potential of ecosystem-based approaches to climate change adaptation and mitigation in Europe[113].

There are powerful economic and social, as well as environmental, arguments for taking action to manage, restore and protect biodiversity. The Ecosystem Approach provides multiple benefits, is cost-effective, accessible to all, and can be aligned with and enhance poverty alleviation and sustainable development strategies. Ecosystem-based adaptation can provide cost-effective protection against some of the impacts of climate change. For example, coastal ecosystems, such as saltmarsh and barrier beaches, provide natural shoreline protection from storms and flooding, and urban green space can reduce the urban-heat island effect, minimise flooding and improve air quality and thus increase the overall quality of life (especially green infrastructure can address connectivity and enhance ecosystem functions) (Nurse, et al, 2010; EEA, 2012d). Planting trees, which are suitable for the respective location, on slopes can protect against soil erosion (mass movement).

Biodiversity and ecosystem services provide and represent a vital insurance policy against irreversible damage from climate change.

A project to develop adaptation indicators (Harley & van Minnen, 2010) assessed measures associated with the Bern adaptation principles (Harley & Hodgson, 2008) in terms of their suitability for individual indicator development and relevance to the biodiversity sector and six associated sectors. This enabled ’high-level’ categories of process-based and outcome-based indicators to be prioritised. These were used by a subsequent EEA project (Smithers,

[113] http://ec.europa.eu/environment/nature/climatechange/pdf/EbA_EBM_CC_FinalReport.pdf

et al, 2011) to prepare the ground for embedding an agreed set of indicators into relevant EC and Member State policies. The project report summarises relevant on-going policy initiatives at an EU level that may have a direct bearing on development and synthesis of biodiversity adaptation indicators. It highlights that there is an urgent need to undertake an in-depth review of the complete spectrum of EU indicators in relation to the high-level biodiversity adaptation indicator categories (and vice versa) to identify those that are relevant by policy area and associated data issues, and where existing indicators need to be modified or new indicators developed.

Appropriate development of biodiversity adaptation indicators, involving stakeholders from across all policy areas, could do much to promote and secure common understanding of and commitment to ecosystem-based adaptation. It would bring cross-sectoral attention to the impacts and dependencies of each policy area on biodiversity, and the associated threats and opportunities that could be addressed by integrated actions that not only support biodiversity but also achieve required sectoral outcomes.

3.4 Autonomous adaptation across sectors

Autonomous adaptation comprise actions that will be taken ‘naturally’ by private actors such as individuals, households and businesses in response to actual or expected climate change, without the active intervention of policy. Many autonomous adaptation decisions are rather taken under short-term perspectives as a reaction to the way climate change is experienced. Climate variability and in particular extreme weather, such as summer heat waves or storms, are likely to constitute important signals, alongside the dissemination of knowledge and information (Stern, 2006). Yet, adaptation activities seem not spread evenly across sectors based on the literature review undertaken and stakeholder exchanges. The seemingly little activity in terms of adaptation to climate change in some sectors may also be a result of no written information available or easily accessible though. Sectors with high levels of activity are those which tend to be most affected by current weather variability and extremes, e.g. the water sector as well as agriculture.

Many actions in response to environmental change also appear not to be purposely undertaken as adaptation to climate change or current weather variability. Still, one can argue, that many of these activities, although triggered by a different purpose, can be regarded as adaptation activity. Drivers of autonomous adaptation action can be manifold, including real or perceived climate change, extreme weather events (mostly severe flooding), risk management and cost savings, competitive advantage (e.g. towards costumers through “greening” businesses) and exploring opportunities.

Other than human systems, natural system autonomous adaptation is obviously exclusively reactive. Biodiversity & ecosystems may adapt autonomously, if other conditions are favourable as adaptation will be limited by land use, dispersal ability and the availability of suitable habitat. A hierarchy of species responses can be identified: behavioural responses (birds that stay longer in some areas, change their migration patterns or don't migrate at all), population dynamic responses, adaptive genetic responses, spatial responses and macro evolutionary responses (EC, 2009b).

Due to the cross-sectoral and transboundary nature of climate change there are inherent shortcomings of autonomous adaptation without any policy steering, in particular to avoid “mal-adaptation” and/or adverse effects on other sectors. Taking into account that autonomous adaptation is undertaken in the main by the private sector (and in unmanaged natural ecosystems) there are several barriers and limits that hinder (cost-) efficient adaptation.

Main barriers to adaptation for private actors include (Stern, 2006):

- Uncertainty and imperfect information:

Without a robust and reliable understanding about the likely consequences of climate change, it is difficult for individuals – or firms – to weigh up the costs and benefits of investing in adaptation. Uncertainty in climate change projections could therefore act as a significant impediment to adaptation.

- Missing and misaligned markets:

Autonomous adaptation is more likely when the benefits will accrue solely – or predominantly – to those investing in adaptation. Even if the benefits of adaptation can be realised over a relatively short time-horizon, unless those paying the costs can fully reap the benefits, then there will be a barrier to adaptation. For example, there will be little financial incentive for developers to increase resilience of new buildings unless property buyers discriminate between properties on the basis of vulnerability to future climate.

Some adaptive responses not only provide private benefits to those who have paid for them, they also provide benefits – or positive spillovers - to the wider economy. In such circumstances, the private sector is unlikely to invest in adaptation up to the socially desirable level because they are unable to capture the full benefits of the investment.

- Financial constraints:

Upfront investment in adaptive capacity and adaptation actions will be financially constrained for those on low incomes. It will be the poorest in society that have the least capacity to adapt. Thus, the impacts of climate change could exacerbate existing inequalities by limiting the ability of poor people to afford insurance cover or to pay for defensive actions.

Further issues across sectors have been highlighted already by the Impact Assessment for the White Paper (EC, 2009c) and are still valid to address:

- Autonomous adaptation actions by farmers can counteract and even reverse some of the potential impacts of climate change which do not consider changes in agricultural management, technological progress and trends to better farming practices adaptation. However in some cases, autonomous adaptation options will also interfere with agri-environmental processes, and could lead to an increased use of pesticides to cope with more emerging and increasing pests, diseases and weeds, an increased use of mineral fertilisers[114] to compensate for a loss of soil fertility, an increase in irrigation, as well as in extreme cases land abandonment (when changes in climatic conditions or frequent extreme events difficult agricultural activity). Biotechnology developments, such as drought-resistant varieties requiring less water, or varieties requiring less fertiliser may offer a solution for some problems, but will have to be used under application of the EU regulatory framework.

[114]The implications of climatic changes on use of fertilisers are very uncertain and will depend on the site-specific effects on agriculture. While fertilisation could increase following expectations of better yields (and the contrary), the shortening of crop cycle in parts of Europe may lead to a decrease of nitrogen fertilisers.

- Increased forest productivity in some regions, together with provisions for climate change mitigation (increased use of biomass as a renewable energy source) may increase the stress on non marketed vital services (such as conservation of biodiversity and protection against avalanches or water pollution). Lost forest ecosystem services (windbreaks, irrigation networks, large scale erosion protection, dams and dikes) will often be substituted by building grey infrastructures to replace, which may result in a mal-adaptation to be avoided.

- Autonomous adaptation consists in adapting to new and constantly changing conditions for fishing. This creates the risk of the development of unregulated fisheries and early measures need to be taken to manage emerging fisheries, which will results more cost-effective than try later to reverse over-fishing. The increased access in the Arctic due to reduced ice cover is a specific case of 'new' resources becoming available to fisheries which need specific mechanisms to distribute access.

- Adaptation of energy supply system to CC impact may trigger building new infrastructure for the protection of existing infrastructure, as well as building new power plants and distribution grid. These projects will have substantial environmental impacts, to be addressed under environmental impact assessment (EIA), and should be compared with alternative solutions such as energy efficiency improvement and infrastructure protection through green structural approach.

- Regional and local authorities may plan to support industry and services most affected e.g. by water or snow scarcity by financing investments in water supply or snow-making equipments, together with helping relocating activities in more favourable areas. Both categories of projects will have substantial environmental impacts, to be addressed under environmental impact assessment.

- Finally, the building of infrastructure to protect from sea level rise or floods, while ensuring that land use can be orderly planned, houses built and transport infrastructure maintained, tends to disturb the natural dynamic nature of coastal and river systems. Maintenance costs are high and the ecosystem services are negatively affected. Hence, we see in many countries a shift towards a more flexible approach that works with the natural processes instead of against it. Examples are the now often used sand nourishments, buffer zones (setback lines) and managed realignment of the coast.

The above highlighted indicative issues mainly suggest the need for mainstreaming climate change adaptation in all concerned sectoral policy areas with the imperative to ensure policy coherence. This can best be done at EU level in cooperation with Member States to provide for a comprehensive policy framework for adaptation. This would also include the public sector´s policy mandate to further encourage the private sector to act, especially through providing relevant and easy accessible information, raising awareness and better communicate the need for adaptation. Vice versa, there is also a need to enable experience exchange and learn from private sector´s approaches for e.g. risk management and market opportunities (cf. chapter 3.9.6).

3.5 Policy context

3.5.1 Economic sectors and systems

3.5.1.1 Agriculture

The European Common Agriculture Policy is the principle policy driving agriculture development. One of the main three aims of the next CAP for the period 2014-2020, currently being discussed with the Council and the Parliament, is to manage natural resources more sustainably and to enhance farmers' resilience to the threats posed by climate change. A climate resilient agriculture is one of the 6 key priorities for the future rural development policy. Within the current Commission proposal, MS are obliged to implement actions related to the six priorities but they may put more emphasis on certain ones according to their situation and priorities. Adaptation is also an aspect to be taken into account when assessing the specific needs of the other five priorities as climate change is considered a cross-cutting issue. However it should be noted, that this proposal will be further discussed with Member States and the EU parliament. It is important to ensure that the existing adaptation measures are not weakened.

In light of the perceived climate variability that will take place in Europe, farmers are already implementing adaptation activities on their own, e.g. changing crop types to ones requiring less water, adjusting growing seasons to maximize harvests and switching to more efficient irrigation systems and schedules.

There are a number of measures in the next CAP under rural development that will help to further existing adaptation efforts in the agriculture sector, ranging from knowledge transfer and advisory services to farm development and disaster relief and agri-environment-climate measures.

3.5.1.2 Forestry

Forests can contribute both to the Lisbon objectives concerning economic growth and competitiveness as well as to the Göteborg objectives concerning the conservation of natural resources. Currently there is no common EU policy but forestry is regulated by a number of legislative acts and policy documents developed in other policy areas/sectors like "the Common Agriculture Policy and Rural Development", NATURA 2000 regulations, plant health[115] and renewable energy regulations.

[115] Please note that the main objective of EU plant health legislation is not to control pest but to protect the safety of food derived from plants and to secure the health and quality status of crops. It therefore regulates the trade of plants and plant products within the EU as well as imports from the rest of the world in accordance with international plant health standards and obligations. It also sets rules for the sale and use of plant protection products, or pesticides and sets standards to monitor and control pesticide residues. It implements preventative measures to guard against the introduction and spread of organisms harmful to plants or plant products within the EU. It also ensures quality conditions for the sale of seeds and propagating material within the EU.

The EU Forestry Strategy (currently in review as recommended by the White Paper on adaptation to climate change (EC, 2009a)) constitutes an EU policy document on forests which should be considered as a basis for joint EU and Member States actions The proposed strategy tries to integrate these different policies into an overall strategic framework In the final report of the ad-hoc Working group of the Standing Forestry Committee recommends that the new EU Forest Strategy "*should be a voluntary instrument, building on subsidiarity, including agreed lines of added value at the EU level with Member States (policy guidance on certain specified topics and for actions) and identifying other areas where some Member States would like to advance further, such as: … climate change adaptation and mitigation*".

Furthermore, there are international commitments which affect forests (binding and not binding), to which the EU and its MS are parties and are obliged to implement them, like CBD, CCD, UNFF process, Forest Europe process, the negotiations on a legally binding agreement (LBA) on forests in Europe, to be launched at the end of February 2012. Most of these initiatives, if not all, address climate change.

3.5.1.3 Transport

Regarding EU transport policies, the majority do not explicitly address the climatic pressures (e.g. increase of temperature) and impacts which can be expected in the future as potentially harming transport infrastructure. However a few policy implementation reports (e.g. Fifth report on economic, social and territorial cohesion (EC, 2010r)) are highlighting the need for climate change adaptation of transport infrastructure. Other policies include mechanism or technical standards which are of importance in terms of adaptation (e.g. Directive on River Information Services requests for implementing information services and providing information on navigation, water level etc.). In addition, adaptation can be integrated in existing policies dealing with new infrastructure projects to ensure climate-proofed infrastructure. In case of the TEN-T-Guidelines[116], adaptation to climate change has been integrated in the proposal for revision.

3.5.1.4 Construction and buildings

Existing EU policies related to buildings do not explicitly address the climatic pressures (e.g. increase of temperature, storms, salt water intrusion) and expected future impacts. Where the climate is taken into account, this is mainly referring to mitigation (e.g. EU Directive on energy performance of buildings) and the relation to the fulfilment of the Kyoto 2°C target.

Since 1975 the European Commission in cooperation with CEN has been developing Eurocodes (Commission Recommendation on Eurocodes[117]), a set of unified international codes of practice for designing buildings and civil engineering structures, which so far likewise do not incorporate the aspects of future changes of climatic conditions. However,

[116] http://ec.europa.eu/transport/infrastructure/connecting/doc/revision/legislative-act-ten-t-revision.pdf
[117] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:332:0062:0063:en:PDF

integrating adaptation in Eurocodes would be an effective method of improving climate resilience of the built infrastructure in Europe since Eurocodes are gradually being transposed into national standards and they are applied in public procurement (see also policy option under chapter 6.5.3.1). Adaptation can also be integrated into the design of new urban development (Altvater, et al, 2011a).

The EU Strategy for the sustainable competitiveness of the EU construction sector mentions climate change as an important challenge for the sector to meet (Ecorys, 2011).

3.5.1.5 Energy

EU main climate policy actions with relevance for adaptation so far were on mitigation and thus demand[118] and the promotion of renewable energy production. Parts of it show high synergies with adaptation, but should be more focussed (cf. cut-off in demand peaks) while other policies for energy supply and transmission/distribution should acknowledge adaptation needs and mainstream adaptation goals and measures into their realm.

Adaptation in the energy sector has a high mainstreaming potential into existing energy policies and initiatives and due to the fact that decisive developments at a general level are taking place right now:

- The smart grid initiative with a high potential to mainstream adaptation with respect to the transmission of electricity. The smart grid initiative as well as the internal energy market shall enable competition, energy efficiency and security. This means a much higher rate of transported energy (basically electricity), for which the infrastructures must be climate resilient, if proper and reliable functioning shall be ensured.

- The expansion of renewable energy with the potential to mainstream adaptation ex ante into the construction and design of new energy production plants. Since renewable energies show very different and more complex vulnerability patterns, new challenges are placed on their secure and efficient operation. For example, the vulnerability patterns for the conventional energy mix (thermal, nuclear) is basically dependent on temperature and run-off (cooling water), the envisaged new energy mix has a higher complexity with respect to vulnerable climate parameters (e.g. solar radiation, wind speeds, precipitation patterns and midterm changes in river run-off regimes are crucial).

- The energy efficiency policy goals with a high potential of adaptation related to the cut-off of demand peaks during extreme weather periods (mainly heat waves/droughts, but also regional cold spells) as these are the forthcoming drivers for

[118] Cf. energy labelling and regulations and directives like directive 2010/31 on the energy performance of buildings (EC, 2010g), directive 2006/32 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC ("The Energy Services Directive") (EC, 2010j) or regulation (EC) No 106/2008 on a Community energy-efficiency labelling programme for office equipment (Energy Star) (EC, 2008m).

cascadal impacts which might ultimately lead to black outs – at least across southern Europe

3.5.1.6 Disaster Risk Reduction

3.5.1.6.1 Linking DRR and adaptation to climate change

Between and within countries, risk is determined not only by the severity of the hazard (for climate hazards cf. chapter 3.1.5) but also by the concentration of people and assets in hazard-prone areas and their vulnerability to the hazard. Countries with different levels of social and economic development experience radically different levels of risks, even when they are exposed to the same hazard (UNISDR, 2009a).

The potential for a hazard to cause a disaster mainly depends on how vulnerable an exposed community is to such hazards. The recently published special report by IPCC on 'Managing the risks of extreme events and disasters to advance climate change adaptation' (IPCC, 2012b) considers exposure and vulnerability to be key determinants of disaster risk. Some of the drivers and causes for disaster risk are:

- Population growth, leading to settlements in areas with a higher risk potential;
- Economic growth: Assuming that the European economy will grow during the 21st century, economic risk will equally increase. According to a study on four economic scenarios for Europe for 2040 (Lejour, 2003) annual GDP growth in the scenario period lies, on average, between 0.6% and 2.5%;
- Human technology and behaviour (nuclear plants, chemical industry, clear-cutting of forests, spilling freshwater resources, arson).

Extreme and non-extreme weather and climate events also affect vulnerability to future extreme events, by modifying the resilience, coping capacity, and adaptive capacity of communities, societies, or social-ecological systems exposed to such events. In particular, the cumulative effects of disasters at sub-national or local levels can substantially affect livelihood options and resources and the capacity of societies and communities to prepare for and respond to future disasters (IPCC, 2012b).

For knowledge on disasters we can draw on two research communities: Climate Change Adaptation and Disaster Risk Reduction. The policy link between disaster risk reduction and climate change adaptation has only emerged since adaptation to climate change has grown in popularity (Schipper, 2009). Both communities focus on society-risk dynamics. However, each field does so through different actors and institutions, and with different time horizons, policy frameworks and patterns in mind (Schipper, 2009).

- Climate Change Adaptation (CCA) as defined by UNISDR is “the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.” (UNISDR, 2009b).

CCA is a long-term strategy, which focuses on increasing social capacity and physical infrastructure to address the changes of a future climate.

- Disaster Risk Reduction (DRR) is defined by the UNISDR as “the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.”(UNISDR, 2009b).

Given the two definitions, DRR is a means to adapt to climate change impacts instead of an entirely separate field, since reducing the risks of disasters and natural hazards is an effective long-term form of adaptation. DRR “is therefore tailor-made to help counteract the added risks arising from climate change” (UNISDR, 2008b). CCA and DRR both require long-term strategies with upfront investment to properly prepare and minimize future risk of disasters. Both focus on taking proactive steps towards reducing risks and adapting instead of simply responding to events. (UNISDR & EUR-OPA, 2011)

However, the definitions and scope of both CCA and DRR are subject to considerable discussion within and across the communities of scientists, practitioners and policymakers. One of the most obvious distinctions is that disaster risk reduction addresses all types of hazards, including geological hazards and technological hazards, while climate change adaptation is only focused on the dynamics of climate. In reality, disaster risk reduction and adaptation are both equally concerned with the developmental patterns and customs that exacerbate or reduce risk posed by bio- and geophysical systems to society. Climate change is a multivariable process that involves both incremental changes in biophysical variables and processes as well as ‘extreme events’. Climate change also affects societies’ and communities’ vulnerability to hazards, through changes in inherent dynamics. From a disaster risk reduction perspective, therefore, climate change affects both the hazard and vulnerability side.

Examination of the overlaps between adaptation and disaster risk reduction highlights striking differences (Schipper, 2009). These are particularly related to terminology, actors involved and types of interventions. Not only are there a number of key terms that are used and understood differently in the two communities, but there is also separate technical language, particularly in the climate change field. The term ‘response’, for example, is used only to refer to post-event action in a disasters context, but is a general term to reflect action taken to address climate change, either in anticipation of expected impacts or in reaction to experienced impacts. Adaptation as a ‘response’ sounds strange to a disaster risk reduction expert, because adaptation is considered to be a process to reduce risk of impacts, something which for disaster risk reduction experts comes before an impact, whereas response comes after. Because of this link with adaptation, it is increasingly suggested that DRR practitioners do more forward-looking scenario planning, rather than conduct planning merely based on historical occurrences of hazards. In this sense, "response" has the connotation of proactive action.

Another significant factor that currently separates adaptation and disaster risk reduction is the difference in levels of governance and actors involved in both formulation and implementation of interventions. Because of the differences in the governance of adaptation and disaster risk reduction, and the legislative and practical ways in which they are implemented, the formulation of interventions is not necessarily comparable either, particularly with regard to the time horizon. This is in part because adaptation is a long-term process of adjustment to both extreme events as well as incremental changes. Changes do not only have to be negative; adaptation can also aim at taking advantage of new, positive circumstances. On the other hand, disasters are by definition disruptive events, which generally take place over a short period of time and require immediate action.

Schipper (2009) also summarises similarities between adaptation and disaster risk reduction approaches:

- Adaptation to climate change and disaster risk reduction are both approaches to reducing risk posed by hazards before and after they occur. Post-impact disaster risk reduction is about thinking ahead to the next hazard and learning lessons from the impact and post-impact adaptation is about this as well as making the best of the situation;
- Adaptation to climate change is about reducing vulnerability to climate hazards; disaster risk reduction is about reducing vulnerability to all natural hazards. For both the emphasis is on vulnerability reduction;
- Development lies at the heart of both adaptation and disaster risk reduction;
- Adaptation and disaster risk reduction are seen as holistic, long-term processes and are not ‘quick-fix’ approaches;
- Community-based adaptation is currently one of the only areas where adaptation is taking place on the ground. It has close links with similar disaster risk reduction efforts in communities;
- Environmental degradation is an important challenge to both adaptation and disaster risk reduction.

Both DRR and adaptation need to focus on the local level in terms of effective risk management. Local-level experiences can be considered the front-line of impacts from hazards and extreme events, thus they can provide important insights on the most urgent challenges associated with extreme weather events in a changing climate. An example of these insights is that non-climatic factors, such as development levels, inequality, and cultural practices play a critical role in extreme events. Vulnerability reduction is thus recognized as an important strategy for reducing disaster risks. In addition, learning from case studies addressing both disaster risk and climate change adaptation can inform EU level decision making in terms of supporting actions to enhance resilience.

Research has shown that scientists need to collaborate more closely with local knowledge networks and take into account people's risk perceptions, as well as the decision-making processes these communities use. However, reducing disaster risk and vulnerability also requires close interaction between scientists who produce knowledge about changing patterns of risk and researchers and practitioners who use such information for disaster risk reduction and climate change adaptation. Currently, the spatial resolution of many climate change projections is too coarse to enable effective disaster risk reduction at the local or regional scale. The gap between climate forecasts and projections and the needs of resource managers may pose some challenges to effective responses.

Although the relationship between climate change and extreme events remains uncertain, it is difficult to distinguish variability and changes in climate-related hazards from the impacts of long-term climate change. Improved knowledge on the linkages between extreme weather events and climate change (e.g. improved data on projected climate change impacts at community level) is needed and can facilitate strategies to reduce vulnerability.

Still, uncertainties (beyond climate change uncertainties) remain explicitly for

- The 'adaptation learning curve': Scenarios for e.g. autonomous adaptation are not existing;
- Economic and demographic development. The SRES scenarios (cf. Nakicenovic & Swart, 2000) comprise a number of plausible demographic, economic, technological and political scenarios oriented towards the global GHG output expected upon these scenarios, but are not operative on the level of *regional* economic and demographic pathways. For example, we have no scenarios for migration from or into risk-prone areas, the economic development therein and thus stocks and flows threatened;
- Evidence regarding how much ecosystems can protect communities from climate change and natural disasters.

3.5.1.6.2 Disaster Risk Reduction policies

In recent years, policies for disaster risk reduction and management have shifted from defence against hazards (mostly by structural measures) to a more comprehensive, integrated risk management approach.

During the 2005 World Conference on Disaster Reduction (WCDR), held in Kobe/Hyogo (Japan), some 168 States endorsed the Hyogo Framework for Action 2005-2015 (HFA), a 10-year plan for global disaster risk reduction efforts. The HFA is expected to deliver a substantial reduction in disaster losses, in terms of lives as well as in terms of the social, economic and environmental assets of communities and countries, by 2015. The Framework provides guiding principles, priorities for action, and practical means for achieving disaster resilience. The Hyogo Framework for Action presents five priorities for action:

1. ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation;
2. identify, assess and monitor disaster risks and enhance early warning;
3. use knowledge, innovation and education to build a culture of safety and resilience at all levels;
4. reduce the underlying risk factors; and
5. strengthen disaster preparedness for effective response at all levels.

The mid-term report (UNISDR, 2011) presents the findings of the Mid-Term Review of the Hyogo Framework for Action (HFA), analysing the extent to which HFA implementation has progressed and helping countries and their institutional partners to identify practical measures to increase commitment, resourcing, and efforts in its further implementation. The report highlights the significant progress that has been made over the past five years in disaster risk reduction and the fact that the adoption of the Hyogo Framework for Action in 2005 has played a decisive role in promoting this progress across international, regional, and national agendas.

HFA implementation at local level is a point highlighted throughout the Mid-Term Review and encompasses issues such as decentralizing authority, empowering local communities and creating a social demand for disaster risk reduction so that individuals realize their own share of responsibility in increasing their resilience and in holding governments accountable for the development and implementation of coherent disaster risk reduction plans and investments. The final sections of the report outline critical elements needed to enhance implementation of the HFA through 2015.

The Cancun UNFCCC Conference established the Cancun Adaptation Framework which invites parties to strengthen adaptation action in nine areas including “enhancing climate change-related disaster risk reduction strategies, taking into consideration the Hyogo Framework for Action; early warning systems; risk assessment and management; and sharing and transfer mechanisms such as insurance, at local, national, sub-regional and regional levels, as appropriate”. UNISDR's briefing note (UNISDR, 2010) on strengthening adaptation through DRR shows that adaptation relies on the reduction and management of climate-related disaster risks, and why both need to become central to development planning and investment. It builds on empirical evidence that illustrates how climate risks are constructed and which risks can be reduced cost-effectively. The World Bank's Global Facility for DRR has developed Country Adaptation Profiles and a Climate Knowledge Portal[119].

The European Union has already developed a set of instruments to address various aspects of disaster prevention, preparedness, response and recovery. These include, inter alia, the

[119] http://sdwebx.worldbank.org/climateportal/index.cfm?page=climate_country_adaptation

Community mechanism for civil protection (EC, 2001d), the European Disaster Risk Reduction Policies, the European Union Solidarity Fund (EUSF; EC, 2002c), and climate change adaptation efforts. These policies rely on systematic collection of information and data related to the frequency, extent and impact of natural hazards including floods. The Climate-ADAPT platform will also include DRR.

In the disaster response domain, the early mark in the field of **Community Civil Protection Mechanism** was set by the Council Decision of 23 October 2001 establishing the Civil Protection Mechanism (hereafter CCPM). The Commission Decision 2004/277/EC of 29 December 2003 laid down the rules for the implementation of the CCPM, defining its duties and the functioning of the various tools made use of. The EU Civil Protection Mechanism has lived up to its initial role of the co-ordination and facilitation of civil protection aid offers from Member States. In 2007, the European Council adopted a Decision 2007/779/EC, Euratom that substantially changed the Community Civil Protection Mechanism (EC, 2007i), introduced initially by the Council Decision 2001/792/EC, Euratom (EC, 2001d).

On 20 December 2011 the European Commission adopted a proposal (EC, 2011a) to revise the existing European Union's Civil Protection legislation[120] in order to ensure more effective, efficient and coherent disaster management and to shift from the current ad-hoc co-ordination to a pre-planned and predictable system. The proposal for a new Civil Protection Mechanism integrates the prevention policy framework with the preparedness and response actions within the Mechanism and requires Member States to communicate relevant risk management plans by 2016. Objective is also to enhance the overall EU level of preparedness for large-scale disasters through development of EU Emergency Response Capacity consisting of Member States' and EU-funded assets ready on stand-by for EU operations and improved planning in all stages of the disaster management cycle. The proposal is currently under discussion in the Council and the Parliament and will be adopted through the ordinary legislative procedure (completion of negotiations in EP and Council expected by end of 2013).

In 2008, the European Union's efforts in disaster risk reduction intensified with the EC Communication on Reinforcing the Union's Disaster Response Capacity (COM(2008)130) (EC, 2008n). The Communication highlighted the need for stepping up the Community capacity and effectiveness to respond to disasters, within and outside the EU. To do so, the EC proposed several tangible means for a better coordination of various EU/Community policies, instruments, services and players (at national, European and international levels). While the Communication focuses on the response to disasters, it acknowledges that a comprehensive approach to disaster management is needed comprising risk assessment, forecast, prevention, preparedness and mitigation. The Communication also laid out the plan to create a European Disaster Response Training Network, drawing on the past experiences

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[120] Council Decision 2007/779/EC, Euratom of 8 November 2007 establishing a Community Civil Protection Mechanism (EC, 2007i), and Council Decision 2007/162/EC, Euratom of 5 March 2007 establishing a Civil Protection Financial Instrument (EC, 2007j).

and scientific knowledge acquired at national and European level through the Framework Programme research projects dealing with natural hazards and disasters issues.

In its council conclusions (November 2009[121]), the European Council considered that Community action to prevent disasters may enhance the protection of people, the economy and the environment from the effects of natural and man-made disasters, and improve the resilience of the EU and its economy to increasing threats of natural and man-made disasters. The Council therefore invited the European Commission to inter alia bring together existing private and public sector data and information on disasters and their social, economic and environmental impact, as well as to identify gaps and issues of comparability between national data collection systems.

From cross-sectoral perspective, the European Commission released the Communication on 'A Community approach to the prevention of natural and man-made disasters' in 2009 (EC, 2009i) and is implementing a series of actions for its implementation. In 2010, it issued Guidelines on risk assessment for disaster management (EC, 2010i)[122] to support Member States in the preparation of their national risk assessments. EU-level disaster risk management policy was also announced in the Commission's Internal Security Strategy, which states that the EU should establish a coherent risk management policy linking threat and risk assessments to decision making by 2014[123].

The **European Union Solidarity Fund** (EUSF) was set up to respond to major natural disasters and express European solidarity to disaster-stricken regions within Europe. The Fund was created as a reaction to the severe floods in Central Europe in the summer of 2002[124]. By the end of 2010, some 42 application were approved with the financial aid summing up to 2,4 billion (COM(2011) 613 final) (EC, 2011x). The EUSF can provide financial aid to Member States and countries engaged in accession negotiations in the event of a major natural disaster if total direct damage caused by the disaster exceeds 3 billion € (at 2002 prices) or 0.6% of the country's gross national income, whichever is the lower. A neighbouring Member State or accession country that is affected by the same disaster can also receive aid, even if the amount of damage does not reach the threshold. The EUSF has an annual budget of € 1 billion. The amount available annually for extraordinary regional disasters is 7.5% of the EUSF's annual budget (or € 75 million).

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[121] http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/jha/111537.pdf

[122] Commission Staff Working Paper on Risk Assessment and Mapping Guidelines for Disaster Management, 21 December 2010, 17833/10, SEC(2010) 1626. The Commission guidelines were welcomed by related Council conclusions on Further Developing Risk Assessment for Disaster Management within the European Union, adopted by the Justice and Home Affairs Council on 11-12 April 2011.

[123] EU Internal Security Strategy In Action: five steps towards a more secure Europe, COM(2010) 673 final of 22.10.2010. Civil protection is also one of five major components in a shared EU agenda for increasing the security of EU citizens and in building resilience to natural and man-made disasters as an important part of the Stockholm Programme: ‘An open and secure Europe serving and protecting citizens’ (document 2010/C 115/01).

[124] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:311:0003:0008:EN:PDF

EUSF's annual 2008 report[125] addresses the weaknesses of the fund. These relate to the lack of rapidity with which financing from the Fund is made available, the transparency of the criteria for mobilising the Fund in the case of "regional disasters" and the limitation to disasters of natural origin. In 2011 the Commission has laid out options for reform of the EUSF (COM(2011) 613 final) (EC, 2011x).

The **Floods Directive** (FD) (2007/60/EC; EC, 2007a) was proposed by the European Commission in 2006, and was adopted by Council and Parliament in 2007[126]. Its aim is to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. The FD requires Member States to first carry out a preliminary assessment by 2011 to identify the river basins and associated coastal areas at risk of flooding. For such zones they would then need to draw up flood hazard and flood risk maps by 2013 and establish flood risk management plans focused on prevention, protection and preparedness by 2015. The Directive applies to inland waters as well as all coastal waters across the whole territory of the EU.

The Directive shall be carried out in coordination with the Water Framework Directive (EC, 2000c), notably by flood risk management plans and river basin management plans being coordinated, and through coordination of the public participation procedures in the preparation of these plans. All assessments, maps and plans prepared shall be made available to the public. Member States shall furthermore coordinate their flood risk management practices in shared river basins, including with third counties, and shall in solidarity not undertake measures that would increase the flood risk in neighbouring countries. Member States shall in take into consideration long term developments, including climate change, as well as sustainable land use practices in the flood risk management cycle addressed in this Directive.

A number of other sector-specific legislative activities have commenced or been extended in recent years, as shown in the list below:

- The Water Framework Directive 2000/60/EC for drought management (EC, 2000c);
- The Seveso II Directive on control of major hazards (EC, 1996);
- Directive 2008/114 on European critical infrastructure (EC, 2008l);
- The Communication on Water Scarcity and Droughts (EC, 2007h);
- Forest fire prevention policies, which were established at European level as early as 1992 and continued until 2006, when the last EU regulation on forest fires, the so-called 'Forest Focus' Regulation (EC, 2003d), expired. The Green Paper on Forest Protection and Information in the EU: Preparing forests for climate change (EC,

[125] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0193:FIN:EN:PDF
[126] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007L0060:EN:NOT

2010p) acknowledges the efforts made by the EU and Member States to address the issue of forest fire prevention and highlights the need to step up these efforts, in view of climate change.

3.5.2 Environmental and human systems

3.5.2.1 Soil

The European Commission adopted a Soil Thematic Strategy (EC, 2006d) and a proposal for a Soil Framework Directive (EC, 2006a) on 22 September 2006 with the objective to protect soils across the EU. The strategy has four pillars, namely awareness raising, research, integration, and legislation. In 2010, a minority of Member States blocked further progress on the proposed Soil Framework Directive. In 2012 a report is published by the EC (EC, 2012f) that invites the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions to submit their views on it in order to protect European soils.

The CAP may have a role in protecting soil fertility by creating subsidies for agro-environmental measures such as stimulation of carbon sequestration, and turning agricultural land into natural ecosystems and forests (Jones, et al, 2012).

At international level several agreements have a relation with soil protection:

- The international Convention on Biological Diversity supports protection of soil biodiversity;
- the Kyoto Protocol highlights the fact that soil is a major carbon store, worthy of protection and development;
- the United Nations Convention to Combat Desertification (UNCCD);
- the Protocol on Soil Protection under the Alpine Convention seeks to preserve the ecological functions of soil, prevent soil degradation and ensure rational use of soil in that region.

At the moment, nine EU Member States have specific legislation on soil protection (mostly on remediation and prevention of soil contamination).

3.5.2.2 Biodiversity

The Convention on Biological Diversity 1992 (CBD)[127], defines biodiversity as: “the variability among living organisms from all sources including *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes

[127] http://www.cbd.int/doc/legal/cbd-en.pdf

diversity within species, between species and of ecosystems". Diversity within species includes genetic diversity within species populations.

The CBD's 'Ecosystem Approach' is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It recognizes that people and their cultural diversity are an integral component of ecosystems. In applying the 12 principles that underpin the Ecosystem Approach, the CBD's operational guidance focuses on:

- The relationships and processes within ecosystems;
- Enhancing benefit-sharing;
- Using adaptive management practices;
- Carrying out management actions at the scale appropriate to the issue being addressed, with decentralization to the lowest level, as appropriate;
- Ensuring cooperation across sectors.

The Millennium Ecosystem Assessment (2005)[128] identifies a wide range of services that ecosystems provide. These include: 'provisioning services', such as food, water, timber, and fibre; 'regulating services' that affect climate, floods, disease, wastes, and water quality; 'cultural services' that provide recreational, aesthetic, and spiritual benefits; and 'supporting services', such as soil formation, photosynthesis, and nutrient cycling.

The EC White Paper on adapting to climate change (EC, 2009a) presents a framework for adaptation policies and measures to reduce the vulnerability of the EU to climate change. It recognises the significance of climate change for biodiversity loss and the increasing pressures on habitats and ecosystems. The White Paper highlights that it is important for the EU and Member States *"To promote strategies which increase the resilience to climate change of health, property and the productive functions of land, inter alia, by improving the management of water resources and ecosystems"*. The new EU biodiversity strategy to 2020 (EC, 2011c) goes on to state that *"Ecosystem-based approaches to climate change mitigation and adaptation can offer cost-effective alternatives to technological solutions, while delivering multiple benefits beyond biodiversity conservation"*.

Over the last 25 years, EU Member States have built up a vast network of 26,000 protected areas, which amount to more than 750,000 km^2 or 18% of the EU's land area. Known as Natura 2000[129], it is the largest network of protected areas in the world, and a testament to the importance that EU citizens attach to biodiversity.

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[128] http://www.maweb.org/documents/document.356.aspx.pdf
[129] http://ec.europa.eu/environment/nature/natura2000/index_en.htm

The legal basis for Natura 2000 comes from the Birds Directive (EC, 2009h) and the Habitats Directive (EC, 1992b), which form the backbone of the EU's internal biodiversity policy. To help the EU's biodiversity adapt to climate change, measures to increase its resilience (e.g. by maintaining and enhancing the ecological quality of existing habitats and reducing external impacts) are paramount (Hodgson, et al, 2009b, 2011) followed by measures to facilitate the movement of species (e.g. by increasing the area of available habitat and increasing/restoring connectivity through landscape-scale action).

3.5.2.3 Health

3.5.2.3.1 Human Health

The IPCC report 2007 concludes that the following changes could be observed in the health sector (IPCC, 2007a):

- North East Europe: Movement of vectors northwards, and to high altitudes;
- Mediterranean, West, South Europe: Northward movement of Visceral Leishmaniasis in dogs and humans (low confidence);
- Mediterranean, Atlantic, Central Europe: Heat wave mortality;
- Atlantic, Central, East, North Europe: Earlier onset and extension of season for allergenic pollen;
- Central and South-West Europe: increase in ozone concentration related to temperature increase.

Thus, a number of activities have been established with the aim to act on health impacts of climate change. For example, in 2010, the European Regional Framework for Action (WHO, 2010a) has been developed by the European Climate Change and Health Task Force with the aim to protect health, promote health equity and security, and provide healthy environments in a changing climate in the WHO European Region. The Fifth Ministerial Conference on Environment and Health welcomed the Framework and recommended that its approaches are used to support action to protect health from climate change. In addition, the Parma Declaration on Environment and Health (WHO, 2010d) has committed to act on climate change as this is one of the key challenges of our time. The main result of the declaration has been the adoption by 53 Member States of the WHO European Region and a Declaration of support by the EC[130].

The project “The Sustainability of DG SANCO policies – New Consumption and Production Patterns” (DG SANCO, 2008)[131] aimed to provide a critical analysis of the sustainability of

[130] http://ec.europa.eu/health/healthy_environments/docs/parma_declaration_en.pdf
[131] http://www.ioew.de/no_cache/en/projects/project_single/The_Sustainability_of_DG_SANCO_policies_New_Consumption_and_Production_Patterns/

EU policies with regard to climate change consequences. Results related to climate change and adaptation highlighted the need for

- a sound knowledge base to identify research needs and gaps,
- an adaptation tool box (e.g. surveillance, monitoring, heat-action plans) to cope with the most current climate change-related health threats,
- collecting more data on EU level to achieve the best possible disease surveillance for the EU, and
- awareness raising and agenda setting related to communication of direct and indirect impacts of human, animal and plant health in a changing climate aiming for a strong protective and also more pro-active approach.

At the EU policy level, the European Environment and Health Action Plan 2004-2010[132] does specifically address climate change and health under Action 8. Besides, the European Commission has adopted the EU Health Strategy in 2007 (EC, 2007c)[133], which foresees actions on climate change adaptation. In December 2011, a proposal for a decision of the European Parliament and of the Council on serious cross-border threats to health has been put forward, including threats deriving from the effects of climate change (i.e. heat waves, cold spells)[134].

In addition, innovative projects promoting health development can receive EU funding from the EU Health Programme (EC, 2007k), as a means of implementing the EU Health Strategy (EC, 2007c). The White paper on adaptation to climate change (EC, 2009a) was accompanied by a commission staff working document on "Human, animal and plant health impacts of climate change" (EC, 2009b).

Other health related policies in place do not include references to climate change (e.g. EU Directive on ambient air quality and cleaner air for Europe (EC, 2008o)).

3.5.2.3.2 Animal Health

The EU Animal Health Strategy (2007-2013) (EC, 2007b) and its Action Plan (EC,2008a) focuses on preventing rather than reacting to animal diseases including considering the influence of Climate Change on animal diseases.

A new Animal Disease Information System (ADIS) is being developed to improve the gathering of epidemiological data. Stepping up animal disease surveillance and the establishment of further vaccine banks for certain animal diseases will enable risk managers

[132] http://europa.eu/legislation_summaries/public_health/health_determinants_environment/l28145_en.htm
[133] http://europa.eu/legislation_summaries/public_health/european_health_strategy/index_en.htm and http://ec.europa.eu/health/strategy/policy/index_en.htm
[134] http://ec.europa.eu/health/preparedness_response/docs/hsi_proposal_en.pdf

to better respond to emerging disease situations. The proposal by the Commission of a new Animal Health Law is foreseen during 2012. It will consolidate the exhaustive existing animal health legislation and put emphasis on preventive measures such as surveillance activities. The rules will be flexible allowing quick adaptation of diseases control measures to changes in disease patterns including those resulting from climate change.

3.5.2.3.3 Plant Health

In several aspects, plant health is a public good. Healthy crops are essential to ensure food security for the ever-growing global population world-wide. Entry and establishment of harmful organisms often results in increases of pesticide use and could impact negatively on the environment and, in some cases, on food safety. Prevention of entry of new harmful organisms and diseases helps limiting the use of pesticides. Moreover, for a number of regulated pests and diseases there are no curative treatments possible at all. Furthermore, citizens value an unspoilt landscape and are concerned about the rapid loss of natural habitats, biodiversity and plant resources worldwide. Entry and establishment of harmful organisms may lead to serious damage to amenity trees, public and private green, recreational forests and to disruption and loss of natural ecosystems and habitats. Due to climate change, forests and natural ecosystems become increasingly susceptible to invading pests and pathogens. Massive forest death due to plant pests may accelerate climate change by changing forests from a carbon sink into a carbon source.

Plant health is also a private good since plant health measures may equally serve to protect the economic value of plants and plant products in agriculture, forestry and trade. Buyers and sellers of plants and plant products do not have the same information on the health status of the materials (seemingly healthy material may be infected inside). Such so-called information asymmetry is known to lead to market failure: the free market does not itself correct this. Regulation of plant health is therefore of interest for the private sector as well.

A new plant health law[135] will be developed so as to better address, among others, the consequences of climate change in the EU plant health legislation.

3.5.2.4 Inland Water

In the field of climate change policy, until recently, the EU legislative and regulatory actions concentrated on climate mitigation, that is reduction of greenhouse gas emissions. The Renewable Energy Directive (EC, 2009m) sets legally binding national targets for electricity and transport from renewable sources, adding up to a share of 20 % of total energy production in the EU as a whole. By June 2010, each EU Member State was required to adopt a national renewable energy action plan (NREAP) addressing national targets for the share of energy from renewable sources consumed in transport, electricity, heating and cooling in 2020. There is no doubt that achieving this targets will require sufficient water in

[135] http://ec.europa.eu/food/plant/plant_health_biosafety/rules/index_en.htm

particular for hydropower generation and also for growing enough crops for achieving sufficient yields of biomass.

The EC White Paper on Climate Adaptation (EC, 2009a) lays out a framework for adaptation measures and policies to reduce the EU's vulnerability to the impacts of climate change. A centrepiece of the framework, meant to enhance Europe's resilience to climate change impacts is a better management of water resources and ecosystems. Nonetheless, policy efforts in the field of natural hazards and civil protection mechanisms have prepared the stage for concerted action that takes into account the impacts of climate change that are unavoidable or unlikely to prevent by climate mitigation.

The Water Framework Directive (EC, 2000c) commits the EU Member States (MS) to achieve good ecological status of all surface waters, including marine waters up to one nautical mile from shore, and good chemical status of groundwater by 2015. The WFD does not explicitly refer to adaptation to climate change. However when drafting the guidance document No. 24 River Basin Management in a Changing Climate (EC, 2009f) it was agreed that from the second planning cycle onwards climate-related threats and adaptation planning should be incorporated in RBMPs. However as a recent assessment shows (EC, 2012i) that climate change is already mentioned in the first set of RBMPs in 87.5% of 112 RBDs in different ways (either by a separate chapter or as a pressure arising from human actions in threats and pressures assessment, as part of state of water and future trends analyses or within the discussion on objectives or Programme of Measures. It is important to note that Member States (e.g. ES, GR) which have not submitted their plans so far are most likely also being significantly impacted by climate change.

According to the above mentioned assessment a "Climate check" of the programs of measures (PoMs) has been carried out for 41% (46 out of 112 RBMP) RBMPs and 31 of those also detail the methodology applied which are predominantly qualitative.

The **Marine Strategy Framework Directive** (MSFD) (EC, 2008k) pursues a similar goal but for marine environment. It creates a framework for marine waters and expands the approaches initiated by the Water Framework Directive (WFD) (EC, 2000c), the Environmental Impact Assessment, the Strategic Environmental Assessment and the Birds and Habitats Directives, amongst others.

The **Floods Directive** (EC, 2007a) seeks to prevent and limit floods and their damages on human health, the environment, infrastructure, cultural heritage and property. The Directive obliges the Member States to assess risks posed by each Member State's water courses and coast lines, and to produce maps of areas subjected to floods of different intensity. The main aim of this assessment is to inform adequate and coordinated management measures to protect assets and humans in these areas. In order to address the issue of water scarcity and droughts in the EU, in 2007 the European Commission issued a **Communication 'Addressing the challenge of water scarcity and droughts in the European Union'** (EC, 2007h). The communication lists a set of policy options that are implementable as a concerted EU action to increase water efficiency and water savings, and to improve drought preparedness and risk management. At the heart of the policy options is the need to price water correctly with the "user pays" principle becoming the rule regardless of where water is taken from. Furthermore, as land and water resources are essential for farming, grazing, forestry, wildlife, tourism, urban development, and transport infrastructure it is now widely accepted that future land use and land planning in water scarce areas is a crucial factor for mitigating water stress. Autonomous farm level adaptation may find its limits as climate change impacts gradually become more drastic. Planned adaptation driven by public authorities, addressing the whole sector, and tailored to the diversity of regional and local agriculture will be needed to facilitate a broader range of responses. The second Pillar of the **Common Agricultural Policy**, which focuses on Rural Development, also includes climate adaptation measures targeted at the agricultural sector.

In the disaster response domain, EURATOM established the **Community Civil Protection Mechanism** (hereafter CCPM) in the European Council's Decision 2007/779/EC (EC, 2007i). More recently, the European Union intensified its efforts in disaster risk reduction with the EC Communication on Disaster Response Capacity (EC, 2011y). This Communication highlighted the need for stepping up the Community's capacity to respond effectively to disasters, within and outside the EU. To do so, the EC proposed several tangible means to improve coordination between various EU/Community policies, instruments, services and players (at national, European and international levels). While the Communication focuses on disaster response, it acknowledges the need for a comprehensive approach to disaster management that includes risk assessment, forecast, prevention, preparedness and mitigation.

3.5.2.5 Marine and coastal zones

To enhance more sustainable coastal development in Europe, the European Parliament and the Council adopted a Recommendation on Integrated Coastal Zone Management (ICZM) in 2002. It defines principles of sound coastal planning and management, including the need to take a long-term and cross-sectoral perspective, to actively involve stakeholders and the need to take into account both the terrestrial and the marine components of the coastal zone. Right now the EU is assessing different policy options for future EU action to further develop ICZM. To complement the efforts by EU coastal Member States and regions to implement the EU ICZM Recommendation, the European Commission launched the OURCOAST initiative. OURCOAST is a web-platform[136] that gathers and disseminates case-studies and practical examples of coastal management practice in Europe. In 2010, the EU strengthened the legal framework for integrated coastal zone management in the Mediterranean by deciding to ratify the ICZM Protocol to the Barcelona Convention, which entered into force on 24th March 2011.

The EU Integrated Maritime Policy seeks to provide a more coherent approach to maritime issues, with increased coordination between different policy areas. It focuses on issues that

[136] http://ec.europa.eu/ourcoast/index.cfm?menuID=3

do not fall under a single sector-based policy *e.g*. "blue growth" (economic growth based on different maritime sectors) and issues that require the coordination of different sectors and actors *e.g*. marine knowledge. One of the objectives there is to create a strategy to alleviate the consequences of climate change in coastal regions.

Another important policy is the Common Fisheries Policy (CFP) which (beside others) is laying down rules to ensure Europe's fisheries are sustainable and do not damage the marine environment. In order to do so potential impacts from climate change on the fish stocks have to be considered. This requires funding scientific research and data collection, to ensure a sound basis for policy and decision making, which is also an objective of the CFP.

3.5.3 Social issues

3.5.3.1 Jobs/Employment

There is mounting evidence that climate policy driven transition towards low-carbon, resource efficient and green economy may positively affect employment market, and create opportunity for more environmentally-related and qualitatively better jobs. Labour market and climate change adaptation policies must be approached hand in hand to make sure adaptation to climate change can contribute to economic transformation.

In 2010, as a part of the 2020 Strategy for smart, sustainable and inclusive growth; the Commission lunched a flagship initiative for a ‘resource-efficient Europe’ (EC, 2011d). This flagship initiative sets out a long term framework to guarantee that several areas such as energy, climate change, research and innovation, industry and environmental policy will lead to a resource efficient Europe. Underlying this strategy is the recognition that efficient use of resources can foster employment, while contributing to the Union’s environmental goals. By coherent pursuing of the above goal, the European economy is believed to benefit from increased competitiveness and new sources of growth and jobs. The water resource efficiency is a pathway to climate adaptation.

Another goal of the EU 2020 Strategy is that of reaching 75% employment of the 20-64 year-olds. To reach this goal, some 7.6 million jobs will have to be created by 2020, at an average annual rate of 0.8% (EC, 2012j). The employment in mid-2011 (68.9%) reflected the loss of some 6 million jobs to the financial and economic crisis between 2008 and 2010.

Boosting green jobs is an important instrument to reaching the goal, and a part of the Strategy and flagship initiative ‘An agenda for new skills and jobs’. The definitions of the green job do not distinguish employment from climate mitigation and/or adaptation from other employments related to environmental protection and sustainable management of natural resources. The United Nations Environmental Programme (UNEP) defines green jobs "… as work in agricultural, manufacturing, research and development (R&D), administrative, and service activities that contribute substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high-efficiency strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution" (UNEP/ILO/IOE/ITUC, 2008). The definition of the International Labour Organisation (ILO) is similar but *significant* contribution to preserving or restoring environmental quality and the compliance with the standard of *Decent Work*[137]. EUROSTAT does not specify green jobs but refers to environmental goods and services sector (EGSS) which may include technologies, goods and services related to environmental protection and resource efficiency. Similarly, eco-innovation denotes opportunities to achieve environmental objectives through innovation. The background document to the EC Communication 'Towards a job-rich recovery' (COM(2012)173 final) offers the following definition: '(green jobs are) all jobs that depend on the environment or are created, substituted or redefined (in terms of skills sets, work methods, profiles greened, etc.) in the transition process towards a greener economy' (EC 2012b).

EMCO (2010) argued that a narrow definition of green jobs may discard wider economic and labour market effects of the environmental challenge. Policy-based approach, the authors argue, should acknowledge the complex inter-linkages between climate change and environmental sustainability on the one hand and labour markets on the other hand.

3.5.3.2 Other social issues

The policies concerned with tackling the social impacts of climate change on the EU level are:

- Migration policies (including external relations and foreign affairs);
- Gender policies;
- Polices that relate to ageing population; and
- Social protection (including disadvantaged population groups).

3.5.3.2.1 Migration policies

The EU has developed a common framework for integration of third-country nationals by adopting 'Common Basic Principles for Immigrant Integration Policy in the EU' (2004)[138] a 'Common Agenda for Integration' (EC, 2005c) as well as 'Council conclusions on the strengthening of integration policies in the EU by promoting unity in diversity' (2007) is taken a step further by the 'Stockholm Programme' (2009)[139]. In 2011 the Commission has proposed a European agenda (The Global Approach to Migration and Mobility – GAMM) (EC, 2011w) for the integration of non-EU migrants aiming to increase economic, social, cultural and political integration if migrants (EC, 2011i). It is very unlikely that the migration

[137] Decent work refers to employment in conditions of freedom, equity, human security and dignity.
[138] http://www.enaro.eu/dsip/download/eu-Common-Basic-Principles.pdf
[139] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2010:115:0001:01:en:HTML

policy will be affected in the short and medium-term by adaptation issues due to climate change but tools in the context of GAMM could be used.

3.5.3.2.2 Gender policies

The Council Conclusions on "Gender equality and the environment: enhanced decision-making, qualifications and competitiveness in the field of climate change mitigation policy in the EU" (2012)[140] state that gender as well as social and employment aspects need to be integrated into climate change issues. These Conclusions – only representing a first step toward woman´s full participation in climate change issues – focus on climate change mitigation. However, climate change adaptation is highlighted as another important issue also requiring attention from a gender perspective.

The Conclusions identify the lack of gender balance in decision-making, and show the need to improve women's access to education in climate change related scientific and technological fields, as well as the need to improve knowledge and the availability of data on the issue of women and climate change.

Equality between women and men is one of the European Union's founding values. It goes back to 1957 when the principle of equal pay for equal work became part of the Treaty of Rome. Three main tasks of EU Gender policy the last decade are:

- equal treatment legislation;
- gender mainstreaming (integration of the gender perspective into all other policies);
- specific measures for the advancement of women.

The Strategy for equality between women and men (EC, 2010o) represents the European Commission's work program on gender equality for the period 2010-2015. The strategy highlights the contribution of gender equality to economic growth and sustainable development, and supports the implementation of the gender equality dimension in the Europe 2020 Strategy. It builds on the priorities of the Women's Charter and on the experience of the Roadmap for equality between women and men. It is a comprehensive framework committing the Commission to promote gender equality into all its policies.

Climate change is not mentioned directly in the strategy, but one "background document" includes climate change issues (EC, 2010o), stating that closer attention could be given to the demographic trends, the globalisation of the economy, migration and climate change.

3.5.3.2.3 Polices that relate to ageing population

In the field of ageing, legislative competence rests almost exclusively with Member States. Indeed, in some cases, important competences are to be found at the regional and local as

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[140] http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/lsa/131111.pdf

well as the national level. On the EU level the situation of older people was first addressed specifically in a number of Resolutions by the European Parliament during the 1980s, beginning with its Resolution of 18 February 1982 on the situation and problems of older people in the EU. The Charter on the Fundamental Social Rights of Workers, adopted by 11 Member States in 1989, refers, in paragraphs 24 and 25, to older and retired people and brings this group within its ambit.

Since that, the EU played a role in supporting common efforts through stimulation of new thinking and exchange of experience. Main focuses of work are pensions and solidarity between generations.

3.5.3.2.4 Social protection policies

Within the EU, social protection and social inclusion (including combating poverty and social exclusion) is mainly the responsibility of national governments. However, the EU provides an important framework on social protection and social inclusion for national strategy development, as well as for coordinating policies between EU countries on issues relating to poverty and social exclusion, health care and long-term care as well as pensions.

Social protection provides a close linkage to the social dimension of climate change, but climate change impacts are not yet directly addressed by and included in social protection strategies or programs, than it could be.

The EU policy related to social protection and social inclusion follows an Open Method of Coordination (OMC) which is a voluntary process for political cooperation. The OMC is based on agreeing common objectives and common indicators. The EU common objectives are translated into national plans (building the bases for national strategic reports) by the national governments. The Commission and Council assess the national reports in joint reports, reflecting what EU-level initiatives have achieved on national level in terms of social protection and social inclusion (e.g. Joint Report on Social Protection and Social Inclusion, 2010[141]). One of the main tools in this respect is the Peer review seminars which encourage the dissemination of good practices across Member States by assessing the effectiveness of key policies or institutions[142].

The OMC includes various social protection issues: Poverty and social exclusion; Health care; Pensions; Long-term care; Social services of general interest (social security, employment and training services, social housing, child care, long-term care, social assistance services).

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[141] The reports by the different Member States are available under http://ec.europa.eu/social/main.jsp?catId=757&langId=en

[142] Cf. http://ec.europa.eu/social/main.jsp?catId=753&langId=en for further details.

3.6 Private Sector, market and finance

This chapter sets out the key issues regarding adaptation in the private sector, markets, insurance and finance. It is intended as a summary of the available literature on the challenges faced by the private sector in relation to climate change adaptation; how the public sector may help businesses face these challenges; and in turn how market solutions can lead to more cost-effective adaptation policy.

For the purpose of this analysis, the private sector is defined as privately owned or controlled companies, organisations and entities.

3.6.1 Risks and opportunities for the private sector

The private sector is exposed to a range of climate change related risks but it also has the potential to play a major role in adaptation to climate change as a consumer of adaptation solutions, a provider of financial resources, and a source of innovative products, services (such as insurance services, technical assistance, etc.) and solutions to manage and mitigate risks more effectively.

3.6.1.1 Climate change risks and challenges

Climate change exposes businesses to a range of operation, profit and growth-related risks. The impacts from these risks may be systemic (at the whole economy level), or they may be sector/industry-wide or company-specific. They will vary depending on the business size, structure, services and geographical level of operation (global/national/local).

The risks presented by climate change to the private sector can be categorised as follows:

- *Physical risks due to e.g. storms or flooding* to a company's assets or to the public infrastructure it relies on to operate (roads, water supply, etc). These are the most direct risks to a company's operation (e.g. disruptions in production) and in terms of financial liability.

- *Supply chain / logistical risks.* This includes the costs and availability of raw materials, and other sources of disruption to supply chains. Changing temperatures and precipitation patterns may lead to decreased availability, and higher and more volatile prices of critical raw materials in the supply chain, especially agricultural commodities. Indeed, the increasing cost of natural resources and raw materials has been identified as one of businesses' main climate change-related concerns (UN Global Compact, et al, 2011).

- *Political risks.* As developing countries might struggle with natural resource, social food security, health and economic challenges associated with climate change, they may face increased domestic conflict and instability exacerbating existing political risks. Weather extremes, food and water scarcity, and climate-related public health threats are projected to displace between 150 million and 1 billion people as climate change unfolds (Waskow, 2009). Climate change may also lead to increased conflict over resources, including across borders. One report estimates that 46 countries will face a "high risk of violent conflict" when climate change exacerbates traditional security threats (Schuemer-Cross & Heaven Taylor, 2009). While local companies based in climate vulnerable countries will be most affected, political instability also poses significant threats for globalized companies operating or dealing with suppliers in those countries, particularly companies with significant on-the-ground physical investments or sizeable market share.

- *Financial risks*. Climate change may affect companies' access to capital, as investors become more aware of climate change impacts and the need for adaptation. Debt financing may be harder to attract or more expensive for companies that are seen to be at "high risk" of climate change impacts (as businesses with operations, employees and supply chains in developing countries will be). Investors will likely have lower confidence in companies that are failing to analyse climate risks and to take proactive action to adapt and manage such risks, and may increase their demands or expectations for full disclosure in this area. The European Bank for Reconstruction and Development (EBRD) for instance now has now integrated an environmental and social risk appraisal as part of its operation. It aims to consider and reduce financial, legal and reputational risks which may arise in relation to environmental and social problems experienced by customers, investees or other parties, and provide demonstrable assurance to themselves, EBRD and their other stakeholders that this aspect of risk is being adequately managed. This applies to projects put forward by EBRD's financial partners such as banks with EBRD credit lines or equity investment, private equity funds with EBRD participation, or other financial institutions supported by EBRD funding. Finally, financial risks may also arise as insurance costs for climate-related events increase.

- *Market demand risks*. In the face of climate change, certain products and services will become more or less relevant and more or less effective requiring businesses to adapt to new market demand drivers in order to remain competitive. The change in products/services as a result of climate change combined with increased energy prices is identified as the main risk related to climate change in a survey (CERES, 2010) of 136 risk managers across a range of sectors. Among customers with higher awareness of climate change, demand could decrease for products and services that make inefficient use of scarce resources like energy and water or that exacerbate climate risks. As consumers across the world are forced to grapple with climate change, they may also have reduced spending power (particularly with respect to non-essential goods and services), thus impacting some companies' profitability. Overall, the impact of climate change on consumer's behaviour is largely unknown but companies which are able to adapt to changes in demand can turn this risk into new business opportunities. Examples of such an approach are provided in the 2011 OECD report (OECD, 2011). The first example is Malmesbury Syrups, a UK-based specialist food company which produces flavoured syrups. Malmesbury Syrups is a small company able to quickly develop new recipes and products. Having realised that the company's products were linked to cold weather and that temperature increases might dissipate the demand for such products, the company decided to offer new products designed to meet the demand of clients living in warmer temperatures, such as syrups used for milkshakes (SWCCIP, 2008). The second example is Unilever which is also exploring ways to adapt its product portfolio in order to respond to the need of consumers in countries facing increased water scarcity and high water prices.

- *Regulatory and legal risks*. As countries adapt to climate change, they are likely to use a range of regulatory tools to better manage their natural resources and reduce their disaster risk. For example, they may enact new land use or zoning regulations, or new building codes. They may put more stringent limits on water use and irrigation. Such regulations will force some companies to undergo operational changes in response, making some activities and processes more expensive or even unfeasible. Corporate decisions that fail to take climate change impacts into account could be subject to a range of legal challenges. Governments may also begin to require companies to disclose their climate risks and adaptation efforts, as the Securities and Exchange Commission has done in the United States.

- *Indirect economic costs* may also occur through reduced workdays and productivity as a result of more severe weather events or health impacts.

- There is significant uncertainty about the exact nature, timing, location and magnitude of climate impacts, making it difficult to quantify these risks both at business and sector level. Surveys provide information on how businesses perceive these risks: according to a 2010 UNEP's survey of 72 companies (UN Global Compact, et al, 2011) that responded to the Caring for Climate survey, their main concern relates to supply chain and physical risks (increasing cost of natural resources, raw materials; water scarcity; energy security) i.e. direct risks.

3.6.1.2 Business opportunities related to adaptation

Commercial opportunities from adaptation vary considerably across sectors but can be grouped into two broad categories:

- *Expanding market share and creating wealth in communities*. Effective adaptation to climate change will require the development and deployment of a wide range of new and innovative products, strategies and services. Climate change presents an opportunity for companies to diversify and expand their market share while simultaneously addressing the consequences of climate change. The potential for innovation and job creation in this emerging market is considerable.

- *Accessing new financing streams.* Under international climate change agreements, there will be increased public funding available at EU and national level for adaptation efforts in vulnerable communities, priority sectors and developing countries. At the same time, the private sector will increasingly be called upon to fill the gap between investment needs and available public funds and governments will look for corporate partners who can deliver appropriate financial products and services. Chapter 3.6.3 provides more detail on these opportunities, in particular on relevant EU funding streams.

As providers of solutions, the private sector can help develop and implement public policy by:

- Working with public organisations and research institutions to improve information on climate-related risks; develop policy frameworks which build resilience of local markets; contribute technical expertise and solutions specific to their sector, increasing capacity for innovation and knowledge-transfer; and as a result devise feasible and effective adaptation solutions.

- *Supplying capital*. Capital may be leveraged through a number of channels such as the planning system (for infrastructure investment); research investment in collaborative projects with the public sector; insurance payments in case of damages; loans and equity finance for adaptation measures.

- *Getting involved in Public Private Partnerships (PPPs)*. PPPs can be a useful tool to combine financial and knowledge resources from both the public and private sectors on specific projects in order to deliver services and products. PPPs with the public sector, scientific organisations and academia can facilitate adaptation by providing companies with guidance, information and shared capacity to help them adapt. As a result they can bring useful lessons on the implementation of adaptation actions and lead to knowledge transfer in the communities in which they take place. Also public budgets can be relieved from coping alone with remediation after climate catastrophes and with all the investments needed for adaptation efforts. PPPs can have applications for adaptation to climate change through:

- *Public contracts.* Public contracting gives public authorities the opportunity to adopt detailed plans and specifications for the provision of work. Hence, the extent and type of the work to be done and the materials to be furnished can be defined in a manner that serves the purpose of adaptation. At the same time, public contracts typically do not involve the transfer of risk for e.g. long-term operation and maintenance, or any other risk apart for delivering the service to the agreed scope and quality. Neither do public contracts allow the government to shift part of the financial burden to the private sector (apart from making sure by the tender process that the service is offered at a competitive price).

- *Service concessions.* Service concessions can be designed in a way that promotes adaptation, if certain regulatory elements are included in the contracts between grantor and concessionaire. For example, the grantor can define mandatory requirements regarding the way the service/good is managed or regarding the extent of "climate-proofing" the service/good. In many cases, service concessions would need to be of very long-term nature, i.e. 20-30 years, in order to set the right incentive for sustainable decision making from the concessionaire's side. It is worthwhile noting that service concessions only reach an intermediary, i.e. the concessionaire, but not the end-consumer. So any incentive that is implemented through a service concession can only have indirect effects on the general public. Service concessions could for example be used in the following areas: Management of water resources with requirements, including water supply, desalination and irrigation systems; installation, operation and maintenance of public transport; access to recreation areas; building or improvement of dikes and other flood-protection measures.

Adaptation activities can offer profitable business opportunities across the economy but it is likely that the following sectors will benefit most (Agrawala, et al, 2011a):

- *Environmental consulting services*. There are many opportunities arising for climate change consulting services. Whereas in the past these consulting services have mostly focused on supporting firms in undertaking mitigation actions, they have now expanded their services to include adaptation to climate change. This also opens new opportunities in the job market for specialised and highly trained individuals.

- *Agricultural technologies*. Opportunities for private companies that can provide agricultural products and services suited to resist the impacts of climate change. For example, new markets are opening for the development and production of drought resistant crop varieties and for drip irrigation systems which provide more efficient irrigation. In addition, warmer weather may mean longer growing seasons in some North European countries.

- *Water management and technologies*. The water sector offers many opportunities in the area of innovative technologies related to adaptation, around issues such as water management, distribution and drainage. For example water saving devices for households or irrigation. Also less water demanding cooling systems are part of adaptation solutions.

- *The built environment*. Multiple opportunities exist for implementing adaptation measures across the built environment and construction sector. For example, building and real estate companies can foster innovative design and new design practices to improve the resilience of buildings to the impacts of climate change. These could reduce the impacts of climate change on energy demand. Other examples of technologies that could help adapt to climate change impacts include domestic flood defences, cooling systems, water recycling systems, and "green roofs" (which are partially or completely covered with vegetation).

- *Insurance markets*. Many insurance companies have been developing specific insurance products to mitigate the risks of climate change, such as weather related insurance and catastrophe bonds and weather index-based insurance for developing countries.

- *Information services* could also offer innovative products for disaster preparedness and recovery. Early warning systems, weather forecasting tools, and risk mapping technologies are all in increasing demand.
- *Educational and training services:* This covers all sectors. The main aim is to ensure that adaptation technologies are applied correctly but also should train staff of companies to chance their management practices.
- *Climate services*: Several private industry activities have some degree of weather and climate risk. This represents a large market for atmospheric information, and it should represent a powerful force for advancing the cause of atmospheric observation and prediction reducing business risks due to better forecasts.
- *Disaster response services:* Several companies already provide business continuity and recovery services and relief to the public in the event of weather related incidences. Alongside this there may be a growing need for interventions at the point at which climate related "disasters" do occur. This will include services to the public and private sector, in temporary accommodation, infrastructure management etc.
- *Banking sector:* e.g. loans for large infrastructure investments but also smaller scale ones.

3.6.1.3 Conclusions

While opportunities for new jobs or securing existing jobs, products and services undoubtedly exist as a result of adaptation, it is likely that the main impacts on businesses will result from the need to adapt their existing processes and products. This makes it very difficult to quantify the benefits from adaptation. On the other hand, the cost of inaction is likely to be high and the damages to businesses potentially very costly. This requires businesses to take the risks seriously and investigate how exposed they are and what responses are available to them. This is what the next section looks at.

3.6.2 Managing climate change risks at business level

3.6.2.1 Definition of risk management

Risk is defined as the combination of the probability of an event and its consequences: there may be more than one event; consequences can be both positive and negative; and likelihoods can be measured qualitatively or quantitatively (ISO, 2009). This definition is appropriate for assessing climate risks and planning adaptation.

Risk management can be defined as the culture, processes and structures that are directed towards realizing potential opportunities whilst managing adverse effects.

3.6.2.2 Risk management approach for adaptation

From a business perspective, environmental risks can be managed following a similar approach to other risks. A number of Governments have put together guidance for businesses to deal with climate change impacts, drawing from commonly used principles in risk management.

The Australian (Australian Government, 2006) and UK Governments (UKCIP[143]) in particular have published detailed and useful guidance for business and governments to manage climate change impacts and risk management. The key steps involved in the risk management of climate change according to these documents are presented below.

Table 31: Key steps for business and governments involved in the risk management for climate change (Source: UKCIP)

Stage	Tasks
Establish the context	▪ Define the business or organisation to be assessed ▪ Define the reason for and scope of the assessment i.e. where does the need for action come from? ▪ Clarify explicitly the objectives of the organisation and of intervention; ▪ Identify the stakeholders and their objectives and concerns i.e. Who or what will benefit or suffer as a consequence of the problem being addressed? ▪ Agree the criteria against which the options will be appraised. They might include: the risk of the option not succeeding, ease of implementation, cost, equity, public approval, public acceptability, etc; ▪ Develop key elements of the organisation (such as its major areas of responsibility) as a means of structuring the process; and ▪ Determine relevant climate change scenarios for the assessment.
Identify the risks	▪ Describe and list how climate change impacts on each of the key elements of the organisation. ▪ Identify receptors at risk and exposure unit.
Establish decision-making criteria	▪ Define the rules for making the decision. For instance, is the organisation risk averse or focused on maximising benefit, or minimising cost? ▪ Who should be involved in the decision making process and who is the ultimate decision-maker? ▪ What resources are available to help make the decision?

[143] UK Climate Impact Programme http://www.ukcip.org.uk/

Stage	Tasks
Clearly defined problem and criteria for assessment	
Analyse the risks	▪ Determine the level of risk to the organisation, for each of the climate change scenarios used in the analysis. This should consider all aspects of the business: assets, logistics, people, processes, markets and finance. ▪ Take into account the uncertainty relating to forecasts for the different climate change variables ▪ Review the controls, management regimes and responses already in place to deal with each specific risk; ▪ Assess the consequences of each risk against the organisation's objectives and success criteria, taking into account the extent and effectiveness of existing controls, the severity of impacts for the business; ▪ Form a judgement about the likelihood of each identified risk leading to the consequences identified.
Evaluate the risks	▪ Re-affirm the judgements and estimates; ▪ Rank the risks in terms of their severity; ▪ Screen out minor risks that can be set aside and which would otherwise distract the attention of management; and ▪ Identify those risks for which more detailed analysis is recommended.
Risks analysed, understood and ranked	
Treat the risks: options appraisal	▪ Identify relevant options to manage or adapt to the risks that are not acceptable and their consequences (cf. below for more detail); and ▪ Appraise the options: ▪ How do the options rate in relation to the criteria established in Stage 1. ▪ Can different levels of confidence be attached to the likely performance of different options? ▪ Can 'no regret' and 'low regret' options be identified? Potential no regret options would perform well both under present-day climate and under all future climate scenarios. ▪ Could the options being considered possibly constrain other decision-makers' ability to adapt to climate change (i.e. contribute to climate maladaptation)? ▪ Select the best option. This may require an iterative process before a final conclusion is reached.
Preferred solution identified	
Implement action	The guidance focuses on reaching a decision, rather than implementing it.
Monitor and review	The outputs of all steps of the risk management process must be kept under review so that, as circumstances change and new information comes to hand, plans can be maintained and kept up to date. Several aspects of the monitoring and review activity are important,

Stage	Tasks
	including: ▪ Keeping the analysis and evaluation up to date; ▪ Reviewing progress on actions flowing from the process, including implementing treatment actions to reduce risks or undertaking further and more detailed analyses

Both sources of guidance stress the importance of communication and consultation each step of the way: ‘In both the planning and execution of the risk management process it is important to ensure that all those who need to be involved are kept informed of developments in the understanding of risks and the measures taken to deal with them. At the very beginning, it will be necessary to engage personnel in the process and help them understand the need for climate change risk management to become part of routine management activity’ (Australian Government, 2006).

The aim of this process is to identify the best way to address the specific risks faced by a given business in relation to climate change and to implement it. There are various ways to tackle these risks. They are presented next.

3.6.2.3 The different types of risk management options

In response to the risks identified as part of a risk assessment an organisation may adopt the following approaches:

- <u>Preventing effects or reducing exposure to risks</u> through relocating, altering products and services and using materials that are less exposed to climate risks, or building climate resilience to allow existing activities to continue. Building resilience, however, does include living with risk by reducing the consequences of impacts and assisting recovery following exposure.
- <u>Tolerating losses</u>, where it is not possible or cost effective to avoid them.
- <u>Sharing responsibility for losses or risks:</u> reducing losses or exposure by transferring the risks (using insurance), sharing the costs of adaptive responses and relief efforts.
- <u>Exploiting opportunities</u>: changing activity or location to exploit market opportunities generated by the need for adaptation, and increasing the organisation’s capacity to manage opportunities as a result of the changing climate. This includes taking advantage of more favourable conditions for existing products or activities as well as introducing new lines.

The choice of the most cost-effective strategy will depend on the risk itself, i.e. whether it is deemed avoidable or not, the company’s risk preferences and capacity. Generally, these options involve either taking action to reduce the risks and/or their consequences or insuring against them. The role of risk prevention and insurance is explored next.

Risk prevention

Risk prevention means preventing disasters from happening where possible, and where they are unavoidable, taking steps to minimise their impacts.

Both the private and public sector have a role to play in risk prevention. The economic concept of market failures is the central tool in order to structure adaptation measures. If no market failure can be detected, autonomous adaptation is the appropriate choice. Individual businesses have a role to play in preventing these wider risks as well as those specific to their own operation. There are three dimensions to consider when identifying possible prevention measures:

- The current level of knowledge on risks, putting efforts on exposure and vulnerability analyses to assess what are the most probable harmful events, and not only on hazard assessment;
- The already implemented risk management policies, focusing on progressive improvements;
- The efficiency of possible measures focusing both on potential losses to be alleviated and on the ratio between costs and benefits from the implementation of such measures.

Risk prevention measures may include: knowledge development (information on hazard and risk, education, research on risk assessment and management); awareness raising and preparedness; implementing early warning systems (monitoring, forecasting, alarms); and capital investment (e.g. refurbish building, back-up generators etc.).

A number of **barriers** prevent the private sector from taking appropriate adaptation actions and future-proofing their business. They can be split into four broad categories which are presented below: information problems, policy and regulatory failures, cost of investment and externalities.

Information problems and uncertainty

The lack of accurate and reliable information hinders the uptake of adaptation investment because of a lack of awareness of climate-change related risks in the first place and even when awareness exists, the inability to model the risks and their impacts satisfactorily in order to inform investment decisions. This is explained in more details below.

- *Lack of awareness of climate-change related risks*. Awareness is growing amongst businesses, although more for some types of risk than others. Companies tend to pay particular attention to physical risks and risks to supply chains and raw materials, and are generally also aware of product demand risks and financial risks. On the other hand, they seem less aware of potential reputational and litigation risks to their businesses. In addition, while awareness is rising, there remains a large gap between businesses recognising current and future risks that climate change may pose to their operations, and engaging in activities to address these risks. The latest study by the Carbon Disclosure Project in 2012 (CDP, 2012) of the Global 500 companies shows that majority of companies (81%) report physical risks and the percentage of companies that view these risks as current has nearly quadrupled from 10% in 201 to 37% in 2012. Prior to this 2012 questionnaire, the OECD undertook a study in 2011 (OECD, 2011) of the 1100 English language company responses to the CDP7 questionnaire, 75% of companies consider physical risks arising from climate change, 23% do not consider themselves exposed to physical risks, and 2% do not know. Of the companies that acknowledge physical risks, the majority (59%) do not take any further action to either assess or manage such risks. Two fifths of these companies (41%) acknowledge and assess climate change risks and opportunities. This analysis indicates that there appears to be widespread awareness of the physical impacts of climate change. However, there is a sizeable gap between awareness and assessment of risks, and a larger gap between awareness and action on adaptation to climate change. Less than a fifth of companies (17%) which assess risks and opportunities take further actions to manage climate change risks (equating to only 7% of those aware of risks).

- *Lack of information, uncertainty and modelling tools*. Climate change impacts are inherently uncertain and the tools for dealing with this uncertainty can require a high degree of technical sophistication. A high level of uncertainty and lack of consensus regarding climate impacts and time frames can make the business case for action difficult to justify to internal and external stakeholders, such as employees, investors and consumers. Indeed, across Europe, there is no such agreed set of climate projections, and so the choices / decisions for those wishing to grapple with the climate science are difficult. If there is substantial uncertainty about the future benefits of adaptation but the current costs are reasonably clear, people may make poor decisions about private adaptation.

- *Short-term versus long-term horizons*. The incorporation of climate risks may require that companies consider longer time frames than those traditionally used in corporate plans (often five years). Companies face difficulties dealing with information about large-scale, longer term trends and incorporating this information into shorter-term financial planning models. It makes it difficult to communicate and champion adaptation inside the company. For many business activities the planning horizon does not extend beyond five years. Timeframes of this length will not be forward-looking enough to consider long-term climate change impacts, and companies will be less likely to adapt to impacts that have not entered into their business planning procedures. In addition, the long-term and uncertain nature of benefit compared to the immediate costs makes the business case for such investment more difficult.

Finally, the long-term horizon of benefits related to adaptation also mean that those who pay the cost may not be those who reap the benefits. For example, there will be little financial incentive for developers to increase resilience of new buildings unless property buyers discriminate between properties on the basis of vulnerability to future climate.

Policy and regulatory failures

Regulation can explicitly compel companies to take adaptation into account. Indeed, according to the Economist Intelligence Unit's survey (2010), 56% of respondents said regulation would have the greatest influence on their environmental strategy the following year (Economist Intelligence Unit, 2010). However, while regulation can promote adaptation, inconsistencies in regulation or uncertainty about the future regulatory environment can be a cause of uncertainty to companies and may even be a barrier to implementing adaptation. In some cases, existing policy may even conflict with adaptation objectives. Consistency and predictability of regulation is therefore important if it is to be effective in encouraging adaptation.

Cost of adaptation investment

Companies' ability to finance adaptation can significantly affect their engagement – companies often state that a main reason for not implementing risk management actions is the high costs of the adaptation options they have considered. In the current economic context, with slow growth and limited access to finance, this argument is stronger than ever. Many of the businesses that do implement adaptation actions are those companies that have been publicly subsidised or that have found it easier to pass on the costs to consumers (OECD, 2011). The costs of adaptation for businesses relate both to resources needed to assess its exposure to risks and to the financial investment needed to address them:

- *Lack of capacity to undertake a risk assessment*. Robust climate change risk assessments are the first step towards adaptation. However, they can be costly and require technical knowledge that companies do not always have in-house. Where these skills exist in house they may not be applied to climate change because of a lack of awareness of or understanding of the significance of climate change impacts The uncertainties around future climate change impacts and the delays until impacts are felt are disincentives for companies to produce detailed assessments, as they may see climate impacts as issues that can be dealt with in the future. This response may be rational if future impacts are mild or if adaptation can be implemented at short notice, but this may only be known if assessments are undertaken (OECD, 2011).

- *Cost and reversibility of adaptation action*. This is particularly relevant to 'hard' adaptation measures i.e. large scale investments with high irreversibility. Hard measures include specific technological and infrastructural changes involving capital goods that consider specific climate change risks in planning and design. The high cost of these investments is a strong disincentive to action. In addition, as companies' investment decisions are based on assessments of costs vs. benefits, they may be reluctant to commit to significant upfront investments given uncertainties around the extent of the end benefits.

Externalities

Some adaptive responses not only provide private benefits to those who have paid for them, they also provide benefits – or positive spill overs - to the wider economy. In such circumstances, the private sector is unlikely to invest in adaptation up to the socially desirable level because they are unable to capture the full benefits of the investment. In some cases, there may be little – or no – private adaptation because the necessary adaptive response is effectively a ‘public good’ in the technical economic sense. Public goods occur where those who fail to pay for something cannot be excluded from enjoying its benefits, and where one person’s consumption of a good does not diminish the amount available for others. In the case of climate change, relevant pubic goods include research to improve our understanding of climate change and its likely impacts, coastal protection and emergency disaster planning.

A key barrier to private sector investment in actions design to address climate change and other environmental issues is the existence of externalities. They play a role in two ways:

- Negative externalities related to pollution, resource depletion, loss of biodiversity etc. are not captured in market prices, leading to environmentally damaging actions. For example, suppose that a forester switches tree species in order to take advantage of a warmer climate. Suppose that the forester only considers the timber benefits against the cost of encouraging the species switch. However, suppose that wildlife species dependent on the old species cannot survive with the new species in place. If the wildlife is valued by others, but the landowner does not consider this effect, the switch in species introduces a negative externality (CEPS, 2010);

- Positive externalities from the restoration of the environment, reduction of emissions, reduced water use are not fully captured by the organisation which invests in actions. In doing so, externalities distort economic activities against the environment on both sides.

The market will not always lead to efficient levels of joint adaptation, i.e. in the case of adaptation measures, which are public goods or at least have strong positive externalities. Joint adaptation will be efficient only through collective action. In general, governmental intervention is necessary if there is market failure and if the costs of the intervention are lower than the welfare loss due to market failure.

The barriers above result in a lack of integration of climate change considerations into business models which need to be addressed in order to ensure that businesses manage liabilities and reduce future costs. Many companies rely on suppliers or have on-the-ground operations in developing countries and emerging economies. By analysing climate risks throughout the value chain and mitigating risks through concrete changes in such areas as production processes, improved management of ecosystem services, infrastructure and asset siting, supply chain communications and management, community outreach, and employee education and benefits, companies can better manage their liabilities and avoid significant costs and disruptions. Businesses' profitability depends on strong, resilient suppliers, employees and surrounding communities. It is important to note that if done well, these changes can create short-term value for businesses and their stakeholders, regardless of whether or when anticipated climate impacts happen.

Risk transfer

Insurance against climate change related events offers a way for individuals, businesses and governments to protect themselves against financial losses incurred as a result of these events. The insurance sector can therefore play an important role in addressing the uncertainty with respect to local effects of climate change. Principally, insurance markets are able to provide protection against climate-induced losses. The transfer of risk from risk-averse subjects to risk-neutral insurance companies leads to welfare improvements and, if well designed, an efficient level of precaution. Indeed, research has found that countries with more developed financial or insurance markets suffer less from disasters in terms of output declines. For further details see chapter 3.7.

It is worth mentioning that there are other instruments which allow a transfer of risks linked to climate change. They include catastrophe bonds and weather derivatives.

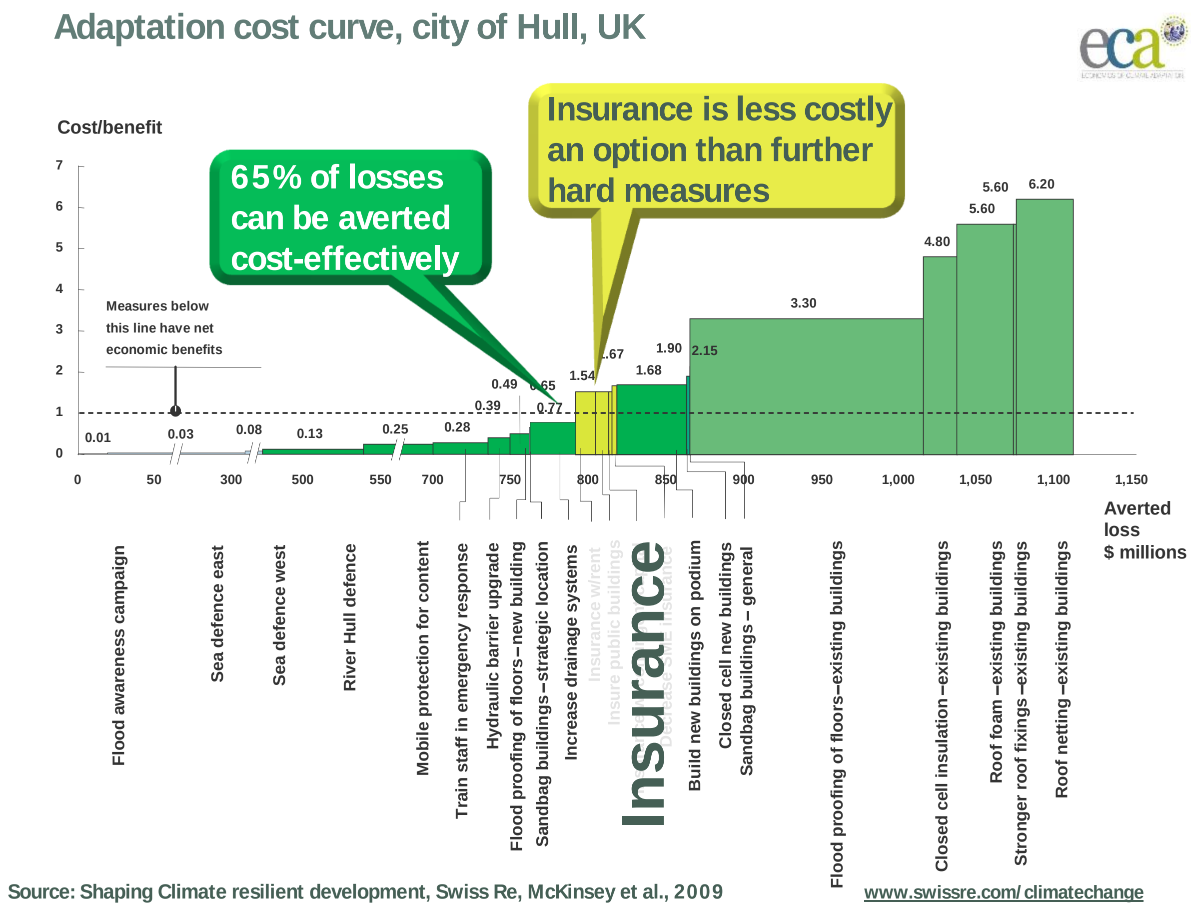
Potential of climate risk disclosure

Climate risk disclosure has the potential to remove the hazard of asymmetric information within supply chains and between customers, suppliers, capital markets and other stakeholders. For further details see Annex 13.

Finding the right balance between risk prevention, transfer and toleration

In response to risk businesses face the choice between preventing (or reducing) risk through adaptation actions, transferring the risk to a third party through insurance or other mechanism or tolerating the risk (and bearing the consequences if the risk crystallises). There may be instances where transferring the risk via insurance is a cost effective alternative to other measures. A study for the City of Hull in UK (Figure 54) identified the potential of insurance to mitigate the consequences of risks that could otherwise not be averted cost effectively.

Figure 54: Potential of insurance to mitigate the consequences of risks



3.6.2.4 Potential solutions for addressing barriers in risk management

Supporting risk prevention

The public sector can encourage and assist private sector adaptation by **addressing the barriers to action** identified in this analysis. The table below summarises these options:

Table 32: Barriers and potential responses for supporting risk prevention

Barrier	Response
Lack of awareness about climate change risks	The public sector can play a critical part in raising awareness of climate change issues and their potential impacts on businesses, as well as the solutions available. In order to be effective, this needs to be done through the collective action at a sector and trade association level where the public sector can support awareness raising through existing networks and structures.

Barrier	Response
Lack of capacity to undertake a robust risk assessment for new projects	The public sector can assist private sector decision-making by providing risk-management guidance and tools that are adapted to suit different users' needs. It could also facilitate best practice exchange. Working with businesses to identify the best methods to communicate this guidance and the business case for environmental risk assessments will be critical.
Uncertainty, lack of information, lack of modelling tools, short-term versus long-term horizons	Public sector institutions do not necessarily need to produce this scientific information themselves, but can act as intermediaries to facilitate information exchange between scientific and business communities and to make information more understandable and accessible for non-technical end users.
Policy and regulatory weaknesses	▪ Demonstrate policy commitment to adaptation. A European Adaptation Strategy will be a step in the right direction. However, it will be equally important to mainstream adaptation in existing regulations and funds which have significant impact on private sector long term planning. ▪ Engage businesses as stakeholder in planning and implementation ▪ Consider Public Private Partnerships
High cost of adaptation measures	Financial and fiscal incentives. This is explored in more detail in chapter 3.6.3.

Supporting the uptake of insurance

Insurance can be used to manage those risks which cannot be prevented or are too expensive to prevent. However, as elaborated further in chapter 3.7, the uptake of insurance is not optimal and a number of barriers are preventing businesses from using this tool.

To use insurance is a private decision but public intervention can create an environment which facilitates the uptake to more optimal levels by:

- Helping economic agents to better understand the nature and impacts of the expected climate change through producing and distributing information;
- Creating an institutional framework where autonomous adaptation can be successful.

The absence of such facilitating adaptation may ultimately lead to inadequate autonomous adaptation and a higher level of necessary planned adaptation in the future.

Solutions which the public sector may consider include:

- Improving the quality and availability of information on climate-change related issues and relevant insurance products;
- Insurance taking-up: Support society to insure against specific risks related to extreme weather events and especially support insurance uptake by key sectors more vulnerable than others to climatic variations, like agriculture and forestry (awareness, market availability, or guidelines, co-financing may be made available).

Table 33: Barriers and potential responses for supporting the uptake of insurance

Barrier	Response
Lack of knowledge on how to use insurance effectively in risk management	Guidance could be developed on how to find the right balance between risk prevention, transfer and toleration.
Correlated risks, i.e. the expectation that climate change means that risks are systematic or more interdependent than traditional insurance risks	Information about the nature and extent of anticipated changes in climate will help and public sector efforts in this regard will need to be available to the insurance industry.
Uncertainty	As above.

Cost effectiveness and affordability could be added the list of potential barriers. Insurance may withdraw from sectors or from high-risk areas.

3.6.3 Finance solutions available for adaptation actions

The cost of adaptation actions are often identified as a major obstacle to the implementation of solutions to the risks presented by climate change. This is another area in which the public sector can offer some support to private companies. Indeed, many financing instruments can potentially support specific types of activities in the domain of prevention. At the European level, a number of grant schemes are available with a remit encompassing climate change interventions which range from research to demonstration and financial support.

Appropriate financing mechanism for adaptation depends on a type of adaptation action. For example there can be adaptation activities that generate revenues so the financial instruments could be used. Some activities might be urgently needed and public authorities might consider financial instruments (loans) for implementation of such actions. There are also activities that can only be funded through the grant schemes. These differences are important to define in order to select optimal instruments for different actions.

3.6.3.1 Financial instruments

Aside from EU grants (cf. chapter 3.9.6), the main financial instruments available to businesses for adaptation can be split into two broad categories: revenue finance (loans) and equity finance.

- Loans and guarantees:

  A business loan is funding given to business by a bank, an individual(s), or an organization usually to be repaid by a certain date with a certain amount of interest. The amount of a loan, the amount of interest, the repayment date, the qualification of the loan recipient to merit the loan, the credit analysis, and the number of lenders used to achieve the desired loan amount are all variable.

- Equity finance:

  Equity finance is a way of raising capital from external investors in return for handing over a share of the business. This may take many forms, including a share of future profits, but is most frequently associated with sharing the ownership of the business to some degree.

  The main providers of equity finance are **venture capitalists** – a type of private equity firm – and **business angels** who are typically high net worth individuals often with experience of being entrepreneurs themselves. Equity investors can intervene at the very start of a business' life with seed / start-up funding and later on, if a business requires a new injection of capital in order to expand.

  Unlike lenders, equity finance investors do not normally have the legal right to charge interest or to be repaid by a particular date. Instead they expect to make a gain on capital dependent on the growth and profitability of the business, and may also receive dividend payments.

  The extent to which equity finance would be deemed suitable or acceptable by businesses to finance adaptation measures will depend upon the nature of the adaptation being supported and on the structure of the entity being supported. The existence of equity gaps in most countries limit the potential of equity finance as a solution, in particular for small firms for which other approaches will be more appropriate.

Loans, guarantees and equity finance by the European Investment Bank

One of the most important provides is the European Investment Bank which provides several types of guaranties and loans which also might play a role for adaptation. A study by IEEP in 2011 identified the following main loans and guarantees:

- Risk sharing instruments are also used in the SME funding schemes JEREMIE. The Joint European Resources for Micro to Medium Enterprises (JEREMIE) is an initiative of the European Commission developed together with the European Investment Fund. It promotes the use of financial engineering instruments to improve access to finance for SMEs via Structural Funds interventions. The proposals[144] for the post-2013 period expanding the scope of financial instruments to all types of projects. The only operational criterion that needs to be taken into account is that projects should be revenue-generating. This means that financial instruments, in the context of climate change objectives, could be used for renewable energy projects and related infrastructure, energy efficiency, sustainable transport, smart grids, electric cars, etc. and to a lesser extent for climate adaptation. In any case, financial instruments offer new opportunities to mobilise additional public and private sources of financing using Structural Funds.

- The Joint European Support for Sustainable Investment in City Areas (JESSICA) which is an initiative of the European Commission in cooperation with the EIB and the Council of Europe Development Bank (CEB). Through JESSICA, Member States may choose to use some of their European Regional Development Fund (ERDF) allocations as ‘revolving funds’. The notion of revolving funds is that the funds are replenished, i.e. managing authorities receive back the capital invested, including revenue generated throughout the operation which can then be reinvested in new urban development projects.

- The Intelligent Energy Europe programme, the European Local Energy Assistance technical assistance facility (ELENA) provides grants for technical assistance for the development of investment programmes and facilitates access to EIB finance or finance from other banks, thereby improving the bankability of projects. The focus is on fostering sustainable energy actions at the local level, with beneficiaries of local and regional authorities, other public entities, or groupings of such entities, including those subscribing to the Covenant of Mayors.

- Risk Sharing Finance Facility (RSFF) which boosts research, development and innovation. RSFF financing products use a wide range of loans and guarantees which can be tailored to individual innovators’ needs. The RSFF has been positively evaluated by the EIB and in a mid-term review of FP7.

- The Loan Guarantee Instrument for Trans-European Network Transport (LGTT) is designed to guarantee medium term revenue risks from public-private partnership transport schemes. It is a forerunner of the RSFF and works in a similar manner but targets projects in the transport sector.

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[144] http://www.eib.org/projects/publications/the-eib-promoting-climate-action.htm

- The 2020 European Fund for Energy, Climate Change and Infrastructure (Marguerite Fund) is a pan-European equity fund for infrastructure investments in the transport, energy and renewables sectors. It was set up in December 2009 following a request by the European Council as part of the European Economic Recovery Plan. The European Commission provides €80 million in risk capital out of the TEN-T budget to the fund. The fund provides equity or quasi equity finance for priority infrastructure in the EU.

Other sources of finance

A range of other sources of finance are available to businesses and include: factoring and invoice discounting (to improve cash flow by selling your invoices to a third party before the invoices are paid by customers); overdrafts; joint ventures etc. In many cases these are unlikely to be affected by climate change or adaptation to climate change however increased uncertainty in supply chains and climate change vulnerability in customers businesses may increase the cost of accessing some of these sources of finance (if the risk of suppliers being unable to pay increase the cost of providing liquidity on the basis of invoices, for example, would be expected to rise). Therefore actions to improve information and transparency discussed above are relevant considerations for other financial sources.

Barriers to using financial instruments for adaptation

Difficulty in accessing finance is often faced by companies. Sometimes that reflects poor business plans from the applicants and weaknesses inherent to their financial situation; as such denying funding would be a rational decision. However, in other cases, the decisions of financial institutions are influenced by other factors including a poor understanding of the business and the sector it operates in, or risk aversion with regards to innovation. It is likely that issues related to adaptation will be particularly vulnerable to this. Financial instruments for adaptation should not become a route to finance for business propositions that are not otherwise viable but should be targeted on those areas where it is the need for adaptation actions themselves that threaten viability (in the absence of available funds).

3.6.3.2 Market based instruments

Mandatory regulations can be a blunt, cumbersome and expensive instrument. For this reason, policy makers have been looking at alternative ways to alter how businesses produce and individuals consume. MBIs[145] can provide such solutions.

[145] MBIs use price or other economic variables to provide incentives for polluters to reduce harmful emissions. The key feature of market mechanisms (or market-based instruments) is that a price signal is used to promote the production of a certain service or good, or to reduce it. MBIs rely on individuals and/or firms having the ability to respond to this price signal – hence choosing a less-polluting good, service or activity or simply less of it if there is no appropriate alternative.

MBIs can take many forms including: taxes, charges, subsidies, marketable (or tradable) permits, deposit/refund systems and fines, payment for ecosystem services, property rights and habitat banking[146]. Other measures such as eco-labelling and specialised funds can also be included under MBIs as they alter prices and production decisions.

In order for the MBIs to be successful instruments of change, a number of complex risks and challenges might be faced. The following factors may limit the effectiveness of MBIs:

- Institutional constraints such as underfunding, inexperience, unclear jurisdiction and lack of political will;
- Administrative intensity (i.e. monitoring, legal, consultation and enforcement requirements) which remains high;
- Setting the right level of the charge, the quotas / allowances, or the deposit-refund;
- MBIs have the potential to be regressive, as they make the cost of goods and services higher. If not designed properly, they may also have perverse effects (e.g. water pollution charge may cause more pollution if based on effluent concentrations and not on total pollution load);
- When MBIs apply to components of the supply chain, the ultimate impact on prices is uncertain. In some situations a change in production costs will result in a change of the price (if the cost increases can be passed on to the consumer) and in other cases there will be less pass through. This is important to understand as it will affect the likely influence of the instrument;
- Finally, even if the price goes up, there may not be an immediate change of behaviour, as there might not be adequate alternatives or substitutes or the ability to reduce consumption. Elasticity of demand to price change is another important issue to integrate into the consideration of which instruments to use.

As a result, while MBIs offer useful and cost-effective solutions, they cannot substitute for weak institutions or command and control policies. They must be considered as one element of a wider, coherent, strategy to address climate change.

MBIs for adaptation

The possibility of using market mechanisms for adaptation has not so far been widely explored and there is therefore limited evidence of their effectiveness or applicability. However, experiences from mitigation show that economic instruments can play a key role in generating action and are therefore an avenue to explore further.

[146] For an overview of MBIs for adaptation, please cf. Perspectives GmbH (2011a, b).

A recent study for DG CLIMA (Perspectives GmbH, 2011b) explored this by looking at a range of economic instruments that can incentivise the reduction of climate change impacts through preventive action and by drawing from instruments used for climate change mitigation and ecosystem services. The key findings are presented in this section.

The following MBI categories are identified as having links with adaptation activities:

- Subsidies, differentiated into grants, tax reductions and price supports. They could be used to finance improvement of infrastructures and adaptive activities with a public good character. Subsidies have already been applied for adaptation in several countries;

- Taxes and fees, differentiated into carbon, energy and land use taxes. Taxes can be used if myopic behaviour of private actors leads to overly risky investments, as taxing specific behaviour can internalize and at the same time signal its negative externalities. Carbon and energy taxes have already been widely applied, land use taxes only sparingly;

- Licences and permits, covering tradable units, project-based offsets and advance market commitments. A trading system can limit a “bad” or require production of a public good, which is denominated in tradable units. Government specifies which entities have to surrender tradable units and how the units are allocated. While trading and project-based offsets are widespread in mitigation, they have not yet been applied for adaptation and neither have advance market commitments;

- Other measures, including payments for ecosystem services (PES), water markets and habitat banking. All these instruments have in the past not specifically aimed at adaptation, but do provide positive adaptive externalities.

The study identifies grants, land use taxes, an Adaptation Market Mechanism, payments for ecosystem services and water markets as **the most promising instruments** in terms of their potential effectiveness:

- **Tax reductions** would provide favourable incentives to engage in activities that increase the resilience of production sites and real estate in general;

- **Land use taxes** could influence land use in areas exposed to extreme events or slow-onset change of parameters which would not allow continuation of current use;

- The study also suggests the creation of an **Adaptation Market Mechanism** (AMM) which could harness a wide range of adaptive activities, particularly those involving actual investment, provided their effect is measurable. A trading system for adaptation could be designed in a way that it limits “risky activities”, and thus would be similar to the permit trading systems for classical pollutants (Perspectives GmbH, 2011b);

- **Payments for ecosystem services** e.g. for the protection of forests and wetlands, can only mobilize adaptive activities indirectly through the remuneration of certain land uses. Its effectiveness is however reduced due to this limited scope of application*;*

- **Water markets** provide an indirect adaptive benefit as (efficient) water pricing will lead to a reduction of water consumption and thus increase the water resources available in case of drought or water scarcity. Effectiveness of water pricing is high; it is especially applicable in areas where water availability is projected to decrease due to climate change. Institutionally, no major challenges occur. Consistency with other instruments influencing land use such as payments for ecosystem services and land use taxes needs to be ensured.

3.6.4 Potential actions and lessons to increase business engagement in adaptation

If the private sector is expected to contribute to resilience-building and adaptation innovation in the countries that need it most, there needs to be increased business engagement in international and national-level adaptation policymaking and planning. To date, businesses engagement has been primarily focused on issues related to mitigation rather than on adaptation. It is time for adaptation to take a more central place on the agenda.

- The public sector must develop a *specific strategy* for mobilising private sector strengths and assets. As part of this strategy, it may also be valuable to consider including private sector representation in public forums / committees / bodies dealing with environmental issues.

- Effective adaptation requires *engagement of all types of businesses*, from global to local companies, including small and medium-sized enterprises and social entrepreneurs. It will be important to stimulate cross-sector discussions to identify broader adaptation needs and linkages between different parts of the economy and society.

- There is some untapped *data and knowledge potential* in the private sector which should be maximised. Businesses can contribute data and information on risks, exposure, and adaptation solutions, and advice on policy and regulatory frameworks.

- National and local-level adaptation and disaster risk reduction and management plans can specify areas where private sector *innovation* is essential, and identify a clear role for the private sector in contributing to the building of a climate-resilient society and economy.

- Access to finance for the private sector to support resilience and adaptation actions can be achieved through the direct provision of grants by the EU (cf. chapter 3.9.6) and other private funding mechanisms described above including traditional loan finance and equity finance.

3.7 Insurance

Insurance can be used as an instrument for adaptation to climate change:

- To manage climate change risks;
- To provide incentives for climate risk prevention;
- To disseminate information on climate change risks and risk prevention measures.

Climate change will affect every class of insurance in some way (Dlugolecki, et al, 1995; CEA, 2007; Geneva Association, 2009). However, the clearest and probably most intense effects will be seen in property insurance and related lines of non-life insurance (Dlugolecki, et al, 2009; CEA, 2009). For that reason, this section concentrates on property insurance.

Large-scale industrial enterprises and national public assets generally have unique characteristics and have the benefit of in-house highly skilled risk management expertise. Therefore this section deals with the consumer sector and the equivalent level of business and tertiary enterprises i.e. SME's or small-to-medium enterprises.

Also, since the predominant tenor or duration of a property insurance contract is one year, individual organisations in the insurance sector do not generally concern themselves with matters which will arise further than five or at most ten years ahead. Thus the focus of this section will be on current and near-term climatic issues, rather than long-term climate change.

3.7.1 Natural catastrophe insurance and climate change

Catastrophe insurance is essentially concerned with the risk of damage from extreme events. Risk is in fact a product of three factors[147]:

Risk = event x **exposure** x vulnerability

In the context of this report, the event is the climatic phenomenon (e.g. wind, flood), exposure is the portion of the built environment that is affected by the event (e.g. houses, roads) and vulnerability is the sensitivity of the exposure to damage (e.g. strength of roofs, quality of flood defences). When an event happens, the risk or potential loss is translated into an actual loss. For insurers, a fourth factor is critical, the terms of risk transfer (RTC), such as deductibles, limits, exclusions, because that determines the insured loss. Note that price is also a key RTC, but it is not involved in the assessment of loss.

Insured loss = actual **loss** x RTC

[147] Some would add a fourth feature: probability of occurrence.

A key precondition of insurability is that the risk can be assessed accurately. This means that the insurer must be able to measure the three exogenous factors (event, exposure, and vulnerability) in order to decide what risk transfer conditions to offer to the at-risk parties.

3.7.1.1 Extreme events

The probability of most types of extreme events is expected to change significantly, in many cases upwards, as a result of climate change (IPCC, 2012a). Several national studies have interpreted the predictions for insurers; for example in the UK (ABI, 2005) and in France (FFSA, 2009). In fact the ongoing rapid changes make it hard to assess the future risk. The most dramatic and reliable changes are predicted for temperature; the historical 500 year heat wave event might become a 2 –yearly (biennial) event by the 2040's (Stott, et al, 2004). There is now strong evidence that extreme high temperature and precipitation events are more common in many regions (Coumou & Rahmstorf, 2012). Already the frequency of hot months in the UK has changed from once-in-100 years to once-in-12 years (Dlugolecki, 2006).

Similar projections for other extremes are less available. For several major European rivers, e.g. Odra, Elbe, Po, Loire, Danube, what used to be a 100-year flood might by 2100 become a one in 50 year or even one in 20 years event (Dankers & Feyen, 2008). The main underlying cause is rainfall; the return period for an event of annual maximum 24-hour precipitation with a 20-year return period in the late-20th-century is projected to be about 5-15 years by the end of the 21st century (IPCC, 2012a). A study of extreme rainfall in London found that daily rainfall with a 100- year return period prior to 1960 has a 10-year return period now (Lloyd's, 2010). However, it should be noted that for some rivers, climate change may even reduce flood risk, due to a difference in the scale of the spring thaw (IPCC, 2012a).

On the reverse side, there is a projected increase of duration and intensity of drought in the Mediterranean region and Central Europe, but this is not well-quantified (IPCC, 2012a).

For storm, the outlook is less clear still, but the consensus is a gradually increasing risk for North-western Europe (IPCC, 2012a).

In the short term (under 5 years say), the effect of climate change on insurance might not be thought to be significant, as long as due allowance is made for the underlying trend[148]. For example, prices would rise gradually, and the market would absorb such changes without disruption. However, risk knowledge often advances in 'steps', which can lead to jumps in the price over a short period. Essentially, the insurance market deals with climate variability or weather.

148 The point is that regulators and insurers must allow for the trend, not simply use the historical averages, which will be somewhat lagging behind, and so will always produce an incorrect response.

In the longer term, particularly in sectors or areas where insurance has not been customary, climate change could create or exacerbate issues[149] with pricing and availability. In particular, sea level rise will become an issue for coastal and estuarine risks. The problem of drought for agriculture and livestock may also become more serious. Drought-related subsidence may also become a greater issue for the built environment in some regions where clay soil is sensitive to the absence of water (Swiss Re, 2011). Potential losses from storm and flood could also rise significantly (ABI, 2005; GDV, 2011), but the actual increase would be highly dependent on changes in exposure and vulnerability.

3.7.1.2 Exposure and Vulnerability

All observers agree that exposure to climatic risk has risen greatly in recent decades, due to rapid economic development, enacted without much risk awareness. This has been a major factor in the trend of increasing losses from climatic events (IPCC, 2011). What is less clear is to what extent changes in vulnerability have influenced the losses. It is difficult to measure, because data on the built environment is not generally very detailed. There is a mixture of structures of different ages and designs; furthermore, actual construction often falls below the design standard. Future exposure is set to rise enormously in the EU region and elsewhere, particularly in coastal cities (OECD, 2007; World Bank, 2011).

3.7.1.3 Loss trends

Munich Re kindly provided an extract of their archive of extreme events for detailed analysis. The data gave details of 4,110 weather–related incidents at national level over the period 1980-2011 for most of Europe. (For further details cf. Annex 12).

Table 34: Cost of weather-related incidents in Europe 1980-2011 (cost in million US $ 2011 values. Data: Munich Re. Analysis A. Dlugolecki)

Period	Insured cost	Total cost	% insured
1980-9	20,880	79,396	26.3
1990-9	57,870	151,334	38.2
2000-9	51,866	155,181	33.4
2010-1	12,459	27,604	45.1
All above	143,075	413,515	34.6

As Table 34 shows, the cost of weather incidents is large - 414 billion US$[150] (~ 328 billion EUR) over 32 years, or an average of $13 billion per year (~10 billion EUR per year). As

[149] For a full discussion of these issues, see Chapter 3.
[150] at 2011 values.

noted in Annex 12, this is an understatement of the position, since there are gaps in the data. The data also shows an apparent upward trend in insurance density or penetration. This should be taken as a provisional conclusion to be confirmed by further analysis, since the data for the last decade only covers two years, and the data for the 1980's is generally less rigorous than for later years.

Roughly one-third of the cost of damage due to weather events was insured. However, the coverage varied greatly depending on the type of weather incident (cf. Table 35).

Table 35: Insurance involvement by type of weather incident (cost in million US $ 2011 values. Data: Munich Re. Analysis A. Dlugolecki)

	Total cost	% of total	Insured cost	% insured
Flood	163,046	39.4	43,883	26.9
Storm	156,096	37.8	84,296	54.0
Drought	69,025	16.7	1,593	2.3
Cold	25,348	6.1	13,303	52.5
All	413,515	100.0	143,075	34.6

Over three-quarters of the costs arose from storm or flood events, with a further one-sixth caused by drought or heatwaves[151]. Only 6% was due to cold weather.

Just over half of the costs of storm and cold incidents were insured. However, only one quarter of flood costs was insured and only one-fortieth of drought events. Examination of the event descriptions indicates that much of the cost of drought events is in the agricultural and forestry sectors, or else it is more properly described as consequential loss, rather than property damage, so does not fall strictly within the scope of this analysis. Thus the biggest gap in property insurance against weather damage is flood coverage.

Generally speaking, weather losses do not appear to be a persistent, major problem for European countries, as shown by the impact indicator in Table 36 (taking average annual weather losses as a percentage of national GDP). However, this would not be a sound conclusion for several reasons. First, some high-risk countries like Netherlands and UK devote considerable efforts to loss avoidance e.g. flood defences. Secondly, a 32 year period is insufficient to gauge the effect of rare, extreme events, which have a much longer return period. Thirdly, the extreme events can produce losses up to several percent of national GDP at one stroke, an effect which is disguised by taking an average across all years, good

[151] For a discussion of how the events were classified, 0.

and bad. Other points are that some countries are much larger than others, which masks the regional impact of extreme events, and finally the data is incomplete, as noted elsewhere.

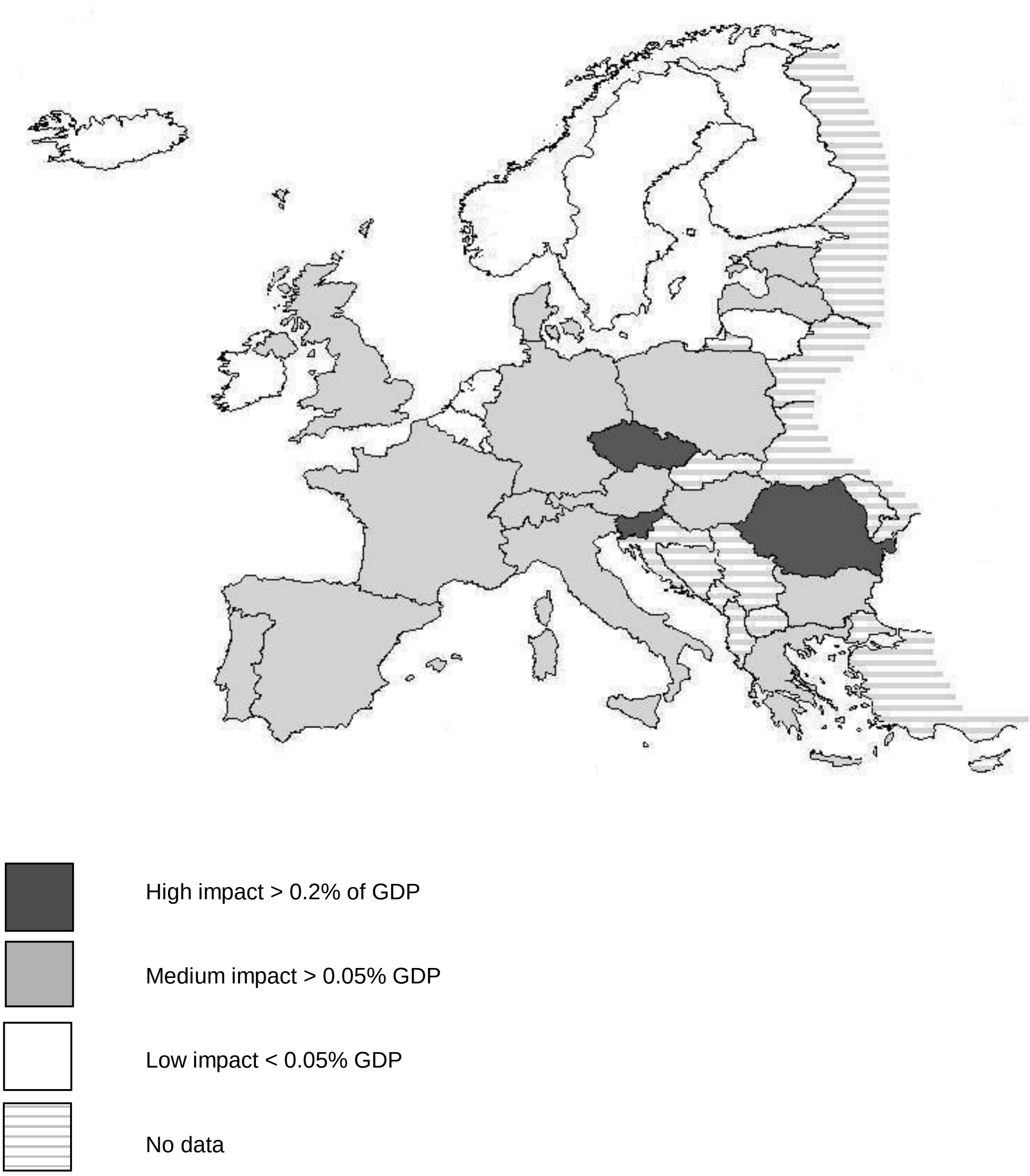
Table 36: Key data on drought and insurance coverage

	All Weather Losses 1980-2011 (million US $, 2011 values)	Weather impact (losses as % of GDP)	% drought in total losses	% of non-drought losses that was insured
	(1)	(2)	(3)	(4)
Austria	12,320	0.13	5.7	33.5
Belgium	4,071	0.04	1.4	52.7
Bulgaria	1,053	0.11	4.8	0
Czech Rep.	8,549	0.21	4.6	35.0
Denmark	10,033	0.13	11.5	66.0
Eire	2,240	0.05	0.1	37.4
Estonia	298	0.08	3.7	12.5
Finland	1,965	0.03	0	16.5
France	63,213	0.10	13.8	53.5
Germany	80,126	0.09	4.0	44.5
Greece	8,149	0.12	75.0	4.1
Hungary	3,654	0.11	60.6	5.4
Iceland	68	0.02	0	33.9
Italy	55,909	0.10	31.2	5.5
Latvia	777	0.16	0.6	7.0
Liechtenstein	7	0.01	0	58.1
Lithuania	279	0.03	47.0	5.5
Luxembourg	601	0.06	1.2	60.1
Malta	71	0.04	0	36.3

	All Weather Losses 1980-2011 (million US $, 2011 values)	Weather impact (losses as % of GDP)	% drought in total losses	% of non-drought losses that was insured
Netherlands	6,933	0.04	0	42.3
Norway	3,209	0.04	0.2	45.5
Poland	13,556	0.15	13.2	7.8
Portugal	8,710	0.15	70.0	7.7
Romania	8,452	0.26	34.0	0.7
Slovenia	2,445	0.22	4.6	11.1
Spain	30,981	0.10	53.4	22.8
Sweden	4,848	0.04	0.5	25.8
Switzerland	18,580	0.15	2.5	48.1
Turkey (Europe)	913	n.a.	7.9	40.3
U. K.	61,505	0.10	1.3	66.0
All	413515	0.07 (ex Turkey)	16.7	41.1

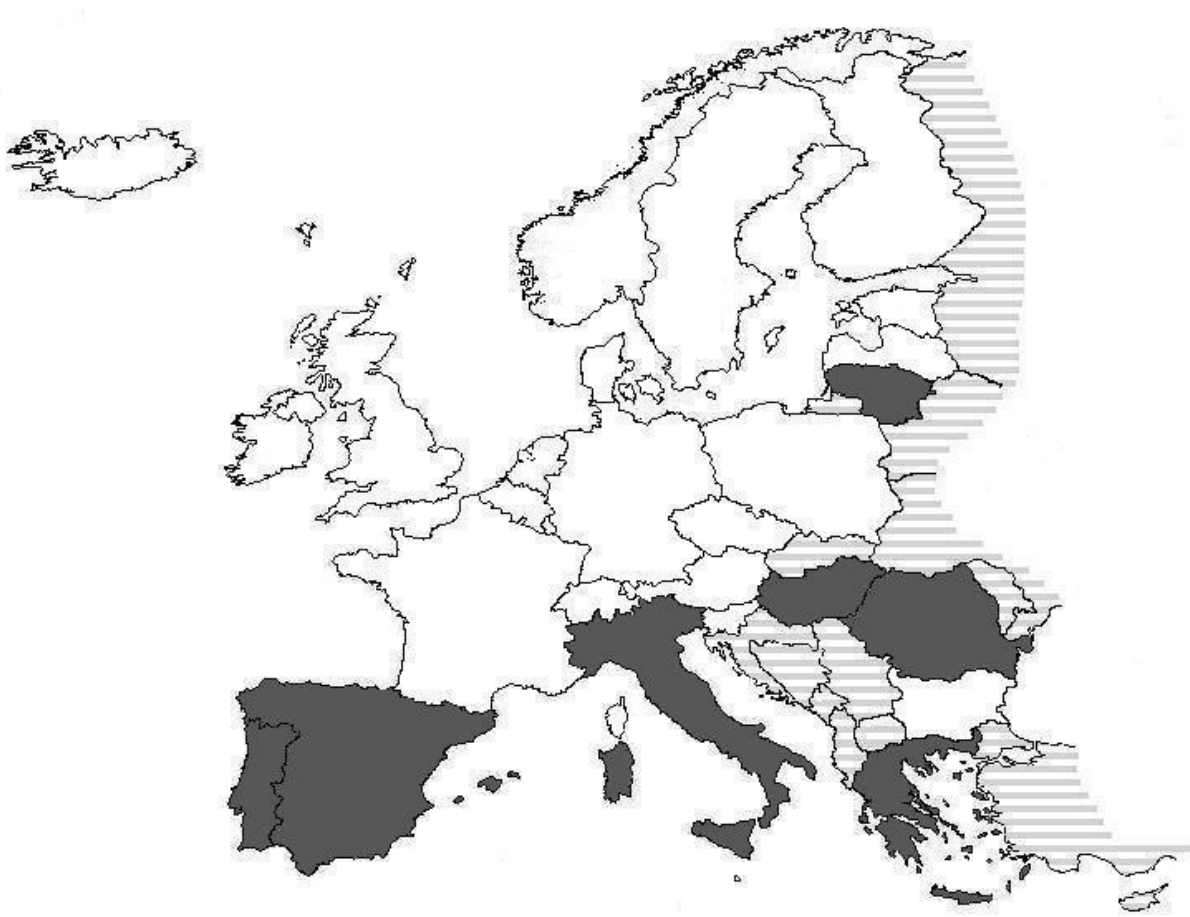
With those provisos, one can make a qualitative division of countries into three groups (cf. Figure 55). The first, high impact group includes 3 Central European nations: Czech Republic, Slovenia and Romania. The second medium impact group has 15 countries: Austria, Bulgaria, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Latvia, Poland, Portugal, Spain, Switzerland and United Kingdom. These are more diffuse, which probably reflects a mixture of underlying risk, with higher attention to risk reduction in some places e.g. in United Kingdom. The third, low impact group has 11 predominantly Northern European states: Belgium, Eire, Finland, Iceland, Liechtenstein, Lithuania, Luxembourg, Malta, Netherlands, Norway and Sweden.

Figure 55: Impact of weather hazards at national level, 1980-2011



The picture varies greatly across European countries, in regard to drought losses, as shown in Table 36 column (3). Figure 56 shows the data pictorially. As can be seen the drought issue is particularly severe in seven countries, mainly southern: Greece, Hungary, Italy, Lithuania, Portugal, Romania and Spain. France, Poland and Denmark are less affected, but still have over 10% of losses due to drought. In Portugal and Greece, droughts cause over 70% of the total loss.

Figure 56: Drought-prone countries



Drought impact

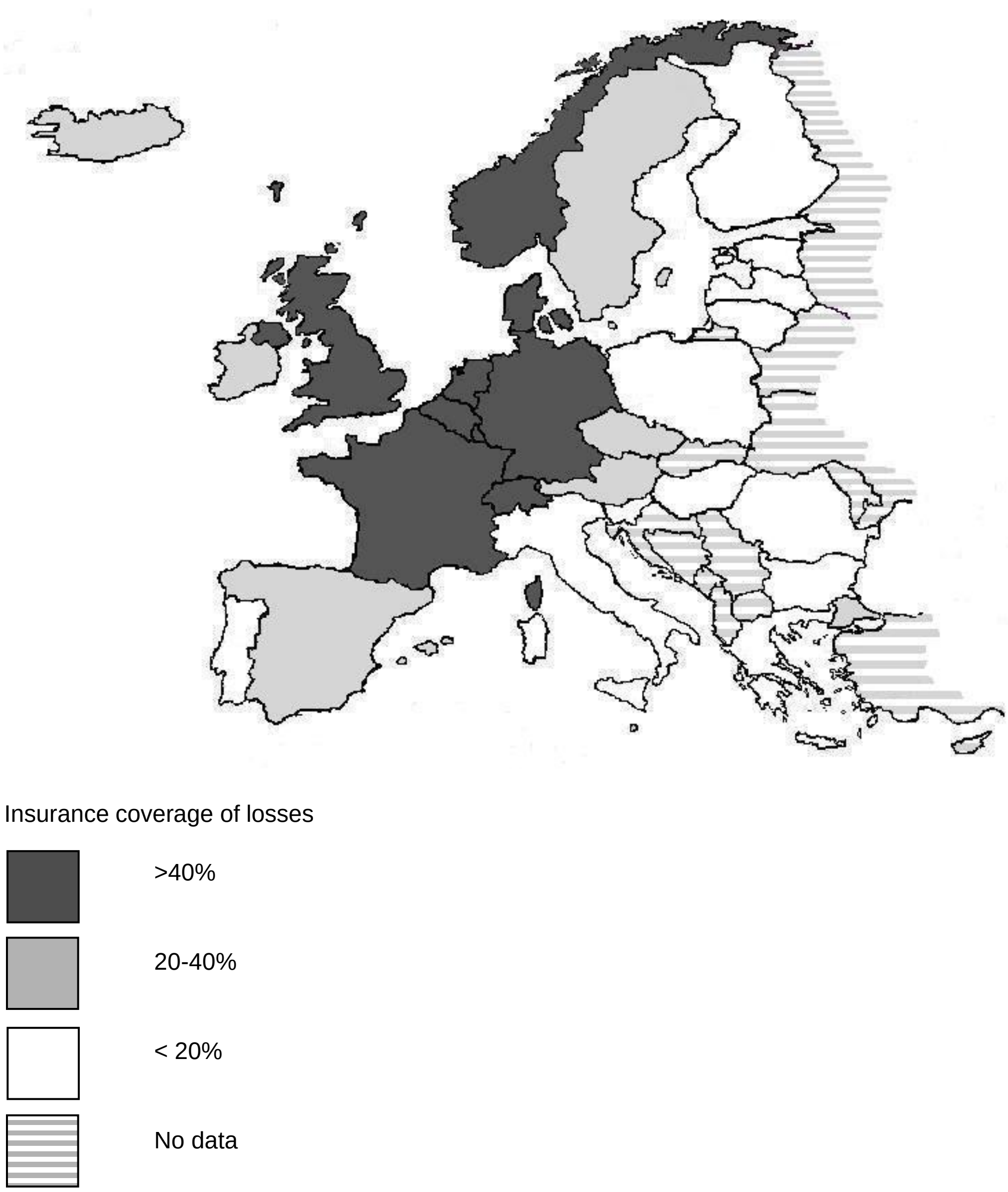
> 30% losses due to drought

< 30% losses due to drought

No data

If one removes drought losses, which are predominantly not related to property, the picture is somewhat altered (Figure 57). Countries fall into three main groups. The first group of ten countries has insurance coverage for over 40% of reported weather losses, and they are mainly located in the north-west of Europe: Belgium, Denmark, France, Germany, Liechtenstein, Luxembourg, Netherlands, Norway, Switzerland and United Kingdom. The middle group of eight countries has coverage between 20 and 40% (Austria, Czech Republic, Eire, Iceland, Malta, Spain, Sweden and Turkey-in-Europe), and are generally adjacent to the first group. Finally, the third group of 12 nations has low coverage, and is predominantly in the east and south of Europe (Bulgaria, Estonia, Finland, Greece, Hungary, Italy, Latvia, Lithuania, Poland, Portugal, Romania, and Slovenia).

Figure 57: Insurance coverage of non-drought losses



It is not possible to discern the contribution of climate change to this, since the natural variability of the weather is high. Also there have been major changes in exposure and possibly vulnerability in recent decades, so that loss trends are heavily influenced by those factors. A few studies have indicated that climate change may be pushing losses up by between 2 and 4 percent per year (Dlugolecki, 2008; Miller, et al, 2008; Schmidt, et al, 2009), but there are no reliable conclusions relating to the EU region. However, one should be wary of studies that claim there is no climate signal, but any trend is due to socioeconomic effects

(Barredo, 2009). In fact the data presented there appears to show a clear trend when normalised for GDP, and the effects of increased loss reduction efforts are ignored.

Since extreme events are infrequent, one cannot merely use the historical losses as a guide to the actual risk, or loss potential. As noted earlier, the Munich Re data is partial and even a period of 32 years is insufficient to capture rare, extreme events. For those reasons it is essential to also consider estimates from catastrophe models, which simulate the behaviour of extreme events. However, catastrophe modelling is an inexact science. The available estimates of risk are incomplete and inconsistent (Perspectives GmbH, 2011a).

One official source of information comes from the Solvency II Directive, which demands a more risk-based approach to asset and liability accounting for (re)insurance companies operating in Europe. In order to test and assess the European industry's solvency in line with the requirements of the Solvency II directive, so called Quantitative Impact Studies are undertaken by EIOPA. Recently, the insurance industry has devoted great efforts to calibrate the capital required to deal with natural disasters in accordance with the Solvency II capital requirements. One important key parameter for such an estimation is the 1 in 200 year gross loss damage ratio for EU Member States (CEIOPS 2010), i.e. country factors representing the cost of a 1 in 200 year loss to the industry as a whole, expressed as a percentage of sum insured.

Preliminary estimates from EIOPA (previously called CEIOPS) are presented in Table 37, which also compares these figures with estimates by IIASA (International Institute for Applied Systems Analysis) in a study commissioned by the EC (Perspectives GmbH, 2011a).

Table 37: Comparison of IIASA risk estimates with CEIOPS: 200 year event loss for windstorm and flood (Source: Perspectives GmbH, 2011a)

	Flood		Windstorm	
	IIASA (% assets)	EIOPA (% Sums Insured)	IIASA (%assets)	EIOPA (% Sums Insured)
Austria	.573	.15	.065	.08
Belgium	.425	.10	.316	.16
Bulgaria	.210	.15	-	-
Czech Rep	.365	.40	n.a.	.03
Denmark	.430	-	.547	.25
Estonia	.267	-	-	-
Finland	.677	-	-	-

	Flood		**Windstorm**	
	IIASA (% assets)	**EIOPA (% Sums Insured)**	**IIASA (%assets)**	**EIOPA (% Sums Insured)**
France	.189	.10	.277	.12
Germany	.092	.20	.134	.09
Greece	.199	-	-	-
Hungary	.646	.40	-	-
Ireland	.293	-	.599	.20
Italy	.198	.10	-	-
Latvia	.464	-	-	-
Lithuania	.248	-	-	-
Luxembourg	1.417	-	.154	.10
Netherlands	.317	-	.405	.18
Poland	.188	.30	n.a.	.04
Portugal	.091	-	-	-
Romania	.221	.40	-	-
Slovakia	.677	.45	-	-
Slovenia	.847	.30	-	-
Spain	.148	-	n.a.	.03
Sweden	.198	-	n.a.	.09
United Kingdom	n.a.	.10	.406	.17

To put the EIOPA figures in perspective, it is interesting to compare them with the rate which insurers charge to cover natural hazards. Often this cannot be distinguished, because it is ‘bundled’ with other hazards, or priced in a different way, as in Denmark, on a flat rate per policy. In three cases, we can see the price distinctly. In Norway the rate is 0.01% and in Spain 0.0092% of the values or sums insured (Consorcio, 2008). In the UK, when flood cover was introduced in 1961, insurers applied a rate of 0.0125% for the additional hazard (Dlugolecki, et al, 1994). Furthermore, those prices all include a load for administration and profit. This indicates that the annual risk premium charged by insurers is around two orders of magnitude smaller than the peak 200-year hazard estimated by EIOPA, as might be expected.

It is important to note that the EIOPA estimates not only take account of the intensity of the hazard but also the vulnerability of the building stock and concentrations of exposure at risk. The methodology for the calibration of key parameters for the Solvency II capital requirements can be found in CEIOPS (2010). However, the full details and the shapes of the loss function are not available, and there are differences of definition (e.g. relating to storm surge) which makes it hard to compare those estimates with others. For flood, there are significant differences between CEIOPS and IIASA's estimates. In general the latter estimates are much higher, but for four countries (Czech Republic, Germany, Poland, Romania) the position is reversed. Further research is needed to establish the reason(s), though clearly the different treatment of storm surge is an important factor. For storm, IIASA's estimates are again generally much higher (apart from Austria), despite the inclusion of storm surge in the CEIOPS definition of storm, but the ranking of countries is quite similar in terms of sensitivity to storm, which suggest the underlying hazard models may be similar. Again, further research is required to explain the differences.

Finally, a note of caution from the field of housing economics: The effect of climate change is likely to alter the accepted relationships between property values and flood risk, due to four factors: future floods may affect areas which are different from those in the past; the scale of events may undermine current cross-subsidies between low- and high-risk parties; second and third order impacts on the labour market and social networks may appear; and economic blight may spread from impacted areas to neighbouring ones (Chen, et al, 2011). If 'the potential magnitude and complexity of future flood impacts on house prices could be considerably greater than existing research might suggest' this could spill over into the insurance market.

3.7.2 The natural catastrophe insurance market and climate change

There are three key barriers to the provision of catastrophe insurance in the EU:

- Risk transfer conditions are not well matched to the underlying risk (cf. chapter 3.7.2.1);
- Insurance is unavailable or insufficient (cf. chapter 3.7.2.2);
- Demand is lacking (cf. chapter 3.7.2.3).

Climate change is likely to affect these areas. These are not one-dimensional problems, and they interact with each other. There are often several contributory factors, so it may require several actions to establish a satisfactory outcome. The following sections examine the areas one by one, consider how climate change will affect them, and then propose possible solutions.

3.7.2.1 Risk Transfer Conditions (RTC)

The most familiar element of the risk transfer conditions (RTC) of an insurance contract is the price or premium, but there are important coverage aspects such as deductibles, exclusions and co-insurance. It is important to realise that these conditions are used in combination by insurers, sometimes even as alternatives. They are not used independently. For easier reference RTC can be divided into price and non-price conditions (deductibles, exclusions, co-insurance, etc.). Price is concerned with generating revenue, while the other RTC's are broadly concerned with reducing outflow i.e. claims payments. A big advantage of price is that it acts immediately, since premiums are paid up-front. In contrast, the effects of non-price RTC's are only felt at the time of a claim generally, and are therefore less likely to affect purchaser's decisions.

The RTC's do not always reflect the actual level of risk, which means that the owner of the activity or asset in question is not aware of the true economic cost, and may therefore make wrong decisions concerning it. This also means that the insurer may not make an adequate return, because the claims will not conform to expectation. Another problem is that the RTC's may vary significantly, up and down, over time. This makes it hard for the at-risk parties to assess the viability of their activities and budget for risk management. It also makes it hard for insurers to maintain a consistent level of profitability. Climate change may exacerbate these aspects further.

3.7.2.1.1 Price related RTC

Potential climate change effects on price

Increase in insurance price

An increase in the event probability and severity would probably lead to price increases. At the same time, changes in the underlying pattern of extreme events would increase the uncertainty of estimation, which would probably mean an additional increase in price to provide a greater safety margin. The increases are likely to be more significant in flood and drought insurance than in storm insurance. While short term increases probably would not be significant, in the long run changes could be substantial.

There is some evidence that disaster insurance is becoming more expensive. In France, CCR, the government reinsurer, has increased the rate for natural catastrophes from 5% of the simple fire premium in 1982 to 12% in 1999, partly due to the rising cost of weather extremes, such as subsidence. Of course other causes such as lack of data have likely also affected the price increase[152].

One follow-up survey of a localised flood in 2008 in UK found that for properties with buildings and contents insurance, premiums increased by 71% if the property had been damaged, by 9% for nearby undamaged properties, but premiums were stable outside the area. The results were similar for contents-only insurance (Morpeth Flood Action Group, 2011).

It is estimated that there are over 100.000 UK properties in areas of significant flood risk that are significantly under-priced as far as the flood hazard is concerned. On average, home insurance for those at significant risk of flood is under-priced by 165% (520 euros per year for the average property). There is wide variation around this average with insurance under-priced by 500% or more in some cases (ABI, 2011)[153].

Anecdotal evidence indicates that there are similar issues with flood insurance in Belgium. The government has enacted and recently strengthened provisions to deal with the flood risk, including a market pool for uninsurable risks.

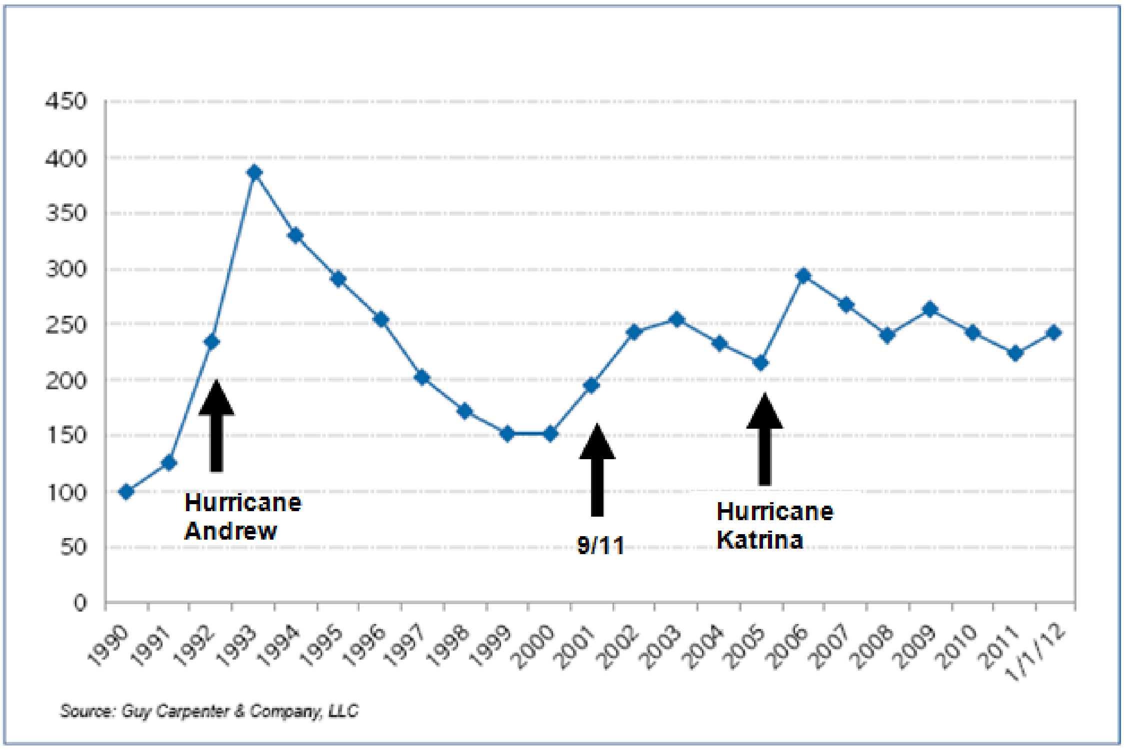
Increase in price volatility

It is to be expected that prices will be more volatile, since it is well established that reinsurance prices react strongly to the occurrence of major events. (Cf. Figure 58 – the index of global reinsurance contract prices rose sharply after each of three major catastrophes, Hurricane Andrew, 9/11, and Hurricane Katrina).

[152] It should also be noted that the Spanish Consorcio Compensacion de Seguros (a compulsory government insurance for natural catastrophe risk) reduced the insurance rate for losses caused by natural catastrophes from 0.09 per mille to 0.08 per mille in 2008 (Insurance Europe, personal communication).

[153] In fact this cross-subsidy situation started in 1963, under an informal agreement between the British Insurance Association and the UK Government, that insurers would provide flood cover at a flat rate to the vast majority of homes and small businesses. This was superseded by the Statement of Principles in 2000, under which the Government undertook to provide risk information and reduce the flood risk, but insurers are withdrawing from this in 2013, since they consider the arrangement has not worked.

Figure 58: Global property catastrophe rol index



Key barriers relating to price related RTC

The key barriers relating to adequate price related RTC are:

- Uncertainty: Calculating the risk of natural hazards is complex, because the events are relatively rare, complicated to model (especially flood), and the socio-economic factors are dynamic. These factors, and the fact that natural hazards insurance is relatively new and much less in premium volume than fire insurance, mean that often a rather simple rating structure is used, not differentiated with respect to levels of risk, because there is less data, and less business to spread the costs across. This is particularly so when smaller insurers are concerned, as they lack resources for risk modelling;

- Administrative costs of implementing complex RTCs. A simple rating structure is much cheaper and easier to communicate (However, information technology is eroding this argument);

- Lack of freedom to manage the underwriting process: A further reason is public policy. Some states prefer to have uniform prices for climate risks, for reasons of solidarity e.g. one study identified seven countries with flat rates for flood: Austria, Bulgaria, Denmark, France, Poland, Spain, Sweden (JRC, 2012).

- Lack of transparency: Often the risk premium (i.e. price of the risk transfer) is not apparent, because several different risks are ‘bundled’ together, and the risk premium is itself combined with other cost elements such as administrative costs, taxes, and commissions to constitute the ‘price’;

- Information imbalance: The at-risk party has little understanding of the risk, because it is a rare occurrence, whereas the insurer often has access to specialised knowledge and large databases.

Potential solutions

- Uncertainty:

    - Better information would help to reduce uncertainty. Public sector agencies could provide stakeholders, including insurers, with affordable access to reliable data on historical and future natural hazards e.g. as a public good from national meteorological offices and flood management agencies. More precise, publicly available results on key climatic variables will provide the basis for sound risk assessment. It is important to note that developing a risk model for flood is expensive, of the order of 5 to 10 million euros per territory, because there are several types of flood, and also the severity of a flood depends upon a number of extraneous factors. Data should also be collected on hazards which are likely to become significant in future;

    - Fiscal regulators could treat catastrophe insurance as more like a long-term class of insurance e.g. alter the taxation rules for catastrophe insurance. This could encourage insurers to build up internal reserves over a period with tax concessions which would reduce the cost of capital for covariate risks, and thereby reduce the loading for uncertainty that is a key feature of catastrophe premiums (CEA, 2005). It is important that releases from these reserves are admissible into the corporate profit-and-loss accounts, in order to smooth the operating performance. At present, this is not so, owing to the accounting principle under International Financial Reporting Standards (IFRS) that the transfer would introduce funds from a different period to that being reported upon. The accounting view would be that this did not give a fair view of the performance of the business in that year. This indicates that accountants do not understand that catastrophe insurance is more akin to a long-term class of insurance, with rare events at irregular intervals.

- Administrative costs and lack of transparency:

  - Parametric insurance[154] could be considered as a solution both for the private and public sectors e.g. for public infrastructure if a storm of a specified strength hits a country the government would get a predefined payout quickly. This could be especially applicable for critical infrastructure in smaller member states. This form of insurance can improve affordability by reducing administrative costs, because there is no claims adjustment process. It also speeds up the payouts, and can be associated with simpler insurance contracts.
    On the other hand, such contracts present a significant *basis risk*[155]and this needs to be understood by all parties concerned. A second point is that the insurer provides no claims management services with such contracts, so that clients are left to cope with all the practical problems of recovery by themselves, or with assistance from a possibly over-stretched public sector. Thus parametric insurance seems to be an interim solution for markets where catastrophe insurance is not developed. It could help in introducing insurance and once markets become mature it could be substituted by more traditional forms of insurance.

- Lack of transparency and information imbalance:

  - Promote price transparency, by mandating disclosure of the components of the premium, including any subsidy, in insurance contracts through consumer legislation or voluntary best practice. This would help to address the issues of lack of transparency, and information imbalance.
    However, 'simple' disclosure of the premium charged for each natural hazard may be impractical in many situations, for a number of reasons: (a) the calculation of the risk premium is a commercially sensitive issue, which insurers would wish to safeguard, often by concealing it within a 'bundle' of risks, (b) the pure or 'technical' premium is often subject to negotiation (c) premium levels fluctuate over time in a so-called 'underwriting cycle', reflecting the intensity of competition, which in turn is a product of recent loss history and investment returns, (d) disclosure of the premium under an optional package of risks may lead the consumer to reject the cover as uneconomical, because he/she does not realise the true risk due to risk myopia, (e) the premium includes a loading for expenses and profit, and this methodology can vary considerably across insurers , so distorting the comparison of risk.
    A possible approach might be to seek relative price disclosure, whereby

[154] Parametric insurance is where the contract pays if a certain event occurs, regardless of the amount of damage that is caused by the event.
[155] Basis risk is the situation where, due to the terms of the contract, the claim payout does not match the actual loss incurred. Under indemnity insurance, the payout does equal the loss.

premium variations according to the adoption of various options in risk management by the purchaser could be disclosed. This could fit within the services provided by intermediaries for example (cf. solution under Non-price RTC later)

- Increase in insurance price and volatility; lack of underwriting freedom:
    - Public authorities could designate high-hazard zones (e.g. a 1% risk of severe damage) as a key element in a general adaptation strategy, with a review process to keep them relevant[156]. Underwriters could adopt risk-differentiated pricing e.g. different levels of price to correspond to measures like zoning, and support publicity for address-level resilience and defence products. This would help to reveal the risk from natural hazards. Hazard zoning would counteract those factors which push prices upwards. This aspect is intertwined with the issue of underwriting freedom and public policy. Clearly, a consistent approach to hazard zoning is desirable across administrative boundaries, and if possible, one that is common internationally.

- Increase in insurance price:
    - More stringent building standards for new-build and resilient standards for the recovery after catastrophes would also help to keep prices down in the long run through lower administration and claims costs. It is more likely to be effective via regulation, since in the short term, premiums would need to rise to absorb the additional cost of higher construction standards.

3.7.2.1.2 Non-price RTC

As noted earlier, insurers use a variety of non-price RTC to reflect the degree of riskiness in an insurance contract. For the consumer market, the main instruments are deductibles and coverage limits (either an upper limit, or exclusion of certain vulnerable items e.g. flimsy constructions). For industrial clients other measures such as co-insurance may also be utilised.

The importance of non-price RTC is shown by a study of potential claims under catastrophe insurance in Austria and Germany - cf. Table 38 (Aon, 2010)[157].

In Austria, storm cover is hardly subject to coverage restrictions like deductibles or limits, so the insurer pays 100% of the claims whatever the magnitude of the event. However, the situation is quite different for flood. Here, coverage is designed so that the insurer pays only around 21% of any loss event, due to significant restrictions. In contrast, for a different

[156] In fact the Floods Directive takes at least 1-in-100 year frequency to define ‘medium risk’ floods, with extreme events at an undefined higher return period.
[157] While the underlying models in this exercise have been superseded, the aspects considered here will not have altered significantly i.e. the effects of coverage limitations on potential payouts.

catastrophe hazard, earthquake, limits are the main lever, and this means that for small (once-in-10 years) events the insurer pays 40% of the cost, but the proportion reduces to 15% for the once-in-1,000 year event.

In Germany, limits and deductibles are used to reduce the number of small claims, not to reduce the overall cost of extreme events. This can be seen from the fact that the impact on the overall cost is proportionally greater for small events (once-in-10year frequency), than for large events (once-in-1,000 years). This is because there are many more large individual claims in the rarer events, and in those claims the effect of a moderate deductible is negligible. For example, the insurer will pay its clients 91% of the cost of a 10-year flood, but 98% of a 1,000 year flood. Furthermore, this approach applies to storm and earthquake cover (Aon, 2010).

Table 38: Proportion of insured loss paid by insurer to at-risk parties (Source : Aon, 2010)

Size of event	Austria			Germany		
	Storm	Flood	E/quake	Storm	Flood	E/quake
1/1000 year	100	20	15	98	98	97
1/200 year	100	21	21	97	97	96
1/100 year	100	21	23	97	96	94
1/50 year	100	21	25	96	95	93
1/10 year	100	22	40	95	91	83

Potential climate change effects on non-price RTC

Increased deductibles

Two recent examples show how deductibles might be affected by future climate change.

A study of a localised flood in 2008 in UK found that the level of deductibles increased strongly, from only 3% of policies over €1,200 in 2008, to 37% in 2010, with some as high as €12,000 (Morpeth Flood Action Group, 2011). In general, high flood excesses for properties at significant risk are rare and are not applied ‘across the board’. They tend only to be applied to properties that have already flooded at least once and are usually under €6,000 (ABI, 2011).

Again in France, the government has introduced a system of escalating deductibles to incentivise risk prevention. Unless a town has an active Risk Prevention Plan (RPP), the deductibles on disaster claims (€ 380 except for drought and heave for which it is € 1,520) are increased as follows: third disaster doubled deductible; fourth time tripled; further events quadrupled.

Reduced coverage limits

If there is a move towards more accurate risk transfer conditions, it is likely that this will increase the use of coverage limits, since fragile constructions are clearly likely to generate greater losses. It is also likely that insurers will seek to control their overall exposure to covariate losses, through the use of upper limits on individual properties.

Barriers related to non-price RTC

- Consumerism: The use of significant deductibles and upper limits is sometimes seen as contrary to the spirit of the insurance contract, because the insurer appears to offer cover for an asset or activity, but then withdraws it through the use of financial limits. This is sometimes referred to by critics as 'using the small print' to avoid paying claims.

Potential solutions

- Consumerism:
    - Greater transparency in insurance contracts will help to reduce consumer distrust. In particular, insurance service providers, particularly intermediaries including 'aggregators'[158], should explain that the contract is intended to deal with unusual impacts, not everyday losses. Also, insurers should ensure that coverage restrictions are clear and reasonable (cf. also solution under Price Related RTC, where relative price disclosure is proposed, linking price and risk management for example).

- Increased deductibles and reduced coverage limits:
    - Public authorities could designate high-hazard zones (e.g. a 1% risk of severe damage) as a key element in a general adaptation strategy, with a review process to keep them relevant[159]. Insurers could set different levels of RTC to correspond to measures like zoning and support publicity for address-level resilience and defence products. This would help to reveal the risk from natural hazards.
    Public authorities could mandate higher building standards for new-build, repairs, and refurbishment, and for business and consumer goods. This would reduce the cost of damage in extreme events, and encourage insurers to offer

[158] Insurance aggregation is a process of finding multiple insurance quotes at one time so the buyer can make a comparison of insurance policies based on identical information given to each company. In practice, often the exercise is based purely on price, and ignores other RTC's.
[159] The Floods Directive uses this approach.

wider coverage. Resilience labelling may be an appropriate tool, at least for new structures and assets.

3.7.2.2 Availability

As the Munich Re data shows (cf. Annex 12), floods and droughts are the two climatic hazards for which availability is weakest. This is particularly so in south and east Europe, as confirmed by (JRC, 2012). In general the coastal zones are problematic due to flood and storm, and coverage for the agricultural sector is low, due to various practical difficulties e.g. the cost of assessing losses.

Potential climate change effects on availability

As a result of increasing risks, insurance might become unavailable in certain areas. It is widely accepted that natural events that are less frequent than 1 in 75 years are readily insurable. Swiss Re (2007) indicates that for risks with a 100 to 200 years return period (0.5% to 1.0% probability), the risk premium is 3.5% of the value of the assets. For more extreme risks, the premium therefore becomes too high as an annual charge. Practice in the UK broadly confirms this – the limit for an insurable flood risk when there is no adverse selection, and the risk is bundled with other hazards is a 75 year frequency, i.e. 1.3% probability (ABI, 2008).

In a press release on 31st January, 2012, the Association of British Insurers warned that as many as 200,000 homes face difficulty obtaining flood insurance when the current agreement with the Government on flood insurance ceases in 2013. Those houses face a risk of greater than 1-in-75 years, and the vast majority are significantly undercharged, due to cross-subsidies from less risky homes (ABI, 2011).

Barriers related to availability

When considering barriers, it is important to identify the underlying causes, not the symptoms of the problem. For example, insurers may be concerned about the inefficiency of a scheme (unsustainable claim ratio), or their inability to make a satisfactory return on capital, but these outcomes are due to more fundamental factors, as listed below.

- Covariate risk: Climatic risks are ‘covariate’, i.e. many claims can occur simultaneously. This means a large capital buffer is needed, and/or heavy reliance on reinsurance, the availability and price of which can change quite quickly (cf. Figure 58). A large pool of risks is needed to provide a spread of risks. If the pool of risk is small, as in small countries, the problem is aggravated, because there will little or no ‘buffer’ from unaffected policies or the recovery system in general, and the government will be unable to provide a reliable financial reserve to cope with the economic impact;
- Relatively small scale of operation (limited number of customers): The reason for the small pool of risks may be that a minority of locations are intrinsically high-hazard and

willing to insure, but other localities at lower risk do not insure.
It is important to note that regulators should allow (re)insurers to pool catastrophe risks across frontiers and sectors, in order to exploit from the reduced variability which a larger risk pool provides. This increases the risk pool; applying solvency tests at too low a level would remove this feature, which benefits all of society. It is understood that this approach is being adopted under the Solvency II Directive;

- Moral hazard: Those who insure do not take reasonable precautions against damage, so that the risk actually becomes worse. In some cases, agencies responsible for risk management like flood control, relax their standards (i.e. cut their budgets), because insurance will pay for any damage. Such behaviour reduces insurers' risk appetite;

- Lack of freedom to manage the underwriting process: Finally, with the increasing emphasis on risk management (Solvency II), insurers and reinsurers will be more discriminating about whether they accept high-hazard risks. This is because the supply of capital is limited, and high-hazard risks would require a much higher return than insurers would be able to achieve.

Potential solutions

- Covariate risk and moral hazard

    - Planning and construction regulators and agencies could mandate improved resilience and minimum risk prevention standards in high-hazard zones e.g. land zoning, climate-resilient structures and education. This could keep insurance available by reducing the scale of covariate risk in terms of exposure and vulnerability as well as moral hazard. Note that there is a distinction between insurance for projects (often called "contractors' risks" with associated cover for "latent defects"), and property insurance, which applies to the finished structures. In fact, project-related insurance may have greater leverage on improving resilience standards, because it is issued at the time of construction, whereas problems under a property insurance cover may arise many years later, when it would be hard to trace the original construction agents;

    - Fiscal regulators could treat catastrophe insurance as more like a long-term class of insurance e.g. alter the taxation rules for catastrophe insurance. This could encourage insurers to build up internal reserves over a period with tax concessions which would reduce the cost of capital for covariate risks (CEA, 2005). It is important that releases from these reserves are admissible into the corporate profit-and-loss accounts, in order to smooth the operating performance, which is not the case at present (cf. also price-related RTC);

    - Planning regulators could develop procedures for making high-hazard assets less risky. This could be mandatory relocation by a 'sunset' date, or reconstruction to higher standards. This would help to reduce the scale of covariate risk progressively over time[160].

Given such a commitment to reduce historical 'legacy' risks which were created before the awareness of climate risk, together with a similar commitment to avoid undue risk in new development, insurers would probably be more willing to consider ways in which insurance could be made available for the old high-hazard risks until they have been rectified;

- Promote risk pooling within states to encourage the development of private risk markets for natural disasters, with appropriate support from public sector resources for 'mega-events'. Box 1 provides an example of such an approach in Belgium, and there are numerous other ways for public-private collaboration to provide sufficient capacity for extreme risks (Monti, 2012; Concorcio, 2008).

[160] It is accepted that in certain coastal locations of exceptional socio-economic activity e.g.the Netherlands, London, then for the foreseeable future the imperative is defend, rather than relocate or to introduce property-level solutions.

Box 1: The Belgian Approach to Flood Insurance

By law, insurers must include flood and geological hazard cover in all simple risk* fire contracts. This includes cover for floods, reversal and overflow of public sewerage systems and other natural catastrophes such as earth tremors, earth slips or subsidence.

The maximum deductible in the private market is fixed at € 1,325 indexed from 2003 (around € 2,100 currently).

A Tariff Bureau has been established with the job of fixing rating conditions for risks which cannot be insured on the private market. The premiums and claims relating to risks rated under the conditions of the Tariff Bureau are shared out amongst all the insurers writing simple fire risks in Belgium, according to their premium income.

The insurance industry collectively is committed per event to an amount of € 700 million for earthquakes and € 280 million for floods. Over these upper limits, the state will intervene for the same limits, through the National Calamities Fund. Beyond the upper ceilings, the system does not operate, so that in principle the excess losses are not indemnified by the state or by insurers.

* "Simple risks" are defined as any property or group of properties whose insured value does not exceed 1.3 million euros (at 1/01/2010). This is 42.7 million euros for properties in which the commercial area is under 20%, and a wide range of other premises used for agricultural and livestock purposes, cultural events and collections, residential care, sport and health.

Source: Consorcio (2008)

- Relatively small scale of operation:
  - The EU could provide a central EU liquidity system for smaller or less wealthy member states, to back up their national catastrophe insurance systems, similar to the CCRIF[161] system in the Caribbean or Europa Reinsurance Facility Ltd[162], a reinsurance company for Southern Eastern European and Caucasian States. It could, for example, enable them to provide liquidity guarantees, as with Pool Re for terrorism in UK, or reinsurance for individual insurers , as with CCR in France. This would help to address the problem of small risk pools. Global reinsurance could also be considered as an option to address covariate risks in small countries;

[161] CCRIF = Caribbean Catastrophe Risk Insurance Facility
[162] http://www.europa-re.eberlesystems.ch/

  - Insurance regulators could promote bundling e.g. through reclassification of insurance, to include natural hazards an intrinsic element of 'property' insurance, in order to enlarge the pool (cf. Box 1 for the Belgian system).

- Lack of freedom to manage the underwriting process:

  - Regulators could promote product innovation relevant for managing weather risk in key sectors e.g. by ensuring insurance regulations do not hamper the use of catastrophe bonds, weather derivatives, multi-annual policies, microinsurance, resilient- reinstatement clauses etc. This could address restrictions on underwriting freedom, and could also enlarge the insurance pool. Some of these innovations would also contribute to reducing the barriers against greater demand. In practice this comes down to a matter of interpretation of basic insurance principles like indemnity[163] and insurable interest[164], which may vary across legal systems.

3.7.2.3 Demand

In general, insurance penetration is low in the EU (JRC, 2012). In particular, lower income segments do not purchase insurance, and the farming sector has limited cover.

Potential climate change effects on demand

It might be expected that climate change will increase the demand for insurance, due to higher risk. However, the increasing stresses may divert disposable income to other purposes, as well as creating greater calls for public relief after disasters.

Furthermore, if not addressed, climate change could lead to insurance becoming less affordable or unaffordable, particularly for lower income population (most vulnerable population).

Barriers related to demand

- Risk myopia: Consumers disregard high-impact, low probability risks (risk myopia). Premiums appear high relative to the long-term claims cost, because of the need to charge a significant loading for the cost of the capital buffer for the very rare but extreme events;

- Affordability (high price, low purchasing capacity): Administration including marketing costs can be 30% or more of the premium, or the risk may be so severe that it is a virtual certainty i.e. uninsurable. On the supply side, the problems in insuring this

[163] Indemnity is compensation of the insured party for losses incurred, but can be interpreted more widely as payment of a defined sum if a specific event has happened.
[164] Insurable interest exists when a person or entity is exposed to a genuine loss if a claim on a policy arises.

sector are administrative expense (a high minimum premium is necessary to reflect fixed costs per case, and also to avoid under-insurance) and anti-selection;

- Financial exclusion: Even in developed countries, this is a major problem. For example in UK, though 80% of households have property insurance, this falls to under half for the poorest decile. Many of these people do not have bank accounts or other basic financial arrangements, and have weak language and numeracy skills. The situation may be worsening with the decline of old distribution channels, (local branch network, home service agents) and the spread of direct debit and the internet;

- Inadequate risk perception: Often consumers focus on 'bargains' rather than value for money, so that there is no demand for more expensive insurance contracts that provide improved resilience as part of reinstatement after a disaster;

- Plentiful relief aid: Many governments provide 'free' or 'cheap' disaster relief. In particular, the poorer segments of society do not buy catastrophe insurance, and so are more vulnerable and reliant on state aid. They are unfamiliar with complex financial products and transactions.

Potential solutions

- Risk myopia:

    - Insurance regulators could promote bundling i.e. including natural hazard risks with standard covers e.g. fire and motor insurance, in order to overcome risk myopia, where at-risk parties ignore certain risks. Insurers could take action on a voluntary basis. For example, German insurers have recently moved from an opt-in, to an opt-out, approach for adding natural perils cover to fire policies (GDV, 2011). Cf. also Box 1 for an overview of the Belgian system.

- Affordability:

    - Regulators and agricultural agencies could work with insurers to promote simple agricultural risk transfer products e.g. weather derivatives against drought. This could improve the affordability of insurance and also avoid reliance on relief aid;

    - Regulators could collaborate with insurers to evolve systems for access to affordable insurance for those in high-hazard areas. This could be through public subsidy or risk-sharing among commercial insurers for example.

- Financial exclusion:

    - Regulators could collaborate with insurance service providers to promote micro-insurance for disaster relief/indemnity for lower income segments e.g. through simple, insure-with- rent monthly instalment schemes for tenants in social housing. The reduced administrative costs with simplified distribution and claims procedures could make coverage affordable for these segments, and reduce the scale of financial exclusion. Such schemes can also reduce the problems of anti-selection165, by providing a wider pool of insured parties (EC, 2011a).

- Inadequate risk perception:
  - Regulators could mandate improved resilience in high-hazard zones, via stronger risk prevention and resilience regulations to reduce exposure and vulnerability. The higher standards could then be embedded in insurance prices and conditions, as happens with fire regulations. This would help with the problem of inadequate risk perception[166].

- Plentiful relief aid:
  - Governments could set low limits on public disaster relief, to encourage the use of private insurance, which will transfer costs away from the public sector167. The system should be well-publicised; currently it is not easy to establish what public relief is available to victims of natural disasters in different Member States;
  - Insurance service providers should also ensure that clients and potential clients understand the differences between insuring oneself and relying on state relief, including the post-event services and likely pay-outs.

3.7.3 Insurance as an instrument for adaptation to climate change

Insurance can be a valuable tool for adaptation in three main ways:

- Helping to manage climate change risks;
- Providing information on risk, and, to a lesser extent;
- Providing incentives for risk prevention (Courbage & Stahel, 2012).

This chapter identifies 'potential solutions', or ways of achieving these goals. Their applicability remains to be researched, and may vary from one jurisdiction to another.

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[165] Anti-selection is the situation where those who insure do so because they believe they have a higher risk than the insurer has assumed.

[166] In fact, this is common practice on Germany, where a 'Mehrkosten' clause in the policy includes the additional cost of repairing to higher standards, or relocating the building if necessary.

[167] The German insurance industry is collaborating with individual Free States, to introduce a policy that presumes that home-owners will buy natural catastrophe insurance, rather than rely on ex post state aid (GDV,2010).

3.7.3.1 Insurance as a tool for climate risk management

Insurance should be part of strategic risk management e.g. state policy for agriculture and forestry, and for renewable energy which is weather-dependent. It is important to remember that climate risk management needs to be observed for existing assets and activities, as well as new ones. It is also important that stakeholders are aware of the available insurance products for their climate risk management portfolio.

Public Private Partnerships (PPP) have an important role to play. Public – private partnership is required if insurance is to be an effective component of the EU's adaptation strategy (WEF, 2011). It is vital that the public sector establishes a strong risk management ethos evidenced in measures to reduce risk (e.g. land zoning) and improve resilience (e.g. building standards), and also provides relevant generic goods and services (e.g. flood defences, risk-relevant information), as outlined under the Hyogo Framework for Disaster Reduction (ISDR, 2005).

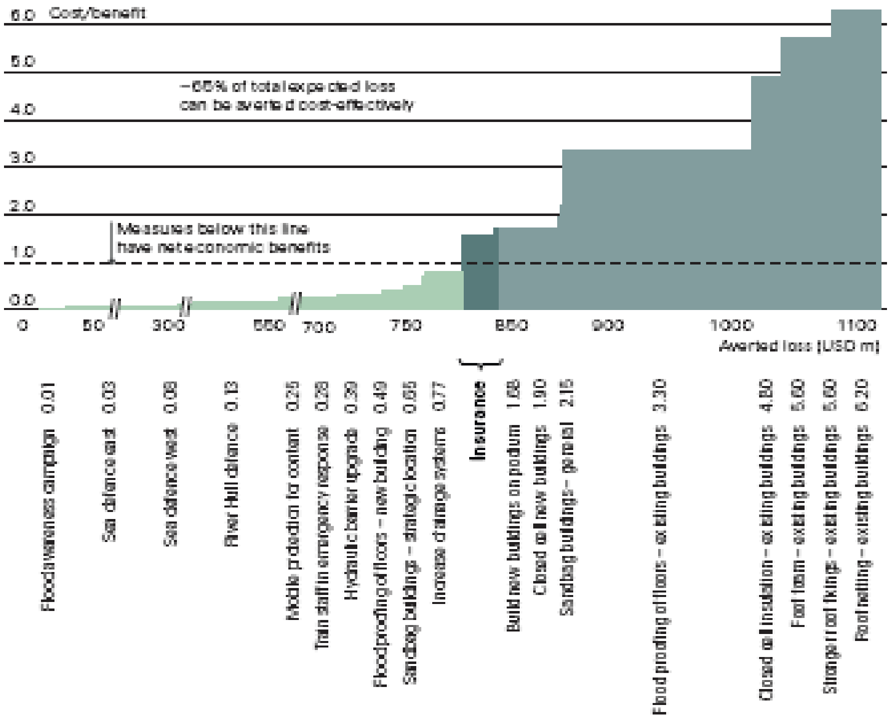
Given that framework, the private sector can provide customer-specific goods and services, including insurance, which will further improve resilience, and spread the burden of the residual financial risk which remains after physical measures have been taken. The use of private insurance also helps to transfer some of the cost of recovery from the public sector to the private sector, which is important at a time of constraint on public sector finance.

One role of the public sector would be to ensure that adequate risk assessment and physical risk management is undertaken, so that risks are insurable (Picard, 2008). Experience in France has indicated the dangers of devolving decision-making to a very local level, without some degree of superior review. Winter storm Xynthia caused extensive damage and took 47 lives, because unsafe development had been permitted by local councils (Lumbroso & Vinet, 2011).

A key issue is to identify the most efficient level of intervention. It may be more cost-effective to introduce community-level risk reduction measures, than to focus on property-level defences for example. Another advantage of a holistic approach is to identify the appropriate entry point for insurance, to deal with the residual risk. For example, a study of the coastal city Hull in the UK, which was badly flooded in 2007, suggested that investment in public awareness, sea and river defence system upgrades, property-level defences, training of emergency services staff, and upgrading the drainage systems were more cost-effective than insurance, which in turn was more cost-effective than trying to retrofit all existing buildings (cf. Figure 59).

An important effect of insurance is enabling rapid post disaster recovery. It is a familiar fact, that post hoc disaster relief often takes considerable time to organise and deploy, which has a negative effect on the pace and quality of the recovery process. When done well, claims handling management can be extremely effective in reducing costs, and also the social impacts of extreme events e.g. through the rapid mobilisation of repairs after hailstorms, or provision of long-term alternative accommodation after floods.

Figure 59: Adaptation Cost Curve for City of Hull, U.K. (Source: ECA, 2009)



For each adaptation measure, the horizontal axis shows the potential loss avoided, and the vertical axis shows its cost /benefit ratio.

For this case, 65% of the loss under a high climate change scenario can be cost- effectively averted by prevention and intervention measures. Insurance covers roughly a further 15% of the expected loss.

Potential solutions

- The public sector should consult insurers and other private sector stakeholders more closely in formulating policy and initiatives to adapt to climate change. It is important to realise that this is more than 'public private partnership'. It means involving civil society at all levels so that solutions are adopted whole-heartedly, with minimal evasion (GDV, 2011; ISDR, 2005; MRN, 2010).

  Insurance experts could provide guidance to decision makers on how to use insurance to support adaptation and other policies. This would improve the overall economic efficiency of policy-making. For example, insurance should be part of strategic risk management e.g. state policy for agriculture and forestry, and for renewable energy which is weather-dependent. It is also important to remember that climate risk management needs to be observed for existing assets and activities, as well as new ones. Research shows that the utility of insurance is location-specific (ECA, 2009; CCRIF, 2010). This is already happening in some places. For example, the French Caisse Centrale de Reassurance and the Spanish Consorcio de Seguros have long traditions of technical support to public authorities and the respective national insurance associations, thereby fostering Public-Private Partnership in their natural catastrophe insurance systems. Again in France, there is currently an extensive reorganisation in the allocation of public finance from the national to the regional risk reduction project level, and insurance representatives are involved amongst other civil society parties (MRN, 2012).

One measure which could make this more effective would be for countries to appoint a Country Risk Manager, to ensure that climatic risk and their counter-measures are given appropriate priority (OECD, 2009). Another approach is to assign disaster management planning to a high-level committee: for example in France Conseil d'Orientation pour la Prévention des Risques Naturels Majeurs (the Advisory Committee for Major Natural Hazards) has this role, while in Britain, it is one of the tasks assigned to the Prime Minister's Cabinet Office;

- Planning authorities could develop a procedure for making high-hazard assets less risky. This could be mandatory relocation by a 'sunset' date, or resilient reconstruction to higher standards for example. Again, insurers could support these measures by incorporating them as a condition of insurance in their insurance policies.

  However, it must be noted that relocation is often unpopular e.g. after Winterstorm Xynthia, the French authorities encountered stiff resistance when they attempted to introduce land zoning and mandatory relocation in 'black' or 'solidarity' zones (Lumbroso & Vinet, 2011). Similar difficulties with the introduction of flood maps have been noted in other countries e.g. USA, Belgium, Australia. Also, in many cases the costs of retrofitting property to a higher standard outweigh the benefits (ABI, 2003, 2009, n.d.);

- Governments could provide more visibility to the available insurance products for climate risk management. The EU Climate-ADAPT platform could be used to collect and make available information on weather related insurance products in different countries. Another approach would be to provide such information as part of a comprehensive package of information on disaster management, under DG ECHO for instance. National insurance associations or regulators could provide the information, and a range of stakeholders, including policymakers would be the beneficiaries.

3.7.3.2 Insurance as a tool to provide incentives for climate risk prevention

In order to give incentives for risk prevention, insurance prices have to be risk based and adequately adjusted according to risk prevention efforts taken by customers. In principle, if insurance prices and conditions were related to the risk, that would send a clear signal to the purchaser, about the economic implications of the present exposure and risk management. In practice this often does not happen, because such measures are voluntary and not common. A regulatory framework that mandated or codified risk resilience would encourage price differentiation.

If insurance risks are not priced accurately in an actuarial sense, this may lead to several problems. Firstly, insurers are exposed to adverse selection, and will not make an adequate return. Secondly, moral hazard will become prevalent, because a higher risk will not have a price penalty. There is clear evidence of this in the United Kingdom, where cross-subsidies in relation to flood risk have encouraged development in high-risk areas (Crichton, et al, 2009). In the USA, the existence of the National Flood Insurance Program (NFIP) is also seen by many as leading to risky behaviour, since flood cover is readily available for high risk properties (Abbott, 2008; AAA, 2011; NYSFSMA, 2011). On the other hand, collaboration between the public and private sector can enable the use of risk- related prices, by ensuring that risk management plans are affordable for communities, and in consequence, that insurance terms are affordable (Picard, 2008). This could even be taken a step further, by ranking political constituencies according to their quality of risk management, which would enable the public to see more clearly the relative positions of their own neighbourhoods[168].

The process can operate at different levels. Ideally, re-insurers could consider how to give incentives for risk prevention to insurers. This would help to reduce the scale of covariate risk.

Some observers have suggested the use of longer-term insurance contracts linked to resilient reinstatement (Michel-Kerjan & Kunreuther, 2011). This may be problematic, due to the greater pricing uncertainty and reduced consumer choice, and would be unnecessary if higher construction and repair standards were mandatory. It is also difficult for insurers to be locked in the conditions for long period – as this increases uncertainty (Maynard & Ranger, 2011). There may be more scope for this type of product at the 'wholesale' levels of risk transfer, e.g. between reinsurers; catastrophe bonds generally last longer than one year.

Potential solutions

- Risk transfer conditions should be adjusted to reflect risk prevention efforts, in a way that is transparent to the buyer, who can then gauge the benefit of risk reduction options;
- Adopt non-insurance measures to differentiate between different levels of riskiness e.g. mandatory physical risk management by communities and insurance purchasers. Insurers can support this by incorporating these requirements as preconditions in their insurance contracts;
- Recovery after the disasters should be done using climate resilient standards, not simply replacing what was lost by the same material and design. If this were mandatory, as with imposing current fire regulations during repairs and refurbishments, ensurers would support this by including it as a standard condition in their cover;

[168] In fact this was done by the Association of British Insurers, ranking parliamentary constituencies according to the number of homes at risk from flood (ABI, 2012).

- Catastrophe insurance (or its equivalent) should be a standard feature for asset-based transactions e.g. mortgages, project finance etc. It should be standard practice for financial institutions, if necessary under regulation, that such insurance should be operative during the term of the finance. This would help to overcome risk myopia and inadequate risk perception. Possibly this could be a feature of the Basel Accords[169], currently entering their third generation (BASEL III), which are recommendations on banking laws and regulations issued by the Basel Committee on Banking Supervision[170];
- A key step in managing disaster risk is to clarify responsibilities and assign duties for managing risks (ISDR, 2011). A consequence could be that, for example, an agency responsible for flood management which fails to take necessary measures, would have to contribute to compensating victims of that failure. This could enable insurers to recover their claims payments in such situations, through subrogation i.e. exercising the rights of the victims to recover their losses. It would counteract moral hazard in such cases therefore. In practice, owing to the considerable uncertainty, cost and length of the legal process, subrogation would only be used occasionally, but the threat of it is a valuable weapon. This approach has been adopted in France, with decennial insurance, to instil better risk management in the construction industry (XL, 2011);
- Treat catastrophe insurance as more like a long-term class of insurance e.g. alter the fiscal procedures for catastrophe insurance, to encourage insurers to build up internal reserves over a period with tax concessions.

3.7.3.3 Insurance as a tool for information dissemination on climate change risks and risk prevention measures

Insurance sector organisations are among the entities which could provide climate change risk related information to clients, since they are already involved in the business of risk management. It could be argued that it is in insurers' interest to divulge information on risk, so that clients make appropriate preparations to deal with climate hazards, and so reduce the scale of potential losses. This has to be tempered by the realisation that there are many small insurance firms and even individuals involved, which do not have major resources for additional activities or research. It is also important to remember that some information may be commercially restricted as to access and dissemination. Furthermore, the format of the insurance contract itself is not 'free-form'; additional information may have to be positioned in supplementary documents, which may not be so well noticed.

An important point is that being in possession of relevant information does not ensure that appropriate action will ensue. Research on consumer take-up of flood resilience measures in

[169] http://en.wikipedia.org/wiki/Basel_Accords
[170] Basel Committee on Banking Supervision (http://en.wikipedia.org/wiki/Basel_Committee_on_Banking_Supervision)

the UK reveals a complicated decision process (DEFRA, 2008: ABI, 2011). It is important to establish the best way to ensure that information will result in action, as consumers fall into a number of different groups, each with its own motivation trigger (Rose, et al, 2005; Futerra, 2009).

Potential solutions

- Intermediaries could provide clients with available information and references to climate change risks and risk prevention measures, assuming that an effective approach can be identified;
- Insurers could provide clients with available information and references to climate change risks and risk prevention measures. This could be done e.g. through involving insurers' associations. However, one has to first ascertain how to ensure that the information will be used.
- Insurers could provide research bodies with data on the cost of events. This could be part of a reciprocal arrangement between public and private sectors on information, where the public sector provides information on the hazard (as in the following solution).
- Provide stakeholders, including insurers, with affordable access to reliable data on historical and future natural hazards e.g. as a public good from national meteorological offices and flood management agencies. More precise, publicly available results on key climatic variables will provide the basis for sound risk assessment. Data should also be collected on hazards which are likely to become significant in future.

3.7.4 Financial performance of insurance sector companies

The European insurance industry is competitive, and business is written on relatively small margins in terms of percentage of premium income[171]. In years where is a large accumulation of losses from extreme events, reinsurers in particular exhibit lower profitability. This can result in a fall in share price, and a higher cost of capital going forward. However, for most insurers, exposure to extreme weather is relatively small in relation to the overall risk portfolio e.g. motor, fire, liability. Thus, while insurers might have a theoretical 0.5 percent probability of becoming insolvent, in the EU, extreme weather has rarely been a significant factor in insurance insolvencies in recent decades (CISS, 1997, 2002).

[171] Over the period 2006-2009, the profitability of the largest five nonlife insurance European markets was: France 9% of premiums, Germany 12%, Italy 8%, Netherlands 3%, and UK 7%. Except for Germany, the profit was due to returns on investment, not the core underwriting operations (Capgemini, 2011).

Potential climate change effects on financial performance of insurance sector companies

- Higher cost of capital: As noted earlier, climate change may increase weather hazards within the EU, and also widen the uncertainty about predicting them. At the same time, socio-economic trends have tended to increase exposure to climatic impacts as well. Furthermore, most major EU insurance companies or their suppliers and clients, are exposed to climate change internationally, which may well be more serious than in the EU. These factors will tend to increase risk, and make capital more expensive as explained above. (A corollary is that the credit ratings of insurance companies might be negatively affected);

- Volume of business: Potentially, greater climatic risk should mean more business for insurers, since there will be more people and entities at risk (assuming no change in public or private sector appetites for risk). However, there is a concern that much of the additional exposure could be high-risk, and at the same time the cost of capital could become higher; both of these points would combine to make a significant proportion of the exposure uninsurable;

- Insolvency: The risk of insolvency might rise significantly for smaller or specialised insurers;

- Other impacts: Potentially some of the 'other risks' could be more severe than the underwriting risks associated with weather risks in the European Union. For example, reinsurance companies and global European insurers already have significant exposures outside Europe; life and pensions companies might be exposed to health and life risks, or investment risks arising out of changes in energy policy; working conditions might deteriorate in an extreme weather situation; or the volume of weather claims might become unmanageable after a series of extreme events.

Potential solutions

- The implementation of Solvency II should ensure that climatic hazards are analysed thoroughly by insurance enterprises, to avoid an increase in insolvencies or a decrease in the supply of insurance for these risks. This should also ensure that insurers have thorough contingency plans to cope with climate-related extremes, including a 'perfect storm' of different but coincidental events;

- National regulatory authorities could mandate more transparent reporting of climate risk by insurers within the European Insurance and Occupational Pensions Authority (EIOPA) framework, so that investors and other stakeholders can be satisfied that boards are addressing the issues properly, and can have better information to make their own decisions and to engage insurers in dialogue about their strategies. There is a trend towards greater corporate disclosure of climate change risk, backed by many significant European institutional investors (CERES, et al, 2011). Some States in the USA have introduced this for insurers, and the UK has introduced mandatory reporting for key service providers (not including insurers). The American process revealed that many insurers in that country are not 'up to speed' on adaptation (Leurig, 2011), which is important to know, even if it is not satisfactory. The British process on the other hand found that many enterprises were already working on the issues, and it confirmed the positive benefits of reporting: greater visibility of climate change risks at all levels, assignment of responsibilities to manage them, and collaborative engagement with stakeholders. Cf. Annex 13 for more detail;

- Planning and construction authorities need to maintain a firm grip on exposure and vulnerability to climate hazards, in order to avoid the possibility of a decrease in the availability of insurance. Regulators could mandate improved resilience in high-hazard zones, via stronger risk prevention and resilience regulations to reduce exposure and vulnerability. Also, they could develop procedures for making high-hazard assets less risky. This could be mandatory relocation by a 'sunset' date, or reconstruction to higher standards. This would help to reduce the scale of covariate risk.

3.7.5 Knowledge gaps

There are 3 types of information necessary to make well informed decisions:

- Information on the insurance market:
    - Precise insurance penetration rate at the MS level is required. Currently available data is imprecise or incomplete (including from Insurance Europe);
    - Knowledge on the structure of the national insurance markets;
    - Information about the capacities and activities of insurance organisations in the arena of natural hazard risks.
- Information on climate change impacts on the insurance market:
    - Gaps in available information on climatic hazards need to be filled. This is likely to be an evolving situation, since scientific methods are continually being refined;
    - Information on historical losses can be assembled using use existing data on losses from Swiss Re and Munich Re, also UK (which is more detailed);
    - Loss potential information is weak. The approach of JRC, using historical losses, is inadequate. Other studies are available, but provide inconsistent estimates.

- Information on the consequences of the possible solutions: When new measures are introduced, they may have a ripple effect on other systems and procedures. It will be necessary to examine this aspect in detail once a short-list of proposals has been developed. In particular, if measures to encourage private sector insurance alter the balance of insurers' risk portfolios significantly, that might warrant more detailed oversight of those risks. In the meantime, chapter 4.9.2.7 provides a brief list of likely 'consequences' to initiate consideration.

3.7.6 Summary of potential actions

Currently in Europe there is a wide diversity of insurance systems to deal with natural hazards (Consorcio, 2008). This diversity is likely to persist, as it is rooted in culture and custom, and indeed diversity is a strength in meeting new challenges (Schwarze, et al, 2011). Nevertheless, some principles have general application, as discussed previously.

3.7.6.1 Addressing current barriers and climate change impacts on the functioning of the disaster insurance market

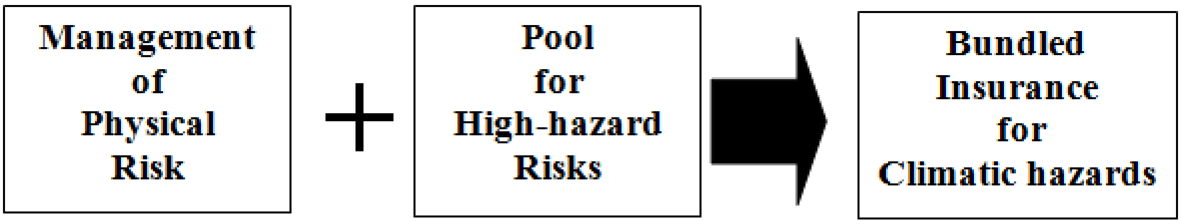
1. Increase sustainability of built environment e.g. by introduction of risk assessment and zoning standards, with associated regulations to control and reduce exposure in high-hazard zones[172];
2. Improve resilience of physical assets e.g. by introducing higher standards for new buildings, repairs and renovations, and for consumer and business goods. Labelling may be an appropriate tool, at least for new goods and structures;
3. Assign responsibility for hazard risk management to appropriate agencies;
4. Improve availability of risk-related information e.g. by establishment of an EU wide permanent risk assessment institution;
5. Promote risk pooling within states to encourage the development of private risk markets for natural disasters, with appropriate support from public sector resources for 'mega-events';
6. Promote bundling e.g. through reclassification of insurance, to include natural hazards as an intrinsic element of 'property' insurance;
7. Promote transnational risk pooling to provide liquidity especially for member states after disasters e.g. through the establishment of an EU risk pool which member states can voluntarily join;

[172] Accepting that in coastal areas of exceptional socio-economic activity, defence may be the preferred strategy.

8. Promote micro-insurance e.g. by introducing less rigorous regulations for simple insurance products like weather derivatives for farmers, and for intermediaries providing 'insurance –with-rent' schemes;
9. Promote the use of longer accounting periods for catastrophe insurance e.g. by tax concessions for catastrophe equalisation reserves;
10. Clarify and publish the level of post-disaster public relief, so that consumers and enterprises can make rational decisions about how they will finance their disaster risk, whether via insurance or some other means.

Ideally, the key actions should be implemented as a suite for maximum effect. Improving the overall management of physical risk (actions 1- 4) would control and progressively reduce the volume of high-hazard risks, which would enable such risks to be handled by an insurance pool (action 5), and thereby make it more likely that insurers could provide comprehensive 'bundled' cover for climatic hazards (action 6), with all its advantages, as portrayed in Figure 60).

Figure 60: A suite of measures to underpin insurance for climatic hazards



3.7.6.2 Using insurance as a tool for adaptation

- Modify the Mediation Directive to include a requirement for intermediaries to provide available information and references to climate change risks and risk prevention measures to their customers;
- Insurers could provide research bodies with data on the cost of events. This could be part of a reciprocal arrangement between public and private sectors on information, where the public sector provides information on the hazard;
- Provide all stakeholders, including insurers, with affordable access to reliable data on historical and future natural hazards e.g. as a public good from national meteorological offices and flood management agencies;
- Promote the provision of risk-relevant information by insurance companies and insurance associations to customers and the general public.

- Promote the use of insurance by the inclusion of information on insurance solutions and schemes in the adaptation tool-kit on the EU Climate-ADAPT platform[173];
- Promote the use of risk- related RTC's in insurance contracts, in a way that signals the risk to the consumer;
- Consult insurers as key stakeholders in drawing up strategies to deal with climate change risk.

3.7.6.3 Financial performance and mandatory reporting of insurance companies

- Promote mandatory reporting of climate risk by insurance companies (As noted previously, Solvency II should ensure that climatic hazards are analysed thoroughly by insurance enterprises. However, that will examine the issue from the viewpoint of risk to the insurance enterprise, so the information will be restricted in scope and technical in nature).

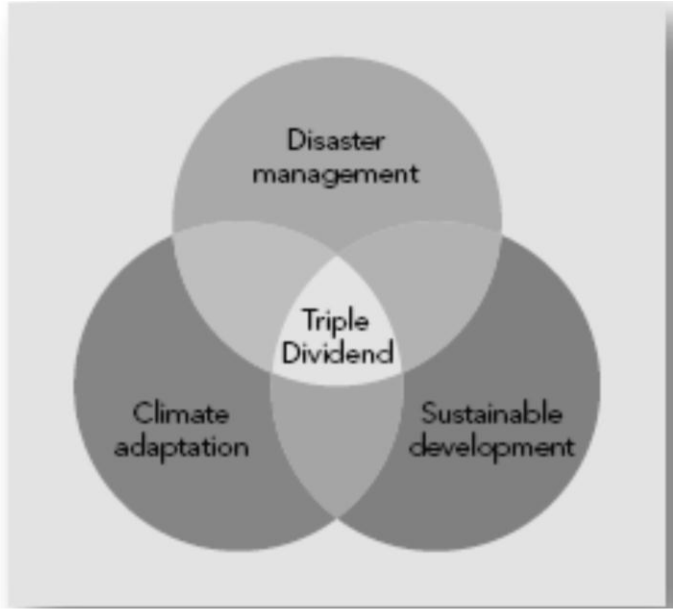
3.7.7 Potential effects of the considered actions

Potential positive effects include:

- The proposed actions would contribute to the sustainable economic development in the EU, by reducing the impact of natural hazards, and fostering adaptation processes;
- The proposed actions would increase coherence of the EU policies in the areas such as disaster management and sustainable development (cf. Figure 61);

[173] It was noted that the EC may be restricted in the degree to which it can identify 'best practice' cases for dissemination, since this could imply a recommendation versus other available actors/products/processes.

Figure 61: A Triple Dividend (source UNEPFI, 2006)



Well designed policies can achieve a 'triple dividend', contributing to disaster management, adaptation, and sustainable development. In fact, adaptation IS development (i.e. development without recognising climate change is not sustainable).

- Public finances would be more robust, since less of the burden of natural disasters would fall on the public sector;
- Environmental effects could be beneficial, since risk transfer and access to information may reduce the volume of wasted resources;
- Some of the measures could help to avoid economic blight in high-hazard areas;
- Some of the measures could foster access to risk transfer for disadvantaged communities;
- There could be beneficial effects on competition if access to information is shared equally between small and large economic entities;
- Investors in insurance companies could benefit from reduced risk to their capital, due to improved information on climate change risk;
- In the longer term, real estate would be a safer investment, since the risk from natural catastrophes will have been more adequately identified and managed.

Potential negative effects include:

- In the near term, real estate values in zones identified as high hazard may be expected to fall;
- Tourism in zones identified as high hazard may also be expected to see a reduction in activity;

- There could be negative effects on freedom of choice, if restrictions are placed on development options and structural designs under zoning strategies.

3.7.8 Implementing proposed actions

For each proposed action, consideration needs to be given as to how to effect the necessary change and whether this can be done by a change to EU law or regulation or whether by any other method (e.g. establishing an advisory body or issuing guidance).

In order for any of the recommendations to become legally binding they would have to be implemented either into EU legislation or into the local law of each Member State.

Theoretically, any legal changes could potentially be implemented into the Solvency II Directive[174] or the Insurance Mediation Directive (IMD2)[175]. However, both pieces of legislation are fairly well developed and have been in the process of being drafted for some time. Therefore, it would be difficult to have further changes implemented for the ongoing process.

In respect of IMD2 there is some scope for certain recommendations to be implemented at the Level 2 or Level 3 stage. The Commission and the European Insurance and Occupational Pensions Authority (EIOPA) are expected to consult on Level 2 measures in relation to IMD2 in 2013 or 2014. Therefore, there is a possibility that the relevant recommended actions could be posed as part of this consultation process, or alternatively, at a later date, when Level 3 measures in relation to IMD2 are being considered. It should be noted however, that any action which is implemented at the Level 3 Stage will only constitute non-binding guidance and will not be legally enforceable.

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[174] **Solvency II** will consolidate the existing insurance directives such as (the First Non-life Directive (Directive 73/239/EEC), the Second Non-life Directive (Directive 88/357/EEC), Third Non-life Directive (Directive 92/49/EEC) and the Reinsurance Directive) (2005/68/EC). In so doing, Solvency II will significantly change the regulatory framework for the supervision of insurers and reinsurers across Europe.Under Solvency II, existing insurance directives will be amended and recast in order to introduce a consistent, risk-based, solvency regime which better reflects modern solvency and reporting requirements. Solvency II will be based on a “three pillar” framework. The pillar system originates from the approach taken in the Capital Requirements Directive, which followed the international Basel II Accord for banks and investment firms. Capital requirements, governance and reporting obligations should introduce greater consistency in terms of supervision. Under Solvency II reporting requirements, insurers will report publicly on their financial condition, providing information on capital.

[175] The Insurance Mediation Directive (**IMD**) (2002/92/EC) came into effect in 2005. IMD introduced consistent registration requirements for insurance intermediaries across Europe and specified certain conduct of business rules. In addition, the IMD supported the creation of a Single Market by allowing the use of the single-passport for the provision of cross-border services and establishment. IMD2 will provide additional conduct of business requirements and further facilitate the provision of insurance mediation across borders. Also, as there is now a highly competitive price comparison market place, aggregators, which previously were not picked up by the IMD, will fall within the scope of the requirements under IMD2.

Solvency II is at rather an advanced stage and it is unlikely that any of the proposed actions could be implemented into the Level 2 or Level 3 measures. However, if there is significant delay to the Solvency II timetable it may become possible to still influence these measures.

Therefore, a better solution may be to wait for amendments to Solvency II and/or IMD2 to be proposed, once they have been fully implemented, and to try and have some of the proposed actions included within these amendments (Norton Rose, 2012, unpublished).

The Commission assigned Norton Rose to consider a number of the recommendations set out above where they relate specifically to the EU level legal and regulatory framework in relation to insurance. The following table provides a summary of the considered actions in terms of their feasibility of implementation.

Table 39: Categories of proposed actions and the feasibility of their implementation

Category	Proposed actions	Can the proposed actions be implemented?	Likelihood of implementation
Data	1 Publication of post disaster public relief 2 Provide research bodies with data on the cost of events) 3 Reliable data on historical and future natural hazards) 4 Provision of risk-relevant information	Yes	All are achievable 1, 2 and 3 will require the co-operation of insurers, intermediaries, government bodies and other relevant organisations. 4 will require legislative change, probably to IMD2.
Risk pooling, disclosure, regulatory programmes	5 Risk pooling within states 6 Trans-national risk pooling 7 Micro-insurance 8 Adaptation toolkit 9 Insurers as key stakeholders	Yes	5, 8 and 9 are workable. 6 may be difficult to implement within existing legal structure. 7 could work, depending on the decision in respect of the stage at which the proposal would be implemented
Reporting	10 Mandatory reporting of climate risk	Yes	Achievable - depending on the decision in respect of the stage at which the proposal would be implemented.
Sales processes	11 Bundling to include natural hazards 12 Providing information to customers 13 Risk-related terms of risk transfer insurance contracts	Yes	Moderate - depending on how consultations with insurers and intermediaries go and the decision in respect of the stage at which the proposal would be implemented.

3.8 How would the problem evolve without new EU action?

3.8.1 Economic sectors and systems

3.8.1.1 Agriculture

Crop Production

Future projected trends in European agriculture include a northward movement of suitable zones for crops with increasing crop productivity in Northern Europe, and declining productivity in Southern Europe (Maracchi, et al, 2005; Olesen & Bindi, 2004; Falloon & Betts, 2010). A projected rise in crop productivity, especially for cereals and cool season seed crops in Northern Europe, is due to lengthened growing seasons, decreasing cold spells and extended periods without frost. Yields could increase as much as 30% by 2050, depending on the crop (Olesen, et al, 2011). However, the potential benefits in Northern Europe will not always fully materialise due to various limiting factors (e.g. extreme events, soil degradation and insufficient water availability) (Maracchi, et al, 2005). Possible negative impacts in Northern Europe include increased pests and diseases, nutrient leaching, and reduced soil organic matter. Various insects, for example the European corn borer (*Ostrinia nubilalis*) and the Mediterranean fruit fly (*Ceratitis capitata*), are expected to show a considerable northward expansion with rising temperatures (Olesen, et al, 2011).

In contrast to Northern Europe, crop productivity is expected to decrease where seasonal precipitation decreases significantly such as in the Mediterranean and southeast Europe. In these regions, yields of energy, starch, cereal and solid biofuel crops could decline up to 30% by 2050; the magnitude of the impact varies, however, from crop to crop. Furthermore, an increasing demand for water for crop irrigation (up to 10%) is likely to occur especially in southern regions, as well as for fruit and vegetables in Northern Europe (Falloon & Betts, 2010). Some crops that currently grow mostly in Southern Europe will become more suitable further north or in higher altitude areas in the South. Projections for a range of emission scenarios show a 30-50% increase in suitable area for grain maize production in Europe by the end of the 21st century (Olesen, et al, 2011).

The expectation is that by 2020, there will be small increases in European crop productivity (EC, 2009n) and resultant yield improvements, particularly in Northern Europe, with the exception of some areas in Central and Southern Europe. The overall yield gain in the EU would be 17% in 2050. However, the predictions for 2080 differ depending on the scenario. For the scenario's which predict less warming, a small yield increase is predicted whereas for the 5.4ºC scenario the yield could decline with 10% (Ciscar, et al, 2009).

The latest AVEMAC report[176] (Donatelli, et al, 2012) released by DG agriculture and the Joint Research Center assesses the possible vulnerabilities in the EU regions and impacts on

[176] http://ec.europa.eu/agriculture/analysis/external/avemac/index_en.htm

main arable crops with two GCM (HADCM3 and ECHAM5) and of one of the IPCC A1B emission scenario. Both realisations do not differ remarkably on air temperature, but they show differences in precipitation patterns comparing Southern and Central-northern Europe. The study estimates yield prospects with the option of no limitations of production by water, diseases well as considering water limiting and diseases impacts constraints.; It also assumes increased photosynthesis efficiency due to elevated CO_2 concentrations, carbon fertilization and the improved thermal regime. At the same time, however, the latter may have led to a shortening of the grain-filling phase in crops. Adaptation measures have not been considered. The main results of the study show that:

- In terms of overall production in the EU for maize, estimates of the warm scenario for 2030 indicated a potential decrease of about 9% in the production of grain maize in comparison to the 2000 baseline. These regions are mainly located areas in France, Romania, Italy, Hungary and Spain. The opposite is foreseen by the cold scenario with a potential increase of the EU overall production of grain maize both in 2020 and 2030 compared to the baseline. Many regions in Italy, Spain, Romania and Greece are expected to have an increase of production; in some cases quite important (+15-20%) while a stable production in France is foreseen;

- Regarding sunflower, the analysis of the warm scenario for 2030 indicates a potential decrease in sunflower production of around 10% in Spain, 4% to 8% depending on the region in France, 14% for Romania, 12% for Hungary, and 13% for Bulgaria. The 2030 cold scenario almost reflects the results obtained with the warm scenario except for French regions, which seem not to be concerned by a potential diminution of the production;

- For wheat, according to the warm scenario in 2030, regions in Northern France, Poland, Lithuania and Latvia could be affected by a potential decrease in the order of 8% to 18% that can be considered significant. On the other hand, analysis results for regions in Italy, Bulgaria, and Spain indicate a significant potential increase in wheat production. The cold scenario for 2030 confirms a significant potential decrease of production in numerous Polish regions. Not expected with the warm scenario, all Romanian, northern Bulgarian and western Hungarian regions will be potentially affected by a significant decrease of production according to the cold scenario;

- For rapeseed, according to the warm scenario, only regions in France are estimated to experience a significant potential decrease by 2030 of -11% to -18%, depending on the region. The same regions would have a slightly positive potential increase, even if not significant, when taking into account the cold scenario.

Finally, the intensity of extreme weather events such as periods of high temperature, heavy storms or droughts is predicted to increase in the coming decades. These extreme weather events can severely disrupt crop production and lead to a greater yield variability. Further they can lead to an increase in fires and pests damaging the crops (Maracchi, et al, 2005). Periods of high relative humidity, frost and hail can further affect yield and quality of fruits and vegetables (Iglesias, et al, 2009). In the Mediterranean region, where mostly permanent crops (olive, grapevine, fruit trees) are cultivated, extreme events such as hail and storms can severely reduce or completely damage harvest.

Economic impacts of changes in crop production

According to Ciscar et al. (2009), the estimated changes in GPD per region confirm the significant regional differences between Northern and Southern European countries. They are positive in all regions except for Mediterranean countries. In Northern Europe the impact in terms of GDP is estimated to be between 0.8 and 1.1 per cent and the welfare change ranges between 0.6 and 0.7 per cent in 2080. In Southern Europe the changes in GDP rages in 2080 between -1.3 and -0.1 per cent and in terms of welfare loss between -1.0 and 0 per cent. The monetary estimates show that in all cases uncertainty derived from social-economic scenarios has a larger effect than uncertainties from climate scenarios. In this study is assumed that the yield is optimal given no limitations with respect to water availability, fertilizer and management. Economic losses as a result of weather extremes can be high. In 2003 the estimated economic losses to farming from the combined effects of droughts, heat stress and fires is estimated at 10 billion Euros.

Tol (2002) compared estimations for agricultural damage cost impacts from different sources. The comparison showed that the impact of a 2.5 °C global temperature rise is on average 0.55 per cent of the Gross Agricultural Product (GAP) for OECD-Europe. With adaptation the rise of GAP will become 2.09 per cent on average. For Central Europe and the former Soviet Union the GAP changes by 0.94 per cent on average. With adaptation the gain for this region will rise to 2.65 per cent of GAP in average.

A scenario study by Fisher et al. (2002) found that the impact of climate change on the GDP (aggregated global level) is rather small. Between - 1.5 % and + 2.6 % where found. These refer to a total GDP of agriculture in the reference scenario ranging from USD 2.9 – 3.6 trillion (at 1990 prices). In this study agriculture in Western Europe losses added value in all scenarios, Under the A2 scenario the loss is between 6 – 18 per cent. The former Soviet Union gains up to 23 per cent under A2 scenario (Fisher, et al, 2002). Darwin (1999) shared the conclusion that the economic impact of climate change on agriculture is relatively small. He found the global impact of climate change within USD -24.5 billion to USD 25.2 billion a year when cropland expansion is allowed. If land use changes are not allowed the world GDP declines from USD 0.7 billion to USD 73.4 billion and the European Community GDP drops by 0.3 to 1.1 per cent (Darwin, 1999).

Agrawala et al. (2010b) performed a global study on the impact of climate change and the costs and benefits of adaptation based on the assumption that CO_2-eq concentrations are stabilising at 550 ppm (corresponding to a temperature of around 2.5 °C above pre-industrial levels at the beginning of next century). This OECD study also used the DICE and RICE model and the WITCH model. For agriculture this study builds on earlier studies by Tan & Shibasaki (2003), Rosenzweig & Parry (1994) and Nordhaus & Boyer (2000). According to

Agrawala et al. (2010b) the agricultural damages related to a 2.5 °C global temperature rise are 0.49 % of the GDP.

For the latest results of the ICES-CGE exercise performed in the context of this study cf. also chapter 3.1.7.2.2.

Livestock production

Livestock systems may both directly and indirectly be influenced by climate change. Therefore it is important to keep in mind that the effects as well as the technological measures differ between livestock in stables and free range livestock.

Direct influences of climate change include effects on animal health, growth and reproduction while indirect effects include impacts on the productivity of pastures and forage crops. Heat stress has several negative effects on animal husbandry, including reduced reproduction and milk production in dairy cows, and reduced fertility in pigs. This can negatively affect livestock production in summer in the warm regions of Europe. Technological developments can reduce the threat for livestock in stables as climate regulation can reduce the heat stress. During the cold period warming is likely to be beneficial for cooler regions due to reduced feed requirements, increased survival, and lower energy costs (Maracchi, et al, 2005). The effects on grassland differ depending on the type. In general, intensively managed and nutrient-rich grasslands will respond positively to both an increase in CO_2 concentration and a temperature increase, given that water supply is sufficient. Nitrogen-poor and species-rich grasslands may respond differently to climate change and increases in CO_2 concentrations (Olesen & Bindi, 2004).

In order to get better and more detailed insights the FP7 project ANIMALCHANGE[177] investigates the future of the livestock sector under climate change and potential adaptation option.

3.8.1.2 Forestry

Until 2020 it is expected that extreme events are increasing with increasing negative impacts to European forest and losses in timber production. In order to address this problem most of the up to date adopted National Adaptation Strategies (NAS) cover the issue of forestry. It can be assumed that the issue will also be addressed by those countries which are currently developing a strategy. Stakeholders' dialogues with the actors of the sector have also indicated that at least those forestry owners which have a business case in forest management will also take adaptation measures in order to ensure the sustainability of the business. However, a new EU Forestry strategy is under preparation. It should address climate change – mitigation and adaptation – as a cross cutting objective.

[177] http://www.animalchange.eu/

3.8.1.3 Transport

Transport infrastructure investments boost economic growth, create wealth, enhance trade, geographical accessibility and the mobility of people (EC, 2011p). Experiences of past catastrophes and research results of the Weather project showed clearly that extreme weather events today are not sufficiently addressed by transport systems and in particular by risk or emergency management procedures within the transport sector (Papanikolaou, et al, 2011). Extreme weather events cause economic impacts, which are closely related to the frequencies of damage-, disruption- and transport restriction events and the availability of transport alternatives. Climate change impacts due to change in precipitation patterns (magnitude and frequency) and to increase of temperature will enhance the pressure on transport infrastructure in future, also in economic terms. Existing EU policies do not accommodate these changes adequately and thus, additional negative effects might be expected. Besides activities at the EU level, adaptation options on national level are also crucial due to the fact that many responsibilities rest with them.

3.8.1.4 Construction and buildings

Climate change affects buildings and construction since buildings typically last for decades or more. New developments offer the greatest opportunity to limit vulnerability (Altvater, et al, 2011a). Certain action at Member State or regional level might be taken already, related to building codes and design standards, preferably in a coordinated and consistent way.

Without taking climate change into account in these long-term investments, new buildings and construction will be more vulnerable to the negative effects of climate change and higher damages might occur. Old-fashioned buildings will be cooled with use of fossil fuel, leading to more CO2 emissions, thus further accelerating climate change and enhancing the need for adaptation. Also, the construction of new developments in flood-prone areas is likely to continue as room for settlements is limited in many European countries.

3.8.1.5 Energy

3.8.1.5.1 Transmission and distribution

The transmission and distribution grid is extended and many projects in all Member States are supported by TEN-E. For the electricity transmission priority axes (cf. Annex I in TEN-E guidelines), a funding of around 10-15 million EUR p.a. is provided to TSOs[178].

However, transmission and distribution is challenged by accelerated exposure of infrastructures to meet i) new (and also climate-induced) demand patterns and ii) new and often remote supply facilities (e.g. offshore wind parks). The following paragraphs highlight some of the trends that have led to additional exposure of energy transmission/distribution infrastructure.

[178] http://ec.europa.eu/energy/infrastructure/tent_e/doc/2012_ten_e_financed_projects_1995_2010.pdf

To fulfil the internal energy market, the extension of the European transmission network is vital, resulting in long-distance and cross-border transmission of electrical energy and the necessary grid infrastructure that is exposed to climate change threats.

Furthermore, the smart grid initiative in connection with the extension of renewable energy production reveals that transmission of energy now and in future is high and will most likely increase further. In many countries the municipal utilities for electricity production have been taken over by big companies leading to the centralisation of energy production. Overloaded transmission lines are explicitly vulnerable to e.g. flash-over, which in the end might cause far-reaching black-outs via cascadal effects.

On the other hand, the trend towards small private power plants (so far mainly PV[179]) could lead to scattered decentralisation of energy production with a complex demand on transmission and in particular distribution infrastructure, with – unless carried out underground – the according exposed infrastructure.

After CEER (2008), the current situation in most countries is very good with respect to electricity system reliability. Countries like Hungary and Portugal, which had high values for minutes without electricity supply (e.g. Hungary > 400 in 1999 and Portugal > 500 in 2001) have reduced black out times since then significantly. And countries that had only little problems with system reliability remained stable or even improved further.

Nevertheless, the challenges for transmission and distribution systems and their operators (ENTSO[180] and EDSO[181]) are increasing to develop a true European energy market which seems a key to enable mitigation goals, but also increases the exposure towards changing climate parameters. Only a strong, reliable, secure and thus climate-proofed transmission and distribution network can effectively connect a region-specific renewable energy production (e.g. solar power in the Mediterranean countries, water and storage power in and around Mountainous regions and off-shore wind power in the North Sea).

Many Southern and Eastern EU countries still face problems with electricity service stability (cf. Figure 36 on page 123). Due to old transmission and distribution infrastructure, their resilience towards an accelerating frequency of extreme meteorological events (drought, heat waves, mass movements etc.) must be regarded as low. Thus, the success of smart grid initiatives, the CEF and TEN-E policy and the implementation of the SET plan is depending on stable infrastructures of transmission and distribution in all parts of the EU.

3.8.1.5.2 Supply/Generation

Supply/Generation of electrical energy is affected by efficiency decreases due to climate change, the more complex vulnerability setting of renewable energy (as compared to fossil fuel based energy supply) to changing climate parameters.

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179 Photovoltaic
180 European Network of Transmission System Operators
181 European Network of Distribution System Operators

Taking Germany as one example, the energy mix of the 90s was mainly vulnerable to temperature (efficiency of thermal incl. nuclear power plants) and river run-offs (efficiency and obligatory cooling water supply for thermal and nuclear power stations), while the current and even more the future energy mix will be much more vulnerable to additional climate parameters such as wind speeds and solar radiation. However, since the uncertainty in climate scenarios is much higher for the climate parameters determining energy efficiency of renewable energy supplies, the vulnerability of the future energy mix cannot be assessed today.

Decarbonisation as one of the main goals for the energy sector is steered by EU policy since many years and is the core of Energy 2020 (EC, 2010l) as well as the Energy roadmap 2050 (EC, 2011o). However, some countries (e.g. France and Finland) plan to fill the fossil fuel gap with renewable energy and massive new investments in nuclear power supply which keeps their vulnerability slightly more in the traditional patterns.

The quick extension of renewable energy production might suffer from not being well-adapted to future climate and thus supplying less power than needed to be able to close down CO_2-intensive energy production. Thermal and nuclear power station shave to be climate-proofed i.e. their efficiency as well as security has to be surveyed basically with respect to sufficient water cooling access (cf. measures set in France, The Netherlands and Germany). Supply contingency plans during extreme meteorological situations are unlikely to be set up without EU action. Most striking supply deficits in Southern Europe will further increase without EU action.

3.8.1.5.3 Demand

Demand of energy is already triggered particularly by extreme periods (floods/mass movements, droughts, heat waves) causing demand-driven overstress of transmission infrastructure, their direct destruction and consequent interruptions in energy supply.

Furthermore, current trends in energy demand allow the projection that electricity demand will also raise due to growing use of electrical devices and also due to rising electrical mobility. Likewise, the share of electricity demand that is climate-sensitive (air conditioning, pumping for irrigation devices) will increase.

The 20% reduction in energy demand and even more a cut-off for climate-induced demand peaks might be out of reach without EU action on energy efficiency. It should be stressed that increased energy efficiency raises the resilience of the energy system synchronously and should thus be regarded as adaptation – especially if it raises the capability to cut-off demand peaks during climate-induced extreme periods (e.g. heat waves). Synergies among efficiency/mitigation and adaptation enhance the resilience of the European energy system. This should be taken into account for adaptation strategies in all energy-intensive sectors.

Energy costs for citizens and companies in Southern Europe might increase disproportional due to higher cooling demand, higher import dependency and insufficient domestic supply.

3.8.1.6 Disaster Risk Reduction

Member States face the challenge of how to prioritise and plan adaptation strategies in the current times of financial constraints, and how to enhance resilience to future risks of natural hazards. Climate change adaptation is fundamentally related to reducing and managing climate related risks. Given that existing climate risk will determine future risk (ECA, 2009), the identification, assessment and understanding of the full spectrum of risks faced in a country and of the underlying drivers that can increase or decrease these risks is a fundamental first step to the adoption of cost-effective adaptation strategies.

Without new EU action the responses in the Member States will vary between trying to be a forerunner and doing nothing at all, depending on the political interest of the national governments in climate change adaptation. A common approach on how to link DRR and climate change adaptation efforts, e.g. through integration of climate change aspects in setting up national risk management plans or vice versa including DRR into National Adaptation Strategies is needed.

National Governments have fiscal responsibility for their historical stock of risk-prone public assets, such as e.g. infrastructure networks, and of the uninsured assets of low income groups. Different risk reduction and management strategies may include the following categories (UNISDR, 2010):

- The most cost-effective way for a country to reduce climate-related risks in the medium term is through factoring risk reduction into development planning, land use, building and environmental management. In the short term, this will reduce extensive risks, while in the medium to long term it can reduce more intensive risks by directing development to less exposed areas, mitigating hazards and reducing vulnerability;

- Correcting existing risk levels, through actions such as retrofitting buildings, relocating settlements and restoring ecosystems is more expensive than avoiding the construction of these risks in the first place. Given the high level of recurrent losses, it is usually cost-effective to correct the more extensive risks but increasingly less so for intensive risks given the costs involved and long periods before benefits are potentially realised. However, investments to protect critical facilities, such as schools and health facilities, against more extreme risks may be justified, for both economic and political reasons;

- For certain intensive risks that cannot be reduced cost-effectively, risk transfer measures such as insurance and catastrophe risk pools/bonds can mitigate disaster impacts on physical assets and enhance Governments' ability to respond effectively.[182]

- Traditional disaster management, including effective early warning, preparedness and response is essential to strengthen resilience to and facilitate recovery from all manifestations of risk.

In most contexts, climate change adaptation should rely on a cost-effective mix of these strategies to manage and reduce climate-related risks. However, being able to organize and implement adaptation depends on a country's risk governance capacities. Furthermore, it should be noted that climate change could be an opportunity to engage investors, rather than be portrayed monolithically as a community risk.

Although the relationship between disaster risk reduction and climate change adaptation is increasingly recognized by researchers, policy makers and practitioners within both communities, the two communities have yet to develop coordinated efforts towards reducing climate change risks and vulnerability, which includes increasing the capacity to cope with and adapt to rapid changes, complex emergencies, and considerable uncertainty about the future.

At the same time, the disaster risk community has not fully incorporated climate change dimensions and information on climate impacts into its work. The risk of more complex, frequent, intense or unpredictable extreme weather events associated with global temperature increases, changing precipitation patterns and sea level rise, coupled with both gradual and non-linear changes to ecosystems and natural resources, suggests the need for a renewed focus on the ways that disaster risk reduction and adaptation can influence the context in which climate change occurs. Adaptation requires strengthening Member States' capacities for risk governance, so that development planning/public investment can include cost-effective strategies for risk reduction and management.

[182] In September 2010, four leading insurance groups—ClimateWise, the Geneva Association, the Munich Climate Insurance Initiative (MCII) and leading insurance companies within the United Nations Environment Programme Finance Initiative (UNEP FI)–launched a declaration about how insurance industry expertise paired with government action can benefit adaptation by reducing climate-related disaster risk (focusing on developing countries).

3.8.2 Environmental and human systems

3.8.2.1 Soil

Soil is considered a non-renewable resource because it is slow to form and easily destroyed (EC, 2006a). Soil degradation in the European Union is accelerating due to inappropriate farming practices (erosion, organic content decline), salinization (irrigation), landslides (intensive land use), contamination (industry and mining) and soil sealing (urbanization). As neither most Member States nor the EU have an integrated soil protection policy in place, the degradation is likely to proceed.

The risk of soil degradation is closely related to climate change and land use development. Future land use and climate depend strongly on scenarios. However, Jones et al. (2012) provided an outlook on European soils in 2020. They state that considerably more effort is needed to model soil state as a result of drivers such as land use and climate change.

The Thematic Strategy for Soil Protection of 2006 indicates that erosion is increasing in Europe; at that moment in time, 3.4% of the area (1.6 million hectares) of the 21 Member States covered in the study is at risk from erosion of more than 10 tonnes per hectare per year, and 18% (54 million ha) are at risk of losing soil above 1 tonne per hectare per year (EC, 2006a).

The potential of soils for carbon sequestration was estimated to be equivalent to 1.5-1.7% of the EU's anthropogenic CO_2 emissions during the first commitment period of the Kyoto protocol. Around 45% of soils in Europe have a low or very low organic matter content (meaning 0-2% organic carbon) and 45% have a medium content (meaning 2-6% organic carbon).

Soil carbon storage

Intensification of agriculture, deforestation and conversion of grassland to arable land (or vice versa) are slow processes leading to changes in soil organic carbon. Some recent studies suggest that soil organic carbon in European agricultural land is decreasing (Jones, et al, 2012).

Erosion

It is difficult to assess the trends in soil erosion due to a lack of systematic approaches and data (Jones, et al, 2012). There is a close link to land use patterns, climate change impacts and erosion rates. As a result of climate change the conversion of permanent pasture to arable crops and increasing demands for bio energy are expected to lead to an increased risk and rates of soil erosion (Jones, et al, 2012).

Salinization

There is no data available to show trends across Europe. National data show increasing salinization levels in Greece, Spain and Hungary (Jones, et al, 2012).

Landslides

There is no harmonized data available for the impact and risk of landslides across Europe. Estimations on the total area affected are available for different member states (Italy 7%, Portugal 1% and Slovakia 5%).

Soil sealing

In the European Union (EU) about 1,000 km² were subject to land take annually for housing, industry, roads or recreational purposes between 1990 and 2006. This is exceeding the size of Berlin. About half of this surface is actually sealed by buildings, roads and parking lots (Prokop, et al, 2011). The formation of new artificial surface was greater than of agricultural land (EEA, 2010e).

3.8.2.2 Biodiversity

Climate change is compounding existing threats to biodiversity, such as pollution, invasive alien species, habitat loss and fragmentation. The long-term ability of ecosystems to regulate climate is being compromised by the continuing loss of biodiversity. Resultant possible feedbacks include melting permafrost, ocean acidification, and deforestation.

Climate change impacts due to increasing temperature and changes in precipitation patterns are projected to increase in the future. Whilst biodiversity policies do address climate change, many associated EU policies (e.g. agriculture, water, cohesion) are less explicit. Additionally, whilst Member State policies to tackle climate change at a national level are essential, the state of development of these across the EU is currently variable.

The EU 2020 biodiversity target (EC, 2011b) is underpinned by the recognition that, in addition to its intrinsic value, biodiversity and the services that ecosystems provide have significant economic value that is seldom captured by markets. Because it escapes pricing and is not reflected in society's accounts, biodiversity often falls victim to competing claims on its use. The EC-sponsored international project on *The Economics of Ecosystems and Biodiversity* (TEEB; European Communities, 2008) recommends that the economic value of biodiversity should be factored into decision-making and reflected in accounting and reporting systems. Quantifying links between biodiversity and ecosystem services, including those that contribute to climate change adaptation and mitigation, and estimating their value is clearly an urgent requirement that currently remains far from completion.

Business has a huge role to play in managing, safeguarding and investing in biodiversity and ecosystem services. *TEEB for Business* (TEEB, 2010) provides guidance on biodiversity-related issues and opportunities across a range of sectors, including those with direct impacts on biodiversity (e.g. mining, oil and gas), those that depend on biodiversity for production (e.g. agriculture and fisheries), and those that sell ecosystem services or biodiversity-related products (e.g. eco-tourism, eco-agriculture and bio-carbon).

Although action to halt biodiversity loss entails costs, these are dwarfed by the costs to society as a whole of biodiversity loss itself, as many economic actors in sectors depend directly on ecosystem services. For example, insect pollination in the EU has an estimated economic value of € 15 billion per year (Gallai, et al, 2009). The continued decline of bees and other pollinators[183] could have serious consequences for Europe's farmers and agri-business sector[184], and for EU agriculture policy and related subsidies. The private sector is becoming aware of these threats. Businesses in Europe and beyond are beginning to assess their dependency on biodiversity and integrating targets for sustainable natural resource use into their corporate strategies[185].

3.8.2.3 Health

It is very likely that the burden of heat-related morbidity and mortality will increase over the coming decades. According to the PESETA project estimates, already by the 2020s (average of 2011-2040), a small increase in the European average heat-related numbers of deaths and the death rate due to climate change (over and above that as a result of changing populations and demographics) are to be expected. At the same time the analysis estimates that there will be a small decrease in the European average cold-related numbers of deaths (i.e. a benefit) and the death rate due to climate change (over and above that as a result of changing populations and demographics). There is greater variation in the analysis, with some 50.000 to 100.000 estimated cold related deaths avoided. By the 2080s (average of 2071-2100), the analysis estimates that there will be a significant increase in the European average heat-related numbers of deaths and the death rate due to climate change with around 105.000 extra heat related deaths per year. At the same time the analysis estimates that there will be a significant decrease in the European average cold-related numbers of deaths with some 86.000 to 184.000 estimated cold related deaths avoided. The net effect is determined by the functions used. With the climate dependent functions, the rise in extra heat related mortality is greater than the decrease in cold related mortality. With the country specific functions, the opposite occurs (cold related mortality benefits are greater, and quite significant so, than heat related mortality). With acclimatisation /with a decline in sensitivity of mortality to cold, the country specific functions show similar levels of heat and cold related mortality. Therefore, the magnitude of the impacts and benefits is strongly influenced by the choice of exposure response function, and the assumption of acclimatisation (Watkiss, et al, 2009).

Other analysis point to a change in the seasonality of mortality, with maximum monthly mortality shifting from winter to summer; the frequency of warm extremes and the number of uncomfortable days will increase, leading to a reduction in human lifespan of up to 3-4 months in 2070-2100 (Ballester, et al, 2011).

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[183] Grassland butterfly populations have declined by over 70 % since 1990.
[184] Over 80 % of the EU's crops are estimated to depend at least in part on insect pollination ('Bee Mortality and Bee Surveillance in Europe', 2009).
[185] 'State of Green Business 2011', GreenBiz Group.

Heat-wave events can have detrimental effects on human health. More than 70.000 excess deaths were reported from 12 European countries in the hot summer of 2003 (June to September). The 2003 heat wave was the most dramatic in recent history, but there have been a number of fatal heat waves in Central and Southeastern Europe over the last ten years (World Bank, 2009). Heat waves in Central and Southeastern Europe between 2005 and 2007 caused at least 839 heat wave related morbidities in Romania, Slovakia and Bulgaria (EM-DAT, World Bank 2009). Long heat waves (more than 5 days) have an impact 1.5 to 5 times greater than shorter events. 86.000 net extra deaths per year are projected for the EU Member States for a high-emissions scenario with a global mean temperature increase of 3 °C in 2071–2100 relative to 1961–1990. For 2030, under scenario with high carbon dioxide emissions, more than 400 heat-attributable deaths per year are expected, for example, in Athens, Budapest, Paris, and Rome (WHO Regional Office for Europe press[186]).

The CEHAPIS study (CEHAPIS, 2012, DAFT) presents state-of-the-art knowledge on health and climate change. Some health effects due to changes in extreme events frequencies and intensity as well as changes in rates of infectious disease distribution (vector-, rodent-, water- or food-borne diseases) have already been observed and are more likely to occur.

As stated in chapter 3.2.2.3, already in the past 20 years, 953 disasters killed nearly 88.671 people in Europe, affected more than 29 million others and caused a total of US$ 269 billion economic losses. Climate projections showcase an increase in heat related events and heavy precipitation as well as other disasters, which causes huge economic loss per capita, partly because Europe is very densely populated. (UNISDR, 2009c) and the economic wealth by capita is high.

Several scenarios are available for European future coastal and river flooding. It is likely (66% probability) that heavy precipitation events will continue to become more frequent in Europe. Even in summer, when the frequency of wet days is projected to decrease, the intensity of extreme rain showers may still increase. In addition, the frequency of several-day precipitation episodes is projected to increase (IPCC, 2007a). In consequence, without adaptation, river flooding is estimated to affect 250.000 to 400.000 additional people per year in Europe by the 2080s, more than doubling the number with respect to the 1961–1990 period (Cisar, 2009)[187]. An increase in people affected by river floods would occur mainly in the Central and Eastern Europe regions and the British Isles (Ciscar, et al, 2009). The total additional damage from river floods in the 2080s ranges between €7.7 billion and €15 billion, more than doubling the annual average damages over the 1961–1990 period (Cisar, 2009).

Due to more frequent heat waves, particularly in Central and Southern Europe, and more intense flooding events, the overall exposure to vector-, water- and food-borne diseases with impacts on human, animal and plant health is anticipated to increase (Semenza & Menne, 2009).

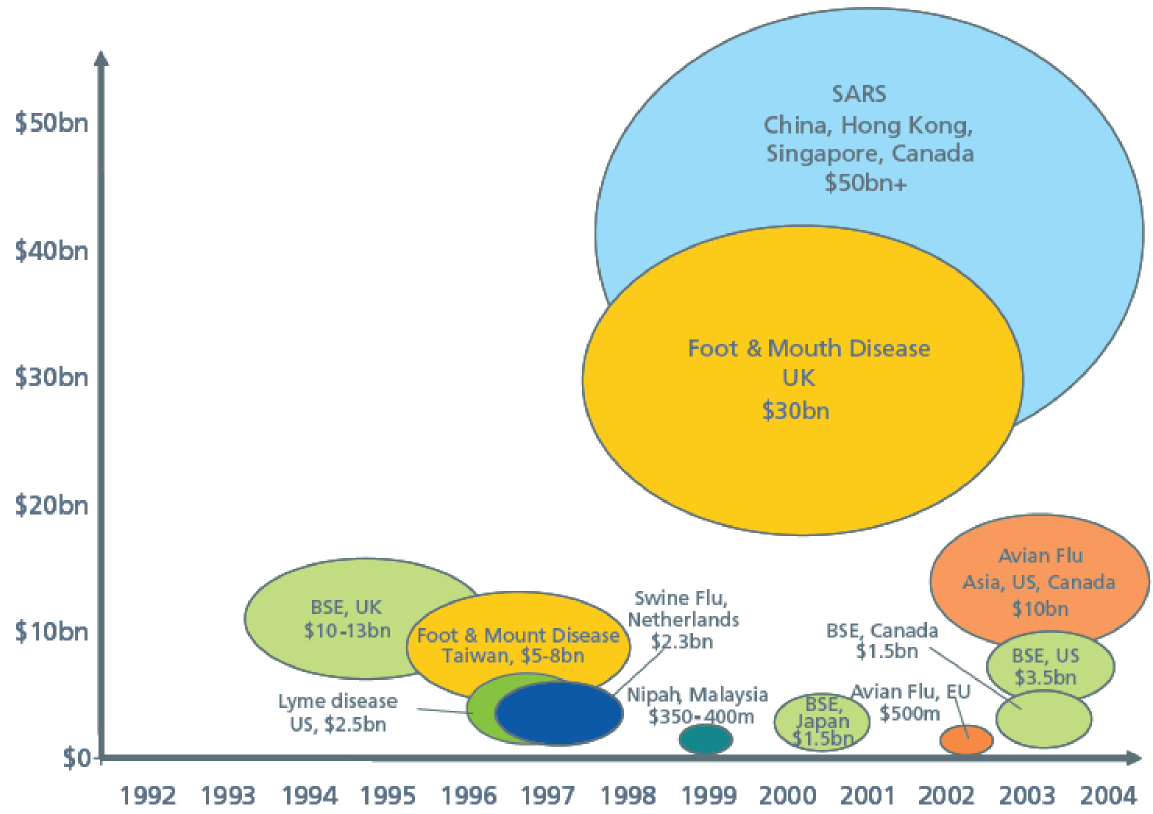
[186] http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/Climate-change/activities/public-health-responses-to-weather-extremes2/heathealth-action-plans/heat-threatens-health-key-figures-for-europe
[187] http://ftp.jrc.es/EURdoc/JRC55391.pdf

One of the most important vector-borne diseases in Europe and some of the countries of the former Soviet Union is Lyme disease, which is transmitted by ticks (Githeko, 2000). Projected temperature increases in the United Kingdom could increase the risk of local malaria transmission by only 8 to 15%; in Portugal a significant increase in the number of days suitable for the survival of malaria vectors is projected.

As stated in chapter 3.2.2.3, the study of Semenza et al. (2012a) showcased that the general expectation that incidence, outbreak frequencies and distribution of many infectious diseases will change as a consequence of climate change. A large majority of respondents agreed that climate change would affect vector-borne (86% of country representatives), food-borne (70%), water-borne (68%), and rodent-borne (68%) diseases in their countries. It was concluded that institutional improvements are needed for ongoing surveillance programs; collaboration with the veterinary sector; management of animal disease outbreaks; national monitoring and control of climate-sensitive infectious diseases; health services during an infectious disease outbreak; and diagnostic support during an epidemic (Lindgren, 2012; Semenza, et al, 2012a).

Late detection and a delayed public health response to these outbreaks can potentially have severe consequences not only for public health, but for a number of other sectors such as the economy (Marsh, et al, 2008). The estimated economic cost of past epidemics and pandemics is illustrated in Figure 62. Adjustments to existing surveillance practices in the EU, will enhance preparedness and facilitate the public health response to EIDs and thereby help contain human and economic costs.

Figure 62: Estimated economic cost of past epidemics and pandemics



[17] Permission to reprint image granted by Bio Economic Research Associates, LLC ©., 12 August 2008. *SARS and the New Economics of Biosecurity*, 2003.

According to the CEHAPIS project report (CEHAPIS, 2012, DRAFT), higher temperatures favour the growth of bacteria in food. Infections with Salmonella spp. rise by 5–10% for each 1°C increase in weekly temperature, at ambient temperatures above 5°C. In the Mediterranean, additional salmonella problems from bathing water quality are projected, which would require proper monitoring and surveillance. The annual health costs of food-borne salmonella in the EU reach up to € 2.8 billion per year.

Climate change is projected to increase diarrhoeal disease cases by 0 to 9% by 2030 in Europe. The total excess cases of diarrhoeal disease by 2030 are forecast to be between 785.000 to 14.386.000. The annual costs of diarrhoeal diseases for Europe for the years 2000-2030 are estimated to reach US$ 12–205 million for diarrhoea (stabilization of greenhouse gas emissions at 550 ppm), US$ 12–270 (stabilization at 750ppm) and US$ 12–260 for unmitigated emissions. The projected excess costs for managing climate change-related cases of diarrhoeal disease by 2030 range from US$ 12–217 million (CEHAPIS, 2012, DRAFT).

According to Agrawala et al. (2010b) the health related damages in Europe for a 2.5°C global temperature rise are 0.02% of the GDP. Costs of climate change impacts on health should be handled with care as the existing evidence base is overall of low quality. Although evidence is incomplete, all published evidence suggests significant health damage and adaptation costs, which are an important proportion of overall damage costs for climate change (Hutton, 2011).

The study "Nature And Health: The Importance Of Green Space In The Urban Living Environment', Proceeding of Green Spaces of the Symposium 'Open space functions under urban pressure (de Vries, 2001) concluded that every 10% increase in green space is associated with a reduction in diseases equivalent to an increase of five years of life expectancy (EEA, 2011d). Easily accessible and safe urban forests and green spaces have also been found to have the following health benefits, many of which are especially important for older people (Nurse, et al, 2010) like:

- increased physical activity and reduced obesity;
- reduced stress levels and improvements in mental health;
- reductions in noise levels — which can improve mental and physical health;
- improvements in hospital recovery times, and
- lower levels of violence and crime and increased social interactions which can also help improve overall well-being.

The combined effect of heat-waves and of peaks of ozone or PM10 (particulate matter with a diameter under 10 μm) air pollution increases mortality, particularly among elderly people (those aged 75–84 years) (WHO Regional Office for Europe[188]).

As an example related to plant health, the forest sector is seen at risk related to pests. Therefore effective monitoring and detection activities are needed to allow for quick action in the face of changing or increasing pest outbreaks including continual pest risk assessments. There is also a need for alternative practices to reduce subsequent vulnerability of forests, such as planting pest tolerant trees identified through breeding programmes; noting however that it is unlikely that such programmes can predict new pest risks in a timely fashion due to shifting species adapting to new environments. Comprehensive risk assessments as well as enhanced knowledge management systems using a variety of information technologies such as simulation models, geographic information systems (GIS) and remote sensing could also play a role in protecting forest health from the impacts of climate change and forest pests.

[188] 'Heat threatens health: key figures for Europe' http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/Climate-change/activities/prevention,-preparedness-and-response/heathealth-action-plans/heat-threatens-health-key-figures-for-europe

3.8.2.4 Inland Water

When the EU water directors adorsed the guidance document on climate change, they also agreed that climate change will be considered in the 2nd and 3rd implementation cycle of the Water Framework Directive (WFD). However the assessment of the first river basin management plans showed that almost all Member States are working on the issue of climate change to a different extend. It is expected that these efforts will be strengthened with the adoption of the EU communication “Blueprint for Safeguarding Europe's Water'[189].” and the commitment made by the water directors. In order words it is expected that several more adaptation measures will be taken in the future to mitigate the impacts of floods and droughts.

3.8.2.5 Marine and coastal zones

It is expected that due to the existing legal framework and increased awareness raising as well as further research under HORIZON 2020 by the Commission and the EEA more adaptation measures will be taken. The planned guidelines on ICZM and climate change adaptation will help Member States in taking action. So it is expected that the vulnerabilities will decrease over the next years. The current policy framework also triggers transboundary co-operation, so it is expected that adaptation will also be dealt in this manner.

3.8.3 Social issues

3.8.3.1 Food security

Currently no full assessment on the potential impacts on food security at the EU level exists. Based on literature survey the following indications on how climate change could impact the four pillars of food security on the EU have been found:

- Physical availability of food: The impacts of climate change on EU production are described in the sections above. For a global perspective the Food and Agriculture Organisation of the United Nations (FAO, 2011b) estimates that global agricultural production needs to grow by 70% between 2005-7 and 2015 to feed the rising world population. Nevertheless, taking into account the adaptability of the agricultural sector, FAO concludes that the climate change influences on global food production and security are likely to be insignificant (FAO, 2011b). For many years the EU has been a net food importer. Today the EU's overall trade is in fairly close balance (livestock and cereals), for many product groups the EU still remains a substantial importer (Fruit, vegetables, cotton, tobacco, oilseeds and oils) (EC, 2011l).

- Economic and physical access: Europe´s food prices are clearly depending on the developments and impacts on the global market but also on the impacts within

[189] http://ec.europa.eu/environment/water/blueprint/index_en.htm

Europe. Raising food prices are often a concern. A study by Parry et al. (1999) compared the HadCM2 with the HadCM3 scenario and the impacts on food supply. Under a HadCM2 scenario the world is generally able to feed itself until 2080. Under the HadCM3 scenario the agricultural production is reduced, leading to increasing food prices and higher risk of hunger particularly in arid and sub-humid tropic areas. Food prices may increase by 45 per cent in 2080 (Parry, et al, 1999). In the case food prices rise dramatically, the EU could increase the agricultural area used for growing cereals; in particular, by cutting back on biofuel and livestock production (Zahrnt, 2011).

- With increasing food prices the need for direct support of EU farmers could be questioned. The money saved could be used to support low income groups to ensure their access to food.

- The utilisation of food and of related resources is due to the high standards and the well-developed social security systems in Europe not endangered.

- The stability of food supply over time (short/medium/long term): While due to adaptation the long and medium term supply should be ensured short term supply might be endangered to more frequent natural disasters, such as floods, droughts and pests[190]. Europe as a market that is well integrated with the international trade is more protected from internal shocks, however, more exposed to external impacts (Sarris, 2009). At the same time, Europe potentially has significant power to exercise restrictive trade policies or provide consumer subsidies that insulate against external shocks (FAO, 2011b).

Having the above mentioned issues in mind the probability of food shortages in the EU is minimal. Nevertheless it is important to note that the assessment level on the relation between the food security within the EU and climate change at the current stage is currently is not very detailed and the result should be treated with precaution. In order to address the issue in a broader scale the Commission published on 28 April 2010 a Recommendation which launched a Joint Programming Initiative on 'Agriculture, food security and climate change', bringing together 20 European countries[191].

3.8.3.2 Other social issues

Already existing social policies in EU have their influence on the adaptive capacity of EU citizens. Currently the assessment of the how and to which extent the current social policy impacts adaptive capacity to climate change is lacking. However, such evaluation is essential for future coordination of social and climate policies so that synergies between them are fully explored and employed.

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[190] Cf. chapter 3.2.2.3 for more details on climate change impacts on the spread of food-borne diseases
[191] http://www.faccejpi.com/

Implemented adaptation measures both if they are directly oriented to address social impacts of climate change or towards mitigating other climate change threats, all have their impact on the adaptive capacity of the society. Either they change the adaptive capacity directly or rather influence the underlying social fabric that in turn changes the adaptive capacity. It will therefore be important for an EU Adaptation Strategy to continuously evaluate its direct and indirect impacts on the social realm and the adaptive capacity of vulnerable groups in particular and pay regard to ensuring equal access to adaptation measures for all members of the society.

So far there is no existing assessment of how the national adaptation strategies in Europe influence the social side of adaptive capacity. This is a knowledge gap that needs to be addressed and if existing valuable lessons from existing experience on national level could be brought up to the EU level.

3.9 Which issues shall be addressed at EU level to add value for enhancing climate resilience?

3.9.1 Economic sectors and systems

3.9.1.1 Agriculture

Since the beginning of the European Union, the CAP has been a central element as the objectives of the CAP are set out in the Treaty of Rome. The CAP is a policy of strategic importance for agricultural development, food security, the environment and territorial balance. Therein lies the EU added value of a common policy that makes the most efficient use of limited budgetary resources in maintaining a agriculture throughout the EU, addressing important cross-border issues such as climate change and reinforcing solidarity among Member States, while also allowing flexibility in implementation to cater to local needs. Mainstreaming climate change adaptation into the CAP would be one important action within the EU Adaptation Strategy. Mainstreaming the CAP has already started through the inclusion of climate change aspects into the proposal for the CAP 2014-2020. Although the negotiations of the future CAP may conclude before the EU Adaptation Strategy is presented, the strategy can influence the integration of adaptation into the upcoming rural development programmes.

3.9.1.2 Forestry

In the context of any EU action it is important to consider structural aspects of the sector. The overall discussions on adaptation at EU level hardly reach the ground (single forest owner) due to the diversity and fragmentation of the sector (few large companies versus several small forest owners). Also small forest owners which are often part time do not have clear forest management objectives and plans which makes the implementation of EU policies on the ground also more difficult.

3.9.1.3 Transport

Climate change will damage Europe`s transport infrastructure and thus, may affect the functioning of the European internal market (e.g. closing of ports, rail infrastructure). Furthermore, transport infrastructure networks are often transboundary and therefore, coordination efforts for adaptation are required. In addition, having the threats as identified above in mind and considering the long-term investments - with a life-span-time up to 100 years (e.g. major transport routes, bridges, tunnels, urban transport) – it is important to take climate change into account already today. But due to the uncertainties in future climate projections, planning new infrastructure should not focus on one single “optimal” solution but should be made more robust to a range of possible climatic changes (Hallegatte, 2009). Dessai et al. (2009) states that “robust strategies” perform well (though not necessarily optimally) over a wide range of assumptions about the future. Thus, in the case of transport infrastructure, multiple-benefits, no-regret and low-regret adaptation options[192] should be favoured with focus on main transport nodes and corridors.

Lack of knowledge on damage costs as well as costs of adaptation seem a bottleneck. In order to make sensible decisions one should be able to compare the investment costs for the measures with the damage costs they aim to avoid. Although more specific information on the costs of impacts and adaptation is needed, several studies and research projects already underline that the cost of actions addressing climate change (including mitigation and adaptation measures) will be much lower than the costs of inaction over the long term (Doll, et al, 2011). First results from existing work estimating adaptation costs estimates high costs for road and rail infrastructure, inland waterways and sea ports (Doll, et al, 2011). In case of aviation, low costs can be expected due to the fact that only a few adaptation measures are available and in addition, the sector seems to be already well equipped with weather-monitoring systems. All together, adaptation costs for the transport sector in Europe are estimated until 2030 between 1 to 17 Billion USD per year (UNFCCC, 2007).

A study conducted by within the Weather project (Trinks, et al, 2012) concluded that the key actors in promoting adaptation activities in transport infrastructure planning and general protection are the European Union and national governments.

A number of relevant existing policies might provide entry points to integrate climate change adaptation. Such relevant policies at EU level for all transport modes are the TEN-T Guidelines (661/2010/EC); the link to adaptation has been included in the revised version of the guideline. Regarding climate change adaptation in rail, policies focusing on the safety of rail networks and on new development of infrastructure are of specific interest (e.g. mainstreaming climate change adaptation into the TSI-Directive 2008/57/EC on the interoperability of the rail system within the Community). In case of roads, the Directive 2008/96/EC on road infrastructure safety management requires the establishment and implementation of procedures relating to road safety impact assessments, road safety audits, the management of road network safety and safety inspections by the Member States for the trans-European road network, whether they are at the design stage, under construction or in operation. When carrying out these assessments, not only the current climate conditions should be taken into account, but also information on possible future climatic conditions should be considered. The EU's maritime transport policy until 2018 [COM(2009) 008 final as well as the Directive 2005/44/EC on harmonised river information services (RIS) might provide further entry points for mainstreaming of climate change adaptation.

[192] Multiple-benefits options provide synergies with other goals such as mitigation or sustainability; No-regret and low-regret actions are beneficial in all plausible climate futures, such as early warning systems and insurance against floods.

3.9.1.4 Construction and buildings

There is significant potential for innovation in developing new materials, products and services to address aspects of climate change such as heat waves and water problems, but, as yet, specific briefing requirements for building design to address future climate impacts are rare. Because of the long timescales involved and the inherent uncertainties in the projections it is difficult for construction companies to build competitive advantage based on adaptive innovations.

EU requirements for incorporating future climate criteria in the procurement of new facilities (e.g. through the integration in the EN EUROCODES, cf. chapters 3.5.1.4, 3.9.5 and 6.5.3.1) will increase resilience and allow for a uniform approach. As the link between adaptation and mitigation is particularly strong for the building sector (because of cooling demand and reduction of flooding events in a low emission scenario) the Eurocodes can provide an integrated approach to more sustainable building practices.

3.9.1.5 Energy

For the scale of the problem and the EU justification to act, the following key rules should be applied:

- The subsidiarity principle;
- The stake of the EU within the energy system compartments;
- The vulnerability of the energy system compartment towards climate change.

3.9.1.5.1 EU responsibilities and justification to act on transmission

While the energy supply mix and the power station endowment is basically under the responsibility of Member States (compliant with the EU 20-20-20 policies) and companies (depending on the level of public ownership of energy companies), the proper operation of the transmission network especially within the EU internal energy market depends on two major EU policies: The internal energy market policy itself as well as the TEN-E/CEF policy.

As namely the high voltage cross-border transmission grids are the core enablers for the internal energy market and the TEN-E/CEF policy, the EU has a clear mandate to ensure a climate-proofed cross-border transmission network.

Setting the 20-20-20 goal and the according extension of renewable energy supply needs additional distribution grids, which should be ex ante climate-proofed. The EU thus has a clear mandate to ensure climate-proofed distribution grids.

Transmission/distribution must be regarded as important field to act for the EU due to the fact that necessary exchange of energy goes through the TEN-E/CEF network and must be secured. The development of a true European energy grid is inevitable for further increasing the share of renewable energy sources. The vulnerability of the transmission/distribution network must be regarded as significant (cf. DG ENER study by Rademaekers, at al, 2011). The interconnection of the grid might also lead to knock-on effects thus justifying action also at the (according to Martikainen, et al, 2010) more vulnerable distribution network. With Energy 2020, the EU supposed important action on e.g. smart grids development and electricity storage – both crucial initiatives to mainstream adaptation. With the TEN-E/CEF policies, the EU implicitly took over responsibility to develop the European energy transmission grids with the goal of having a coherent EU-wide network of energy and transport infrastructure that enables equal living conditions in the European regions.

For TEN-E/CEF this means a high COM responsibility for energy security – of course together with Member States and TSOs.

Investments into energy infrastructure are long-term investments and thus have to be robust towards a range of plausible climate futures. The EU with its many comprehensive research projects (on climate modelling: PRUDENCE[193], ENSEMBLES[194] and many more) and the access to leading experts is in 'pole position' to act, at the same time involving Member States and ENTSO. Robust investment decisions are especially important for transmission infrastructure since they are vulnerable mainly to extreme weather events/periods. Projections of extreme events still exhibit a wide range of uncertainty. Public-private partnerships between EU, Member States and TSOs are thus vital to make research results available to TSO companies.

Another necessity for the COM to act is the internal energy market: It can only function when transmission infrastructure is reliable and thus also climate-proofed.

3.9.1.5.2 EU responsibilities and justification to act on supply/generation

With the 20-20-20 goals and the national obligations to expand the share of renewable energy production within the existing national energy mixes, the vulnerability patterns of energy supply/production might change significantly in some countries.

Meanwhile a conversion in energy production takes place (cf. Figure 35) in many countries underpinned by the mitigation goals (in addition to the necessity to become independent from shrinking fossil fuel resources) that the EU and its Member States are committed to. There is a significant mainstreaming potential to adapt the energy system towards more climate resilience. The costs for adaptation might be significant, but will surely pay off once the new plants and transmission infrastructure are robust and resilient to the range of plausible climate scenarios. According to Reichl & Schmidthaler (2011), black-out costs for Vienna sum up to around 61 million EUR/1h, 122 million EUR/5h and 165 million/10h. These

[193] http://prudence.dmi.dk/
[194] http://www.ensembles-eu.org/

numbers might illustrate that avoided black-outs mean a strong benefit and costs for making energy supply more climate-resilient are smart investments.

Since energy supply is very much triggered by local, regional and national policies as well as accesses to resources or natural prerequisites for the exploitation of renewable energy sources, EU action for adaptation might be restricted to advises, exchange of good practice and – most important – advancement of new energy supply technologies, which is foreseen in the SET plan[195]. The SET plan itself does not mention adaptation as such, but implies a further diversification of energy supplies and thus gives leeway to mainstream adaptation.

3.9.1.5.3 EU responsibility and justification to act on energy demand/efficiency

Energy demand might rise explicitly in southern EU Member States, in which air conditioning and irrigation surplus demands will possibly outweigh energy savings for heating. This is threatening the general EU policy target to aim for equal living conditions throughout the EU as it exacerbates regional disparities.

Thus EU action on adaptation for demand management is vital. Especially the climate-induced demand patterns challenge the transmission grid especially in those countries with high electricity import dependence. Several EU policies on energy efficiency are crucial for adaptation purposes as well, since all measures to manage and reduce energy demand are important for sector adaptation as they reduce also seasonal peak demands, which often coincide with periods of lowered peak supply capacities.

In order to avoid the deepening of pre-existing economic disparities in the EU, the necessity to act is clearly addressed by:

- Transmission: Ensuring climate-proofed transmission and distribution explicitly into import dependant countries and during climate-triggered extreme situations
- Supply: Maintaining sufficient supply to meet new climate-triggered demand patterns and support countries with domestic leakages in supply
- Demand: Enforcing energy efficiency and sufficiency measures in all Member States to relieve transmission and supply by cutting off demand peaks during situations in which these are hard to meet (e.g. heat waves, droughts or during extreme events causing transmission interruptions)

3.9.1.6 Disaster Risk Reduction

The EU has various strong arguments to act for DRR in relation to adaptation:

[195] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0847:FIN:EN:PDF

- Experience has shown that when a major disaster strikes and national capacities are overwhelmed, a common European response is more effective than individual Member States acting alone. Conversely, disaster risk reduction can benefit from EU-level action;

- To address the increasing risks for 'domino effects' arising from destroyed stocks and disrupted flows respectively is a core objective and prerequisite for the EU's economic policy (cf. Europe 2020 strategy[196]);

- Avoiding regional economic downturns in European regions hit by disasters is clearly justifiable by the EU's cohesion policy;

- Playing a role in addressing the cross-border nature of disasters. In many areas adaptation and risk reduction procedures will affect multiple countries, as disasters are not contained to single country borders. Actions will need to be taken at both a local and national level, but where possible operations should be coordinated in a cost-effective way in order to mobilise actors at all levels across borders. Also, action done on the territory of a Member State can directly benefit a neighbouring Member State;

- Given the economic, demographic and social drivers and developments for DRR and adding climate change to it will lead to new disaster risk 'landscapes' and distribution of hot spots. If taking the (compared to climate change) rather static geophysical disaster hot spots, these are now amended by regions becoming climate change impact hot spots such as coastal areas with net SLR and high storm frequencies/amplitudes, regions being prone to droughts and forest fires, catchments prone to river floods, valleys prone to mass movements, etc. steered by changing climate parameters.

3.9.2 Environmental and human systems

3.9.2.1 Soil

Soil is part of the EU environmental policy as set out under Article 175(1) of the EC Treaty. The European Commission favours a flexible Soil Framework Directive, setting common principles and objectives at Community level, leaving the identification of the areas and sites at risk, definition of targets and design of appropriate measures to Member States and regions. This should be complemented by fostering an improved knowledge base, and better awareness of soil issues as well as greater coordination between the various EU and national policies which impact on the soil (improved integration) (EC, 2006l). The framework

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[196] http://ec.europa.eu/europe2020/index_en.htm

would consist of a risk analyses by the Member States for erosion, organic matter, salinization, compaction and landslides. Climate change is increasing these risks. Member States need to adopt risk reduction targets and programs of measures to reach those targets.

Soils are an essential natural resource. Nearly all food, fuel and fibre used by humans are produced on soil. Soils are also essential for water and ecosystem health (Jones, et al, 2012). In many parts of Europe, soils are over-exploited, degraded and irreversibly lost due to human activities (Jones, et al, 2012). Soil degradation also takes place through climate change impacts. The Common Agricultural Policy can provide a basis for sustainable land use and management and therefore facilitate soil climate adaptation.

3.9.2.2 Biodiversity

Ecosystem-based approaches to climate change adaptation and mitigation, and the development of green infrastructure, provide multiple benefits at a comparatively low cost (cf. chapter 3.3.5). Therefore, these approaches should form an integral part of the overall adaptation and mitigation effort. However, care must also be taken to prevent, minimise and offset any potential damage to biodiversity arising from climate change adaptation and mitigation measures[197].

The use of ecosystem-based approaches to address climate change and biodiversity loss and ecosystem service degradation in an integrated manner and to develop strategies that achieve mutually supportive outcomes was advocated by the EU *Ad Hoc* Expert Working Group on Biodiversity and Climate Change in its discussion paper *Towards a Strategy on Climate Change, Ecosystem Services and Biodiversity* (2009)[198]. Ecosystem-based approaches provide an important route to sustainable action and represent a vital insurance policy against irreversible damage from climate change. The paper aims to demonstrate the interdependencies between climate, biodiversity and ecosystem services and how strategies that achieve mutually supportive outcomes can support society to successfully tackle both climate change and biodiversity loss. Based on this rationale, policy recommendations and actions for immediate implementation applicable at national, European and international level are suggested.

A subsequent DG ENV study *Assessment of the potential of ecosystem-based approaches to climate change adaptation and mitigation in Europe* (Naumann, et al, 2011) aimed to address current knowledge gaps regarding the uptake and implementation of ecosystem-based approaches and thereby gain a better understanding of their role and potential in climate change adaptation and mitigation in Europe. A database of 161 applicable projects, five in-depth case studies, targeted interviews with EC officials and a literature review served as the basis for this assessment. Using these sources, this study sought to illuminate the

[197] http://ec.europa.eu/environment/nature/climatechange/index_en.htm
[198] http://ec.europa.eu/environment/nature/pdf/discussion_paper_climate_change.pdf

success factors leading to and obstacles hindering the implementation of ecosystem-based approaches in climate change programmes at local, regional, national and transnational levels and provide appropriate recommendations for overcoming existing obstacles. Furthermore, evidence on the costs and benefits of ecosystem-based approaches was collected and compared to the costs and benefits of traditional engineered approaches for addressing climate change and its impacts.

A complementary study for the German Federal Agency for Nature Conservation BfN (Doswald & Osti, 2011) documented and analysed good practice examples of ecosystem-based approaches to climate change mitigation and adaptation in Europe and showed how they brought environmental, social and economic benefits. In the EU Outermost Regions and Overseas Countries and Territories, the BEST preparatory action[199] is financing a programme to promote the conservation and sustainable use of biodiversity and ecosystem services. Specific objectives include addressing the wider ecosystem challenge of climate change by maintaining healthy, resilient ecosystems and fostering green infrastructure and ecosystem-based approaches to climate change adaptation and mitigation to bring multiple benefits.

Climate change should be considered in the planning and management of protected areas in Europe. This will include securing the coherence and resilience of the Natura 2000 network. The size and quality of protected areas and habitat connectivity may have special significance for the survival of species that become endangered as climatic conditions change. Areas of suitable habitat are more likely to remain available as refuges for endangered species in protected areas that are larger in extent. As stated in the Habitats Directive (Article 10) (EC, 1992b), protected areas should also be connected to form coherent and resilient ecological networks that will allow plants and animals to adjust their distributions according to changing conditions. More attention should be given to the possible impacts of climate change when decisions are made about the locations of protected areas. It is also important to not only protect areas where threatened species occur today, but can also where they might be expected to occur in the future. Species that live in small isolated populations will only survive if there are sufficient patches of suitable habitat in close proximity to enable individuals to move between them – especially if conditions change and some habitat patches are lost. The need for integrated landscape-scale action is highly relevant here and is reflected in the EU's development of a strategy for green infrastructure across Europe (EC, 2010b).

Target 2 of the new EU biodiversity strategy (EC, 2011b; c), "By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15 % of degraded ecosystems", aims to reduce land fragmentation, restore degraded ecosystems, and maintain and enhance ecosystem services by incorporating green infrastructure into spatial planning. Investing in green infrastructure is essential to the

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[199] EC BEST decision: C(2011) 1258 final http://ec.europa.eu/environment/funding/pdf/wp_best.pdf

delivery of ecosystem-based approaches to climate change adaptation and mitigation within multi-functional landscapes. Action 6 of the EU Biodiversity Strategy foresaw that the Commission would: '*develop a Green Infrastructure Strategy by 2012 to promote the deployment of green infrastructure in the EU in urban and rural areas, including through incentives to encourage up-front investments in green infrastructure projects and the maintenance of ecosystem services, for example through better targeted use of EU funding streams and Public Private Partnership*s'. To assist in the preparation of the Green infrastructure Strategy, DG Environment has commissioned a series of studies[200].

The EU biodiversity strategy (EC, 2011b, c) highlights biodiversity loss, alongside climate change, as the most critical global environmental threats. Both are inextricably linked. While biodiversity can make a key contribution to climate change mitigation and adaptation, achieving the EU target to limit the increase in global temperature to a maximum of 2 ºC above pre-industrial levels, coupled with adequate adaptation measures to reduce the impacts of unavoidable effects of climate change, are also essential to avert biodiversity loss.

3.9.2.3 Health

The EU has a mandate to complement national action on health. This consists mainly of:

- protecting people from health threats (e.g. disasters) and disease (e.g. vectors);
- protecting animal and plant health[201] related to healthy food production and the well-being of European citizens;
- promoting healthy lifestyles; and
- helping national authorities in the EU cooperate on health issues.

The Stern review illustrated that 5-20% of annual global GDP would be lost by the end of this century through climate change if nothing is done, globally. The estimated EU annual welfare loss, without public adaptation and if the climate of the 2080s occurred today, would be in the range of 0.2% to 1% of GDP, depending on the climate scenarios. In economic terms, the annual GDP losses for the European economy in agriculture, river basins, tourism and coastal systems are estimated at € 20 billon with damages mainly in the Southern Europe, and Central Europe's northern regions (CEHAPIS, 2012, DRAFT).

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[200] http://ec.europa.eu/environment/nature/ecosystems/index_en.htm

[201] Please note that the main objective of EU plant health legislation is not to control pest, but to protect the safety of food derived from plants and to secure the health and quality status of crops. It therefore regulates the trade of plants and plant products within the EU as well as imports from the rest of the world in accordance with international plant health standards and obligations. It also sets rules for the sale and use of plant protection products, or pesticides and sets standards to monitor and control pesticide residues. It implements preventative measures to guard against the introduction and spread of organisms harmful to plants or plant products within the EU. It also ensures quality conditions for the sale of seeds and propagating material within the EU.

With the entry into force of the Lisbon Treaty, the EU has been empowered to support, coordinate or supplement the action of Member States (MS) in the area of the protection and improvement of human health (Article 6(a) TFEU[202]). The Treaty states that EU action must be directed towards improving public health, preventing physical and mental illness and diseases, and obviating sources of danger to physical and mental health, and monitoring, early warning of and combating serious cross-border threats to health (Article 168 TFEU).

When dealing with new challenges such as climate change, a cooperative approach is needed. Thus, it is a core part of the COM´s role in health to coordinate and response rapidly to health threats and to enhance the capacities to do so.

Health services play an important role in identifying impacts as well as raising awareness about and adapting to climate change (Altvater, et al, 2011a). The short- to medium-term impacts of climate change on health are mainly expected to be exacerbations of existing effects. In this case, it can be concluded that much of the expected increased burden could be avoided through scaling up existing cost-effective interventions (e.g. surveillance, early warning, disaster management) (Hutton, 2011) or prevented by introducing new instruments (e.g. heat health action plans in order to prevent, react upon and contain heat-related risks to health).

As stated in the Article 168 TFEU, action to **fight against** the major health scourges include monitoring, early warning of and combating of **cross-border health threats** and encourage the **improvement of MS health services in cross-border areas** (transboundary collaboration). The EU plays an important role in Generic Preparedness Planning, in response to cross-border threats.

Effects of climate change are one of the cross-border threats and the Commission needs to take initiatives to promote Member States coordination, especially to establish guidelines and indication, organise exchange of best practices and prepare the necessary elements for periodic monitoring and evaluation. Based on the principle of subsidiarity in public health, MS responsibilities for the definition of health policies are strongly respected.

The estimated economic costs to the EU for a more coordinate EU health security approach has been estimated in the recent impact assessment, to be around €1-2 million Euro per year, while limited additional costs would be occurring to countries. However, the expected costs of preventive interventions, under the responsibility of the health authorities, will vary by disease burden, and activity. Early detection and response to infectious disease outbreaks could substantially reduce the associated economic and human costs. ECDC is in the process of developing the European Environment and Epidemiology (E3) network for the monitoring of environmental and climatic precursors of disease outbreaks (Semenza & Menne, 2009). This system will help respond more rapidly to emerging threats. While a European – wide integration of different early warning systems, would have marginal costs,

[202] Treaty on the Functioning of the European Union

for the European Union, the implementation of measures in countries would require some additional financing to implement the plans (CEHAPIS, 2012, DRAFT).

From a macroeconomic point of view a healthier population means less sick days due to acute and chronic conditions, less dependence on others to earn income and lower coping costs. From Europe, a study by the European Observatory on Health Systems and Policies[203] shows that health significantly affects economic outcomes at individual and household levels.

The active involvement of non-EU countries in health intelligence will be very important to on the one hand be rapidly informed on new threats and on the other hand to apply joint methodology and tools for cross country comparison. **Non-EU countries** - especially neighbours with whom there is more movement of people and trade - will benefit from less infectious diseases and risk of epidemics originating from within the EU. Also, EU will be interested to follow some climate sensitive health burdens in neighbouring countries, and lend technical assistance or give resources to control those burdens to protect the EU itself. Strengthened interregional (Eastern Europe – European Union; Africa – European Union) cooperation in surveillance of certain climate sensitive infectious diseases (e.g. chikungunya fever, dengue fever, Rift Valley fever, Lyme disease, tick-borne encephalitis (TBE), Vibrio spp. (except V. cholera O1 and O139) and visceral leishmaniasis) is to be further explored (Lindgren, et al, 2012). Strengthened inter-sectorial cooperation on zoonosis is further required. In addition cross regional networks for vigilance of newly emerging diseases as well as potential new diseases need to be explored. The cooperation with WHO and other partners will be essential (CEHAPIS, 2012, DRAFT).

The new Community Animal Health Strategy focuses on preventing rather than reacting to animal diseases.

A new Animal Disease Information System (ADIS) is being developed to improve the gathering of epidemiological data. Stepping up animal disease surveillance and the establishment of further vaccine banks for certain animal diseases will enable risk managers to better respond to emerging disease situations.

The new Animal Health Law will offer sufficient flexibility to address influences of Climate Change on existing animal diseases covered by these rules or those of an emerging nature.

The current EU plant health regime – currently under review – focuses on quarantine to combat pests and diseases that can impact agriculture, forestry and the natural environment. A new plant health law will be developed so as to better address, among others, the consequences of climate change in the EU plant health legislation.

[203] http://ec.europa.eu/health/ph_overview/Documents/health_economy_en.pdf

3.9.2.4 Inland Water

As recently developed under the Commission Communication “blueprint to safeguard Europe’s waters” (EC, 2012m), the following actions are proposed which are also highly relevant to tackle climate change:

- Support to environmental flows through guidance and technical annexes to the WFD;
- Support to setting up water allocation mechanisms through guidance and technical annexes to the WFD and support water pricing and water trading;
- Support to drought management through recommendations or an amendment to the WFD or a new directive;
- Support natural water retention measures through guidance, a WFD amendment, through rules on CSF funds;
- Support water efficiency through performance ratings for buildings or water efficiency requirements;
- Reduce leakages by prioritizing CSF funds, through public-private partnership investments, by developing methods to determine the sustainable level of water leakage;
- Reducing the barriers to re-using wastewater in agriculture;
- Promoting metering by setting criteria for the use of CAP and CSF funds or through amending the WFD;
- Guidance on estimating environmental and resource costs of water services;
- Improve governance at EU level on water management through introducing peer review process for RBD authorities, introduce legally binding measures or introduce a strong mediation role for the EC.

3.9.2.5 Marine and coastal zones

At the moment, the EC is not considering to develop any actions to increase the resilience of coastal and marine areas. However, the legal proposal for a Directive of the EU Parliament and of the Council on establishing a framework for Maritime Spatial Planning and Integrated Coastal Zone Management requires considering climate change adaptation when achieving the Directives´ aim of securing sustainable economic growth of marine and coastal economies.

Knowledge gaps in relation to climate change adaptation for marine and costal issues are handled with in the overall strategy on knowledge gaps of DG CLIMA (under development) and when adopted under the Commission's Green Paper on Marine Knowledge 2020.

3.9.3 Social issues

The social disparities and inequalities leading to higher climate change vulnerability in Europe are not only present in especially vulnerable groups within countries, but are also evident between the EU Member States (EUROSTAT, 2010a) leading to the need of higher social cohesion in EU.

The European Commission and other relevant institutions are in the position to address these intra-EU social inequalities by promoting knowledge exchange, capacity building, upholding the quality and effectiveness of European social policies and stimulating research in the existing knowledge gaps in relation to climate-social interactions. EU-level action could be based, inter alia, on:

- Articles 2, 3, 21 of the Treaty on European Union (TEU),
- Article 157 of the Treaty on the Functioning of the European Union (TFEU),
- Title IV of Part II of the Charter of Fundamental Rights of the European Union.

3.9.4 Environmental Impact Assessment / Strategic Environment Assessment

Climate change poses a serious challenge to economic development. Therefore, it has been widely recognised that there is a need to integrate consideration of climate change and its impacts in development plans and projects. The project level is particularly critical for the consideration of climate change risks and for incorporating suitable adaptation measures. Infrastructure projects, which are a crucial vehicle for economic development, could be particularly sensitive owing to their long lifetimes during which many impacts of climate change may become progressively more and more significant. Vice-versa, a project may also affect the vulnerability of natural and human systems to climate change and could therefore lead to mal-adaptation (OECD, 2011).

Environmental Impact Assessment (EIA) is a procedural and systematic tool that is in principle well suited to incorporate considerations of climate change impacts and adaptation within existing modalities for project design, approval, and implementation. The International Association for Impact Assessment (IAIA) defines EIA as "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made" (IAIA, 1999). EIA can therefore ensure that future developments are themselves resilient and that their environmental impacts do not exacerbate climate change's effects on human or natural systems.

The EIA Directive (EC, 1985) requires that EIA shall identify, describe and assess the direct and indirect effects of a project on the … interaction between: human beings, fauna and flora, soil, water, air, climate, the landscape, material assets and cultural heritage (Article 3). Conversely, assessing the resilience of a proposed development to the impact of climate change is not clearly required (IEMA, 2009).

One of the main reasons to look at EIA as a tool to facilitate the successful "climate proofing" of projects or to avoid mal-adaptation to climate change, is that EIA is a well consolidated and publicly accepted process in the European Union and worldwide.

The key aspect for consideration in the context of EIA is to determine how and when climate change adaptation becomes triggered within an EIA process. Experience suggests that the earlier these considerations are made, the easier they can be incorporated into the project development process, and at the least financial cost (OECD, 2011).

Strategic environment assessment (SEA) can be an effective tool for climate change adaptation, by introducing climate change considerations into development planning. The Intergovernmental Panel on Climate Change (IPCC) concluded that consideration of climate change impacts at the planning stage is key to boosting adaptive capacity: "One way of increasing adaptive capacity is by introducing the consideration of climate change impacts in development planning, for example, by including adaptation measures in land use planning and infrastructure design" (IPCC, 2007a).

SEA provides a framework for assessing and managing a broad range of environmental risks which may contribute to the integration (or "mainstreaming") of climate change considerations into plans and programmes (PPs) that fall into the scope of the SEA Directive (EC, 2001c). The integration of climate change into strategic planning through the application of SEA should lead to better informed, evidence-based PPs that are more sustainable in the context of a changing climate, and more capable of delivering progress on human development (OECD-DAC ENVIRONET, 2008).

Indeed, SEA can help to ensure that plans and programmes take full account of climate issues within a clear, systematic process.

Climate change impacts due to increasing temperature and change in precipitation patterns will enhance in future. The EIA and SEA Directives do not yet explicitly accommodate these changes and thus, negative effects might be expected. Both EIA and SEA are well suited tools for the consideration of climate change issues that might improve the resilience of project, plans and programmes being assessed to natural climate variability and natural hazards.

3.9.4.1.1 Scope of EIA/SEA

A number of recent studies on the vulnerability of the EU and specific sectors and territories to the changing climate have shown that Europe's infrastructure needs to be more adapted to natural phenomena caused by the changing climate as over the potentially long lifespan of a project the parameters of design at inception may not be valid as the climate changes. This represents a shift in thinking from the traditional assessment of the impacts on the environment alone to one where the likely long-term risks are taken into account (Milieu, et al, 2011).

Environmental Impact Assessment (EIA) applies to certain project types, usually exceeding a determined threshold. These projects are inter alia refineries, power stations, nuclear plants, railway lines, airports, motorways, ports and waterways, waste disposal installations (cf. Annexes of COUNCIL DIRECTIVE of 27 June 1985 (EC, 1985) on the assessment of the effects of certain public and private projects on the environment). Climate change may affect all major developments subject to EIA.

For SEA, the context of a PP will determine whether or not climate change adaptation is a relevant consideration in the SEA process. For example, this will depend on how sensitive the affected sectors are to climate change. In some instances it will be clear that adaptation to climate change is highly relevant to a PP, as the associated development activities are inherently sensitive to climate variability and change (e.g. agriculture, water resources), while in other cases climate change may not necessarily pose any direct threat. Deciding on the context is subject to defining the scope of the assessment as a first step in the SEA process.

3.9.4.1.2 Climate change as cumulative issue under EIA/SEA

Climate change poses a cumulative issue under EIA/SEA. This applies in particular to the description of the affected environment, where it would be imperative to assess the extent to which climate change would or could change the "baseline" environment in terms of additional pressures in the future and, if necessary, evaluate how the proposed action could adapt to the impacts of climate change. It should also be cautioned that several climate change parameters might act together in a cumulative fashion.

3.9.4.1.3 Assumptions, risks and uncertainties in EIA/SEA

Due to uncertainties in climate change projections, in particular with regard to confidence in accuracy at the local or regional levels, and the limitation inherent in existing data, judgment-based tools may be useful when compiling climate change information. Rather than the conventional approach based on climate prediction, it will be necessary to focus on exploring how well projects/plans/programmes perform across wide ranges of assumptions and uncertainties to foster robust decision-making.

In response to changing climatic parameters, any measures applied need to be flexible and adaptive to cope with uncertainties about vulnerabilities and risk. An adaptive management approach applied to monitoring can serve as an important learning tool for climate change action, where response measures shall be continuously reviewed with evolving climate change knowledge.

3.9.4.1.4 Policy context – current requirements to consider climate change in EIA/SEA

EIA was first introduced in 1985 in the EU and is now well-established as an important environmental decision-making tool. It is widely used to determine the criteria and thresholds by which a project should be implemented and operated. This is done, for example, through the introduction of conditions of approval, which become important benchmarks in terms of both controlling development and having reference points by which performance or assumptions can be tested and reviewed.

Certain characteristics of the EIA process mean it is particularly effective for the consideration of climate change. Not least, the requirements to engage and consult with key stakeholders as part of EIA process present an opportunity to consider a range of parameters which may not necessarily be included within the initial project design process.

The EIA Directive does not yet explicitly address the climatic pressures (e.g. increase of temperature) and impacts which can be expected in the future as potentially harming project types mentioned under the EIA Directive. However, a new “Practical Guidance for Integrating Climate Change and Biodiversity into Environmental Impact Assessment (EIA) Procedures” is under way, aiming at supporting EU Member States, its administration, public and private authorities and planning bodies.

Taking into account current shortcomings, the Commission adopted a proposal for a revised EIA Directive (EC, 2012k) on October 26th, 2012. As regards the quality and analysis of the EIA, is proposed to introduce amendments towards addressing new challenges, i.e. biodiversity, climate change, disaster risks and availability of natural resources throughout the whole EIA process. For climate change, especially the impacts of a project on greenhouse gas emissions as well as climate change impacts on a project and related adaptation measures shall be considered (EC, 2012l).

As evidence for and awareness of the risks associated with climate change and its impacts grows, plans and programmes subject to SEA often need to incorporate considerations of climate change. However, experience and empirical evidence on the inclusion of climate change adaptation considerations in PPs through SEA is not yet well developed. This is in part attributable to the fact that awareness of the need for adapting to climate change is relatively recent. Moreover, the primary focus of SEAs so far has been to evaluate the impact of a PP on the environment rather than the impact of environmental change on a PP. This is also applicable to EIA practice where mitigation issues are already recognised, but adaptation is still a new arena.

Existing policies comprise:

- COUNCIL DIRECTIVE of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment (85/337/EEC) (EC, 1985).
- DIRECTIVE 2001/42/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (EC, 2001c).

3.9.4.1.5 Which issues shall be addressed in EIA/SEA to add value for enhancing climate resilience?

Considering the long-term investments of many EIA projects - with a life-span-time up to 100 years (e.g. major transport routes, bridges, tunnels, urban transport, urban developments, power plants, treatment plants, refineries, airports, ports) – it is imperative to take climate change into account already today. The same applies to SEA assessing plans and programmes that constitute the basis for future development and investments (based on the planning cycle).

From an implementation perspective it seems appropriate as well as more efficient and effective to broaden the scope of existing EIA and SEA modalities to include climate change and adaptation considerations, as opposed to establishing and implementing parallel procedures for including climate change considerations.

EIA as a tool to facilitate successful “climate proofing”

- EIA is a well consolidated and publicly accepted process;
- Consequences of a changing climate have the potential to lead to significant environmental effects on all other EIA topics – e.g. human beings, fauna and flora, soil, water etc.;
- Consideration of climate change issues shall also aim to improve the resilience of the project being assessed, both to the anticipated negative impacts and positive opportunities of climate change.

SEA as a tool to facilitate successful “climate proofing”

- SEA provides an independent framework for assessing and managing a broad range of environmental risks, including climate change;
- SEA is capable of addressing adaptation and mitigation as complementary aspects of climate change risk management;

- The primary focus so far to evaluate the impact of a PP on the environment (mitigation) needs to be extended to an estimate of potential impacts of environmental change on a PP (adaptation), exploring climate change scenarios;
- The integration of climate change into strategic planning should lead to better informed, evidence-based PPs that are more sustainable in the context of a changing climate (Adaptive management approach).

3.9.5 Standards

Standards in the context of climate change adaptation are particularly important for the construction and infrastructure sector due to the following reasons:

- The impact of climate change is particularly pertinent to the construction industry given the life expectancy of buildings and long-term investments;
- There is a high innovation potential for optimizing building materials to provide structural stability and weather resistance for extreme events that are expected to increase with climate change;
- One of the most important type of instrument used to regulate construction are standards, which often include references to (directly or indirectly) weather/climate related pressures.

European standardisation supports important Community policies such as consumer welfare, environmental protection, trade and the single market. The European Union has, since the mid-1980s, made an increasing use of standards in support of its policies and legislation. European Standards are developed in one of the three European Standards Organisations. The EN EUROCODES[204] have been developed by CEN/TC250, following a mandate of the Commission. They are stepwise incorporated into the national norms of EU-27 (with certain transitional periods) and by this becoming legally binding.

They provide a common approach for the design of buildings and other civil engineering works and construction products. They aim at eliminating the disparities that hinder free circulation within the Community, are meant to lead to more uniform levels of safety in construction in Europe, and are designed to become the reference design codes replacing national codes. They cover earthquake resistance, but not yet climate proofing.

[204] Eurocodes are a set of unified international codes of practice for designing buildings and civil engeneering structures, which will eventually replace national codes. Cf. Commission Recommendation 2003/887/EC (EC, 2003b).

EU requirements for incorporating future climate criteria in the procurement of new facilities (e.g. through the integration in EUROCODES) would increase resilience and allow for a uniform approach (currently only earthquakes are treated in EUROCODE 8).

3.9.6 EU grant schemes

EU programmes which are most likely to provide extended sources of funding for adaptation actions include:

- The Common Agricultural Policy (see also chapter 3.5.1.1), mainly the *European Agricultural Fund for Rural Development* (EAFRD) which is also called Pillar 2.
- The *Cohesion fund*, are designed to reduce disparities in the development of regions, and to promote economic and social cohesion within the European Union. They are intended to be used to support projects which will directly address locally identified needs (e.g. to help train people with new skills, or help set-up new businesses).
- *European Regional Development Fund*: The European Regional Development Fund (ERDF) aims to strengthen economic, social and territorial cohesion in the European Union by correcting imbalances between regions. The ERDF supports regional and local development to contribute to all thematic objectives, by setting out detailed priorities.

  The Cohesion and Regional Development Fund both propose to allow to support:

  - The development of strategies for adaptation to climate change at national, regional and local level and for building up a knowledge base and data observation capacities;
  - Investments aimed at increasing adaptation to climate change including avoiding damage to the built environment and other infrastructure, protecting human health; decreasing future pressure on water resources, investing in flood and coastal defences; and decreasing the vulnerability of ecosystems to enable ecosystem-based adaptation and making agriculture less vulnerable;
  - Investments and the development of tools to facilitate disaster prevention and management policy for natural risks including weather related (such as storms, extreme temperature events, forest fires, droughts, floods) and geophysical risks (such as avalanches, landslides, earthquakes, volcanoes) as well as supporting societal responses to industrial risks (e.g. early warning systems, risk mapping).

- European Social Fund (ESF) is the main financial instrument for investing in people. It aims increase the employment opportunities of European citizens, to promote better education, and improve the situation of the most vulnerable people at risk of poverty. According to the proposal the ESF should contribute to other thematic objectives such as supporting the shift towards a lowcarbon, climate-resilient and resource-efficient economy; enhancing the use of information and communication technologies; strengthening research, technological development and innovation; and enhancing the competitiveness of small and medium-sized enterprises (SMEs).

- European Maritime and Fisheries Fund (EMFF): The current proposal for the Regulation on European Maritime and Fisheries Fund aims at achieving the objectives of the reformed CFP (Common Fisheries Policy) and of IMP (Integrated Maritime Policy). It is based on these objectives, redefined in terms of funding:

  - promotion of sustainable and competitive fisheries and aquaculture;
  - fostering the development and implementation of the Union's Integrated Maritime Policy, in a complementary manner to cohesion policy and to CFP;
  - promotion of balanced and inclusive territorial development of fisheries areas (including aquaculture and inland fishing);
  - contribution to the implementation of the CFP.

- *Competitiveness and Innovation Framework Programme (CIP)*. With small and medium-sized enterprises (SMEs) as its main target group, the Competitiveness and Innovation Framework Programme (CIP) supports innovation activities (including eco-innovation), provides better access to finance and delivers business support services in the regions.

- *The HORIZON 2020* which is the financial instrument with the aim to implement the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness. Running from 2014 to 2020 with an €80 billion budget, the EU's new programme for research and innovation is part of the drive to create new growth and jobs in Europe. The aim is achieve 35% of climate- related expenditure[205].

- *LIFE:* The future LIFE instrument is designed to target specifically environmental and climate mitigation / adaptation measures. The proposed budget for the new phase 2014-2020 is €3.2bn. The fund will have environment and climate change sub-programmes. The objective of the climate change sub-programme will be to 'contribute to the implementation, updating and development of EU climate policy and

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[205] http://ec.europa.eu/dgs/jrc/downloads/events/20120306-copenhagen/andrea-tilche.pdf

legislation, including the integration of climate concerns into other relevant policies, thereby contributing to achieving the EU's specific climate objectives'.

Under the new LIFE (2014-2020), sub-programmes will change and be split between Environment and Climate Action. LIFE covers both the operational expenditure of DG Environment and the co-financing of projects. Five main categories of activities are proposed for co-financing under this instrument:

- Knowledge sharing - building capacity through sharing good or best practice solutions;
- Collaborative action - building capacity through working together;
- Pilot projects to test and demonstrate solutions - policy, technology, technical and financial;
- Studies to support policy development and implementation; and
- Communication and awareness-raising.

LIFE provides financial support through action grants with most projects funded at the rate of around 50%. It also includes operating grants for NGOs that are 'primarily active in protecting and enhancing the environment at European level and involved in the development and implementation of Community policy and legislation'. For these organisations, the EU Budget contribution varies from 15% to 70%.

3.9.6.1 Barriers to effectiveness of EU funding on climate change adaptation and ways to overcome them

A number of barriers have been identified to the effective preparation of climate change projects and the uptake of existing funds. These may be institutional (i.e. linked to administrative capacity), informational (i.e. lack of information, knowledge and skills to make use of available climate change funds), or linked to excessive transaction costs and bureaucratic procedures, problems of cultural and economic transition, problem of monitoring implementation, etc.

- Absence of a European strategy for disaster prevention. It would be necessary to define and implement a common framework, including various steps and necessary aspects such as applied research, education and training, integration of prevention of most development and public management projects, governance improvement at all levels regarding prevention, dissemination of information, technical codes development, vulnerability reduction programmes, legal and financial tools for relocation of industries and inhabitants for risk mitigation, monitoring and control, efficacy and efficiency indicators and specific equipment to enhance protection (such as individual systems in floodable areas…) and emergency response (focusing for example on interoperability between institutions involved in emergency and risk management).

- A general lack of knowledge on MS and regional/local level of possible support for disaster prevention through existing EC financial instruments.
- Assessment of environmental, human, social, economic, financial and fiscal consequences of disasters is still at early stage in terms of methodology, whereas it is needed to monitor and justify investment in prevention projects.

Table 40 outlines potential responses to the above mentioned barriers for funding adaptation actions.

Table 40: Barriers and potential responses to funding of adaptation options

Barrier	Response
Absence of a European strategy for disaster prevention.	Guidance could be developed on how to find the right balance between risk prevention, transfer and toleration.
A general lack of knowledge	Improve knowledge and awareness through focused support to interpret and utilise available data.
Lack of experience in risk and cost assessments	Guidance and good practice guides developed and disseminated appropriately.

4 MAIN ARGUMENTS STRESSING THE NEED OF A EUROPEAN ADAPTATION STRATEGY

Planning for adaptation requires a strategic approach to ensure timely, efficient and effective adaptation actions, coherency across different sectors and levels of governance (EC, 2009a). Hence, gathering knowledge and outcomes from ongoing or previous studies and making them transferable and applicable to all policy levels is a basic prerequisite. In addition, adaptation needs to be integrated at all levels of decision making from EU down to the local level. As set out in the White Paper on adapting to climate change (EC, 2009a) the EU has a strong role in supporting measures to be taken by the public and private sector at national, regional or local level by providing clear advice and a coherent framework for adaptation action. This particularly applies to transboundary issues and certain sectors that are closely integrated at EU level through the single market and common policies. Coordinated EU action shall also ensure a common understanding of “good adaptation” (i.e. when objectives of adaptation are reached without negative impacts for others (Adger, et al, 2005) by providing guidance and facilitating experience and knowledge exchange. While conventionally adaptation has been focusing on the public policy area, the huge potential of innovative power, economic efficiency and the sectoral expertise of markets and entrepreneurs need to be captured as well.

Thus, a comprehensive EU Adaptation Strategy will be developed with the general aim to enhance the preparedness and capacity to respond to the impacts of climatic change of the EU, its Member States and regions, down to the local level. The EU Adaptation Strategy is planned to be adopted in spring 2013.

The following issues aim to highlight areas where EU action is needed, addressing shortcomings and possible value added through a comprehensive EU Adaptation Strategy:

- Generation and dissemination of information relevant for all countries across the European Union;
- Systematically identifying and closing knowledge gaps that limit adaptation decision making;
- Further strengthening and institutionalising mainstreaming of adaptation into EU policies;
- Exploring and capturing the potential of the private sector for adaptation;
- Climate-proofing of infrastructure;
- Supporting Member States in the case of cross-border and transnational issues;

- Decreasing existing barriers that might hinder Member states to act on adaptation;
- Fostering exchange of good practice between Member States and with the EC.

4.1 Generation and dissemination of information relevant for all countries across the European Union

In order to use synergies and decrease the costs, comprehensive and most recent information on climate change impacts and adaptation with relevance for many European countries (e.g. European wide vulnerability assessment, compilation of adaptation options) need to be generated, provided and disseminated centrally. This can be done by the EC as a rich knowledge base is available and will continuously be expanded through various projects financed by the European Commission (e.g. within the Framework programmes and the new HORIZON 2020, service contracts of different DGs).

Climate-ADAPT already provides a vast amount of information from various sources, including observed and expected climate change in Europe, vulnerability of regions and sectors at present and in the future, information on national and transnational adaptation strategies, case examples of adaptation and potential future adaptation options, tools that support adaptation planning, an overview of relevant EU policy processes. However there are still major gaps for certain issues that need further research, in particular for damage and adaptation cost across all relevant sectors/policy areas as well as for monitoring and evaluation.

To guarantee European wide comparison, EC support is needed in harmonisation of certain methodologies (e.g. in estimates of damage costs, but also of adaptation costs and costs of inaction; monitoring and evaluation methodologies). The EC/JRC PESETA project (Projection of Economic impacts of climate change in Sectors of the European Union based on boTtom-up Analysis[206]) and the follow-up PESETA II is to make a multi-sectoral assessment of the impacts of climate change in Europe for the 2011-2040 and 2071-2100 time horizons with the use of common socioeconomic and climate scenarios. In addition, European wide data sets are of specific importance in case of transboundary issues (e.g. water run-off, monitoring on vector-borne diseases).

Further work is also needed to enhance the use of Climate-ADAPT, provide trainings for the various tools and develop innovative approaches for engaging platform users to upload relevant information. Dissemination activities linking to various related events/conferences/meetings shall further raise awareness for the platform and encourage the use of information.

[206] http://peseta.jrc.ec.europa.eu/

4.2 Systematically identifying and closing knowledge gaps that limit adaptation decision making

Knowledge gaps clearly limit decision making as they increase uncertainty. Therefore it is important to close these knowledge gaps in the coming years. However, as resources at national level are limited, a cooperative approach led by the EC can provide support.

In order to identify the most promising approach for closing each of the identified knowledge gaps and do so in a coordinated manner and make best use of available EU funding for research, a comprehensive classification and ranking of research needs is recommended. Possible "entry points" of climate change adaptation research management and funding on EU level are: HORIZON 2020, European innovation partnerships, European Research Area Networks (ERA-Nets) like CIRCLE-2, the Joint programing initiative, European Innovation partnerships, Climate-KIC, EEA Financial Mechanism and Norwegian Financial Mechanism, service contracts of specific line DGs, LIFE+ programme, INTERREG programmes, JRC and EEA research.

A number of knowledge gaps that might still serve as barriers to adaptation activities are, inter alia: Information on damage and adaptation costs, models and tools to assess the effectiveness of adaptation measures, approaches for monitoring and evaluation, technology development (e.g. heat-resistant materials for infrastructure), socio-economic effects that interact with climate change impacts, detection and communication salutation with ICT technology (e.g. damage prevention through early warning), social implications.

4.3 Fostering exchange of good practice between Member States and with the EC

Sharing good adaptation practice among Member States and with the EC supports knowledge transfer and allows learning from each other. Good practice examples show different approaches for responses to climate change impacts for various situations. They highlight courses of adaptation actions that are expected to be most efficient and effective by taking into account relevant factors of successful adaptation. Sharing existing information on good adaptation practices and experiences also aims to optimise individual resource and effort management and can thus advance adaptation on a larger scale. Besides, good practice examples help to raise awareness for the most relevant aspects in adaptation planning and play an important role in motivating decision makers, adaptation planners and further stakeholders.

To make existing examples of adaptation available to stakeholders and the general public, the European Commission with its Climate-ADAPT can act as a platform for knowledge exchange. Climate-ADAPT already experienced a very high web use/traffic during and immediately after the launch on 23 March 2012, which was high compared to launches of other EEA products. The use was reduced to more normal levels some days after the launch which is common for EEA (and other) websites.

Although the existing Climate-ADAPT platform provides already a rich source of information, additional elements are needed. For example, an update of the adaptation support tool is needed in order to provide target-specific support for Member States when preparing, implementing and monitoring/evaluating their adaptation policies. In addition, the collection of good practice examples should continuously be extended as more and more cases will become available. Furthermore, dissemination and training activities for the practical use and application of the information and tools provided are needed.

4.4 Further strengthening and institutionalising mainstreaming of adaptation into EU policies

Climate policy 'mainstreaming', 'proofing' and 'integration' are increasingly important in EU policy making, reflecting the view that adaptation to climate change cuts across various policy areas/sectors that are affected by climate change. Thus, to allow synergies and decrease the costs of adaptation, EU instruments in place with relevance for adaptation should be reviewed and modified to cope with current and future impacts of climate.

The EC has recognized the need to foster mainstreaming into all EU sectoral policies, such as those on water, land use, health, infrastructure, disaster risk reduction, agriculture, etc. The aim is to integrate climate change considerations into relevant EU policies that are suited to help increasing societal and ecosystem resilience from the European to the sub-national level. Overall, the EU 'Strategy for smart, sustainable and inclusive growth' ('Europe 2020'), through its 5 headline targets and 7 flagship initiatives, also highlights the importance of mainstreaming and notes in particular that 'We must strengthen our economies' resilience to climate risks, and our capacity for disaster prevention and response'.

Mainstreaming activities at EU policy level have already been started through implementing the EC 2009 Adaptation White Paper. Climate-ADAPT provides an up-to-date overview and state-of-play of initiatives and main policy developments to integrate adaptation into EU sector policies[207] (cf chapter 6.4.1).

One major achievement for future mainstreaming is laid down in the next Multi-annual Financial Framework (MFF). The Commission has committed that climate related expenditures will represent at least 20% of the overall EU budget and will be tracked according to a specific methodology.

Looking at the EU sectoral level, mainstreaming has been initiated already in the area of agriculture (through mainstreaming efforts in the CAP reform), water (in particular with the

[207] http://climate-adapt.eea.europa.eu/web/guest/eu-sector-policy/general

WFD and the forthcoming 'Blueprint to safeguard Europe's Waters' (EC, 2012m)), biodiversity, disaster risk reduction and health. More efforts for mainstreaming climate change with regard to enhancing climate resilience deem to be needed for European transport and energy infrastructure, forestry and soil, jobs and employment and collaboration with the private market. In addition, ways for mainstreaming are also needed in areas where EU competence might not be obvious (e.g. for social issues).

To support a systematic approach for mainstreaming at EU level, an inventory of key EU policies relevant for climate change adaptation has been conducted. This overview is meant to identify the current status of climate change considerations in key EU policies and highlights needs for further integration, taking into account the respective policy review cycles.

Beyond increasing the sectoral coverage of "climate-proofed" EU policies, meaningful integration of climate change consideration also calls for clear guidance for both anticipated climate change impacts relevant to be considered in the respective policy area (based on scientific evidence) and appropriate policy responses. For new policy proposals and revisions of EU policies the EC has a wide-ranging impact assessment system in place that shall address all significant economic, social and environmental impacts of possible new initiatives. The EU impact assessment procedure seems to be best suited to introduce new guidance for assessing the implication of future climate change and suitable policy responses.

Mainstreaming adaptation into EU policies also affects the national and sub-national level: Provisions foreseen in EU policies for adaptation will need to be integrated in national (and potentially sub-national) legislation, which assures that adaptation will be considered and transposed into concrete actions.

Furthermore, national adaptation policies in place do not necessarily guarantee that responsibility to implement adaptation action is taken up by all relevant stakeholders of affected sectors. Thus, mainstreaming at EU level might foster adaptation at Member States level in sectors/policy areas that are not active yet on the national level as EU effort on adaptation will help to raise awareness for the need of adaptation among different stakeholders.

4.5 Exploring and capturing the potential of the private sector for adaptation

The private sector is important to adaptation within Europe because it is responsible for a large proportion of decisions and investments that determine the resilience or vulnerability of the economy, environment and society to climate change. The private sector has the potential to play a major role in adaptation to climate change as a consumer of adaptation solutions, a provider of financial resources, and a source of innovative products, services (such as insurance services, technical assistance, etc.) and solutions to manage and mitigate risks more effectively.

While traditional responses to climate change have been centred on risk management, the private sector shows a growing interest in new commercial opportunities, e.g. new shipping possibilities due to reduced sea ice or increased agricultural production in areas that were previously not economically viable. There is also increasing awareness about arising adaptation market opportunities for products and services that would help people to adapt, including e.g. water management technologies, healthcare, agricultural products, heat-resistant materials, building designs. Additionally, businesses can steer consumer behaviour through developing and propagating new products suited to future climatic conditions (such as cleaning products that require less water).

Nevertheless, there are a number of barriers that prevent the private sector from taking appropriate adaptation actions and future-proofing their business. Main barriers can be grouped in (1) information problems, (2) policy and regulatory failures, (3) cost of investment and (4) externalities; all of which enhanced collaboration between the public and the private sector could assist to overcome them. The following table briefly describes main barriers and corresponding suggestions for EU support.

Table 41: Main barriers for the private sector with regard to adaptation actions and corresponding suggestions for EU support

Barrier	Brief description	Potential EU support
Information problems	The lack of accurate and reliable information often hinders the uptake of adaptation investment because of a lack of awareness of climate-change related risks in the first place and even when awareness exists, the inability to model the risks and their impacts satisfactorily in order to inform investment decisions. Thus, an important role for the public sector is providing and dissemination information that end users can access, understand and use for their specific purpose. Vice versa, the public sector should also seek to learn from the private sector, particularly in relation to risk management and changing behaviour.	Climate-ADAPT as a rich source of information on climate change adaptation could become an entry point also for businesses to find and share relevant information for the private sector.

Barrier	Brief description	Potential EU support
Policy and regulatory failures	Regulation can explicitly compel companies to take adaptation into account. This is out of all EU Member States currently only in place in the UK with its Climate Change Bill. However, while regulation can promote adaptation, inconsistencies in regulation or uncertainty about the future regulatory environment can be a barrier to implementing adaptation action. Further, existing policies may even conflict with adaptation objectives. Consistency and predictability of regulation is therefore important if it is to be effective in encouraging adaptation.	The EU has a strong role in providing a coherent framework of policies and regulations. These need to balance requirements for climate change adaptation with the private sector´s technical limitations and financial concerns and avoid creating harmful incentives and subsidies which could potentially limit adaptation. This is mainly to be done under future mainstreaming efforts, paying particular attention to potential market and regulatory failures and establishing regulatory regimes that allow the private market to effectively plan for the future. A DG CLIMA study on applying economic instruments for adaptation to climate change was finalised in 2011 analysing the potential of risk management and market based instruments as well as public private partnerships from two perspectives: Promoting adaptation to climate change and sharing (transferring) the risks of climate change. Results of this study can inform further exploration of potential regulatory approaches.
Cost of investment	Companies' ability to finance adaptation can significantly affect their engagement – companies often state that a main reason for not implementing risk management actions is the high costs of the adaptation options they have considered. Many of the businesses that do implement adaptation actions are those companies that have been publicly subsidised or that have found it easier to pass on the costs to consumers. The costs of adaptation for businesses relate both to resources needed to assess its exposure to risks and to the financial investment needed to address them.	Enabling and encouraging private investments in resilience is a core imperative for the public sector in terms of sharing responsibilities. Engaging with the private sector at EU level is crucial to pave the ground for mutually acceptable "benefit-risk balances" with regard to a fair return for the risks both the public and private sector face. This is especially important for sectors of economic significance and which are particularly vulnerable to climate change impacts. More interaction is also needed with businesses on project and product development by e.g. incentivising adaptation, providing resources and guidance for climate resilient decision-making. Further, the EU can help in particular SMEs to adapt by providing advice on financing their adaptation efforts.

Barrier	Brief description	Potential EU support
Externalities	Some adaptive responses not only provide private benefits to those who have paid for them, they also provide benefits – or positive spill overs - to the wider economy. In such circumstances, the private sector is unlikely to invest in adaptation up to the socially desirable level because they are unable to capture the full benefits of the investment. Thus, the market will not always lead to efficient levels of joint adaptation, i.e. in the case of adaptation measures, which are public goods or at least have strong positive externalities (e.g. restoration of the environment, reduction of emissions, reduced water use).	Further work needs to be done to identify areas of potential significant market failures due to externalities. If appropriate, EU intervention is needed when clearly identifying market failures and the costs of the intervention are lower than the anticipated welfare loss.

4.6 Climate-proofing of infrastructure

Climate change impacts will enhance the pressure on infrastructure in the future, also in economic terms. In particular, the projected increase in frequency and intensity of weather and climate extremes, such as heavy rain (e.g. causing floods), heavy snowfall, extreme heat and cold, drought and reduced visibility can enhance negative impacts on infrastructure, causing injuries and damages as well as economic losses. Addressing climatic changes early on is of particular importance considering the long-term investments - with a life-span-time up to 100 years.

While infrastructure sectors are often strongly regulated and thus policies governing these sectors play an important role, the majority of existing EU infrastructure regulations do not explicitly address the climatic pressures and impacts which can be expected in the future. One of the most important type of instrument used to regulate infrastructure sectors are standards at EU level, which often include references to (directly or indirectly) weather/climate related pressures.

The next Multi-annual Financial Framework (MFF) with climate related expenditures of at least 20% of the overall EU budget foresees also a focus on infrastructure. The EC is currently working on a comprehensive energy infrastructure package. Elements such as increasing resilience of energy transmission infrastructure to cope with extreme weather condition, positioning of over-head power lines, impacts of climate change on Liquefied Natural Gas (LNG) infrastructure will be examined in the TEN-E revision process. For transport infrastructure the EC has been announced a proposal for the revision of the TEN-T guidelines that includes the requirement for assessing climate resilience. In addition, the Commission proposal for a revised EIA Directive (EC, 2012k) integrates provisions to consider climate change (both mitigation and adaptation).

The White Paper 2009 already noted that the EU has an important role in promoting good practice, via support for infrastructure development and also in developing standards for construction. Improving the resilience of existing transport infrastructure and energy networks requires a common and coordinated approach for assessing the vulnerability of infrastructure to extreme weather events. Among other suggestions for mainstreaming, it has been noted that the feasibility of incorporating sustainability criteria (including taking into account climate change) into harmonised standards for construction shall be investigated, with for example a possible widening or extension of the existing Eurocodes. Work towards a systematical review of relevant standards in order to enhance the climate resilience of the corresponding infrastructures and the livelihoods and economic activities depending on them still needs to be taken up.

4.7 Supporting Member States in the case of cross-border and transnational issues

The direct and indirect impacts of climate change are largely of cross-border nature. In particular, continuous changes in climatic conditions lead to widespread climate impacts, e.g. changes in species composition, damage to ecosystems and their services as well as to infrastructure associated with socio-economic consequences for European society. Extreme events such as storms, droughts, forest fires or floods can also lead to large-scale damage of natural resources, infrastructure failures and an increased need for disaster operations in many parts of Europe.

Sectors/policy areas primarily affected by large-scale effects of climate change are water management (including marine), soil, biodiversity, agriculture, forestry, health, energy, transport, and disaster risk reduction. Also, several adaptation measures (e.g. monitoring, change in transport routes) require cross-border and/or transnational cooperation. Cross-border and transnational issues are also related to disaster and risk management, both in terms of early warning systems and civil protection and emergency aid.

Transboundary issues create interdependencies between countries (e.g. hydrological, social and economic ones in the case of water) and may contain a growing potential for conflicts (e.g. competition over dwindling water resources) when not taken into account properly (UNECE, 2009).

Cross-border activities addressing climate change and jointly developing adaptation responses are already taking place in European macro-regions such as in the Alpine Space, the Carpathians, North West and South East Europe, the Baltic sea and under the Danube strategy[208]. Another cross-border activity at regional level is the currently on-going

[208] More information to be found on Climate-ADAPT: http://climate-adapt.eea.europa.eu/web/guest/transnational-regions.

development of an adaptation strategy for the Pyrenees. All of these large-scale activities involving several countries receive funding from the EU.

Nevertheless, cross-border and/or transnational cooperation in developing national adaptation policies is currently almost non-existent with only one national adaptation strategy (NAS) addressing them and thus, experiences with climate change adaptation in the transboundary context are still very limited (cf. chapters 3.3 and 6.3). Therefore, they require coordination over different political, legal and institutional settings as well as over different information management approaches and financial arrangements.

As existing institutional settings at national level might be challenged by these complex and far-reaching transboundary issues, support from European level is required in order to allow good practice in adaptation.

4.8 Decreasing existing barriers that might hinder Member states to act on adaptation

Member States are faced with a number of barriers which might hinder successful adaptation policy making and the implementation of adaptation actions. At the stakeholder meetings to support the development of the EU Adaptation Strategy, participants mentioned that the lack of human and financial resources and the lack of political commitment/will as key barriers. Respondents to the public consultation (The "Consultation on the preparation of the EU Adaptation Strategy" was open from 21.05.2012 – 20.08.2012 on the website "Your Voice in Europe"; for a detailed analysis please cf. Background report to the IA, Part II) also felt that the EU should be more involved in funding adaptation projects. Increasing direct funding for research was viewed as a highly potential action by around ½ of the respondents.

Furthermore, stakeholders at all meetings raised the issue of uncertainty and reported that the lack of dedicated research hinders the adaptation process. This is also supported by the feedback to the public consultation, where training and awareness was well received as well as strengthening policy-making overall and the science-policy interface specifically. In addition, communicating relevant information to decision makers was named as a challenging task. This goes in line with the barrier to create a common understanding for adaptation (e.g. including distinction between mitigation and adaptation) among all affected stakeholders. Participants to the public consultation also viewed communication and awareness-raising as topics that should especially be addressed by the EU.

The European Adaptation Strategy can support Member States in overcoming certain barriers such as the lack of political will as the EC is taking a pioneering task within its responsibility. In addition, the EC aims to support Member States financially in developing adaptation policies, e.g. through LIFE+. However, guidance and assistance for Member States in need of financial support is required to provide equal access to funding from the EU. Through further improving the knowledge base, systematically closing knowledge gaps and thus reducing uncertainties for taking adaptation action, the EU has a strong role to provide Member States with comprehensive information that is relevant and up-to-date for practical use. This is mainly to be done via Climate-ADAPT by ensuring continuous update of most relevant information. Climate-ADAPT shall also further extend the presentation of good practice examples, which supports to facilitate learning from others how to address and overcome certain barriers that are similar in many countries. However, further improvements and potential extension of Climate-ADAPT need a clear mandate from the EU. Additionally, specific guidance for developing national adaptation policies, also addressing potential barriers and offering tools and suggestions to overcome them, is under development and aims to support a coherent approach across EU Member States which needs to be embedded in an EU wide framework for adaptation.

5 OBJECTIVES OF A EUROPEAN ADAPTATION STRATEGY

5.1 What are the general and more specific/operational objectives?

5.1.1 General objective of the EU strategy on adaptation to climate change

The general objective of the EU Adaptation Strategy is to most effectively contribute to a more climate resilient Europe. This means enhancing the preparedness and capacity to respond to the impacts of climate change of the EU, its Member States and regions, focusing in particular on transboundary issues and sectors that are closely integrated at EU level through common policies.

5.1.2 Specific objectives

To meet this general objective, and to address the problems listed above, three specific objectives have been identified:

1. **Better informed decision making**: the EU Adaptation Strategy should further the understanding of adaptation, improve and widen the knowledge base where knowledge gaps have been identified and enhance dissemination of adaptation-related information

2. **Increasing the resilience of the EU territory**: the EU Adaptation Strategy should promote adaptation action at sub-EU level, and support and facilitate exchange and coordination. In doing so, the Strategy should address cross-border climate impacts and adaptation measures.

3. **Increasing the resilience of key vulnerable sectors:** The EU Adaptation Strategy should develop initiatives for a consistent and comprehensive integration of climate change adaptation considerations into sectors that are closely integrated at EU level through common policies

5.1.3 Consistency with EU policies and horizontal objectives of the European Union

The Strategy supports the overarching EU objectives of a smart, sustainable and inclusive growth as stated in the Europe 2020 (EC, 2010d) – Europe's growth strategy. The strategy falls under the Resource-Efficient Europe flagship initiative.

Adaptation to climate change is a multi-sectoral and cross-cutting issue (cf. also chapter 3.1.6) and will affect key EU policies including: Cohesion policy, Common agricultural policy, policies related to disaster risk management, maritime policy and environmental policies.

This initiative is part of a broader climate change response strategy, which includes mitigation efforts and adaptation actions. Mitigation aims particularly at avoiding the serious impacts associated with continuing, longer-term changes in the climate system as well as limiting the risks of large-scale discontinuities in that system. Adaptation aims particularly at reducing unavoidable negative impacts already in the shorter term, reducing vulnerability to present climate variability, and exploiting opportunities provided by climate change.

6 SUGGESTED POLICY OPTIONS AND ANALYSIS OF POTENTIAL ECONOMIC, SOCIAL AND ENVIRONMENTAL IMPACTS

The following chapter has been largely prepared as a stand-alone document to provide input for the assessment of policy options proposed in the Impact Assessment (IA) accompanying the development of the EU Adaptation Strategy. In particular the problem descriptions are based on all information gathered and presented in the previous chapters. For the sake of completeness and in the interest of improved readability, all necessary descriptions have been left in this chapter, even though the essence of the problems is already presented elsewhere in the background report.

Climate change adaptation is a cross-cutting issue, which potentially requires action across all sectors, and at all levels of intervention, including at EU level. Based on the problem analysis presented in chapter 3 the following six main problems have been identified for which EU added-value can be expected. For each problem, specific policy options are considered and assessed. The following overview table presents the options described and assessed in the background report as well as options taken forward for the Impact Assessment (IA) by the EC, which are not included in this report.

Table 42: Overview of all policy options, differentiated between those described and assessed in the background report and others analysed by the EC

Problem	Described and assessed in the background report	Analysed by the COM
Problem 1: Research, data and knowledge generation	▪ Guidance document for developing and setting up interfaces between Climate-ADAPT and other databases ▪ Develop a knowledge gap strategy in collaboration with MS Developing a common climate vulnerability assessment in the EU	

Problem	Described and assessed in the background report	Analysed by the COM
Problem 2: Knowledge Dissemination	▪ Improve Climate-ADAPT beyond BAU by regular voluntary updates by Member States on adaptation activities, information on insurance and business and on national risk assessment ▪ Support exchange between science and policy in the field of adaptation ▪ Propose a legal action to set up national information platforms for adaptation and link them to Climate-ADAPT	
Problem 3: Strengthening adaptation efforts at all levels and enhance cooperation	▪ EU guidance for national adaptation policy processes ▪ Use LIFE+ funding for cooperation and experience exchange in relation to the development and implementation of National Adaptation Strategies and climate risk assessments ▪ Use LIFE+ funding for Lighthouse projects and pilot implementation of cross-sectoral policies	▪ Call for adoption of national adaptation strategies, accompanied by guidance for developing national adaptation strategies and include the possibility of mandatory requirements at a later stage ▪ Impose mandatory adoption of national adaptation strategies, and provide guidance for developing them ▪ Impose inclusion of transboundary considerations for national and/or regional/local adaptation strategies ▪ Legal act making mandatory the adoption of regional and local adaptation strategies
Problem 4: Mainstreaming CC adaptation considerations into EU polices	▪ Listing mainstreaming priority in EU legislation and policy initiatives by 2020 and engage with relevant stakeholders ▪ Set new calendar for revision of key EU legislation ▪ Institutionalise mainstreaming at EU level by providing for Commission internal IA procedure on how to consider climate change adaptation considerations for amendments and new EU policies	▪ Guidelines on how to climate proof investments and measures under CP and CAP ▪ EU to identify and promote sectoral coverage at national level in line with mainstreaming activities at EU level

Problem	Described and assessed in the background report	Analysed by the COM
Problem 5: Vulnerability of Infrastructure	▪ Mainstream climate change into EU wide standards ▪ Impose mandatory requirements in terms of resilience of current and future infrastructure	▪ Obligatory climate proofing and guidelines for EU funded major infrastructure projects ▪ Non-binding guidance for climate proofing for major infrastructure projects
Problem 6: Capture the potential of the market	▪ Engage with commercial banks ▪ Explore market based approaches ▪ Legislative actions asking all companies to undertake risk assessments along their supply chains	▪ Awareness raising campaign for SMEs on climate change adaptation

6.1 Problem 1: Research, data and knowledge generation

6.1.1 Problem definition

Currently information related to adaptation to climate change is unsystematically collected and processed at different governmental levels. Information is often patchy and several knowledge gaps exist. In general the level of effort in closing these knowledge gaps is depending on the importance of climate change in a Member State. Already the EU White Paper „Adapting to climate change: Towards a European framework for action" (EC, 2009a) identified this problem and highlighted the need to further advance methods, models, data sets and prediction tools. In addition, the European Environment Agency (EEA) reported in 2010 that further EU-funded and national research is needed to fill these (EEA, 2010i).

The results of the public consultation of the EU Adaptation Strategy confirm that 'uncertainty of the impacts and modelling tools' can be a barrier preventing the economy from becoming more climate resilient (56% of the 161 respondents consider it as more or highly significant, 90% consider it as significant to highly significant). Moreover, when asked about the three most pressing issues to be addressed by the EU for adaptation policies and measures to be effectively implemented, the promotion of research that improves data and scenario availability was mentioned several times as a priority.

To improve information sharing and management, the White Paper proposed to establish an online platform to maintain a wide range of information related to climate change adaptation covering European, national, regional and sectoral levels. The platform was supposed to link to other similar or related initiatives such as the Biodiversity Information System for Europe (BISE)[209], European Community Biodiversity Clearing House Mechanism, the Water Information System for Europe (WISE)[210] and the Global Monitoring for Environment and Security (GMES) (EEA, 2010i).

Major research efforts on climate change have been promoted and financed at the European level within the 7th Framework Program for Research (FP7)[211]. A number of projects funded under FP7 have and will contribute to the understanding of the climate system, the quantification of climate change impacts on human and natural systems (including extreme events), and to the identification and assessment of adaptation options including their costs. Further, in the context of the PESETA project (Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis[212]) the Commission developed a multi-sectoral assessment of the impacts of climate change in Europe for the 2011-2040 and 2071-2100 time horizons. In parallel, part-financed by the European Regional

[209] http://biodiversity.europa.eu/
[210] http://water.europa.eu/
[211] http://climate-adapt.eea.europa.eu/web/guest/research-projects
[212] http://peseta.jrc.ec.europa.eu/

Development Fund, the ESPON Climate[213] project has been carried out. The project developed a new comprehensive vulnerability assessment methodology and applied it to all regions across Europe on NUTS 3 level[214]. This had the aim to create the evidence base needed for a "climate change responsive European territorial development policy".

In addition several approaches at Member States level (e.g. UK, NL, DE) in modelling climate impacts exist, establishing their own projections (climate and socio-economic) and models over the last years that provide the basis for adaptation decision making at national level and possibly beyond. The EU has no mandate to push for a common approach (even if e.g. agreement has been reached in other areas[215]), but noted already in 2008 in its Staff Working Document "Integrated climate change research following the release of the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and most recent research developments" (EC, 2008j) that there is "*an increasing need for more accurate regional climate change information to improve the analysis of impacts and contribute to adaptation policy needs*". However, given varying approaches and different input data used, results from regional models are difficult to compare showing high variability in risks and vulnerabilities and thus do not provide for a solid basis for decision-making. This applies to all EU assessments carried out under several research activities as well as for the Member States level. Differing results lead to higher uncertainties for decision-making and might in particular constitute a barrier for cross-border cooperation.

However a comparison between the research gaps identified by the above mentioned 2008 Staff working Document (EC, 2008j) and the ones identified in the context of the service contract to support the development of the EU Adaptation Strategy (for details cf. Annex 8) clearly shows that while some progress have been made there are still several knowledge gaps in relation to climate modelling, impacts of climate change and the effectiveness of adaptation options. The assessment made clear that a majority of EU research projects have neither led to coherent, integrated and exhaustive results, nor were the necessary linkages among projects established. For example ClimateCost aimed to assess the economic costs of climate change (the costs of inaction) and the costs and benefits of adaptation. The results produced are still patchy and do not answer most of the policy questions. There is also a high uncertainty if these projects have provided input to the policy needs.

[213] http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/climate.html

[214] The NUTS classification (Nomenclature of territorial units for statistics) is a hierarchical system for dividing up the economic territory of the EU; NUTS 3 stands for small regions for specific diagnoses.

[215] Safeguarding the sustainability of public finances is a key policy objective in the EU. In order to achieve this objective, reliable and comparable information on possible challenges to fiscal sustainability is required, including the expected strains caused by the demographic changes ahead. In 2009, the ECOFIN Council gave a mandate to the Economic Policy Committee (EPC) to update and further deepen its common exercise of age-related expenditure projections by 2012, now reaching the fourth edition on the basis of a new population projection by Eurostat (EUROPOP2010), which was released in April 2011. The latest version of the work can be found at http://ec.europa.eu/economy_finance/publications/european_economy/2011/pdf/ee-2011-4_en.pdf.

Also only a few models and tools are available to evaluate adaptation measures quantitatively. For example one of the objectives of the project ClimWatAdapt was to quantify the impacts of certain adaptation measures. Out of 30 adaptation actions only 9 have been assessed quantitatively (Flörke, et al, 2011).

As mentioned already beside the above mentioned research framework programs, several further "entry points" for climate change adaptation research management and funding on EU level exist. Due to this broad variety of research activities there are several un-coordinated overlaps between the different research streams. Even though setting priorities for further research needs is a joint and coordinated effort by the EU and Member States, single projects funded by JPI or other various research funds do not necessarily co-operate, align approaches and seek to deliver complementary results. Some efforts have been initiated by the EC to enhance co-operation between FP7 projects, e.g. for MEDIATION and RESPONSES, both focussing on policy responses for adaptation. However, coordinated research appears to be limited, it is rather overlaps that occur by using varying methodologies and sometimes even producing partly contradictory results (e.g. the RESPONSES project completed an EU-wide impact and vulnerability assessment, very similar to the work undertaken by ESPON Climate, but again showing varying results and not clearly taking stock of already existing exercises with regard to impact and vulnerability assessments). In the public consultations opinions regarding 'more support of coordination' were largely split into two groups: 55% ranked this option as having 'more potential' or 'high potential', while 45% considered this option has having 'low, somewhat potential'.

In relation to data sets some progress has been made on the EU level. Data bases have been further developed or new ones have been set up (e.g. Climate-ADAPT, Water information system Europe (WISE), Community Research and Development Information Service (CORDIS)[216], OURCOAST[217], Global Monitoring for Environment and Security (GMES) services[218], etc.). (All of them are concurring in creating wide and reliable but non-harmonized and scattered data sets. This is because existing databases have been developed from different perspectives, for example by using their own ideas to determine what to register. Even in the (few) cases where common attributes have been used one will find that these have been implemented in different ways and that the content over databases is hardly comparable.

Climate-ADAPT currently does not interact with relevant data and information bases and linkages are dealt with on a case by case basis. The majority of data are not transformed according to the ISO standards or are not following the INSPIRE Directive (EC, 2007e) yet.

[216] http://cordis.europa.eu/

[217] Through OURCOAST, the European Commission aims to ensure that lessons learned from the coastal management experiences and practices will be shared and made accessible to those who are seeking sustainable solutions to their coastal management practices.

[218] In the public consultation increased support for pan-European Climate Services' as foreseen by GMES received the lowest ranking with the majority of respondents (31.7%) ranking it a '3'.

Therefore interoperability is not given[219] and only a small amount of datasets and services are ready to be accessed directly via Climate-ADAPT via e.g. the Map viewer (providing access to climate related observations and projections of climate change impacts, vulnerability and risks from the following projects and organisations: ClimWatAdapt, ESPON Climate, JRC-IES and ENSEMBLES). Another problem is that research projects mostly focus on reporting results, not on publishing datasets and maps in a standardized manner. Until now there is no requirement for e.g. FP projects to technically harmonize and standardize their data (e.g. following INSPIRE Directive (EC, 2007e), OGC data and metadata standards). Consequently a lot of valuable research data remain in documents and never become publishable e.g. through web services and are thus not further used.

There is also a lack of organised collection of data and information from the local and regional level. The public consultation clearly highlighted the need for national and more local level administrations should support and participate in research relating to adaptive capacity and adaptation options. This gap is not only referring to costs or physical data but also to a general lack of inventorying information that relates to experiences made when setting up an adaptation process. Some Member States set up national databases that aim to offer a platform to collect and disseminate relevant data and information, both for research and good practices. Climate-ADAPT provides links to these national portals, nevertheless there is a clear language barrier in accessing and sharing information as most portals are only available in the national language and not in English.

Even if the amount of data collected and created has been increased, a survey carried out in the context of the preparation of the impact assessment shows that data gaps still exist, especially when it comes to impacts and effectiveness of responses, impeding thus comprehensive assessments. On the other hand, even data on state and pressures which are streamlined for collection at EU level have significant gaps: For example data on water availability are mostly lacking, as well as data on environmental requirements associated with water stress conditions.

These existing gaps are also recognised in the proposal for the 7 Envrionmental action programm (7EAP)[220] has a specific priority objective which calls “to improve the evidence base for environment policy”. There it says: “*Advanced research to fill data and knowledge gaps and adequate modelling tools are needed to better understand complex issues related to environmental change, such as climate change and disaster impacts, the implications of species loss for ecosystem services, environmental thresholds and ecological tipping points.”*

[219] AEA (2009b): Preparations for the establishment of European Climate Change Impacts, Vulnerability and Adaptation Clearinghouse – Sharing of good practice in the EU- Final Report to the European Commission Reference: ENV.D.2/ETU/2008/0070r.

[220] http://ec.europa.eu/environment/newprg/pdf/7EAP_Proposal/en.pdf

6.1.2 No policy change

Under the no policy change scenario research on climate change adaptation would remain patchy and un-coordinated and the objectives set in the 7EAP will not be met[221]. The issue would be addressed in the different research activities carried out by various EU bodies and Member States, hence actions continue unchanged. The proposed HORIZON 2020 will remain the main source for research (proposed are around 80 billion Euros under the next MFF period) with a 35% dedicated budget to climate change (mitigation and adaptation). This amount of money represents a significant increase[222] of resources dedicated to climate change and has the potential to close several of the knowledge gaps mentioned above.

On the Member State level it is assumed that existing national platforms will be further maintained and improved. It is further assumed that only a few countries which have no platforms in place at the moment will set up such. Instead they will use Climate-ADAPT.

However it is difficult to predict how these rather general objectives of the Horizon 2020 will materialise in the call for proposals and who finally will take the decision which knowledge or data gaps should be closed first. Under the no policy change scenario, it is assumed that the different DG´s will have a significant role in the programing and priority setting, even if currently no explicit agreement exists on the interaction between Commission services. DG´s are supposed to be part of different steering boards and will be invited to participate in 'challenge boards' to provide thematic guidance. A current proposal by European Parliament Rapporteurs on HORIZON 2020 foresees “Sectoral Steering Boards” (Carvalho) and “Strategic Advisory Boards” (Madurell). However it remains unclear how this will organised in detail and in which boards the different DG´s will participate. The role of the Member States in this process remains unclear as well resulting from the fact that the overall coordination mechanism for programing is not yet defined[223].

In parallel JPI Climate[224] will follow its agenda having the aim to facilitate the coordination, collaboration and exploitation of synergies while working against fragmentation and duplication of efforts. However it remains unclear how this Member States driven process will

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[221] This can be assumed on the basis that also some actions outlined in the White Paper on Climate change have not been put into place or completed.

[222] Within the FP7 'Cooperation' Programme, the theme dealing with environment (including climate change) has a budget of 1.9 billion. Even if assuming that other themes will also contribute to climate change research the total amount is significant lower compared to what is proposed under HORIZON 2020.

[223] The current proposal states that “Detailed priority setting during implementation of HORIZON 2020 will entail a strategic approach to programming of research, using modes of governance aligning closely with policy development yet cutting across the boundaries of traditional sectoral policies. Priority setting will equally be based on a wide range of inputs and advice. It will include, where appropriate, groups of independent experts set up specifically to advise on the implementation of HORIZON 2020 or any of its specific objectives. These experts group shall show the appropriate level of expertise and knowledge in the covered areas and a variety of professional backgrounds, including industry and civil society involvement.”

[224] For details see http://www.jpi-climate.eu/_img/article/JPI-CLIMATE_Strategic_Research_Agenda-adopted_111109.pdf

link to HORIZON 2020 in practical terms[225] and therefore it is assumed that the cooperation will remain loose and be based on an ad hoc basis.

Even if there is quite some vagueness regarding the priority setting HORIZON 2020 is expected to improve the coordination of research activities compared to the current FP7. This is due to the fact that priority setting may also take into account the strategic research agendas of European Technology Platforms or inputs from the European Innovation Partnerships.

Having this in mind, the baseline scenario assumes that no systematic mechanism of mapping knowledge gaps, screening of on-going research and support activities and prioritising along policy needs will be developed on the European level, hence the lack in coordination will remain. Due to the significant amount of money to be provided by HORIZON 2020 it is expected that several current knowledge gaps will be addressed. However the impact assessment related to HORIZON 2020 describes these achievements only in a very general manner: "*improved provision of reliable climate projections; assessing impacts, vulnerabilities and developing innovative cost-effective adaptation measures*." These rather broad outcomes reflect the uncertainty of what can be achieved.

Climate-ADAPT currently does not specify how other databases should be linked to the platform. Only the idea of linking WISE and BISE is discussed, but no specifications have been developed so far. Links to the OURCOAST database are assumed to be established, but there is no clear format of this link so far. It is assumed that databases would be kept individually and no harmonisation and cross linking of data will be made with Climate-ADAPT. It is further expected that the number of such databases will grow over the next few years with wider implementation of the INSPIRE Directive and SEIS principles which might help resolving the problem. Nevertheless, existing technical problems of interoperability are expected to remain, as no efforts (e.g. guidance, mandatory provision of data according to common standards) to improve the situation are expected.

The work under INSPIRE is assumed to continue with defining the 34 spatial data themes needed for environmental applications further. In relation to climate change the current Annexes of the Directive partly address the issue (e.g. natural risk zones) but the issue of climate projections is not foreseen and thus not expected to be covered until 2020. This also applies to the production of more complex vulnerability maps.

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[225] The Position Paper JPI Climate and HORIZON 2020 (available under http://www.jpi-climate.eu/_img/article/JPI_Climate_and_Horizon_2020_PositionpaperV21112011.pdf) does not specify any concrete coordination mechanism.

6.1.3 Policy options addressing problem 1

6.1.3.1 Guidance document for developing and setting up interfaces between Climate-ADAPT and other databases

Description of the option

This option has the main objective to increase the interoperability between Climate-ADAPT and other databases. The aim is to ensure a high level of combination of datasets and information sources and to allow services to interact without repetitive manual interventions in such a way that the results are coherent and the added values of datasets and services is enhanced. Such a service-oriented architecture should be seen in a way of sharing functions in a flexible and cost-efficient way without merging existing systems. Data storage and data flow could still be strictly separated.

Under this policy option key databases worth linking to would be identified. In a second step the database owners/decision-makers and staff would meet to explore the options of linking to Climate-ADAPT (including limitations of the software compatibility, responsibilities, defining metadata attributes, setting up service agreements). Based on this a guidance document would be developed.

The guidance would also establish a link to GMES Climate services which should describe the current and historical status of the Earth environment from national to global scales along a set of impact indicators.

This detailed guidance document would highlight the higher level user requirements and system definition necessary for linking existing or new databases to Climate-ADAPT. It will also include certain data quality standards and a process for quality assurance. The guidance is assumed to be made freely available under Climate-ADAPT.

Assessment of the option

The one-time, fixed cost to develop this guidance document are estimated to range between 50.000 and 100.000 euros for writing the guidance and about 20 man days for one to two expert meetings[226]. The wider economic benefits of this option is clearly depending on the extent to which the guidance will be applied and therefore a quantification in monetary terms is currently not possible. At this stage only the types of benefits can be listed, namely:

- Avoided operating costs for data integration into Climate-ADAPT at a later stage on an individual database level. This covers the development of an integration approach but also all technical works to ensure interoperability (e.g. manual transformation of dataset or the programming of automatic software that converts the data). These cost

[226] based on expert judgment.

savings would occur on both the EEA side but also on the side of those who want to link to Climate-ADAPT.

- Reduced staff costs for the end users in compiling and processing data due to increased data availability ("one-stop-shop" principle). For certain needs/policy requirements data from different sources might need to be compiled and processed by the end user. However these policy needs might occur several times across Europe and without interoperability each end user has to develop its own solution. Interoperability at the EU scale might reduce the need for singe solutions and might allow the development of a single tool that can be used by different end users.

- Reduced operating and staff costs might also occur due to better quality control of data in-put, more coherence as regards input of data categories and improved user-friendliness.

- Guidance for database interfaces makes the application development faster and easier and therefor cheaper.

- The main benefits from a "one stop shop" approach are an improvement of communication within the authority and with the developers and better working relationships between the different agencies. For the end user, it is a gage of efficiency and quality as it increases the speed of access to information from validated sources and reduces the need for matching information (Department for Communities and Local Government, 2008).

In the case of public funded databases all mentioned above will allow a more efficient use of tax payers money.

Using this guidance social benefits will mainly relate to reduced barriers between institutions (e.g. EEA and others) cooperating and better collaborating. This might improve the working relationship as well as lead to a better structured and coordinated information infrastructure for climate change adaptation in Europe.

Users will also benefit from better linked databases as the information that will be linked to Climate-ADAPT will deliver trusted, consistent data and services due to increased quality assurance.

Linking different datasets to Climate-ADAPT will also allow strengthening the different tools (e.g. map viewer) by providing more or detailed data, enabling users to improve problem solving.

Direct environmental impacts are not expected but efficient sharing of data and methods is vital on the track towards more comprehensive and reliable assessments in environmental decision problems[227].

One of the reasons for setting up INSPIRE (EC, 2007e) was that "the problems regarding the availability, quality, organisation, accessibility and sharing of spatial information are common to a large number of policy and information themes and are experienced across the various levels of public authority. Solving these problems requires measures that address exchange, sharing, access and use of interoperable spatial data and spatial data services across the various levels of public authority and across different sectors." This option would contribute to solving this issue, in particular as INSPIRE has no climate change adaptation compound so far.

This "one stop shop" was also considered in the Commission "Guidelines for an Integrated Approach to Maritime Policy: Towards best practice in integrated maritime governance and stakeholder consultation" (EC, 2008q) where a one shop stop approach is recommended to avoid duplication of regulatory powers of different national or regional authorities in the Member States and to replace overlap and double-track decisions.

6.1.3.2 Developing a knowledge gap strategy in collaboration with Member States

Description of the option

This option envisages in a first step a systematic collection of knowledge and data gaps. In a second step the results will be clustered into thematic areas (e.g. modelling, effectiveness of adaptation measures, sectors) and prioritized by a specific working group (e.g. the already established Working Group on Knowledge base). The findings will then be mainstreamed into HORIZON 2020 and other research schemes using existing mechanisms mentioned above. The exercise is supposed to take place every two years.

Assessment of the option

It is important to note that the impacts of the HORIZON 2020 are not subject to this assessment as they have already been assessed in the related impact assessment[228]. This assessment focuses on the listing of the knowledge gaps and the identification of areas for priority research.

One-time, variable costs arise mainly for collecting the information e.g. via a questionnaire or dedicated meetings, analysing and assessing the results, organising and hosting the working group (e.g. Working Group on Knowledge Base) and writing a list of priorities. It is assumed that some of the work would be carried out by external consultants. The administrative costs

[227] http://lib.tkk.fi/Diss/2003/isbn951226577X/article7.pdf
[228] http://ec.europa.eu/research/horizon2020/pdf/proposals/horizon_2020_impact_assessment_report.pdf#view=fit&pagemode=none

for the Commission are marginal. The administrative costs for Member States and stakeholders would relate to the format the information is collected (e.g. filling in a questionnaire is more time consuming than just writing an informal letter) and the fragmentation of information available at Member States level. For example if structures that coordinate research activities are already in place efforts are less than in cases were various research institutions have their own independent agenda and no overall coordination exists.

A survey among researchers and research institutes showed that there is a widespread support for a higher participation of stakeholders in European Research Area processes (where HORIZON 2020 is a part), mainly through dedicated working groups[229]. Falconi (1999) identified several positive social impacts if priority setting in research is done in a participatory mode. They refer to:

- the more efficient resource allocations (reducing the risk of potential double funding) and allocating them more transparent and unambiguous,
- better achievement of a consensus of the research agenda due to allowing different staff levels to participate in the process as well as discussing a broader set of alternatives in a transparent way,
- Strengthened credibility of an institution or program and helps it to take a proactive role in soliciting government and donor support for crucial areas to research.

In January 2012 the European Commission published the summary and analysis of the response to the ERA Framework Public Consultation. The on-line public consultation generated a total of 590 replies, most of which came from individuals (63%) and the rest (37%) responding on behalf of organisations, universities, research performing or funding organisations, businesses or others. Even if adaptation to climate change is not addressed as a single issue the results from the consultation are valid as well (EC, 2012e). In the context of the study and in relation to the policy option the following positive social impacts have been identified:

- Joint Programming Initiatives and Alliances between research institutes are considered appropriate mechanisms for cross-border research. As climate change has wide-spread effects and can potentially cause interdependencies between countries, this option will most likely strengthen cross-border cooperation for issues of common interest.
- Lack of political commitment is considered to be the major difficulty for transnationally coordinated research. The agreement on common priorities could be seen as a way of increasing the political commitment.

[229] http://ec.europa.eu/research/era/pdf/era-summary-report-2012_en.pdf

- Ensuring a closer cooperation and coordination in policy development and implementation is considered to contribute to reducing the research and innovation deficit and inefficiency in the EU.

The results of the public consultation of the EU Adaptation Strategy confirm enhanced support for research initiatives. When asked which actions could improve the use of EU funding for projects, respondents rated ‘coordination among research projects’ and ‘strengthening the science-policy interface’ as having medium to high potential (55% and 81% of respondents, respectively). Moreover, 76.4% of respondents agreed that ‘supporting pan-European discussion fora on adaptation to share experiences and good practices’ would help to facilitate dissemination.

However there is also the risk, that with such a priority setting process certain issues will be overlooked (e.g. risk exists that the priorities may concentrate too much on diagnosis and improving the understanding without arriving at testable solutions). This risk can be reduced due to the development of a list of key questions against the priorities assessed. Further, knowledge gaps are closely correlated with decision-making needs and adaptation governance. While research for climate change had a strong focus on assessing vulnerabilities, a shift towards more research activities on adaptation actions is already noticeable. When listing knowledge gaps, it needs to be acknowledged that the compilation will need to be regularly checked and updated reflecting demands for adaptation policy processes.

No direct environmental impacts are expected. Indirect environmental impacts are expected if knowledge gaps related to environmental issues are taken up under HORIZON 2020 and research provides solutions for improving the environment which can then be taken up in the policy making or implementing process for adaptation.

6.1.3.3 Developing a common climate vulnerability assessment in the EU

Description of the option

Vulnerability assessments tend to focus on the vulnerable system and the multiple stresses that may threaten it rather than on the multiple effects of a particular stress factor such as climate change (Ribot, 1995). Therefore, they rely heavily on the availability of consistent scenarios for the different stressors, in particular when they are causally related to each other. The latest set of IPCC emission scenarios, the so-called SRES scenarios (Special Report on Emissions Scenarios (Nakicenovic & Swart, 2000), are an important step forward to this end. These scenarios aim at being consistent in terms of emissions and non-climate drivers, in particular demographic and economic development.

Currently several climate vulnerability assessments have been or are carried out on the European level. Often they use different SRES scenarios (e.g. PESETA, cf. also below, used the A2 and B2 SRES scenarios as references; more recently the FP6 CIRCE project and the FP7 ClimateCost project used the A1B SRES scenario as reference; the FP6 ENSEMBLES project even focused on an ad hoc non SRES stabilization scenario: E1). More importantly they apply different models or combination of models[230] that would be best suited to answer their research question. In this context the European Commission mainly uses the PESETA project as a basis for its vulnerability assessment, as it has the merit of being the first attempt to provide a comprehensive (multi-sector and EU wide) and integrated (internally consistent and comparable) impact assessment exercise.

A key issue in the PESETA project is the use of the same set of socioeconomic and climatic scenarios in all the six sectoral studies conducted (agriculture, coastal systems and river basin floods, human health, tourism and energy demand). Two global scenarios have been selected from the IPCC's Special Report on Emissions Scenarios, belonging to the A2 and B2 scenario storyline. This choice partly covers the range of uncertainty associated with the driving forces of global emissions: demographic change, economic development, and technological change. Those CO_2 concentration levels translate into the following global mean temperature increases in 2071-2100 relative to 1961-1990: under a scenario A2 there will be an increase of 3°C, and under scenario B2 there will be a temperature increase of 2.2°C.

Under this option it is assumed that Member States and the Commission agree on PESETA as a common European wide approach for climate vulnerability assessments. It is further assumed that in order to develop PESETA further experts from 27 Member States, the Commission (represented by different DG´s), Eurostat and the EEA would form a working group. The activities could cover:

- further regionalisation of the model.
- improving the database by collecting more regionalised data in a systematic manner.
- develop methodologies and underlying assumptions, projection methodologies and coverage (sectors) further.
- provide technical expertise to the JRC.

Based on the outcomes of this working group, JRC is expected to develop PESETA further. The PESETA projections would feed into a variety of policy debates at EU level and Member States are invited to use the same project on a voluntary basis for carrying out their assessments.

However, the recognition that not only the same anthropogenic pressure (GHG emissions and then concentrations above all) can originate different impacts on the climate system (e.g.

[230] e.g. strictly restricting to the economic models used: GEM E3 and ICES CGE models in PESETA and CIRCE; ICES and GRACE CGE models and FUND integrated assessment model in ENSEMBLES; GEM-E3, ICES CGE models and POLES bottom-up model in ClimateCost.

temperature increases), but also that the same climate forcing (e.g. temperature increases or precipitations) can originate totally different economic consequences depending on the social economic context, is at the basis of the recent IPCC Representative Concentration Pathways (RCPs) approach (van Vuuren, et al, 2011). IPCC decided to leave new scenario development to the research community with full flexibility, following a three step procedure (Moss, et al, 2010). Development of a scenario set containing emission, concentration and land-use trajectories (the RCPs *strictu sensu*); a *parallel* development phase with climate model runs and development of new socio-economic scenarios; a final integration and dissemination phase.

This would answer the three basic needs of the climate change community: more detailed information for running the current generation of climate models than that provided by any previous scenario sets; increasing interest in scenarios that explicitly explore the impact of different climate policies in addition to the no-climate-policy scenarios explored so far (e.g. SRES); increasing interest in exploring the role of adaptation in more detail.

Assessment of the option

Improving the coordination of research efforts, the comparability of research methodologies and outputs, and the consistency of policy messages is of utmost importance. However, these goals are not achievable imposing the use of one single climate scenario, one single social economic scenario, not to mention a single evaluation tool.

There are in fact various on-going activities for model comparison and model combination. In the “impact and adaptation” area probably the most important is the on-going and abovementioned IPCC RCPs action; in the assessment of mitigation policies that developed by the various Energy Modelling Forum exercises (e.g. EMF, 2011). All of these show that comparability is indeed possible also in a multi model approach once the assumptions and structure of the models are transparently communicated.

Both scenarios and models are continuously improved by a dedicated science community (Randall, et al, 2007). Proposing one standard would lock the current state-of-the-art, and might hinder improvements and unconventional solutions. Moreover, different models can be better suited to answer different sets of questions. Accordingly, it would be important to exploit rather than limit this richness.

Using a broader set of scenarios, models and data sets allow quantifying and better communicating the uncertainty. For example so called multi-model ensemble is used to sample uncertainties in model formulation. Initial condition ensemble runs can be used to estimate the uncertainty in the projections of future climate change due to the incomplete knowledge of the present state of the climate system[231]. The different spatial resolution of these assessments allows serving different specific purposes. This is particularly relevant

[231] http://ensembles-eu.metoffice.com/tech_reports/ETR_3_vn0.pdf

when adaptation is addressed, as different measures are effective at very different spatial scales.

The IPCC is currently developing new scenarios for a possible use in its AR5[232]. Europe should link its assessment to this global work, for scientific, but also for cost saving reasons.

The White Paper already stated that vulnerability should be assessed against a wide range of climate scenarios and on different geographical scales to facilitate the definition of adaptation measures.

Anyway, to improve the comparability of results, in particular out of the future HORIZON 2020 EC funded projects, the Commission could prescribe which emissions scenarios shall be used (based on the EU mitigation goals), but then leave flexibility in the choice of the environmental, social economic impact assessment tools to apply.

Alternatively (but also in addition), it could set the development of some key social economic driving forces (e.g. population and GDP), responding to some specific policy interest. But even in this case it should still allow for the use of different economic models to investigate different aspects of mitigation and adaptation policies and to produce potentially different emission paths. In addition the Commission could mention good practice examples of such assessments in the context of Climate-ADAPT.

Finally, this option might lead to the fact that some of the research groups not following such an European approach might suffer from lack of funding. This might hamper the development of alternatives and approaches outside the mainstream.

The project costs for developing this option further might relate to several million euros as formers projects show:

Table 43: Project costs for different vulnerability assessments

Project/Model	Total Budget (in €)	Vulnerabilities included
ENSEMBLES	22,793,436	The project developed a high resolution regional climate model ensemble system using 10 different models to simulate multi-decadal climate at 25 km. Uses multi-model seasonal, annual and multi-annual hindcast simulations. Looks into climate variability, predictability and probability of extreme events, and the project assessed the impacts of climate change and reviewed the economic assumptions of SRES scenarios.

[232] Cf. http://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/index.html for further details

Project/Model	Total Budget (in €)	Vulnerabilities included
SCENES	10,301,007	SCENES analysed a set of comprehensive scenarios of Europe's freshwater futures up to 2050 and identified water-related drivers.
MOVE	2,650,841	MOVE took into account past projects on vulnerability in Europe and analysed major gaps in knowledge that they have left. It considered the applicability to Europe of vulnerability concepts and frameworks used in other regions of the world; MOVE identified which quality criteria are needed to improve the framework for vulnerability assessment for Europe.
MOTIVE	9,070,933	The project evaluates the consequences of the intensified competition for forest resources given climate and land use change. The project focuses on a wide range of European forest types under different intensities of forest management. In particular, MOTIVE examines impacts with respect to the disturbance regimes determining forest dynamics.
CECILIA	3,367,022	The main objective of CECILIA was to deliver a climate change impacts and vulnerability assessment in targeted areas of Central and Eastern Europe. The project contains studies of hydrology, water quality, and water management, air quality issues in urban areas, agriculture and forestry.
ClimWatAdapt	605,646	Based on SCENES it focused on vulnerability of water and related sectors all over Europe.

6.1.4 Effectiveness, efficiency and coherence of the options addressing problem 1

In comparison to the baseline, all the options will improve and widen the knowledge base and the tools and strategies to do so and contribute sowith to the first objective "Better informed decision making". The option "Guidance document for developing and setting up interfaces between Climate-ADAPT and other databases" will improve knowledge by specifically targeting data management, access, sharing, harmonization, interoperability as well as the seamless integration of data and services. The option "Develop a knowledge gap strategy in collaboration with MS" will strengthen knowledge generation, in particular in relation to existing policy needs. The third option on developing a common climate vulnerability assessment in the EU will have a much more limited impact on knowledge generation as it focusses only on one approach for assessing climate vulnerabilities.

Regarding effectiveness, all options contribute positively, but indirectly, to fostering the integration of climate change into sector policies by providing better information. The effects are expected to be strongest for the option "Develop a knowledge gap strategy in collaboration with MS", which is supposed to provide significant new data on an EU wide basis. The option “Guidance document for developing and setting up interfaces between Climate-ADAPT and other databases” will not increase the knowledge base, but will make access to existing knowledge easier and therefore it contributes to the objective of better dissemination.

All options will also contribute to the objective “Increasing the resilience of the EU territory”, as they require interactions between different governmental, research and private bodies. The option “Develop a knowledge gap strategy in collaboration with MS” should have a stronger impact as more interaction beween the MS is required to implement the objective. Therefore, the option is expected to impact to the mainstreaming objective, as the identified and prioritised knowledge gaps will be mainstreamed into HORIZON 2020, but could also be taken up in other research pathways (e.g. national, service contracts, LIFE+).

Impacts on the objective “Increasing the resilience of key vulnerable sectors” are expected to take place. Private companies might use the opportunity under the option “List knowledge gaps, in collaboration with MS and other stakeholders, and identify broad areas for priority research to further mainstream adaptation” to get involved and to develop new adaptation options. However, this involvement is considered more as a result of the new rules under HORIZON 2020 than under this option. Also, the development of a common climate vulnerability assessment is expected to have no impact as it will mainly involve research institutions and administrations.

The first two options are expected to have a positive impact on efficiency. However, a comparison among them is not possible as they focus on different issues. Costs are expected to be lowest for the guidance document as this does not require maintaining a process or data collection. Once the guidance is developed, as an update might only be needed if Climate-ADAPT updates its data management system technically. Efficiency is also improved for the user, as they can rely on the one stop- one shop principle. The second option coordinates research and research requests more efficiently. This is valid for internal Commission activities but also between MS and the Commission. The third option will increase efficiency only for the preferred vulnerability assessment, as it will focus all resources towards this single approach.

All the options are considered to be coherent with other EU policy objectives such as the ones set out in the HORIZON 2020. It will also support the actions (in particulary those under priority 5) proposed in the seventh Environment Action Programme (7EAP), which aims to improve the evidence base for environmental policy making. The option “List knowledge gaps, in collaboration with MS and other stakeholders, and identify broad areas for priority research to further mainstream adaptation” and the development of a common vulnerability assessment will also support the EU 2020 target that 3% of the EU's GDP should be invested in R&D. It will also support the Commission’s intention to increase the proportion of climate related expenditure to at least 20% in the MFF.

6.1.5 Comparative table of the options addressing problem 1

The options set out to address the knowledge base are not contrasting or alternative options. None of the options or the first two could be taken forward. The third option is not recommended to be taken up as it would streamline research into a single channel that is not necessarily the “optimal” one.

Table 44 compares and summarises how the options contribute to the effectiveness of achieving the operational objectives of the strategy and to the overarching objective of improving efficiency and coherence.

Table 44: Comparative table of the options addressing problem 1

Options	Economic, social, and environmental impacts	Effectiveness			Efficiency	Coherence	Acceptability
		Objective 1: Better informed decision making	Objective 2: Increasing the resilience of the EU territory	Objective 3: Increasing the resilience of key vulnerable sectors			
No policy change		0	0	0	0	0	0
Guidance document for developing and setting up interfaces between Climate-ADAPT and other databases	+(avoided costs, increased inter-operability, increased data sharing and cooperation among researchers and data providers ≈ environmental impacts)	≈ to +/? (better access and dissemination of information, improves cooperation between organisation by developing the guidance)	≈ (no impact expected)	≈ (no impact expected)	≈ to++/? (could allow user to get all relevant information from one entry point)	+ (supports the Horizon 2020 and 7EAP objective)	? (the uptake is not clear to predict)
Developing a knowledge gap strategy in collaboration with Member States	-/+(increased costs for collecting information and organising the process, reduced costs due to better coordination of research funds	++ (better coordination of research need, improved knowledge generation in particular in relation to policy needs, improves cooperation	+ (will mainstream adaptation into HORIZON 2020 and other research paths)	≈ (marginal impact expected. Some companies might use this opportunity to develop adaptation solutions)	++ (improves the coordination of research)	++ (supports the Horizon 2020. EU 2020, 20% MFF and 7EAP objective)	++ (such approaches are more and more often discussed among scientist and policy makers)

Options	Economic, social, and environmental impacts	Effectiveness			Efficiency	Coherence	Acceptability
		Objective 1: Better informed decision making	Objective 2: Increasing the resilience of the EU territory	Objective 3: Increasing the resilience of key vulnerable sectors			
	++ increased cooperation among MS, COM and research institutions ≈ environmental impacts)	between organisation by discussing, negotiating and agreeing on research priorities)					
Developing a common climate vulnerability assessment in the EU	-(reduces the options to deal with uncertainty -lack of funding for those research groups, which do not follow this single approach ≈ environmental impacts)	≈ to+/?(better access and dissemination of information, but only for a certain type of assessment, improves cooperation between organisation by developing the common vulnerability assessment)	≈ (no impact expected)	≈ (no impact expected)	+/- (improves the coordination of research for a certain assessment, but reduces the possibilities to deal with uncertainties)	++ (supports the Horizon 2020. EU 2020, 20% MFF and 7EAP objective)	- (will not be accepted by the research community and policy makers)

Magnitude of impact as compared with the baseline scenario (the baseline is indicated as 0): ++ strongly positive; + positive; – – strongly negative; – negative; ≈ marginal/neutral; ? uncertain; n.a. not applicable

6.2 Problem 2: Knowledge dissemination

6.2.1 Problem definition

To successfully implement adaptation policies and plans, information must be collected and disseminated in ways that serve those who need it, such as affected local communities and government decision makers. Knowledge of environmental issues has improved over time, but still around 40% of European citizens consider themselves badly-informed on environmental issues, indicating that considerable work is still needed to raise awareness and spread knowledge (Eurobarometer, 2011a). The level of understanding of environmental issues, however, varies greatly among at Member State level: whereas in Sweden, Denmark and the UK citizens - 81%, 80% and 76% respectively - stated that there is a decent amount of information available to them, agreement was as low as 46% in Portugal and in Spain, 47% in Romania, 48% in Bulgaria and Czech Republic, 52% in Greece and 54% in Slovakia (ibid). This has implications for society-driven action at local community level.

Enabling societies to adapt to climate change will require establishing systems that transfer relevant information both from the national to the local level and vice versa[233].To improve knowledge management, the White paper on adapting to climate change (EC, 2009a) proposed a Clearing House Mechanism (IT tool and database on climate change impact, vulnerability and best practices on adaptation). In March 2012 this objective was achieved with the launch of Climate-ADAPT. Several online, interactive tools (e.g. case study, map viewer) have been developed for the Climate-ADAPT platform.

Climate-ADAPT already experienced a very high web use/traffic during and immediately after the launch, ranking high compared to launches of other EEA products (cf. Figure 63).

Figure 63: Main statistics for Climate-ADAPT for the period 23 March – 23 August 2012

In the context of several research and support actions at EU level (Proposal for HORIZON 2020[234], service and research contracts of specific line DGs, proposal LIFE+[235], JPI

[233] http://www.worldresourcesreport.org/expert-perspectives/question-five
[234] http://ec.europa.eu/research/horizon2020/index_en.cfm?pg=h2020-documents

Climate[236], Climate KIC[237], JRC internal research activities, EEA Financial Mechanism and Norwegian Financial Mechanism[238]), new adaptation knowledge is or will be produced continuously. However, these new results are mostly not systematically mapped and reported into Climate-ADAPT. Therefore, the information presented at Climate-ADAPT is not sufficiently comprehensive and users are required to consult several other sources of information. An indication for this assumption gives the amount of time spent on Climate-ADAPT and the number of pages visited. The web analytics for Climate-ADAPT show clearly, that the majority of users only stay for one minute and leave the platform after just looking at one page and without exploring the platform further. A first attempt to resolve this problem was taken within the last call of FP7 where reporting to Climate-ADAPT is mandatory.

In addition to Climate-ADAPT, many of the Member States already have developed national platforms[239] and further ones also are under development. These websites are well-visited, for example the German adaptation site has had in 2012 (until mid-November) around 150,000 visitors and the Danish site around 120.000 visitors[240]. Currently the link between Climate-ADAPT and these national portals are only via a web-link with formal co-operation agreement. The main obstacle to access and make use of the information provided at national portals is still the language barrier, as many national portals are not made available in English and Climate-ADAPT does not provide for a translation facility.

Further, researchers and policy-makers have experienced obstacles in building up and sustaining the kinds of relationships that ensure the link between science and experienced policy making. According to a study on scientific evidence for policy-making carried out by DG RI[241], these are:

- Contextual. Policy-makers and researchers work in very different environments with few opportunities for meeting during the normal course of their work. This difference is compounded by significant variations in the timescales to which both the language they use to describe their experiences and needs and their differing perspectives on how knowledge and information are used. Policy-makers need information which will inform their decision-making process, either ex ante in defining policy or ex post in evaluating policy choices. This information must be accessible, politically useful, and contribute to finding practical solutions to problems. The challenge for researchers in

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235 http://ec.europa.eu/environment/life/about/beyond2013.htm
236 http://www.jpi-climate.eu/
237 http://www.climate-kic.org/
238 http://www.eeagrants.org/projects/#results
239 Austria, Belgium (focus on mitigation), Denmark, Finland, France (only medium level information), Germany, Hungary (broad focus) Ireland (only medium level information), Netherlands, Portugal (only focuses on NAS), Sweden and the UK.
240 Data based on personal communication with the relevant authorities hosting the platforms.
241 http://ec.europa.eu/research/social-sciences/pdf/scientific_evidence_policy-making_en.pdf

this context is to be capable of understanding the constraints of policy-making. They also need to understand the importance of translating their research findings into policy useful material and the importance of supporting policy-makers in identifying appropriate solutions to problems.

- Structural: structural differences can be found in terms of the working methodologies and the way in which decision-making happens. Scientists are motivated to achieve high-quality, scientifically robust results, which may or may not have an immediate impact on society or on policy-making. Policy-makers on the other hand are generally required to think in the short and medium as well as the longer term, and must be able to respond effectively to sometimes rapidly evolving political and social challenges. Policy-making is increasingly required to interact with a range of stakeholders, and in many cases the subjects of their policy-making, in order to provide solutions which are based on consensus. Researchers do not generally operate under such constraints

- Cultural: Some countries (Scandinavia and the United Kingdom, and countries with more decentralised models of decision-making) have a greater tradition of encouraging communication between both fields and in providing appropriate forums and channels to facilitate communication.

Climate change adaptation does not only require a link between the research and science community, it also calls for horizontal integration of different policy areas and scientific disciplines. On the EU level this integration on the policy side is ensured through the inter-service consultation process. Dissemination among different science areas happens in a random manner, mostly via international conferences or publications in journals, which are selected by the researcher.

A particular focus should also be paid to decision making under uncertainty. This was also confirmed by the public consultation where 55% of the 161 respondents considered that action at European level was needed. The high uncertainties related to climate impacts are a challenge to adaptation practitioners. It is therefore instrumental to facilitate the exchange of information on successful adaptation measures between stakeholders themselves and with the scientific community.

Further, according to discussions with stakeholders language barriers exists when assessing the information provided by Climate-ADAPT in English only[242]. While policy makers at the EU and national level are mostly familiar with reading English, regional and local policy makers have more difficulties. This leads to the problem that even if relevant information is provided it cannot be assessed due to the lack of language skills.

[242] This statement was made several times during the stakeholder workshops on the EU Adaptation Strategy in Rome (May 29, 2012) and Vienna (June 27-28, 2012).

It is important to note that 'better dissemination of research results' received ranking of either 'more potential' or 'highly potential' by 66.5% of respondents under the public consultation.

6.2.2 No policy change

Under the no policy change scenario it is assumed that Climate-ADAPT will be further financed under the MFF and that the EEA (supported by ETC CCA) will ensure regular maintenance and updating of Climate-ADAPT. This includes ensuring inclusion of this work within the EEA annual management plans and in the annual ETC CCA implementation plans. It also includes regular reporting on progress, e.g. through the EEA (and ETC CCA) progress reporting. EEA (with ETC CCA) will organise regular training sessions and meetings but also develop information and publicity material such as a newsletter and a tutorial video.

Except for the generated knowledge under HORIZON 2020, the reporting to Climate-ADAPT would depend on voluntary efforts by the different research institutes, own resources of the EEA (supported by ETC CCA) and the Commission to collect information and data. According to on-going discussions for 2012/2013, the following content related updates are planned[243]:

- EEA reports and indicators. EEA will publish a range of indicators on climate change impacts and vulnerability (in the EEA indicator management system) and various reports on its web site for subsequent inclusion in Climate-ADAPT.
- Updating content as newer, relevant information and data sets are published and can be added to Climate-ADAPT, e.g. those studies contributing to PESETA-II or other Commission funded projects
- Adding relevant new content sources (e.g. information on national risk assessments) and data types (e.g. time series at individual locations) not covered by phase 1 of the White paper.
- GMES Climate relevant projects

In addition, the European Commission signs several dozen knowledge development projects (e.g. HORIZON 2020, INTERREG, ESPON) and services contracts per year, many of them provide relevant information and results for adapting to climate change. These results, as well as primary data often generated in this context, is reported systematically to Climate-ADAPT on a voluntary or mandatory basis, as the Climate-ADAPT platform is the EU entry point to adaptation information in Europe. For the last FP7 call in 2012, a requirement to link to Climate-ADAPT was introduced for the first time. This is expected to continue under

[243] Please note that the work program is only officially 'approved' once the EEA 2013 Annual Management Plan has been approved by the EEA Management Board and the ETC CCA 2013 Implementation Plan has been approved by EEA.

Horizon 2020. The inclusion of the results from the Joint Programming Initiative "Connecting Climate Knowledge for Europe' (JPI Climate) is expected to take place from 2014 onwards.

Beyond 2014 it remains unclear how Climate-ADAPT will further develop and which dissemination activities will be carried out. This is partly due to the fact that EEA is developing its next Strategy and Multi Annual Work Programme for 2014-2020, which will be agreed by mid/end 2013. In addition, as mentioned above, formally only annual management plans can be regarded as 'officially approved'[244].

On the national level it is assumed that Member States having a national platform or a NAS will spend more effort on data collection and dissemination than those without.

6.2.3 No EU-action

Under this scenario it is assumed that after 2013 Climate-ADAPT is not updated anymore, and so the information currently available becomes obsolete quickly. Due to this fact, national platforms will gain importance, and data and information related to adaptation will be spread out in various databases at EU and national level. It is expected that Member States which have already a platform or are in the process of developing one will continue with their activities. In addition a few MS who will decide to set up NAS will also set up platforms in this context. Due to these national activities which will also refer to EU research activities under HORIZON 2020 a patchy system of information platforms is expected to last with different levels of maturity in terms of functionality, quality assures, interconnectivity of data sets and level of information. This will also influence their use in dissemination and awareness raising. Due to the use of national languages also dissemination of EU relevant information will be hampered.

For research it is expected that CORDIS will remain the main source of information. In addition, the results of the different service contracts from the different DG´s will only be available via the related websites, which mostly are not further maintained beyond the life-time of the project.

[244] Personal communication with Mr. Jol - Head of group vulnerability and adaptation, European Environment Agency.

6.2.4 Policy options addressing problem 2

6.2.4.1 Improve Climate-ADAPT beyond business as usual (BAU) by regular voluntary updates by Member States on adaptation activities, information on insurance and business and on national risk assessment

Description of the option

This option covers a broad set of information to be voluntary reported by individual Member States and other relevant stakeholders on a regular basis via the Adaptation Steering Group (ASG). In particular, the following information would be requested via the ASG:

- By the end of 2011, Member States were asked to provide national information on adaptation to Climate-ADAPT[245] through the national representatives in the ASG. Under this option a voluntary agreement between the Member States´ representatives and the European Commission would be set up. This agreement would specify certain information on climate change adaptation Member States would voluntary upload on Climate-ADAPT on a bi-annual basis.

- Following the 2011 Council conclusions on Further Developing Risk Assessment for Disaster Management within the European Union[246], Member States have been asked by the Commission to prepare and report on national risk assessments. This option would consider the possibility of uploading the information received from Member States on Climate-ADAPT or providing a summary report (e.g. Commission Staff Working Document) by the Commission.

For other stakeholders from the private sector and NGO´s this policy option requires the creation of a new portal within via Climate-ADAPT. This portal would provide sectoral assessments on risks and adaptation actions towards climate change. The information would be provided by the business associations and NGO´s represented in the ASG[247]. This could, inter alia, also be used to collect and make available information on weather related insurance products in different countries.

Assessment of the option

National information on adaptation was voluntarily reported to Climate-ADAPT the first time end of 2011. The identified running costs for national administrations in reporting to Climate-ADAPT are between a few days and some weeks (cf. Table 45).

[245] http://climate-adapt.eea.europa.eu/web/guest/countries
[246] http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/jha/121462.pdf
[247] http://expertgroups.govtrace.com/steering-group-on-adaptation-to-climate-change

Table 45: Time for first time filling the Member State template (source personal communication with Member States)

Country	Cost estimates
UK	20 person days
Germany	20 person days
Austria	3 person days
Belgium	12 person days
Switzerland	2 person days
Czech Republic	1000 Euro
Ireland	1,5 person days
Slovenia	3 person days

Quality assurance of data provision by Member States may become burdensome for the Commission and EEA, leading to maintenance issues. The QA/QC process of country pages was reported to be 17 working days (this includes both EEA's and EC's time spent) by the EEA. However, this might increase if more information is reported in the future.

In the case Member States reports on national risk assessment are uploaded to Climate-ADAPT no additional cost/time for reporting for the Commission and national administration can be expected as this information has to be reported already. Marginal operational costs might occur for uploading onto Climate-ADAPT. In the case a Commission Staff Working Document is produced, a marginal additional administrative burden for the Commission could be expected.

Additional operational costs will occur from creating a sub-portal for businesses and NGO´s. These costs would mainly be borne by the sector as Climate-ADAPT already has several sub-portals that could be used as a basis for the creation of additional portals. For developing the template for Member States, 4 working days (this includes both EEA's and EC's time spent) have been used. The operational costs to be borne by for other areas would relate to e.g. collecting the information from national business associations and the compilation of the report. However, these costs would depend on the starting point (such a report has already been prepared for other purposes) and the level of effort carried out. According to expert judgment, minimum costs (if such a report would be carried out by external consultants) to be expected are 100.000 Euros. These costs might lead to the fact that some business or business associations will oppose reporting or will just provide very general information. The option would ensure coherence of reporting on EU adaptation efforts. Member States would benefit from harmonised reporting. The increased frequency of reporting compared to UNFCCC requirements would provide additional information to the Commission on the implementation and state of the EU adaptation efforts. On the other hand, Member States might oppose an increase in reporting frequency due to increased administrative burden (cf. above).

For the private and business sector caution has to be paid to confidentiality issues.

It is also important to note that not all business sectors are represented in the ASG (e.g. the private bank and forestry sector are missing). So under the current format there will not be a full coverage of the situation in the private sector. However, under a new mandate more business associations could be included under the ASG to better balance the different sectors.

Due to increased reporting better information would help to reduce uncertainty. Public sector agencies could provide stakeholders, including insurers, with affordable access to reliable data on historical and future natural hazards, e.g. as a public good from national meteorological offices and flood management agencies. More precise, publicly available results on key climatic variables will provide the basis for sound risk assessment. A range of stakeholders, including policymakers, would be the beneficiaries (cf. chapter 3.7).

No direct environmental impacts are estimated. Indirect environmental impacts might result from better decision making.

In the public consultation it was asked which additional actions could be considered at EU level to facilitate further knowledge dissemination and sharing. A majority of respondents (54.66%) consider 'Activities to promote the use of the European Climate Adaptation Platform' as relevant. However, this option was considered as less relevant compared to the other proposed actions, for example training/dissemination activities for stakeholders or support of pan-European/pan-regional discussion. Responses within the public consultation included the need to increase knowledge about impacts and vulnerability at regional and local level. Also from the stakeholder meeting it came clear that the strategy should enhance the sharing of experiences and good practice on climate change adaptation, which can be provided by strengthened the European platform on climate change adaptation, Climate-ADAPT.

6.2.4.2 Support exchange between science and policy in the field of adaptation

A review of EU supported International Cooperation in the field of water research from FP4 to FP6 found that the integration of science with policy priorities has been enhanced and awareness among stakeholders regarding the challenges facing policy-makers and end-users has increased (Gyawali, et al, 2006). However, there is considerable room for improving the uptake of research outcomes because there is still inefficient communication between science and policy communities. Barriers were identified such as fragmentation of activities and the lack of communication between projects; limited effectiveness in research dissemination due to the lack of stakeholder participation; and limited exploitation of research results due to short project timeframes, project-driven research and difficulties in researching the intended end-user. Conclusions on how to overcome these barriers highlight the need for science-policy interfaces, as recommendations emphasized the need for project clusters, setting up follow-up activities and the development of exchange networks (Depietri & Giupponi, 2008).

In order for policy makers to make sound decisions in the field of adaptation policies, a comprehensive understanding of the current state of the art in climate change science is essential. To facilitate the exchange between scientists, policy makers and end users, science-policy interfaces (to be described in detail below) have been set up that bring together these stakeholders through projects, meetings, conferences, etc. The objective of this option is two-fold: 1) to introduce climate change adaptation topics to experts of other environmental fields as well as business sectors and 2) to bring together experts in the field of climate change adaptation to exchange best practice information.

What are Science-Policy Interfaces?

Science-policy interfaces (SPIs), which aim to bridge between the two actors, can be defined as “social processes which encompass relations between scientists and other actors in the policy process, and which allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision-making” (van den Hove & Sharman, 2006). According to interview studies with policy makers (Innvaer, et al, 2002), the best way to enhance interactions between scientists and policy-makers is to develop personal contact. However, there are two pre-requisites: scientists have to make science more understandable for non-scientists while policy-makers have to improve their scientific level, what is not done for the moment.

Four generic SPI types include (Timaeus, et al, 2010):

1. Interest groups: NGOs and learned societies. Such groups can promote research that feeds into a specific policy process.

2. SPI of research projects: SPIs of science projects and SPIs of supporting projects. According to Timaeus et al. (2010), the objective of science projects is to link a specific project to policy-making, while supporting supporting projects aim to increase collaboration within the science community or help establish a research/innovation platform.

3. Expert groups: mandated expert groups and non-mandated expert groups. Participants come from different institutions with the goal to assess existing scientific knowledge and identiy research needs and gaps.

4. State agencies or institutes. These are separate organisations organised by a formal political mandate to conduct research related to specific policy fields.

To achieve their aim, SPIs use a range of tools to facilitate exchange such as publications, working group meetings, conferences and web-based platforms that centrally house knowledge and research material.

Extended literature on the effectiveness of science-policy interfaces indicates that the most important characteristics of SPI are salience, legitimacy, and credibility. According to Koetz et al. (2008), the key features of effectives SPIs include: (i) processes allowing for the participation of and open dialogue between stakeholders, (ii) process that provide the opportunity for co-producing deliverables and iii) process that allow for transparent and direct lines of responsibility and accountability in both the science and policy communities. It is also important to keep in mind the ultimate goal or purpose, whether it is to ‘open up' a policy process by offering scientific alternatives or to ‘to assist' decision-making by providing uniform scientific advice (ibid).

Existing science-policy interfaces

SPIs can be found at all levels of government, including the EU level. They often are sector-specific. At the EU level, a number of SPI research projects already exist for the following sectors. A non-exhaustive list includes:

- **Agriculture and rural development**: SEAMLESS “System for Environmental and Agricultural Modelling, Linking European Science and Society (www.seamless-ip.org) from 2005-2009

- **Biodiversity**: Alter-net “A long-term Biodiversity, Ecosystem and Awareness Research Network (www.alter-net.info) 2004-2009; SPIRAL “Interfacing biodiversity and Policy” (www.spiral-project.eu); BISE “Biodiversity Information System for Europe”.

- **Marine**: STAGES “Science-policy interface support the implementation of the MSFD**Transport**: EPTS “European Platform of Transport Sciences”; EFP “European Foresight Platform supporting forward looking decision making (www.foresight-platform.eu) 2009-2012

- **Water**: SPI-Water “Science-Policy interfacing in Water Management” (www.spi-water.eu) 2009-2012; STREAM “Water research meets policy and industry” 2009-2012; Step-Wise “Science, Technology and Policy interface using WIDE-RTD 2009-2012; WaterDiss2.0 “Dissemination and uptake of FP water research results” (www.waterdiss.eu) 2009-2012;

- PSI-Connect “Connecting Policy and Science through Innovative Knowledge Brokering in the field of Water Management and Climate Change”,

- Circle-2 “Climate Impact Research and Response Coordination for a Larger Europe,

- Mediation "Methodology for Effective Decision-making on Impacts and Adaptation".

However as one can see these SPI´s are often not permanent and after a long phase that is needed to establish and run them, they are split again and the information exchange is not fostered any longer.

However there are some examples for SPI´s which are established for a longer period and the exchange between researchers and policy makers is proven to have a benefit for both sides.

The implementation of the Water Framework Directive and other (European) water related policies requires the use of the best available knowledge. Most of this knowledge is, however, often poorly accessible. To improve this situation two initiatives have been set up:

- The SPI Water adhoc group under the Water Framework Directive, which is currently ending its 3-year mandate, is expecting to be renewed for another 3-year cycle.

- The WISE-RTD Web Portal has been launched as a direct result from the European funded Harmoni-CA and SPI-Water projects and further enhanced in the projects STEP-WISE and FLOOD-WISE. WISE-RTD is one of the pillars of the Water Information System for Europe (WISE, www.water.europa.eu). It is maintained by the WISE-RTD Association, which is a non-profit organisation that has as goal to enhance interfacing between knowledge and policy in the environmental field.

Initially begun as an EU-funded research project, Alter-Net is now an independent organisation continuing its work on biodiversity. At national level, the Marine Climate Change Impacts Partnership (UK Expert Group) provides a framework to transfer research on marine climate change impacts and develop guidance on adaptation and related advice to policy advisors and decision-makers.

In addition to the EU funded projects, there are a large number of regional and national level initiatives taking place (e.g. BaltCICA "Climate Change Impacts Costs and Adaptation in the Baltic Sea Region, Knowledge Transfer Network from England covering many topics including Industry, Energy, Environmental Sustainability etc.).

Nevertheless, as a rough screening conducted, many SPIs have not yet taken up the issues of climate change adaptation into their work, which is why the exchange of information needs to be strengthened for both experts as well for those working on non-climate change topics.

On the global level the best known SPI in the context of climate change is the Intergovernmental Panel on Climate Change (IPCC) which produces a series of assessment reports regularly. The aim of these advisory bodies is to provide, on a continuing basis, scientific and technical advice for the implementation of a convention. These advisory bodies set their agenda in accordance with the programme of work decided by the international oversight body for the implementation of a convention (i.e. the Conference of the Parties).

Description of the option

This option focuses on two target groups: non-experts and climate change adaptation experts in the area of research and policy making. The overall aim is to bring these people together and ensure that the most recent scientific knowledge is brought to policy makers and that the policy needs are expressed to the research community. In order to do so three approaches are possible:

1. Climate change adaptation topics can be included upcoming SPI research projects under Horizon 2020 SPI research projects could take two approaches: 1) they could include specific work packages dedicated to climate change adaptation and 2) research projects could “climate check” their results and recommendations ex-ante to identify where climate change adaptation would be needed. Specifically, terms of references for future Horizon2020 research projects should focus on the knowledge gaps identified with respect to adaptation in different sectors with a special emphasis on the transport, energy and health sectors where major research gaps have been identified.

   SPI research projects are especially helpful at bringing new research results to policy makers; however, their impact is inherently limited as they often have a 3-5year mandate. Once the project is over, interactive meetings cease and project results remain on the web. Research projects represent an important part in SPI as they further science, develop new adaptation approaches and promote exchange. Their weakness is their limited contracts. This option should therefore be seen as just one part in a multi-package approach.

2. Secondly, existing expert groups, state agencies or business clusters could provide another key part of an adaptation SPI framework. They offer permanent structures where climate change adaptation could be incorporated into their existing agendas, for example by adding a ½ day-full day workshop or mini-session to existing meetings that focus on adaptation needs within the targeted sector (e.g. CIS working group on water management and climate change). This would require identifying climate change adaptation experts to invite them to carry out presentations on how climate change adaptation (CCA) is important for the relevant sector. In this way, CCA would be mainstreamed into all sectors and levels of policy making and science research, filling the existing gaps where efforts thus far have been limited. This more permanent option helps to avoid pitfalls of research being forgotten when project coordinators leave and helps to maintain the link between policy makers and researchers when a project is over, thus ensuring sustainability of cooperation. Whether incorporating adaptation into existing groups or setting up new expert groups, experience (e.g. in the Forestry sector) has shown that members of the science-policy community agree that increase involvement of science in policy advisory meetings and increased networking (i.e. personal contact) between scientists and policy-makers are important for improving communication in the science /policy interface (Janse, 2008).

3. A third promising approach is to set up expert or adhoc groups (e.g. Knowledge Group on Climate Change Adaptation) with the sole objective of addressing specific climate change adaptation questions The meeting format of such adhoc groups could be either in small meetings/workshops or having a conference at national and sub-national level (e.g. every 18 month, 400 participants are expected for 2 days). The idea of these ad hoc groups is to have dedicated exchange on ideas and experiences on climate change adaptation measures and/or programmes to ensure that across Europe stakeholders are working with the highest level and most up-to-date information. The conference would bring together experts in the field of climate change adaptation to exchange on good practice in decision-making and foster exchange on information needs. The program could cover different regional aspects of Europe as well as sectorial issues. The Commission, with the help of the EEA, will identify good practice examples to be presented. In addition, Member States and or regions can suggest what they consider as good practice, but can also request certain issues to be addressed.

   It should also be an occasion to initiate the validation of these research needs expressed by policy makers against knowledge already made available by the research community. . It is assumed that the conference will be organised with the help of external contractors, carrying out preparation and organisation of the conference (in particular announcements, invitations, registration, invitation of speakers, distribution of promotional material), the execution of the event (including the organisational management, the distribution of conference material, etc.) and the promotion of the conference before, during and after the event (including the dissemination of promotional material).

The Commission or research teams will support these meetings of the different SPI formats with a systematic review process. Such a review is a very formal/structured process for assessing all the information that is known to answer a specific question. Once the question is set, the team undertaking the review will search all literature, published and not, and all other sources of information. Once all the information is collected it is analysed for use (included or not) and then given a weighting to ensure highly scientific (e.g. before and after) studies are given a higher weighting and more informal evidence given a lower weighting. This is approach is already used in the UK[248].

Assessment of the option

While in theory, the main aim of SPIs is to improve decision-making through interactions of scientists and policy makers, in practice science-policy exchanges do not always lead to their intended outcomes due to outside factors that cannot be controlled. The potential impact, therefore, on climate change adaptation being incorporated into governance structures and

[248] http://www.environmentalevidence.org/index.htm

decision-making is not guaranteed. Analyses into SPIs found a few common factors that affect the effectiveness of SPI in bringing out their intended changes. With the Alter-Net SPI on biodiversity, a case study on SPI on nature in Flanders, Belgium identified the following factors affected the positive outcome of the SPI work, namely (van Reeth, et al, 2005):

- Communcation of the policy community' information needs. At the outset of starting a SPI, policy makers need to communcation their science needs to researchers. Poor communication from the beginning can hamper the outcome and cause mis-understandings.

- Receptiveness of the administrative stakeholders: A report undertaken in Flanders, Belgium on Nature met resistence from administrative staff who felt that information on environmental planning and programming was not the domain of scientists and therefore rejected or were suspicious of the outcome. Here, a paradigm change regarding strict division of responsibilities need to be addressed.

- Receptiveness of the political context: A change in which political party was in power shifted the political goals in Flanders and thus the research goals.

Events that help to broker knowledge between stakeholders, whether expert or non-expert, could bring about important benefits that outweigh the costs of hosting such events. As one of the intentions of this option is to organise a dedicated session back-to-back with existing meetings of CCA experts and non-experts, the individual economic impact would be rather low. Extending existing meetings could result in some additional costs of renting meetings rooms for another half day but the impact would be low. The administration burden would therefore be limited. Incorporating adaptation into research projects is a more costly option, although this depends on how it is included. An additional work package under a FP7 project, for example, could result increase a project's budget by an additional 50-100,000€ depending on the size; the additional project costs would be justified as the research outputs would be tangible and beneficial to the CCA community.

A large conference would lead to the most one-time, additional costs: according to a service request under the "Framework contract for services in the field of policy development and assessment in relation to climate change[249]" the total costs for such a large-scale conference shall be in the range of 45,000-50,000 Euros. However, it can be assumed that this is the lower boundary for such an event as similar conferences where covered by larger budgets (e.g. 2st EU water conference[250] € 60.000, 3rd EU water conference and final Blue Print

[249] Cf. Contract DG CLIMA.A.4/FRA/2011/0027

[250] Cf. Terms of reference for "European Water conference 2009 on public participation and river basin management planning (2 lots) - ENV.D.2/SER/2008/0041: OJ 2008/S 107 – 142552"
European Water conference 2009 on public participation and river basin management planning (2 lots)

conference[251] € 200.000.) The administrative burden for the Commission would relate to i) managing the contract, ii) discussing the details of the program and background information provided, iii) briefings, iv) participation at the event, v) report back and approval of the minutes. For Member States the administrative burden would relate to i) participation at the event, ii) reporting back and disseminating the gained information and ii) in the case a presentation is given to setting up such.

Such events will not likely lead to new job creation[252], although it might require hiring climate change adaptation experts. However, as mentioned above, these additional costs would be outweighed by the benefits as events targeting non-experts and experts stimulate research and development and learning from each other. Moreover, it would drive innovation in the field of climate change adaptation in a broad spectrum of sectors, thus placing the EU well on the international market. Climate change mainstreaming into science and policy research will help the EU economy increase its resiliency against climate change. Addressing decision making under uncertainties by building upon experiences allows identifying good adaptation practices, drivers or triggering factors of successful actions. It also allows to discuss adequate management practices to deal with inherent uncertainty such adaptive management and/or adaptation pathways.

Conferences and workshops that publish summary documents provide information in a single, coherent way, allowing both policy makers and the public to inform themselves. Given that meetings bring together people from distinct parts of the EU, such an event enhances social skills of the attendance and allows to bridge language barriers. Through interaction, meetings enable the attendees to learn other people's cultures, traditions, languages, beliefs, values and customs, but also to make business contacts. This might foster individual, collective and organisational learning, leading to changes in organisational practices and culture, improvements in managerial styles, better communication and co-ordination between and within ministries might result in more efficient decision making. Providing necessary skills for the successful implementation of legislation and good practice will lead also to improvements in the quality and performance of decision making although these cannot be quantified. This is an important pre-requisite for developing European policies further.

Increasing interaction between scientists and end users (policy makers, representatives, consumers) has the potential to improve the critical evaluation and the integration of research findings, clarify expectations of different stakeholders and SPIs provide a platform where questions can be raised and positions clarified (Totlandsdal, et al, 2007). The benefits of SPIs rest on how often stakeholders meeting and the proper dissemination of research materials. For example, the development of the AIRNET Thematic Network (SPI on air pollution) was found to have facilitated the development of new networks within and across

[251] Cf. Terms of reference for "Service contract to support the impact assessment of the blueprint to safeguard Europe's waters (3 lots) -ENV.D.1/SER/2011/0015: 2011/S 80 - 130818 (23/04/2011)"
Service contract to support the impact assessment of the blueprint to safeguard Europe's waters (3 lots)
[252] However conferences have a positive impact on the economy of a region.

the various scientific disciplines and policy-makers by establishing sub working groups, publishing papers including non-technical summaries and organising meetings (ibid).

SPI working groups can also help to mould or better structure future research needs. The SPI group for the Water Framework Directive carried out a prioritisation exercise regarding research needs between 2010 and 2012 to support the work of the other working and expert groups in the CIS process of the WFD. This exercise brought together 150 participants from 15 MS, of with 35% were from the scientific community and 65% from the WFD "end-users", leading to the identification of 59 priority research areas and 180 specific research issues[253]. Another important outcome of science-policy interfaces is that they promote the dissemination of already available research outputs to avoid repeating research that has already been done. Under the mandate of the SPI for the implementation of the WFD, the group carried out an inventory of knowledge related to the topics initially prioritised. Scientific research projects can occur in isolation of other projects, so SPIs can bring together the experiences and knowledge to other researchers and policy-makers to ensure that research is better taken up and not "forgotten". The environmental impacts of hosting meetings and conferences would be the same with or without the inclusion of climate change. Indirect positive environmental impacts can be expected due to improved decision making.

When asked to judge additional actions that could be considered at EU level to facilitate further knowledge dissemination and sharing, 76.40% of the respondents considered 'Support of pan-European discussion forums to exchange best practice' as relevant. This was the most often selected option, which indicates a high level of acceptance by stakeholders. 'Training and awareness' was also ranked as having a high potential by around 40% of respondents. 'Better involvement of the policy-making community' and 'strengthening the science-policy interface' was also well-ranked: 81.3% of respondents ranked this option as either having 'more potential' or 'high potential'.

6.2.4.3 Propose a legal action to set up national information platforms on adaptation and link them to Climate-ADAPT

Description of the options

Under this option the Commission would force Member States to develop national information platforms. As mentioned before several Member States have already developed national adaptation platforms. Existing portals are already web-linked to Climate-ADAPT and new ones mandatory required by the Commission under this option are to be expect to be linked as well.

[253] Science-Policy Interface (SPI) activity on priorisation of research needs, knowledge availability and dissemination for the Working Group E (Chemical Aspects) 2010-2012. Available at: https://circabc.europa.eu/.

Given that many of the climate change impacts take place at local level and the identified language barriers, such national platforms could be seen as valuable tools for knowledge dissemination and information sharing on the national level.

Assessment of the option

National information platforms for adaptation have a clear benefit in bringing together national information and providing it together with guidance for national, regional and local planners (cf. the amount of users in Figure 63). In cases where national platforms already provide IT-based analytical tools or databases for impact, vulnerability and adaptation assessment (e.g. adaptation measures inventories, interactive maps on impacts, etc.) benefits could result from the fact that climate change information is taken into account at an early stage of the planning process. Providing in some cases a high level of details in CC impacts is very important for adaptation in the local level.

Such platforms on the national level can also avoid competition and duplication of efforts (e.g. data gathering, data cataloguing, assessment of adaptation option, etc.) and enhancing complementarities between the various systems. This is in particular an important issue in countries with decentralised research activities or federal structures.

In the Nordic countries the development of national platforms was driven by the fact that apart from projects and networks, very little cooperation has taken place between national authorities due to the lack of an identified focal point for climate change adaptation[254]. Such platforms could strengthen the national cooperation.

Finally the information can be made available in the national language and therefore reach a broader range of stakeholders. However it should be noted that this multilingualism will be the major challenge in integration the information into Climate-ADAPT. While datasets could be linked following certain standards (cf. option “Promoting interfaces between Climate-ADAPT and other relevant databases and climate services”) all textual information would require translation into English or at least English summaries. Considering the amount of information that is already provided by the existing platforms, such translation would take considerable resources. The effort required could be reduced if the Commission and the Member States would agree on certain protocols and standards for textual information exchange.

Such platforms are costly to develop and financial and administrative barriers may hamper their effective development. For example in Germany a national platform (KomPass[255]) was developed together with the NAS. The start-up costs including the development of the platform and research dedicated directly to NAS was 48 million Euros. The highest portion of

[254] http://www.nordregio.se/en/Metameny/About-Nordregio/Research--Development/Geographical-scope-we-cover/Norden/Addressing-climate-change-adaptation-at-the-Nordic-level/
[255] http://www.anpassung.net

expenditures was dedicated to research, especially climate change modelling at approximately 40 million Euros. It is important to note that these costs arose within a time span of nearly 10 years. Additionally, this does not include costs of the salaries of responsible Ministry and Ministries working in inter-ministerial working groups. One of the reasons for developing Climate-ADAPT was the lack of financial resources in the Member States[256].

Another crucial issue is the agreement on common quality standards across Member States and ensuring that the national and EU level information is following them.

6.2.5 Effectiveness, efficiency and coherence of the options addressing problem 2

All the options support the objective to “Better informed decision making” by adding additional paths to knowledge dissemination. In particular, the option on SPI fostering meetings that allow a very direct exchange between MS, the Commission and stakeholders, private companies and the research community are viewed as highly effective tools for dissemination and improving the knowledge base for decision making. This kind of exchange is seen as more effective than just providing information, data or knowledge on Climate-ADAPT or national platforms. This can be argued by the fact that human interaction is more effective than just information provision (IAP2, 2007). However, the constant provision of data in a fixed platform is essential as it assists decision makers in analysing a situation at any stage of the decision making process.

The policy option fostering events also support the achievement of the facilitation of the objective “Increasing the resilience of the EU territory”. They all facilitate the coordination of developing adaptation strategies at all levels of governance and the inclusion of cross-border considerations. These meetings provide a good platform to share experiences and to discuss solutions for common problems. Events allow personal, institutional and organisational learning.

It is assumed that better information and better access to information will support also mainstreaming of adaptation to climate change into other policy areas and sectors. However, the level of impact will mainly depend on other factors, such as political willingness, financial capacity and public pressure. It is therefore difficult to assess to which extend the presented policy options will support the overall mainstreaming process.

Impacts on the objective ” Increasing the resilience of key vulnerable sectors“ for all options except “Improve Climate-ADAPT beyond BAU by regular voluntary updates by MS on adaptation activities, information on insurance and business, and on national risk assessment” are considered marginal, even if an improved knowledge base might allow

[256] http://ec.europa.eu/clima/tenders/2011/208209/clearinghouse_concept_note_en.pdf

further developing existing or new market based instruments. However an improved knowledge base might also strengthen the adaptive capacity of the private sector. Positive impacts on the market objective can be expected from the option “Improve Climate-ADAPT beyond BAU by regular voluntary updates by MS on adaptation activities, information on insurance and business, and on national risk assessment”, as this option clearly foresees a strong involvement of the private sector, giving them a platform for exchange.

In terms of (cost-) effectiveness of the options, it can be assumed that options that are using existing structures, such as existing workshops or SPI, are more effective than those that require new structures (e.g. Support annual Climate-ADAPT conferences focusing on the latest developments on adaptation science and policy and on building the bridge between science and policy that Climate-ADAPT strives to form). Reporting to Climate-ADAPT or national platforms increases efficiency in data provision and reduces efforts to search for data in various places due to the application of the one stop one shop principle. However, there are additional costs for reporting.

All the options are considered to be coherent with other EU policy objectives such as the ones set out in the HORIZON 2020. It will also support the aims set out in the seventh Environment Action Programme (7EAP), which aims to improve evidence based environmental policy making. The options will also support the EU 2020 target that 3% of the EU's GDP should be invested in R&D. It will also support the Commission’s intention to increase the proportion of climate related expenditure to at least 20% in the MFF.

6.2.6 Comparative table of the options addressing problem 2

The options set out to address the knowledge base are not contrasting or alternative options. None, one or all of them could be taken forward.

Table 46 compares and summarises how the options contribute to the effectiveness of achieving the operational objectives of the strategy and to the overarching objectives of improving efficiency and coherence.

Table 46: Comparative table of the options addressing problem 2

Options	Economic, social, and environmental impacts	Effectiveness			Efficiency	Coherence	Acceptability
		Objective 1: Better informed decision making	Objective 2: Increasing the resilience of the EU territory	Objective 3: Increasing the resilience of key vulnerable sectors			
No policy change		0	0	0	0	0	0
Improve Climate-ADAPT beyond BAU by regular voluntary updates by MS on adaptation activities, information on insurance and business, and on national risk assessment	- (additional costs for reporting and quality assurance, but saved costs for the user for collecting information + better information provision ≈ no environmental impacts)	+(better access and dissemination of information, provides a forum for exchange)	+/? (can improve decision making and the consideration of adaptation, but there is quite some uncertainty as other factors tend to be more important)	+ (specific involvement of the private sector foreseen, allows better	+ (increases efficiency in data provision and reduces efforts to search for data in various places. Additional costs for reporting)	++ (supports the Horizon 2020. EU 2020, 20% MFF and 7EAP objective)	++(there was a high level voluntary reporting when the first request by the COM was sent out to MS and the public consultation concluded that this option is favoured)
Set up and liaise with events such as conferences and meetings to support the exchange between science	- (additional costs for new events + increased interaction and exchange ≈ marginal	++(better access and dissemination of information, provides a forum for exchange)	+/? (can improve decision making and the consideration of adaptation, but there is quite some uncertainty as other	≈ (no impact)	+ (requires new structures, but costs are low)	++ (supports the Horizon 2020. EU 2020, 20% MFF and 7EAP objective)	++ (such approaches are more and more often discussed among scientist and policy

Options	Economic, social, and environmental impacts	Effectiveness			Efficiency	Coherence	Acceptability
		Objective 1: Better informed decision making	Objective 2: Increasing the resilience of the EU territory	Objective 3: Increasing the resilience of key vulnerable sectors			
and policy in the field of climate change adaptation	environmental impacts)		factors tend to be more important)				makers)
Propose a legal action to set up national information platforms on adaptation and link them to Climate-ADAPT	- (additional costs for reporting and quality assurance, but saved costs for the user for collecting information + better information provision ≈ no environmental impacts)	+(better access and dissemination of information)	+/? (can improve decision making and the consideration of adaptation, but there is quite some uncertainty as other factors tend to be more important)	≈ (no impact)	+ (increases efficiency in data provision and reduces efforts to search for data in various places. Additional costs for reporting)	++ (supports the Horizon 2020. EU 2020, 20% MFF and 7EAP objective)	- (The acceptance of this option will be limited as many MS already have a national platform and the need for legal action is not seen)

Magnitude of impact as compared with the baseline scenario (the baseline is indicated as 0): ++ strongly positive; + positive; – – strongly negative; – negative; ≈ marginal/neutral; ? uncertain; n.a. not applicable

6.3 Problem 3: Strengthen adaptation efforts at all levels and enhance co-operation

6.3.1 Problem definition

The objective of the EU's Adaptation Framework is to improve the EU's resilience to deal with the impact of climate change. The framework respects the principle of subsidiarity and supports overarching EU objectives on sustainable development. In order to strengthen adaptation, three areas of action have been identified 1) national level, 2) cross-border issues 3) regional and local level. The first and third area of action are also stressed by Article 4 of the UNFCCC, which stipulates that every effort must be made to adopt national or regional adaptation strategies.

National adaptation efforts

Since the adoption of the White Paper, some efforts have been made at Member State level. 14 EU Member States have adopted a national adaptation policy (strategy and/or plan) to date and others are in the process of establishing their strategy. Overall, current National Adaptation Strategies (NAS) are comprehensive and well-established, some even set out concrete action plans, namely Finland, Germany, Denmark, France and Austria. All NAS appear to be intended as evolving documents that will be reviewed and updated to take account of advancing climate change science, research and technology. However, some gaps have been identified:

- Not all Member States have a national adaptation strategy.
- The level of effort and the level of detail provided differ widely among Member States.
- None of the national adaptation strategies in place deal with employment or social issues.
- The funding of adaptation options remains vague in many cases.
- There are still some political barriers to invest in adaptation in certain sectors.

Cross-border and transnational adaptation efforts

Direct and indirect impacts (e.g. to floods, droughts, pest and diseases) of climate change are largely cross-border in nature and create interdependencies between Member States. Sectors/policy areas primarily affected by large-scale effects of climate change are water management (including marine), soil, biodiversity, agriculture, forestry, health, energy, transport, and disaster risk reduction. Also, several adaptation measures (e.g. monitoring, change in transport routes) require cross-border and/or transnational cooperation. Cross-border and transnational issues are also related to disaster and risk management, both in terms of early warning systems and civil protection and emergency aid.

Trans-boundary issues are rarely covered in NAS with only one out of the 13 NAS currently adopted addressing them. Although large-scale climate change effects (e.g. flooding events) are well recognized, there are hardly any institutional or legislative settings to foster cooperation across country borders on issues of common interest or risks. Mostly recognized and addressed are transboundary issues in the water sector, as there is a mandatory requirement under the WFD and MSFD to do so. Inland water is also treated in a trans-boundary manner under the UNECE Water Convention. The UNECE further encourages the ratification of the Convention on Environmental Impact Assessment in a Trans-boundary Context, which sets out the obligation to assess the environmental impact of certain activities, as well as to notify and consult each other on all major projects under consideration that are likely to have a significant environmental impact across borders.

However, some cross-border activities addressing climate change and jointly developing adaptation responses are already taking place in European macro-regions, such as in the Alpine Space, the Carpathians, North West and South East Europe, the Baltic sea and under the Danube strategy. Another cross-border activity at regional level is the currently on-going development of an adaptation strategy for the Pyrenees. All of these large-scale activities involving several countries receive funding from the EU.

The European Commission provides also several funds that foster cooperation between Member States and regions in terms of climate change. These funds are i) the Cohesion fund; ii) the European Regional Development Fund (ERDF) iii) European Social Fund (ESF) and iv) LIFE+ funds. Several transnational cooperation projects on adaptation have been initiated over the last years[257]. They are typically partially financed by EU-funds such as the LIFE+ and INTERREG programmes. INTERREG activities have been initiated in all regions in Europe. However, most focus on North-West Europe and the Alps while fewer adaptation projects address the Mediterranean and Eastern Europe.

Regional and local level

In 2009 the European Commission contracted the development of guidelines for how to set up regional adaptation strategies (Ribeiro, et al, 2009). Based on the figures from July 2011 to July 2012 (744 download of these guidelines) it can be assumed that these guidelines have attracted quite a broad audience and it can be assumed that they have been used in

[257] An overview of on-going and finalized projects can be found on CLIMATE-ADAPT: http://climate-adapt.eea.europa.eu/web/guest/transnational-regions

practice (e.g. the Pyrenees region covering both, Spain and France used the guidelines for their work[258]).

Some information was provided by Member States on the countries webpages on Climate-ADAPT[259] on a voluntarily base in 2011. Most of the local actions reported seem to be triggered by research programmes, either on national or EU level. Many EU Member States also established databases on their national climate change website that collect and present good adaptation practices at regional and local level. On the policy level, only Denmark is particularly focusing its adaptation efforts on municipalities, with all of them having to prepare climate change adaptation plans within the next 2 years.

Regional adaptation initiatives have also been set up, steering research activities and developing sectoral actions. For example, the Brittany region in France carried out a study[260] about the evolution of climate change impacts towards 2030 to analyse different adaptation possibilities. In the region of Bourgone, its regional adaptation project is studying climate change impacts towards 2040 and has developed an adaptation strategy for each sector[261]. Similar work is being carried out in additional 5 regions in France. Regional level adaptation and mitigation strategies have been found in 10 regions in Spain, and each of the federal states in Germany have regional level adaptation strategies in place or in the process of development (5 states). The Pyrenees region also launched a regional adaptation strategy development process involving both sides of the Pyrenees (France and Spain) In addition the sub-national programmes, supra-national adaptation strategies have been developed in the Danube (e.g. "Climate proofing the Danube Delta through integrated land and water management"[262]) and in the Baltic[263].

A significant share of local adaptation activities takes place at city level. The issue has been addressed in detail in an EEA report in 2012 (EEA, 2012a), which provides a wide range of examples of local adaptation action in various European countries. Furthermore, there are many examples of cities in Europe that have adopted adaptation strategies or action plans or are in the process of developing them. A number of cities or city regions have initiated specific measures. It is also common to include adaptation measures in existing climate strategies or to develop strategies that cover both mitigation and adaptation. For example, Dublin's climate change strategy includes adaptation objectives that initiate, modify and

[258] Information based on personal communication with the Région Midi-Pyrénées and the project support team, lead by ACTeon.

[259] http://climate-adapt.eea.europa.eu/web/guest/countries

[260] http://www.developpement-durable.gouv.fr/Bretagne,554.html

[261] http://www.bourgogne.ademe.fr/adaptation-au-changement-climatique-en-bourgogne-boite-outils

[262] http://wwf.panda.org/what_we_do/where_we_work/black_sea_basin/danube_carpathian/our_solutions/freshwater/climate_proofing_the_danube_delta_through_integrated_land_and_water_management/

[263] E.g. through the INTERREG programme: www.baltcica.org and www.baltadapt.eu and through German funding: www.klimzug-radost.de

improve existing policies, and in Finland several municipalities and regions have climate strategies that cover mainly mitigation but address also to some extent adaptation. Several countries (for example CH, ES, FR, HU, NO, RO) have cities that form collaborative networks of climate change mitigation and adaptation activities with other cities (e.g. "The Cities of the Future"[264]. (RECC)[265]).

Given, that climate change impacts mostly unfold on the local level, adaptation actions are still very scarce. In particular for the regional and local level it appears that adaptation activities are mostly limited to research, but do not lead to concrete actions yet. The fact that less than 50% of Member States have a national framework for adaptation adopted might explain the limited uptake of concrete adaptation responses at regional and local levels.

Overall, there are several barriers that hinder adaptation efforts across all governance levels, including the lack of political will on federal and regional levels to support adaptation policies and concrete actions, limited funding to foster the uptake of adaptation measures proposed e.g. by research outcomes and/or related policies, little possibilities to exchange on good practices with other regions/countries on topics of mutual interest and generally a lack of a common understanding of what adaptation is versus climate change mitigation and targeted communication on this issue.

The results of the public consultation the EU Adaptation Strategy confirm the need strengthen adaptation efforts at all levels of governance. In response to a question concerning pressing issues that need to be addressed, respondents mentioned on the one hand that the EU should facilitate knowledge sharing, programmes supporting knowledge awareness and helping stakeholders exchange information at the local level. EU action is seen as especially important regarding transboundary issues. On the other hand, respondents felt that the individual Member States should rather focus on concrete regulatory and/or strategic actions to better account for regional differences. This too was confirmed by the public consultation results: just under ½ of participants selected reviewing EU legislation to facilitate mainstreaming as having added value.

6.3.2 No policy change

Under the no policy change scenario several more Member States (MS) will adopt a National Adaptation Strategy (NAS), leading to a better preparation in several Member States. They will likely vary in terms of scope, level of ambition and agreed financing of adaptation measures. Also the timeframe for adaptation will differ. Trans-boundary issues will remain a gap in most of the strategies. Some countries might develop sectoral approaches only,

[264] http://www.regjeringen.no/en/sub/framtidensbyer/cities-of-the-future-2.html?id=551422
[265] http://www.redciudadesclima.es/index.php/

covering only certain sectors, others might include adaptation in existing management plans such as biomass action plan, sustainable development plans, etc.).

In particular due to the lack of financing on the national level it is assumed that regional and local approaches will prevail. Communities, regions will develop their own approaches, leading to an in-homogeneous pattern of adaptation efforts within a Member State. This might lead to greater economic, social and territorial disparities counteracting with the community objectives on cohesion.

With no further policy action, many issues highlighted above remain to be addressed in an uncoordinated manner. Further, existing institutional settings at national level might be challenged by these complex and far-reaching trans-boundary issues, both in terms of appropriate instruments to foster cross-border and transnational cooperation (with potentially conflicting national legislation) and financial constraints with regard to burden sharing in case of extreme events.

Trans-boundary issues are more complex than issues mainly affecting national and sub-national issues because procedures, laws, etc. might vary from country to country. A lack of coordination on trans-boundary issues could potentially lead to conflicting adaptation responses and would not provide for an effective approach to tackle common risks. Under the no policy change scenario, mainly the water sector would develop transboundary cooperation further as the legal framework and the existing efforts would further be strengthened. Adaptation therefore would be further included in the river basin management plans.

Cross-border and transnational coordination will continue under the European Territorial Co-operation, but will remain mostly not to be linked with national and sub-national adaptation policy developments as having their focus on joint management of programmes and projects. Trans-European networks (TEN-T and TEN-E) will most likely start to take climate change implications into account when undergoing an Environmental Impact Assessment (EIA). A revision of the EIA Directive is on-going and the current proposal includes climate change considerations (EC, 2012k). Nevertheless, negotiations about the amendment could take some time and it will be years until the effects unfold through implementation on the national level.

It is difficult to estimate what these developments would mean in terms of social, environmental and economic impacts, but the following examples show that i) the losses were higher than what they could have been, had the affected MS been better prepared, and ii) the negative consequences went beyond the affected area and spilled over other MS.

- During the summer 2010, mean temperatures were between 4 and 8°C above normal during July and the two first weeks of August in Western Russia and Eastern Europe. It was the most extreme heat wave in the instrumental record of 1880-present for that region. The extreme heat and the absence of rain led to the worst drought conditions in more than 100 years and also to the worst wildfires in decades. Munich Re estimated 56,000 people died from the effects of this heat wave. This heat wave also led indirectly to an increase in the price of staple goods like pasta and bread all over Europe because Russia's wheat crops failed[266].

- In November 2005, Western Europe was hit by an ice storm which causes the death of 2 persons in Belgium, 800 km of traffic jam in the Netherlands and a train derailment in Scotland. It also broke 70 transmission towers and prevented 200.000 people from electricity for four days for some of them in Germany. In France, 20.000 people were out of electricity and many roads were blocked (Broström & Söder, 2007; Météo World, 2005).

- In February 2010, the storm Xynthia hit the French Atlantic coast. Its combination with the high tide and large waves caused the fail of flood defences, which led to the flooding of more than 50 000 ha. 53 people died because of the storm itself or the flooding and the cost of the damages is estimated around 2.5 billion €. Infrastructures and tourism also suffered from the storm but the cost is hard to estimate. Many flood defences that failed presented maintenance delay partly because maintenance responsibility was not always clear. In term of management, there was a big fail on population warning. People were aware about the risks of wind burst but the information about flooding was not clear enough and thus people were not prepared to it, which has sometimes led to deaths. (Slomp, et al, 2010).

- Major funding has also been put into increasing the capacity to combat forest fires in Europe. For example, Italy has Europe's largest fleet of aircraft and helicopters, and has on several occasions loaned out its planes to France and Spain. The high level of preparedness requires significant resources, but has shown good results: the year 2000 saw 6,600 fires destroy 58,000 hectares of forest, while almost the same number of fires in 2006 only destroyed 16,000 hectares (Swedish Commission on Climate and Vulnerability, 2007).

- In the last week of March and the first weeks of April 2006 many flood events have been recognised in Austria and in the Czech Republic. The important railway line from Vienna to the North (main connection to Brno, Prague, Berlin and Poland) had to be closed due to enormous damage on the permanent way. For 8 weeks it was not possible to use parts of the railway line and for six weeks longer only one of the two tracks could be used with a maximum train speed of 40 km/h. Seven month after the flood, at 13. November 2006, ÖBB started its normal operation in both directions. For

[266] http://www.ecad.eu/

the ÖBB[267] infrastructure manager the track closure due to the flood caused EUR 240,000- lost revenue by passenger trains and EUR 380,000- by freight trains (Maurer, et al, 2012).

6.3.3 Policy options addressing problem 3

6.3.3.1 Guidelines on developing adaption strategies

Description of the option

The guidelines aim to support EU countries with adaptation policy processes. They intend to provide a framework for generating the information needed to prepare, implement and evaluate a national adaptation policy. They shall foster a common understanding of key aspects relevant to any adaptation process and provides clear terms of references. Thus, they aim to deliver a common basis for cooperative adaptation activities between different actors/stakeholders concerned with climate change which deems necessary to avoid conflicts and make use of existing synergies.

Although there is no “one-size-fits-all” framework for adaptation in place, certain aspects of good adaptation are in common. The guidelines shall highlight these key issues to give direction on how successful adaptation policy processes should be carried out. In addition, they will present various adaptation approaches as good practice examples taken by European countries in order to foster knowledge transfer and lessons learnt. To allow wide uptake of the guidelines among European policy and decision makers, a pragmatic approach for adaptation will be presented.

Taking into account that a number of European countries have their national adaptation strategies and action plans already in place, the guidelines also put emphasis on providing support for the implementation and monitoring and evaluation stage as well as on showing how the EU can support national adaptation processes. Further, they provide the link to activities carried out in the area of disaster risk reduction (DRR).

Assessment of the option

The development of the guidelines for adaptation policies takes stock of on-going adaptation activities in EU Member States and beyond, draws on lessons learnt and experiences and specific exchange with stakeholders on certain issues of common interest.

Recommendations shall be relevant for all EU Member States throughout all policy process steps, independent from their state of adaptation efforts. Those countries, which already

[267] Austrian Federal Railways

have a National Adaptation Strategy (NAS) in place, will be finding information on how to tackle implementation challenges (e.g. such as financing, assigning clear responsibilities) and setting up appropriate mechanisms for monitoring and evaluation. Member States further advanced with adaptation might be already in the stage to learn from the implementation (e.g. FI) and start revising their NAS accordingly. This might be opening up key issues to re-consider throughout all steps of the policy process where the guidelines provide recommendations (e.g. one conclusion could be that there is a need to involve more stakeholders by setting up a broader stakeholder process; another conclusion might be that with evolving adaptation knowledge more and/or different adaptation responses might be needed). Other countries, which are still in the course of developing a national adaptation policy, will get support for current "state-of-the-art" key issues and the given examples to consider when preparing the ground for adaptation and policy development.

Thus, the guidelines will allow all Member States to prepare, implement and evaluate their adaptation policy in a cost-effective way as they will find detailed information on the process of adaptation as well as on methods and tools for reaching good adaptation. Practical examples on adaptation across Europe included in the guidelines strengthen the share of expertise and good practice. Compiling a set of recommendations for all steps of an adaptation process will also help to avoid "re-inventing the wheel", learn from (good and bad) practices, exchange on potential barriers and how to tackle them. Tacking stock of "state-of-the-art" adaptation knowledge and giving comprehensive recommendations for key issues to consider reduce time and resource intensive efforts that each Member State would have to invest otherwise to gather all relevant information. It became clear from the workshops organised with Member States to exchange on national adaptation policy processes that all face similar barriers and learning from each other can substantially reduce individual efforts and thus operating costs. Even only getting to know about activities and approaches addressing issues of common concern reduces time and financial efforts needed for single Member States. However, highlighting key issues and presenting various tools to approach them in the guidelines cannot substitute personal exchange of knowledge and experience. Nevertheless, making use of the guidelines will better inform policy makers about promising approaches throughout the policy process, where to find useful information and whom to contact for further details, based on the examples or references given. Cost savings for each Member State are thus mainly to be expected by proving a comprehensive compilation of all issues needed to be addressed for national adaptation policy making complemented with various tools and information sources.

Furthermore, if recommendations from the guidelines are taken up by Member States to develop, implement and evaluate national adaptation policies cost-efficiency can also be expected by addressing negative impacts from climate change before they even occur (cf. examples under the "no policy change" scenario). Preparing for a range of risks that are to be anticipated with climatic changes and developing preventive response actions will increase coping capacity and reduce potential damage costs. The more detailed a national adaptation policy is being developed considering a broad variety of key issues as highlighted in the guidance, the better a Member State is prepared for future challenges due to climate change. Furthermore, more efforts invested in a comprehensive adaptation policy will ease the implementation thereof and prepare all necessary mechanisms for monitoring and evaluation in advance, thus reducing costs at a later stage of the policy process.

Cost-efficiency can also be expected to be increased by sharing financial burdens of implementing adaptation measures as joint activities in a cross-border context.

Giving advice on linking adaptation efforts better to Disaster Risk Reduction will furthermore facilitate joint activities with natural hazard management and thus share financial efforts for preventive approaches to extreme events.

The above highlighted cost savings for Member States and potentially further stakeholders that make use of the guidelines clearly outweighs the one-time investment cost to develop the guidance, which is estimated to be between 50.000 and 90.000 Euros[268].

In terms of social implications, the guidelines can assist in enhancing the preparedness of Member States and the adaptive capacity of society, especially of those population groups that are most affected. Assuming that suggestions in the guidelines would be followed by Member States, large-scale impacts caused e.g. through extreme events such as heat waves that would highly affect vulnerable groups (e.g. children, elderly) can be reduced or even avoided. Social issues can be best tackled by involving stakeholders from all potential affected population groups throughout the adaptation policy development process. Taking into account recommendations from the guidelines for stakeholder involvement can thus ensure that no potential risks will be overlooked and social implications of climate change are dealt with in a preventive manner. Further, potential political conflicts over un-coordinated responses could be prevented when mechanisms are established to engage in cross-border cooperation. Exchange of good practices in dealing with climate change impacts would be fostered and brought to attention to a larger community. Emerging themes such as awareness raising and climate change adaptation communication are important to all Member States when it comes to taking up the national responsibility for enhancing adaptive capacity, especially for those population groups that are socially deprived.

Environmental impacts of providing guidance for adaptation policy processes and thus following common approaches are to be expected merely positive. By introducing a comprehensive process when setting up an adaptation policy a variety of environmental issues need to be assessed. Climate change as a cross-cutting issue unfolds various effects on a number of environmental systems (such as water, soil, biodiversity). Through dealing with all those issues an integrative manner, thus ensuring that cross-cutting issues and interdependencies are thoroughly assessed and developing appropriate adaptation

[268] Figures are based on the contracts No ENV.G.1/ETU/2008/0093R and CLIMA.C.3/SER/2011/0026

responses it can be assumed that this would long-term enhance the adaptive capacity of environmental systems.

As an outcome of the public consultation for the EU Adaptation Strategy respondents felt that 'guidance on developing national adaptation strategies' would have the most value added (60.25%) when asked to select which type of instruments would bring the most added-value in national adaptation strategies. Further 63.35% of replies considered that 'Enhance awareness and develop guidance on the transboundary adverse effects of climate change' was an action EU should consider. However, this option was less often chosen compared to 'Facilitating cooperation among countries' and 'providing EU funding to address transboundary adverse effects of climate change' (respectively 82.61% and 76.4% of the answers). This underlines, inter alia, that guidelines can provide an important framework for national adaptation policy making but does not substitute additional exchange of knowledge and experiences on a personal basis.

Representatives from Member States also widely agreed that the development of guidelines for national adaptation policy making would be of added value. They suggested that the guidelines should be generic to cover differences among Member States (e.g. different governance structures) but also specific in providing tools and recommendations. The guidelines should also provide support to the process of setting up national adaptation policies but also on key issues to be considered when implementing and monitoring/evaluating.

6.3.3.2 Use LIFE+ funding for cooperation and experience exchange in relation to the development and implementation of National Adaptation Strategies and climate risk assessments

Description of the option

The Commission proposal for a Regulation on the establishment of a **Programme for the Environment and Climate Action** (**LIFE**; EC, 2011u) encourages transfer of knowledge and experiences across Member States or among relevant stakeholders. The Article 15(c) includes among objectives of the climate action sub-programme the development of adaptation strategies and action plans at local, regional or national level. The LIFE programme can contribute to the development and implementation of Union policy and legislation on adaptation, including mainstreaming across policy areas, in particular by developing, testing and demonstrating policy or management approaches, best practices, and solutions, for climate change adaptation in transboundary areas (Art. 15a). This option encourages cross border and transnational cooperation, knowledge transfer and capacity development, facilitated by exchange of experienced staff. The aim of this option is to foster: 1) development of National Adaptation Strategies (NAS) in the Member States (MS) countries with no strategy in place or where its development is only in an initial stage; 2) development of regional strategies as platforms for a closer coordination of national adaptation strategies and harmonisation of therein included policies and measures.

Assessment of the option

Coordinated, inclusive and outcome-oriented climate adaptation is a far more effective and efficient way of delivering high quality results (Swart, et al, 2009). It ensures a better harmonisation of private and public, autonomous and policy-induced adaptation efforts across multiple sectors, policy domains, and geographic regions. The persistent financial and economic crisis though makes it difficult to confer necessary financial resources for the revision of existing and development of new and better tailor-made national climate adaptation strategies. The cross-border or trans-national adaptation strategies on the other hand prevent or reduce risk of negative spill-over of the effects of unilateral adaptations on other parts of the regions; and ensure effective adaptation policies for large-scale ecosystems, interconnected communities and conurbations (cf. also Ribeiro, et al, 2009, UNECE, 2009).

Building upon experience and knowledge from other countries where comprehensive adaptation strategies have already been adopted and are being implemented can reduce the time and resources needed. Staff exchange schemes are beneficial both for *outgoing*- and *incoming* partner institutions. Projects under this scheme can contribute to building new or strengthen existing networks and collaborations between Member States and associated countries and other third countries BMWI (2009). The proposed LIFE+ regulation for the next financing period offers the possibility to develop a proposal that involves knowledge transfer and capacity building across Member States. This will be associated with some administrative costs, which may be reduced by creating a roster of experts with required competences. The development of such a roster is eligible under activities listed under the Article 22 of the proposed LIFE 2014-2020 regulation. GHK et al. (2011) have demonstrated that the transaction costs of the LIFE projects are small; they estimate the costs of application for a LIFE+ (Nature) project to 12,000 Euro accounting for the involved administration and technical staff (ca. 0.6% of the project average size); and the costs of project management to 25,500 Euro (ca. 1.2% of project budget).

A coordinated approach to climate adaptation in the transnational region and the implementation of optimal measures and policies included therein are expected to preserve existing and may create new employment opportunities. Although the latter is hard to underpin empirically, because of the lack of in-depth assessments, it is reasonable to expect that coordinated adaptation efforts measures (e.g. flood risk protection) are adopted most efficient and effective, independently of the political boundaries. The joint strategy can foster better climate governance and increase public awareness of the expected climate change impacts in the region. Past experiences from the staff exchange schemes in other fields such as the Community Mechanism for Civil Protection, the International Research Staff Exchange

Scheme, and Twinning projects show high added value in terms of achieved outcomes, best practices sharing, and networking (EC, 2011z; CEI, 2011) .

The eligibility of the LIFE funding for the development of adaptation strategies and action plans can include obligation to apply good practices and guidance; cover all important sectors and ensure compatibility with the EU environmental policies; and foster transnational collaboration and cooperative problem solving. Furthermore, the Member States benefiting from the LIFE programme may be compelled to endorse and implement the strategy once devised. Currently, based on a limited sample of projects the estimated share of projects leading to legislative, policy or planning documents to be formally approved as a result of LIFE funded project is ca. 50% (GHK, et al, 2011).

When asked which actions could improve the use of EU funding for projects, 40% of respondents rated ‘Training and awareness’ as having a high potential and 60% rated it as either ‘medium potential’ or ‘high potential’. In the field of transboundary issues ‘Facilitation of cooperation among countries’ and ‘provide EU funding to address transboundary adverse effects of climate change’ were the most selected options with respectively 82.61% and 76.4% of the answers.

6.3.3.3 Use LIFE+ funding for Lighthouse projects and pilot implementation of cross-sectoral policies

Description of the option

The Commission proposal for a Regulation on the establishment of a **Programme for the Environment and Climate Action** (**LIFE**; EC, 2011u) encourages projects sets to develop, testing and demonstrate policy or management approaches, best practices, and solutions, for climate change adaptation in, but not limited to, *transboundary* areas (Art. 15a). Demonstration, pilot or lighthouse projects are a common form of best practice development/sharing and exploration of innovative solutions to intricate problems.

Among several innovations the proposed regulation introduces a new type of instrument with even greater potential to catalyse better environmental protection: the Integrated project (IP). The IP are designated to ‘improve the implementation of environmental and climate policy and their integration into other policies, especially by ensuring a coordinated mobilisation of other Union, national and private funds towards environmental or climate objectives’ (COM (2011) 874 final, p. 5). A typical IP would receive funding from several sources – Community, public and private – not only the LIFE programme. The co-financing rate of the latter can exceptionally by increased to 80%. The IP are best suited to serve as demonstration (lighthouse) projects, even if major break-through may be sometimes achieved in smaller projects. The IP will operate on a large regional or sub-regional scale or cross-sector manner. These projects could be tackling pressing issues of mutual concern in many EU countries and develop innovative solutions.

From among the topics that are suitable for *transnational lighthouse projects* (TLP) under the proposed regulation of LIFE 2014-2020 programme those which deserve particular attention include preservation and restoration of large scale, cross-border wetlands; assisted migration of species whose habitat is endangered by climate change; coastal and inland flood defence measures especially where unilateral risk reduction measures may increase flood risks upstream or downstream in other Member States (Article 7 of the Directive 2007/60/EC (EC, 2007a)); efforts to combat spread of invasive species; adaptation in cross-border conurbations and metropolitan regions; trans-boundary management of water resources; set-up and operation of translational environmental monitoring, early warning and alerting systems; adaptation of the critical cross-border infrastructure to increased intensity and frequency of climate extremes, etc.

Based on an assessment of on-going regional projects and considering the proposed legal framework of the LIFE+ proposal the following potential areas for lighthouse projects have been identified:

- Cross-border management of floods: The funded project should foster collaborative agreements based on the EU Floods Directive and the UNECE Model Provisions on Transboundary Flood Management; development of basin-wide forecast and early warning systems; knowledge and information sharing; and assessment of flood mitigation measures in particular of green infrastructure. The projects may also focus on an analysis of past significant flood events and ex-post assessment of the wider economic, social and environmental effects of these events. The assessment results should provide input into the envisaged European Flood Impact Database currently explored by the European Environmental Agency. Best practice example from the deployment of market based instruments to reduce or transfer risk should be developed.

- Trans-boundary coastal management: The funded projects should improve risk and vulnerability assessment and projections of future coastal change due to climate and other drivers, building upon the existing field observations, models and pilot experiments. They should develop a better understanding of the coastal communities' adaptation in the coastal areas. Interdisciplinary research is required to analyse complex natural-human sub-system interactions. Emphasis should be given to vulnerable and densely populated deltas and coastal cities. As several project for the Baltic and North Sea region exist, the focus should be on other regions. In-depth assessment of coastal adaptation options and knowledge/experience sharing should be promoted across the coastal regions[269].

[269] The research priorities draw on the recommendations in the IPCC 4AR – Parry et al. (2007).

- Critical infrastructure protection: The funded projects should explore alternative diagnostic stress-test approaches that identify conditions which may lead to a failure or disruption of critical infrastructure systems and explore a combination of hazards that may produce such conditions. Innovative risk and vulnerability assessment methods should draw on the recent advancement in disaster economics and take into account the full social welfare impacts of critical infrastructure failure. The projects should typically focus on a combination of critical infrastructures, including transnational and Pan-European transportation corridors, water and energy networks, information and communication systems, government services, banking and finance, health structures, food supply, and ecological and social networks whose disruption may lead to significant effects on vital social function, health, safety, security, economic or social well-being of people. The project should inform the European Programme for Critical Infrastructure Protection (EPCIP), the Directive 2008/114/EC, and the EU Strategy for Integrated European Infrastructures.

- Market-based water allocation instruments including tradable water entitlements: The funded projects should test in practice and demonstrate benefits and potential drawbacks of different water trading mechanisms (water banking/brokerage, open call, continuous double auction, futures and options) and arrangements (short- to long-term lease or permanent contracts, intra- and inter-basing transfers) typically through a number of policy pilot studies in, but not limited to, countries with permanent water scarcity and stress. The pilot studies should draw on and contribute to further development of the Guidance Document proposed in the *Blueprint for Safeguarding Water Resources* for 2014. Through policy trials performed over sufficiently long time spans (5-7 years or longer) funded projects should explore the basic traits of sustainable water markets, economic efficiency and social fairness of the instruments, institutional and other trade barriers, and (positive and negative) third-party and environmental effects. The expected results of the pilot projects should allow to identify areas/river basins in which water trading may yield good results, develop best practice examples and inform the legislative review of the Water Framework Directive (2000/60/EC), expected not later than in 2019. The funded projects could combine funding from the Horizon 2020 Programme, and resources from the European Regional Development Fund, European Agricultural Guarantee Fund and the European Agricultural Fund for Rural Development, in addition to funding from LIFE Programme.

- Adaptation to climate change in urban areas: The transfer of experiences from “early adapters” to other cities can be greatly facilitated by LIFE+ Lighthouse projects, the more so if cross-border co-operations between urban authorities is encouraged and cities are supported in their attempts to elaborate shared adaptation strategies that should include ecosystem services of urban green and blue areas, exchange experiences and build commitment for sustainable adaptation strategies. The funded projects may encourage knowledge and experience sharing in the areas of risk and vulnerability assessment and implementation of pilot adaptation measures, mainstreaming of adaptation planning into urban land use planning, building layouts, public procurement practices, natural resources management (green areas, water and wastewater management, improvement of air quality), and disaster risk reduction. Good practice examples should comprise both strategic approaches to assessment and implementation, including innovative strategies for conservation of green areas from urbanization and planning and implementation of innovative solutions, including, inter alia, the maximization of urban ecosystem services and the creation of win-win solutions with regards to the reduction of greenhouse gas (GHG) emissions.

- Forest management: The funded projects should elaborate ways and approaches to mainstream adaptation to climate change into forest management considering the aspects set by the new forestry strategy. The project should include different objectives of forest management (e.g. timber production, protection, nature conservation) and should bring together different types of forest owns (private and public). Furthermore, the projects should overcome barriers in the integrated assessment research to advance analysis on forest fires particularly in the Mediterranean. Two main issues should be addressed: i) land use/cover change (LULC) should be expressed as a function of socio-economic dynamics in addition to biophysical factors; ii) LULC classification should be further adapted to requirements of regional climate, fire-behaviour and risk-exposure modelling parameterization. Also, time variant LULC scenarios should be considered as the land-atmosphere coupling component in regional climate model simulations. These model advancements should meet the needs of the EU-authorities and allow a more efficient ex-ante and ex-post adaption to fire, through a better uncertainty characterization in fire management strategies.

Assessment of the option

Since 1992, the LIFE programme has financed some 3,115 projects with an EC contribution amounting to 2.7 billion Euros[270]. The benefits of the current programming period LIFE+ (2007-2013) are estimated to 600 million Euros/year. Traditionally, the LIFE programme served as a catalyst for improved implementation of EU environmental policies (EC, 2010j).

The economic costs and benefits of the Lighthouse projects (LHP) depend on the size and number of the projects and whether a critical mass for a significant change will be established. It has been proposed that the IPs should be equipped with substantial contribution from the LIFE programme. Medhurst et al. (2011) suggested that the average budged of the projects should be around 13 million Euros and the IPs should account for at

[270] As in October 2011.

least 50% of the expenditure. Thus one may deduce that around 5 IPs of the above size may be funded annually in the Climate Action sub-programme alone. As discussed earlier, the transaction costs of LIFE+ (2007-2012) projects are typically low and did not exceed 2%. The administrative burden of the LHP might be higher but still negligible compared to the achieved benefits.

GHK et al. (2011) estimate that 150 full time equivalent jobs have been created by all LIFE+ (2007-2013) Nature and Biodiversity projects, provided that the same involved in the survey was representative. Indirect social impacts of this policy option are likely higher. Because of their larger size, the social impacts of the LHP may be larger and will depend on the specific area of implementation.

Some concerns have been expressed in terms of access to the LIFE funding and participation in the LIFE projects. The proposed LIFE deregulation specifies the maximum co-financing rate as 70% or, by way of exception for some project types only, as 80% of the eligible costs. In addition, the personnel costs related to permanent staff not recruited for the scope of the project might be either limited or excluded. In an opinion from 25 April 2012, the European Economic and Social Committee has criticised this rule on reason of harming small civil society organisation whose involvement could in this way be prevented or limited (EESC, 2012).

The LIFE+ Programme (2007-2013) has improved conservation and restoration of some 4.7 million hectares of land, supported environmental improvements of ca. 3 mil ha area, and played a vital role in increasing awareness, good governance and public participation (EC, 2011z)[271]. Transnational and interregional co-operation in environment and climate adaptation provide high added value and ranks among the priority actions for the Community policies.

The environmental benefits of coordinated climate adaptation strategies and, more importantly, action plans included therein, and lighthouse projects will be significant and ubiquitous. The EU added value for transnational geographic regions is evident. Transnational cooperation can contribute to harmonisation of climate change adaptation efforts across Member States and ensuring comparable breadth and depth of the respective policies. The proposed regulation foresees a geographic balance of the funded IP taken into account principle of solidarity and effort sharing.

Transnational and interregional co-operation in environment and climate adaptation provide high added value and priority action for Community policies.

The proposed regulation of LIFE 2014-2020 programme includes the option to purchase of land under specific conditions (Article 20). This provision may enable transnational

[271] As in October 2011.

environmental restoration projects similar in scale to the Everglades Restoration Plan in central and southern Florida that consists of purchasing privately hold agricultural land in order to restore wetlands able to retain 1.2 cubic kilometres of water.

6.3.4 Effectiveness, efficiency and coherence of the options addressing problem 3

The main objective of the two sub options is to increase the adaptive capacity and adaptation efforts at national level. Therefore, both options clearly contribute to increasing the resilience of the EU territory. While the positive impacts of the LIFE+ policy options can be ensured throughout the given legal framework, the extent of the application of the guidance is dependent on the use and the specific circumstances within a MS. The extent –in particular the crossboarder impact - will depend on the project design. This refers to the specific objectives as well as to the sectorial and geographical coverage. Depending on these factors, mainstreaming and or cooperation might more likely take place on the local or regional level. On the other hand, LIFE+ has already been used to mainstream adaption at the national level (e.g. developing a NAS for Malta) and some coss borader projects have been taken place (e.g. CHAMP[272]). These design factors will also define the contribution to the knowledge and market objective. The projects can be used to strengthen the knowledge base and could therewith also contribute to the objective of "Better informed decision making". Outside the project area, the magnitude of impacts depends on how well the dissemination strategy is designed. If the private sector (in particular SMEs) is encouraged to get involved in the funded projects, a positive impact on the market objective can be reasonably assumed. In any case, LIFE+ will contribute to the facilitation and cooperation objectives, as the terms of reference require interaction between different stakeholders and bodies.

It cannot be guaranteed, however, that all MS will follow the guidelines on developing adaptation strategies, in particular those who have already developed a NAS. Hence, in these cases the impact towards mainstreaming might be marginal. This uncertainty also applies to the first two objectives. The guidance might be the starting point for new cooperation efforts and the exchange of knowledge. A similar experience was made when developing guidance documents for the implementation of the Water Framework Directive, which requires transboundary cooperation. Several MS did not follow these guidances[273].

The efficiency of the guidelines is clearly determined by its uptake. From a cost effective point of view, and considering a high uptake, this option can be considered as highly effective. Low costs for development can trigger greater efforts in adaptation. The sub option

[272] For details cf. http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3245
[273] Cf. various reports at http://ec.europa.eu/environment/water/blueprint/index_en.htm

focussing on experience transfer across Member States or relevant stakeholders is considered as highly efficient as similar approaches (e.g. Exchange in FP7, Twinning) in other policy areas have been used for several years in the EU already.

The option promoting guidelines on developing adaptation strategies is coherent with the better regulation objectives of the EU, which aim for:

- Working more closely with Member States to ensure that better regulation principles are applied consistently throughout the EU by all regulators;
- Reinforcing the constructive dialogue between stakeholders and all regulators at the EU and national levels.

Life+ provides specific support for developing and implementing Community environmental policy and legislation, in particular to the objectives of the proposed Seventh Community Environment Action Programme (7th EAP)[274]. Environmental protection is one of the key dimensions of sustainable development of the European Union.

6.3.5 Comparative table of the options addressing problem 3

The options are not contrasting or alternative options. None, one or all could be taken forward.

The following table compares and summarises how the options contribute to the effectiveness of achieving the operational objectives of the strategy and to the overarching objectives of improving efficiency and coherence.

[274] http://ec.europa.eu/environment/newprg/pdf/7EAP_Proposal/en.pdf

Table 47: Comparative table of the options addressing problem 3

Options	Economic, social, and environmental impacts	Effectiveness			Efficiency	Coherence	Acceptability
		Objective 1: Better informed decision making	Objective 2: Increasing the resilience of the EU territory	Objective 3: Increasing the resilience of key vulnerable sectors			
No policy change		0	0	0	0	0	0
Guidelines on developing adaptation strategies	≈/+ (marginal costs for the development but costs savings can be achieved due to drawing on lessons learned from others ≈ marginal social and environmental impacts)	≈ to ++/? (depending on the acceptance it provides good practice examples and insights on different MS approaches, cooperation within a MS will be triggered. In some cases cooperation between MS might result, because of requests to the examples provided)	≈ to++/? (the main objective is to give guidance on how to mainstream, but the level of uptake is a limited factor)	≈ (issue is only marginally addressed)	≈ to++/? (depends on the uptake)	+/? (contributes to the better regulation and environmental protection objectives)	++(high acceptance as such a guidance was requested several times during stakeholder workshops)
Use LIFE+ funding for cooperation and experience	+ to ++ (for all impacts depending on the extent MS	+ to ++ (within the LIFE+ project area, knowledge can be	+/++ (depending on the extent to which the MS include CCA	+ (depending on which stakeholders are invited to	++ (former LIFE+ project have	++ (Environmental protection is one of the key	++ (the LIFE programme has a high acceptance

Options	Economic, social, and environmental impacts	Effectiveness			Efficiency	Coherence	Acceptability
		Objective 1: Better informed decision making	Objective 2: Increasing the resilience of the EU territory	Objective 3: Increasing the resilience of key vulnerable sectors			
exchange in relation to the development and implementation of National Adaptation Strategies and climate risk assessments	take advantage of the funding to exchange info)	increased and cooperation of different parties facilitated. Outside the project area it is depending the dissemination strategy)	into their information exchange activities, mainstreaming on MS level or regional level can be achieved. Sectoral coverage might vary)	participate. It is possible that private sector stakeholders are included	demonstrated a high efficiency)	dimensions of sustainable development of the European Union)	since it was set up)
Use LIFE+ funding for Lighthouse projects and pilot implementation of cross-sectoral policies	+ to ++ (for all impacts depending on the type of project)	+ to ++ (within the LIFE+ project area, knowledge can be increased and cooperation between the different parties facilitated. Outside the project area it is depending the dissemination strategy)	+/++ (depending on the focus of the project mainstreaming on MS level or regional level can be achieved. Sectoral coverage might vary)	+/? (depending on the future design of the projects. There is a possibility to involve private market players)	++ (former LIFE+ project have demonstrated a high efficiency)	++ (Environmental protection is one of the key dimensions of sustainable development of the European Union)	++ (the LIFE programme has a high acceptance since it was set up)

Magnitude of impact as compared with the baseline scenario (the baseline is indicated as 0): ++ strongly positive; + positive; – – strongly negative; – negative; ≈ marginal/neutral; ? uncertain; n.a. not applicable

6.4 Problem 4: Mainstreaming of CC adaptation considerations in EU policies

6.4.1 Problem definition

Climate change is a key concern for the European public. Just over half (51%) of citizens consider climate change one of world's most serious problems, and 20% of citizens consider climate change the world's single most serious issue (Eurobarometer, 2011b). The need to mainstream adaptation into EU policies has been confirmed by the wider European public. The majority of citizens consider that action to protect the environment should be carried out at European level. In a survey by Eurobarometer (2011a), 81% of citizens support environmentally-focused legislation as a way to help solve problems, and 64% believe that changes should be made at the European level. Majorities in nearly all Member States – except the UK, Finland and Austria – believe that decisions concerning the protection of the environment should be made jointly within the EU. The strongest support for joint decision-making can was found in Cyprus (81%) and Spain (78%) (ibid).

The objective of mainstreaming climate change adaptation is to ensure that sectors are able to carry on with their core tasks even within the circumstances of a changing climate. Therefore, the EU White Paper on adaptation (EC, 2009a) strongly recommends climate proofing of key EU policy areas. This objective was renewed within the EU 'Strategy for smart, sustainable and inclusive growth' ('Europe 2020' (EC, 2010d)), through its 5 headline targets and 7 flagship initiatives, also highlighting the importance of mainstreaming and noting in particular that 'We must strengthen our economies' resilience to climate risks, and our capacity for disaster prevention and response'.

An assessment carried out in the context of the service contract supporting the development of the EU Adaptation Strategy has shown that mainstreaming efforts in some key EU sectors have been achieved in line with what was proposed in the White Paper and beyond: A more detailed assessment of what has been achieved since the adoption of the White Paper can be found in Annex 9. These efforts can be distinguished between legal issues, funding issues and "soft" measures:

- The consideration of adaptation is legally binding in the context of marine and inland water issues[275], forestry[276], Disaster Risk Reduction[277], and transport[278]. Eleven of 19

[275] Cf. Council Directive 2008/56/EC "Marine Strategy Framework Directive" (EC, 2008k), EU Regulation No 1255/2011 establishing a Programme to support the further development of an Integrated Maritime Policy (EC, 2011q) and Directive 2007/60/EC on the assessment and management of flood risks (EC, 2007f)

[276] Regulation (EC) 2152/2003 (EC, 2003d) forces the establishment of a Community scheme on monitoring of forests and environmental interactions to protect the Community's forests

[277] COM(2011) 934 final - Decision of the European Parliament and of the Council on a Union Civil Protection Mechanism (EC, 2011a)

countries responding to a survey by the UNISDR on climate change adaptation stated that they have disaster risk reduction legislation which enables climate change adaptation to be part of national or local work on disaster risk reduction. Almost all of countries agreed that linking DRR and climate change mainly occurred as a result of enacting legislation[279]. In addition legal proposals considering climate change adaptation have been tabled by the Commission in the area of agriculture[280] and forestry[281], energy[282], transport[283] and research. Climate change was one of the four key policy areas identified in the Communication on "Halting the loss of Biodiversity by 2010 – and beyond" and the Biodiversity Action Plan includes the objective "to support biodiversity adaptation to climate change". Further, a new forest strategy, a proposal for a new plant health law, a dedicated legislative instrument on Invasive Alien Species[284], a proposal for a blueprint to safeguard European waters (EC, 2012m) and a framework for Maritime Spatial Planning and Integrated Coastal Zone Management are expected to be adopted by 2012. All of these actions are foreseen to address the issue of climate change adaptation.

- In the context of funding one major element for future mainstreaming is laid down in the next Multi-annual Financial Framework (MFF). The Commission has committed that climate related expenditures will represent at least 20% of the overall EU budget and will be tracked according to a specific methodology.

- Soft measures refer to the development of guidelines, voluntary agreements and internal Commission procedures. Guidelines for climate change adaptation have been developed for the water sector, for the development of national adaptation strategies, for disaster risk reduction (various) and energy. There is also a voluntary agreement that climate change adaptation will be included in the next cycle of river basin management plans. Finally, it was agreed that Member State programs for the five CSF-Funds[285]covering the period 2014-2020, will be subject to internal consultation within the different Commission services, among others Directorate General for Climate Action. The overall objective of this consultation is to mainstream

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[278] Decision TEN-T Guidelines (661/2010/EC). (EC, 2011k)
[279] http://www.unisdr.org/archive/28860
[280] Cf. Legal proposals for the CAP after 2013 under http://ec.europa.eu/agriculture/cap-post-2013/legal-proposals/index_en.htm
[281] Regulation (EC) 2152/2003 (EC, 2003d) forces the establishment of a Community scheme on monitoring of forests and environmental interactions to protect the Community's forests
[282] Proposal for a regulation of the European Parliament and of the Council establishing the Connecting Europe Facility, COM(2011) 665/3 (EC, 2011r)
[283] COM(2011) 650/2, proposal for a Regulation of the European Parliament and of the Council on Union guidelines for the development of the trans-European transport network (2011s)
[284] http://ec.europa.eu/governance/impact/planned_ia/docs/2012_env_011_invasive_alien_species_en.pdf
[285] European Regional Development Fund (ERDF), European Social Fund (ESF), Cohesion Fund (CF), European Agricultural Fund for Rural Development (EAFRD), and the European Maritime and Fisheries Fund (EMFF)

climate change into Member States Partnership Contracts and Programmes for the CSF-Funds 2014-2020. Finally, with the setup of the Adaptation Steering Group a specific forum to i) support the Commission in the preparation of the Communication on Mainstreaming Climate Change Mitigation and Adaptation into Community policies; ii) carry out preparatory work on the design of national adaptation strategies; and iii) to contribute to the implementation of the EU's adaptation framework.

Based on the assessment the following conclusions can be drawn:

- Only a limited number of legislative acts are considering climate change (cf. above). However, the survey showed that mainstreaming adaptation into a much wider set of policies and legal actions is needed.
- Mainstreaming has not yet taken place in social and education policies, tourism, fisheries, insurance[286] and trade. It has also not taken place in the framework regulating standards (cf. problem 5) and the private sector (cf. problem 6).
- In the case of energy (only TEN-E), transport (only TEN-T) or health only limited efforts have been achieved so far.
- While some policies are currently under review, others are supposed to enter into a review process only shortly before 2020 (e.g. the WFD, the MSFD). Some Legislation has no built in review process for legislative amendments (e.g. Directive 2005/44/EC on harmonised river information services (RIS) on inland waterways in the Community, Directive 2008/96/EC on road infrastructure safety management, Directive 2005/89/E concerning measures to safeguard security of electricity supply and infrastructure investment). The latter is particular an issue for the construction, transport and energy sectors which are most vulnerable to climate change.
- Mainstreaming climate change adaptation into "horizontal legislation" such as the EIA and SEA Directive would mainstream adaptation into a broad range of sectors, but this has not been achieved so far.
- In relation to funding there is a lack of guidance on how to use the proposed CSF funds, but also other funds such as LIFE+ for mainstreaming climate change adaptation. Further, the White paper proposed guidelines on adaptation and coastal zone management. These guidelines have not been developed so far. Closing this

[286] Insurance laws - those relating to the terms of the insurance contract itself - are largely outside the realm of the EU insurance directives and are prescribed by the legal framework in each member state. However EU insurance legislation is currently going through a period of fairly dramatic change with the potential implementation of the Solvency II Framework Directive 2009/138/EC (Solvency II) and a revised Insurance Mediation Directive (IMD2) in the next few years.

gap is of particular importance for adaptation actions at the local level, which are often financed by EU funds.

Another issue in relation to mainstreaming are conflicting objectives set by other policy areas. For example with the Directive 2009/28/EC on renewable energy, to be implemented by Member States by December 2010, ambitious targets for all Member States have been set. The EU aims to get 20% of its energy from renewable sources by 2020. Considering that the electricity demand in Europe[287] is increasing steadily, this target is becoming even more ambitious. With a decrease in water resources due to climate change in many areas of Europe hydropower and bioenergy production will suffer. In other words achieving this renewable energy objective will counteract to adaptation efforts.

Responses from the public consultation identified the 'contradictory requirements from different EU policies' as a barrier. Moreover, several respondents, considered 'coordination with other EU strategies and policies by focusing on cross-cutting issues and approaches and mainstreaming of Adaptation within key EU policies' as one of the three most pressing issues to be addressed by the EU.

6.4.2 No policy change

Under the no policy change scenario it is assumed that mainstreaming activities remain implemented on an ad hoc basis. No priorities in terms of sectors will be set and no specific mainstreaming legislation (e.g. mandatory sectorial coverage) would be proposed. Under this scenario water, environment, agriculture and forestry would further develop their own agendas to integrate climate change and to adapt. Other sectors such as health, social or fishery will clearly lack behind and only a few legal attempts can be expected.

Even if some more guidelines are expected to be developed (e.g. adaptation and integrated coastal zone management) the lack of guidelines on how to use EU funds most efficiently will be lacking. The available resources might not be spent in the most efficient way and in some cases mal-adaptation might be funded (e.g. artificial snow making in southern European mountain areas).

Under this scenario, due to lack of leadership of the European Commission, Member States would develop their own approaches for mainstreaming. Thereby the focus will be on technical aspects of adaptation, less on social issues. This can be explained that technical adaptation prevails in the existing NAS and social issues are less high on the agenda when it comes to adaptation.

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[287] http://www.eea.europa.eu/data-and-maps/figures/final-electricity-consumption-by-sector-1

Even considering that the ASG will continue to act as a platform for exchange huge differences in mainstreaming efforts at Member State level can be expected. Western European countries will be more advanced than the rest of Europe. In this context disparities between Member States will increase further.

6.4.3 No EU-action

Under the no EU action scenario it is assumed that no more mainstreaming takes place in the future. The current achievements (existing legislation and proposals by the Commission) are considered as final. Further mainstreaming will remain an issue to be dealt by the Member States. In this context Member States will continue to cooperate amongst each other in some sectors (e.g. water, disaster risk reduction) on a voluntary basis, while the Commission will have the role of an observer but nothing more.

The ASG as an information and exchange platform is not expected to continue, thus leaving Member States to uncoordinated bilateral or multilateral discussions. This will lead to further disparities within the EU. EU funded climate change research is going to be patchy and without any policy context. Several Member States will develop their own research activities, which might lead to extra costs as the same research question will be addressed several times by different Member States.

In areas where limited or little effort towards climate change adaptation has been taken (e.g. standards, social issues) no new developments will be made. Member States might co-operate instead on an ad-hoc basis. The private sector will get involved where adaptation outweighs the benefits or business cases can be expected. However, due to lack of awareness and access to information these efforts will be rather limited and on an ad-hoc basis.

The implementation of the MFF will take place but with less ambition to consider adaptation. Focus will be put on mitigation efforts instead.

6.4.4 Policy options addressing problem 4

6.4.4.1 Listing mainstreaming priorities in EU legislation and policy initiatives by 2020 and engage with relevant stakeholders

Description of the option

The aim of this policy initiative is to propose a strategic approach for mainstreaming climate change adaptation into EU legislation. This initiative would provide a list of priority initiatives until 2020 for mainstreaming and how to reduce vulnerabilities and thus enhance climate resilience. This would set out a plan for the political and structural change needed up to 2020. Areas where policy action can make a real difference are of particular focus. Based on the assessment described in the problem description the priority initiatives in mainstreaming should focus on the following priority areas and actions:

- Transport: Ensuring that transport related infrastructure is made more climate resilient (cf. also options under problem 5)
- Energy: Ensuring that energy related infrastructure is made more climate resilient (cf. also options under problem 5)
- Construction/Buildings: Ensuring that the built environment is made more climate resilient (cf. also options under problem 5)
- Health: Early warning should be improved and an EU wide integration should take place. Also surveillance mechanism and periodic monitoring should be improved. This requires fostering better cooperation among regions and Member States.
- Social issues: Particular focus should be spent on vulnerable groups (e.g. the elderly), but also on how to take account of gender issues in strengthening adaptation efforts.
- Insurance: With the Lamfalussy process[288] a system has been set up that enables the Solvency II[289] and IMD[290] 2 regimes to keep up-to-date with future market and

[288] The Lamfalussy Process is an approach to the development of financial service industry regulations used by the European Union. Originally developed in March 2001 the process is named after the chair of the EU advisory committee that created it, Alexandre Lamfalussy. It is composed of four "levels," each focusing on a specific stage of the implementation of legislation.

[289] Directive 2009/138 /EC on the taking-up and pursuit of the business of Insurance Reinsurce (Solvency II) is a review of the capital adequacy regime for the European insurance industry. It aims to establish a revised set of EU-wide capital requirements and risk management standards that will replace the current solvency requirements.

[290] i.e. the Insurance Mediation Directive (IMD2), which aims to achieve a market throughout the EU for insurance intermediaries is currently under review.

technological developments. This can be used as a starting point for mainstreaming (For a detailed assessment of potential actions and their feasibility to be implemented please cf. chapter 3.7).

- Coastal zone management and marine issues: Climate change needs to be considered within planning activities. This also requires increased awareness and better cooperation among the different stakeholders involved.

Mainstreaming should not only focus on introducing adaptation to climate change into legal actions or developing guidance. There is also the need to tackle specific bottlenecks like inconsistencies in policy (e.g. renewable energy) and market. These priority initiatives should prevent failures to ensure that policies are all going in the same direction. Cross-cutting themes such as social policies are also addressed. The roadmap provides a framework in which future actions can be designed and implemented coherently. It sets out a vision for the political and structural change needed up to 2020, with milestones to be reached by 2017. These milestones illustrate what will be needed to put Europe on a path to mainstream climate change adaptation into all EU policies.

Assessment of the option

The direct costs for listing mainstreaming priorities are seen to be marginal. When amending or developing new EU legislation, a dedicated impact assessment will have to consider the implications from a climate change adaptation point of view. It requires mapping the current status of adaptation efforts in EU legislation (Directives, Regulations and Commission Decisions) and other policy documents.

Listing priority initiatives for further mainstreaming will further raise awareness of the need to integrate climate change considerations in key EU policy areas beyond the recommendations of the White Paper on adapting to climate change. It will foster a dialogue with respective Commission services, but also with Member States and other stakeholders.

For this initiative as such, it can be assumed that the overall benefits relate to a clear commitment to act at EU level to integrate climate change considerations in all relevant EU policies in a coordinated and well-planned manner. It will further increase awareness of the necessity to address climate change adaptation in various policy areas projected to be affected by climate change impacts. Furthermore it can be expected that agreeing on these priorities would allow to anticipating and allocating better European Commission resources.

Further, listing mainstreaming priorities in EU legislation and policies allows for greater transparency for Member States. They would be able to prepare better for respective implementation in various sectors. Anticipatory policy making on Member States level can save costs, while avoiding potential overlaps in mainstreaming efforts at national level. Furthermore, processes to develop national adaptation policies can be better informed by a roadmap for upcoming EU level mainstreaming efforts.

A roadmap will also clearly outline potential conflicting policy objectives as well as highlight synergies that can be achieved through aligning mainstreaming efforts in several EU policy areas.

Assuming that the above mentioned priority areas and actions will form the core of the option the following more detailed impacts can be assumed:

- For the transport, energy and construction sector climate resilience will be improved. There are several existing EU policies that may serve as entry points to include climate change considerations in particular with a view to taking into account future climatic conditions. Most policies take due account of climate mitigation issues, but not yet of assessing risks posed by future climate change and developing appropriate adaptation responses.
    - For the transport sector this applies to all transport modes where climate change impacts are expected to pose increased pressure on the infrastructure in the future, also in economic terms. This is of particular importance considering the long-term investments (e.g. major transport routes, bridges, tunnels, urban transport). Taking account of future climatic conditions is thus of high importance to both prevent potential damage costs and safeguard the functioning of European transport systems (cf. also options under problem 5). Identifying and listing related policies that serve as entry points for mainstreaming adaptation are relevant for both existing infrastructure (such as e.g. safety management for roads) and new infrastructure to ensure that any investment is “climate-proofed”.
    - For the energy sector EU policies helping to reach adaptation targets (e.g. cutting down seasonal demand peaks, Connecting Europe Facility, Smart Grids initiative) are in place and emerging, although not named as such – thus having high mainstreaming potential. Anticipated threats on the European energy system such as (i) aggravated extreme events, ii) increasing interconnection of grid-dependent European internal energy market and thus increasing amounts of transmitted energy/less domestic supply in many regions, iii) projected further shift towards increasing electricity demands and according shifts in primary energy consumption and iv) increasing share of renewable energy generation that will entail a more complex picture of climate threats (e.g. increasing dependency from solar irradiation, wind velocities, river run-off regimes) will need to be taken into consideration in various related policies. Listing those with high mainstreaming potential and assuring a coherent approach will allow taking preventive action to address the above highlighted threats. Cf. also options under problem 5.

- For the construction sector EUROCODES as a set of unified international codes of practice for designing buildings and civil engineering structures are regarded as having high mainstreaming potential, however so far do not incorporate aspects of future changes of climatic conditions (for more details cf. option under problem 5).

- In the case of mainstreaming in the health sector, integration of future climate change risks is expected to improve, inter alia, the following:
  - Less heat related deaths through improved surveillance mechanisms and contingency planning taking due account of potentially more frequent and extreme weather events due to climate change
  - Foster preventive actions to reduce the risk of spreading of pests and diseases considering changes in certain disease carriers (e.g. by the Asian tiger mosquito)
  - Safeguard adequate financial resources for health in the EU Cohesion Policy from 2014 onwards to deal with climate challenges and link forecasting tools (e.g. for heat, floods, wild fires, storms) with the health sector on a cross-border scale
  - Connect early warning for air pollutants, especially ozone, closer to health services in order to effectively react and ensure timely actions
  - Support the monitoring (e.g. detection via early warning mechanisms and rapid eradication) and reporting procedure, monitor climate related changes on invasive species distribution, survival and spread, and foster the exchange of information on potential eradication strategies.

- Even if there are quite some uncertainties related to mainstreaming adaptation into the EU social policies, doing so could mitigate growing disparities in society due to climate change. Social harmony which is a cornerstone of the EU will also be secured. The mainstreaming of adaptation to climate change in social policies might not always involve direct additions or edits of the texts of current legislation and other policy documents, however, it certainly does provide additional reasoning and importance for the development of EU social policies due to the fact that successful achievement of social policy aims is inseparably linked to successful strengthening of the adaptive capacity of societies. For example:
  - Reduction of forced climate migration (internal and external) through the development of adaptation policies in potential source countries and regions (including EU Member States) could reduce the need for people moving away from marginal areas and supporting livelihoods that are more resilient.

- Economic disparities lead to differences in adaptive capacity between man and women. Climate change should be used as a further argument to reduce these disparities and to reduce vulnerabilities in particular of women.
- The IPCC recognises the elderly as a group of greater vulnerability, which is mainly due to people of older age being more sensitive to health impacts (IPCC, 2007a), especially caused by heat, as well as to stress associated with losses and physical damage during extreme weather events (CAG Consultants, 2009). They are also more likely to have reduced mobility and therefore reduced access to essential services. Additionally, older people are less likely to be willing to relocate away from exposed areas due to general reluctance to migrate, which rises sharply with age (Huber & Nowotny, 2008). Considering these aspects in the context of planning for adaptation could reduce the vulnerabilities of elder people.

- For the insurance sector mainstreaming could mean to open some confidential information to the general public. However this option provides the opportunity to improve the use of insurance in managing climate risk, as part of the adaptation mission to protect people and assets in the EU against climate change efficiently and effectively
- As mentioned in chapter 3.2.2.5, coastal zones are one of the high risk – but on the same side one of the most dynamic and developing – areas in the EU territory. Increased mainstreaming into this policy area could reduce this risk but could also contribute to a sustainable development in the future.

6.4.4.2 Set new calendar for revision of key EU legislation

Description of the option

Despite the strides being made to better mainstream climate change into all relevant sectoral policies (e.g. Transport, energy, health, social) some policies are currently not planned to be reviewed in order to mainstream climate change.

It is possible for Directorate Generals to modify the timeline under which policies are revised and amended. This option would, therefore, define priority legislation whose timelines should be revised so that climate change adaptation can be inserted into legislation. By prioritising legislation, the Commission would carry out a process under which legislation would be screened for their links to climate change adaptation.

Assessment of the option

This option would be difficult to carry out given its political nature. Certain revision dates have been subject to long political negotiations between the EU, the Council and the Commission with input from the Member States. Changing this timing could cause political conflicts. Furthermore, there is a possibility that moving the legislative revision forward might result in the introduction of other (hidden) political agendas. Given the current financial climate in the EU, there could be a potential for watering down hard amendments to allow for more time to achieve objectives given financial difficulties. Whether this would occur is not clear. The 2009 Health Check of the CAP brought about a number of positive environmental changes, including making climate change a new challenge. However, the milk sector was also designated as a “new challenge”, thus allowing for special interests to remain.

As highlighted by the developments in water policy in the EU, voluntary action can pre-empt the need for causing legislation to be revised at an earlier stage. Climate change action is not required under the WFD, but in 2009 the Water Directors agreed to follow CIS guidance on how to climate check river basin management plans already in the 1st cycle. Most RBMPs (87.5% explicity refer to climate change, indicating a high level of participation and acceptance, a little less than half of the RDs (40%) included a specific chapter on climate change adaptation and 41% of the RBMPs already carried out a climate check of their PoMs (EC, 2012i)[291]. In addition, about half (46.4%) of the RBMPs already included or outlined future specific adaptation measures to climate change. 11 of 25 Member States can be considered as actively working on the identification and development of climate change adaptation measures as part of RBMPs (ibid).

Another consideration regarding this option is that some sectors would not be affected as their “policies” or “standards” do not have a review process that could be speed up to include climate change adaptation. The environmental guide for product standards under CEN standards was recently updated: while it addresses CO_2 emissions in the context of mitigation, adaptation is not mentioned. It is unlikely that this guidance will be reviewed before 2020; this guidance is also not mandatory. The situation is similar for EU buildings regulations in the form of Eurocodes. Climate change adaptation has not been addressed by these standards. One way to reach such standards would be through the Directives on public procurement. But these Directives currently have no criteria for taking adaptation into account and no review process is foreseen before 2020 or beyond to do so in the future.

The potential benefits for other sectors are the same as for option “Listing mainstreaming priorities in EU legislation and policy initiatives by 2020”.

Nonetheless, the added value of moving up the review deadline for policies where it is possible that climate change adaptation issues will be brought to the forefront sooner. It may be advantageous to do so, given the EU 2020 Strategy (EC, 2010d): this option could help make sure that all existing legislation takes adaptation into account and thus help to achieving the 2020 Strategy’s targets as well. On the other hand, there is no guarantee -

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291 http://ec.europa.eu/environment/water/water-framework/implrep2007/index_en.htm#third

given the varied political interests across the EU - that moving up the review would ensure that adaptation is included in articles. The impact of this option, therefore, is not certain and could face a lot of resistance.

When the consultation asked respondents to select which type of instruments would bring the most added-value in national adaptation strategies, 42.86% of them selected the option 'Review of existing EU legislation such as horizontal directives and regulations (mainstreaming/integration of adaptation into EU legislation)', indicating that this option would not rank high on the agenda compared to other options under this problem.

6.4.4.3 Institutionalise mainstreaming at EU level by providing guidelines for Commission internal IA procedure on how to consider climate change adaptation considerations for amendments and new EU policies

Description of the option

The Commission guidelines for carrying out impact assessments (EC, 2009k) are, for the analysis of environmental impacts, requiring considerations on the climate and in particular whether the option assessed affects the ability to adapt to climate change. Thus, the impact assessment procedure is seen as an important instrument to assure mainstreaming adaptation. All policy initiatives and legislative proposals that are made subject to an impact assessment should already take into account the aspect of climate change both in terms of mitigation and adaptation. For the latter the principle suitability of the policy in terms of strengthening climate change resilience should be considered.

For the assessment of environmental impacts of policy options the current Impact Assessment Guidelines require to address 3 questions:

- Does the option affect the emission of greenhouse gases (e.g. carbon dioxide, methane etc.) into the atmosphere?
- Does the option affect the emission of ozone-depleting substances (CFCs, HCFCs)?
- Does the option affect our ability to adapt to climate change?

These questions are very generic and do not give explicit advice on which approaches could be applied and what kind of background information could prove useful. In the Annexes to the Guidelines there are a few more references to climate change, but only for mitigation and also giving little guidance for the assessment. However for other topics additional operational guidelines provided by different DG´s exist (e.g. Operational Guidelines to Assess Impacts on Micro-Enterprises)[292].

[292] http://ec.europa.eu/governance/impact/key_docs/key_docs_en.htm

To further improve COM services' capacity to analyse climate change-related issues in a thorough and proportionate manner, this options suggests to develop specific guidelines on how to include climate change considerations (mitigation and adaptation) in the Commission´s Impact Assessment procedure and would thus complement the 2009 general Guidelines. The operational guidelines would build on the 3 questions cited above that relate to climate change considerations and would not set out any new requirements. They would aim to give specific advice in a non-exhaustive manner on the assessment of a policy option´s impact on emissions contributing to climate change as well as impacts on the ability to adapt. Both aspects may require a variety of issues and data to be taken into account, where the operational guidelines could suggest pragmatic approaches, while still ensuring sufficient quality of the overall impact assessment analysis.

The 2011 report of the European parliament on guaranteeing independent impact assessments (2010/2016(INI); EP, 2011) stresses under the general requirements "*the need for thorough impact assessments as a prerequisite for high-quality legislation and correct transposition, application and enforcement*". On the potential for improvement at Commission level, the report "*acknowledges that the quality of Commission impact assessments has gone up in recent years, but stresses that there is further need for improvement"*. Providing more accurate advice on how to address climate change in EU impact assessments could contribute to improving the quality of assessments and thus support high-quality legislation taking into account more precisely future challenges posed by climate change.

Assessment of the option

Supporting the analysis of an option´s potential impact on climate change both in terms of mitigation and adaptation would likely enhance cost-effectiveness of proposed policy actions. Taking both issues into account in a detailed assessment would ensure that mitigation and adaptation complement each other and thus avoid overlaps in financial efforts.

A solid assessment of potential emissions is also contributing to meet the Europe 2020 targets set out in the Europe 2020 strategy (EC, 2010d).

EU guidelines on climate impact assessment could also provide a common approach for Member States to be applied at national level or via impact assessment procedures, such as EIA or SEA. Thus, developing operational guidelines for climate change at EU level would potentially save Member States the efforts and costs to elaborate similar guidance.

Social impacts can only be expected if the respective policy proposal undergoing an IA would affect social issues that are expected to be aggravated by climate change. Thus, operational guidelines to comprehensively take climate change considerations into account could enhance appropriate policy responses that in turn e.g. enhance the adaptive capacity the population groups that are most affected.

Using the existing IA procedure as an instrument for thoroughly taking into account climate change mitigation and adaptation would long-term ensure a comprehensive "CC-proofing" of all upcoming EU policy initiatives. Through making use of the IA procedure a harmonized approach for CC considerations for policy developments could be reached and thus institutionalize mainstreaming efforts at EU level.

Nevertheless, mainstreaming must take place at all levels of policy making: If EU policies already take climate change into account and give clear recommendations for implementation, CC proofing will thus also need to take place on a Member State level and beyond ('tiered approach'). Explicit requirements arriving from the EU level (for various policy areas/sectors and not only through the EU Adaptation Strategy as a framework) would also help national processes (e.g. implementation of national adaptation policies) in pushing competent authorities to take action. Further, if the EC can show mainstreaming efforts for their own policies first it would ease requesting Member States to act on adaptation.

The costs to develop operational guidelines on climate change are estimated between 25.000 and 40.000 Euros.

6.4.5 Effectiveness, efficiency and coherence of the options addressing problem 4

All the options contribute to making the EU more resilient (objective 2 and 3) of the strategy. For the first two options ("Listing mainstreaming priorities in EU legislation and policy initiatives by 2020 and engage with relevant stakeholders", "Set new calendar for revision of key EU legislation") the impacts on mainstreaming will clearly depend on the concrete actions proposed/taken. Through guidance a harmonized approach for CC considerations in policy developments could be reached, thus institutionalizing mainstreaming efforts at EU level. However, as these guidelines are not mandatory, the level of application will be a limiting factor. All options might also contribute to the objective of "Better informed decision making" and therewith to the objective of "Increasing the resilience of the EU territory". In order to carry out a proper IA or to change legislation additional studies could be launched that trigger the generation of knowledge. Cooperation might be strengthened under all three options; however, under the first two options also political conflicts might occur.

Improved knowledge and is also contributing to "Increasing the resilience of key vulnerable sectors". due to positive stimulations are most likely (e.g. new technologies, new insurance schemes).

The effectiveness of the options is mostly positive if maladaptation is prevented and adaption is introduced into policy making at an early stage. Under the third option, the administrative burden might be high.

The option "Institutionalise mainstreaming at EU level by providing guidelines for Commission internal IA procedure on how to consider climate change adaptation considerations for amendments and new EU policies" clearly contributes to the smart regulation objectives of the EU. A solid assessment of potential emissions also contributes to meeting the Europe 2020 targets set out in the Europe 2020 strategy. The first two options contribute to the achievement of other policy objectives as mainstreaming climate change adaptation will make these policies more climate resilient. The 7EAP calls that sectoral policies at EU and Member State level are developed and implemented in a way that they support relevant environment and climate-related targets and objectives, which requires, in particular (a) integrating environmental and climate-related conditionalities and incentives in policy initiatives, including reviews and reforms of existing policy, as well as new initiatives, at EU and Member State level.

6.4.6 Comparative table of the options addressing problem 4

The first two options "Listing mainstreaming priorities in EU legislation and policy initiatives by 2020 and engage with relevant stakeholders" and "Set new calendar for revision of key EU legislation) are alternative options and only one of them can be taken forward. The third option can be combined with any of the first two

The following table compares and summarises how the options contribute to the effectiveness of achieving the operational objectives of the strategy and to the overarching objectives of improving efficiency and coherence.

Table 48: Comparative table of the options addressing problem 4

Options	Economic, social, and environmental impacts	Effectiveness			Efficiency	Coherence	Acceptability
		Objective 1: Better informed decision making	Objective 2: Increasing the resilience of the EU territory	Objective 3: Increasing the resilience of key vulnerable sectors			
No policy change		0	0	0	0	0	0
Listing mainstreaming priorities in EU legislation and policy initiatives by 2020 and engage with relevant stakeholders	≈ to ++ (impacts depending on concrete actions proposed, costs are considered as marginal)	≈ to + (as new knowledge might be generated to better address climate change in policy making, might strengthen cooperation but might also increase conflicts between the different commission services and MS)	++ (high as it would address climate change adaptation at an very early stage in the policy cycle)	? (depending on concrete actions proposed)	++ (high as it would address at an very early stage and can avoid male adaptation)	++(mainstreaming adaptation into existing policies makes them more climate robust and therewith contributes to the achievement of the objectives, 7EAP proposes a specific action on mainstreaming)	? (depending on concrete actions proposed)
Set new calendar for revision of key EU legislation	≈ to ++ (impacts depending on concrete actions proposed, costs are considered as marginal)	≈ to + (as new knowledge might be generated to better address climate change in policy making, might strengthen cooperation but might also increase conflicts between the	++ (high as it would address climate change adaptation at an very early stage in the policy cycle)	? (depending on concrete actions proposed)	++ (high as it would address at an very early stage and can avoid male adaptation)	++(mainstreaming adaptation into existing policies makes them more climate robust and therewith contributes to the achievement of the objectives, 7EAP proposes a specific	? (depending on concrete actions proposed, but in general a low acceptance is expected due to political concerns)

Options	Economic, social, and environmental impacts	Effectiveness			Efficiency	Coherence	Acceptability
		Objective 1: Better informed decision making	Objective 2: Increasing the resilience of the EU territory	Objective 3: Increasing the resilience of key vulnerable sectors			
		different commission services and MS)				action on mainstreaming)	
Institutionalise mainstreaming at EU level by providing guidelines for Commission internal IA procedure on how to consider climate change adaptation considerations for amendments and new EU policies	≈ to ++ (impacts depending on the uptake of the option, costs are considered as marginal)	+(additional studies to close knowledge gaps might be launched)	+(might reduce maladaptation)	≈ (no impact)	++ (high as it would address at an very early stage and can avoid male adaptation) - (increases the administrative burden for the Commission)	++(would serve the better regulation objectives, 7EAP proposes a specific action on mainstreaming)	-(due to additional administrative burden)

Magnitude of impact as compared with the baseline scenario (the baseline is indicated as 0): ++ strongly positive; + positive; – – strongly negative; – negative; ≈ marginal/neutral; ? uncertain; n.a. not applicable

6.5 Problem 5: Vulnerability of Infrastructure

6.5.1 Problem definition

The vulnerability of the EU's infrastructure - whether related to transport, energy or nature – is high on the agenda for improving Europe's resilience to climate change impacts. The results of public consultation undertaken in preparation of the EU Adaptation Strategy proved that infrastructure resilience is a significant issue in the context of climate change. The majority of respondents considered Energy, Transport and construction as 'medium relevant' or 'highly relevant' (respectively 72.76%, 55.9% and 54.04%) sectors where action needs to be taken.

Infrastructure related to transport, energy, ICT, buildings

Europe´s infrastructure has enormous value, both directly as a capital asset and indirectly as an essential element contributing to a productive economy. As set out in chapter 3.2.1.3, infrastructure is also highly vulnerable to climate change.

Within the EU Adaptation Strategy, only infrastructure related to transport, energy, information and communication technology (ICT), buildings and green infrastructure will be further addressed. Infrastructure related to water supply and waste water treatment is covered under the "Blueprint to safeguard Europe's waters" (EC, 2012m) and infrastructure related to disaster risk reduction/human protection (dykes, avalanche barriers) is expected to be covered by the communication on DRR.

In the area of transport, climate change affects not only road, rail, aviation and shipping infrastructure, but also the distribution of transportation and traffic flows, e.g. as a result of changing tourism patterns. Conversely, trans-European transport network (TEN-T) plans can affect the vulnerability of other sectors, such as the ecological infrastructure by fragmenting rather than connecting habitats. Therefore the recently published strategy paper (White Paper on Transport (EC, 2011v) explicitly addresses the need for adaptation to climate change in the transport sector and suggests enhancing adaptation by establishing a link to funding mechanisms. In addition, a few policies (e.g. Fifth report on economic, social and territorial cohesion (EC, 2010r)) highlight the need for climate change adaptation of transport infrastructure. Other policies include mechanisms or technical standards which could be extended with regard to adaptation. In addition, adaptation can be integrated in existing policies dealing with new infrastructure projects (especially those who receive EU funding) to ensure climate-proofed infrastructure.

As mentioned in chapter 3.9.5 infrastructure is mainly ruled by EN EUROCODES (EC, 2003f)[293] which are a set of harmonized technical rules developed by the European Committee for Standardisation for the structural design of construction works in the European Union. Ten EUROCODES in a total of 58 parts cover: basis of design; actions on structures; design of structural elements in concrete, steel, composite steel and concrete, timber, masonry and aluminium; together with geotechnical and seismic design. They cover the design of bridges, buildings, silos, tanks, pipelines, towers, masts and more. The EUROCODES therefore replace the existing national building codes. They cover earthquake resistance, but not yet climate proofing.

Since March 2010 the EUROCODES are mandatory for European public works and the de-facto standard for the private sector[294]. Each country is expected to issue a national annex to the EUROCODES, which will need referencing for a particular country. These annexes would be crucial for climate change adaptation as they allow adjusting the standards to potential regional climatic impacts (e.g. snow load resistance of roofs).

An analysis of the progress in the implementation of the EUROCODES has been performed based on the information provided by the members of the Eurocodes National Correspondents (ENC) group. Concerning the EU Member States, the situation on 25 January 2010 (most recent data) was as follows[295]:

- 83% of all parts have been published as national standards and 66% of all parts have been translated in national languages. It was expected that the adaptation of national building regulations, will be completed at the latest in 2011.
- National Annexes have been published for 38% of all parts and are available in English for 18% of all parts.

It can be assumed that the general situation has further improved since 2010 and EUROCODES are used widely. However, as there is no penalty mechanism for non-compliance not all Member States are assumed to have a national annex.

Already the 2009 White Paper on adapting to climate change (EC, 2009a) recognised this fact and raised the need to increase the resilience of production systems and physical infrastructure to climate change. It was argued that the EU has an important role in promoting good practice, by encouraging adaptation of current standards for buildings and construction and developing new standards where appropriate. They are particularly important for the construction and infrastructure sector due to the following reasons:

[293] Eurocodes are a set of unified international codes of practice for designing buildings and civil engeneering structures, which will eventually replace national codes. See Commission Recommendation 2003/887/EC (EC, 2003b).
[294] http://eurocodes.jrc.ec.europa.eu/
[295] http://eurocodes.jrc.ec.europa.eu/showpage.php?id=31

- The impact of climate change is particularly pertinent to the construction industry given the life expectancy of buildings and long-term investments;
- There is a high innovation potential for optimizing building materials to provide structural stability and weather resistance for extreme events that are expected to increase with climate change;
- One of the most important type of instrument used to regulate construction are standards, which often include references to (directly or indirectly) weather/climate related pressures;
- Standards are also regulating processes and operations (e.g. operation of electrical installations in hospitals). Adapting operations and process or use might be more cost effective than changing infrastructure.

Moreover, in the public consultation, some respondents emphasized that ‘the assessment of vulnerability of infrastructure and enhancement of its resilience is clearly a critical component of any adaptation strategy’.

Beside EUROCODES several thousand other harmonized EU wide standards exist, covering almost all activities in the European Union. Their relation to climate change adaptation is mostly unknown. There is not even a systematic overview on which standard could be used for adaptation. Having the importance of standards on the European market in mind, it comes clear that standards could also play an important role in mainstreaming climate change adaptation into the private sector, thus enhancing overall climate resilience of the built environment. However this potential needs to better understood in order to make the most beneficial use of this instrument.

For the rail sector the European railway system has been standardised and regulated for more than 150 years and is defined through a complex and large hierarchical standardisation and regulatory landscape. Standardisation starts with the basic functional requirements at a company or activity level and goes up to European or International Technical Recommendations or standards like UIC Codes, UIC/UNIFE Technical Recommendations and CEN/CENELEC/ETSI European Standards / Technical Specifications or ISO/IEC/ITU standards. The European regulation comprises a national framework as well as Technical Specifications for Interoperability (TSI) and the European Commission’s Directives ensuring the interoperability of the trans-European rail system. However, these TSIs do not apply to the urban rail systems (CER et al., 2012).

A sector position paper has been published by CER, UIC, EIM, UNIFE, UITP, UIP and ERFTC end of December 2012[296], which highlights the need for the sector to focus on

296 http://www.cer.be/media/article/2386/Rail%20Sector%20Position%20Paper%20Climate%20Change%20%20and%20Standardisation.pdf

standardisation where major activities to adapt to climate change shall be carried out. These include:

- Short-term activities: The exchange of good practices should be intensified. Benchmarking studies within the sectors and cross sector information exchange platform could help to find solutions quickly and efficiently;

- Medium-term activities: The existing standardisation needs to be adapted or extended accordingly. Firstly, a complete mapping of the existing standards and regulation is required to identify the gaps between the current situation of the overall rail system and subsystems and a target mainline railway system resilient to climate change. The existing R&D activities are to be taken into account (i.e. the ARISCC project). It is to be underlined that only the existing rail Standardisation framework shall be revised to take climate change resilience into account. The creation of additional standards exclusively focusing on climate change aspects is to be avoided;

- Long-term activities: The European Member States shall be encouraged to require and financially support a more resilient mainline (conventional) railway network for the future.

In order to put in place a general framework to promote and ensure a better inclusion of environmental aspects in European Standards, CEN has published a guideline called “CEN approach on addressing environmental issues in Product and Services Standards”. The document provides guidance on addressing environmental issues in product standards. It is primarily intended for product standards writers. Its purpose is to outline the relationship between the provisions in product standards and the environmental aspects and impacts of the product and to assist in drafting or revising provisions in product standards in order to reduce potential adverse environmental impacts at different stages of the entire product life-cycle. The CEN approach intends to address particularly those Technical Bodies and Sectors with significant environmental impacts while raising awareness on environmental issues in all CEN Technical Bodies. The guide is well accepted within the CEN/CENELEC community.

Climate change is currently mentioned as one environmental aspect to be considered; the guide text implies mitigation, but not adaptation. For example, transport and energy, water supply and land-use are included in the guide as essential additional services and/or inputs to production from the perspective of sustainability. As those modes will also be highly influenced by climate change, it is also important that they are covered by climate proofing.

Also the precautionary principle is highly relevant for adaptation. If the environmental impact of a product or process is assessed during its life-cycle, it is important that the product or process does not behave differently in a different environment than the current one.

Green Infrastructure

Green infrastructure, which covers a broad spectrum of land use measures, is one way to encourage landowners to adapt to a changing climate and to minimize their impact on the environment. Due to their diversity, a number of environmental regulations in the EU set the framework for the implementation of measures targeting land use measures that address a host of pressure such as flooding, landslides, avalanches, fires, storms etc. Funding mechanisms play a major role in influencing land use management, including for example CAP, the LIFE+ regulation (EC, 2007g) and Structural Funds.

Despite the policies in place, there are nevertheless barriers to implementation of such measures. Work carried out under the development of the "Blueprint to safeguard European Waters" (EC, 2012m) analysed key barriers to the implementation of green infrastructure (Farmer et al., 2012). These are among others, the lack of clear definitions and rules for implementation; concrete financing and the narrow geographic scope some policies have to support projects. Moreover, the lack of political will to impose such measures, especially those that take land out of production has been identified as another barrier. Naumann et al. (2011), which analysed ecosystem based approaches for adaptation, largely confirms this picture, also adding barriers such as technical capacity gaps in innovation design and problems overcoming resistance or doubts about the value of some measures. Also the fact that several of the measures are of voluntary nature is considered as a main barrier.

As a result of these barriers, green infrastructure projects and measures are sometimes not applied by the Member States or taken up at a regional and farm level. Support actions to facilitate the implementation of technical measures are clearly lacking. There is a general lack of willingness to implement "soft measures" for natural hazards and there are no incentives to move thinking away from hard defence measures to focus more on natural approaches (e.g. natural water retention for flooding or afforestation for landslides).

6.5.2 No policy change

Infrastructure related to transport, energy, ICT, buildings

Under the baseline scenario it is assumed that the proposed TEN-E and TEN-T guidelines will be adopted and that climate change needs to be taken into account for new projects. While the proposal for the TEN-T guidelines include requirements to take climate change into account in several articles, the proposed TEN-E regulation (EC, 2011t) only generally states that "*the Union's energy infrastructure should be upgraded in order to prevent and increase its resilience to natural or man-made disasters, **adverse effects of climate change** and threats to its security, notably concerning European critical infrastructures as set out in Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection*" (EC, 2008l). There are, however, more explicit references in Annex IV (Rules and indicators concerning criteria for projects of common interest) outlining that "*Interoperability and secure system operation shall be measured [...], taking into account expected* ***changes in climate-related extreme weather events and their impact on infrastructure resilience****";* that the criterion for security and quality of supply (applicable to electricity, Annex II 1 (e)) shall be evaluated, inter alia, by taking into account climate related disruptions, and concerning oil transport projects efficient and sustainable use of resources shall be evaluated by, inter alia, assessing the contribution to minimising environmental and climate change burden. However, it can be anticipated that the rather general guidance and recommendation will be more affecting the overall design of a project and not detailed construction elements.

For roads it is assumed that national and regional approaches will prevail and existing efforts in road maintenance will also be reflected in considering climate change. Further adaptation on important transport routes is more likely to happen.

For the rail sector depending on the importance of rail in the overall transport sector activities will differ among Member States. While some Member States already have started to deal with the issue of climate change impacts and some companies (e.g. UK, France, Austria) have prepared strategies on how to cope with these impacts, others will lack behind. Current adaptation activities within the European Railway community are ranging from monitoring and mapping efforts to assessments of impacts of extreme weather events on assets (UIC, 2011). More attention will be paid to important passenger and freight routes. Adaptation will also focus on operational aspects (e.g. better cooling, secured snow clearance) than on infrastructure aspects.

Coastal areas are exposed to climate change due to sea level rise. Under the rising sea level conditions a threat to be flooded increases significantly in the event of storm surges and particularly during storm surges in combination with high tide periods. All this could entail heavy consequences for shipping transport infrastructure, which may involve damage to terminals, intermodal facilities, freight villages, storage and warehousing areas, containers and cargo. Coastal protection against flooding is therefore one of the main infrastructure adaptation measures. It has been applied for a fairly long time in form of dikes, seawalls, floodgates, flood plains or drainage systems. The existing systems are in many cases not capable anymore to cope with the changing climate effects in the coming century (Doll et al., 2011).

In the case of aviation, adaptation to climate change is not yet recognized by the airline industry as a growing problem. Nevertheless, a number of technologies are discussed in literature and are tested by airlines and air traffic control to make flying more resilient to external factors and to increase airspace and airport capacity. Harmful weather conditions are one among several motivations for improving communication systems, technologies and procedures (Doll et al., 2011).

It is assumed that current adaptation activities in the energy sector including infrastructure will basically take place at different national levels, namely in Member States with a National

Adaptation Strategy. Due to increased extreme events and therefore a higher level of black outs public pressure to adapt the existing infrastructure will increase. This will increase also the adaptation actions taken by the Commission and Member States in the context of developing new infrastructure coping with new energy production patterns due to increasing renewable energy sources. This will mainly be done in the context of existing and emerging policies (e.g. cutting down seasonal demand peaks, Connecting Europe Facility, Smart Grids initiative).

For all constructions falling under EUROCODES it is expected that some Member States (mainly those who address the issue in their NAS) will modify their national Annexes.

Green Infrastructure

The proposal for the 7EAP states that *“Incorporating green infrastructure into related plans and programmes can help overcome fragmentation of habitats and preserve or restore ecological connectivity, enhance ecosystem resilience and thereby ensure the continued provision of ecosystem services, including carbon sequestration and climate adaptation, while providing healthier environments and recreational spaces for people to enjoy.”* This is has been taken up by the European Commission’s, DG Environment’s Water Unit in its Communication on a Blueprint to Safeguard Europe’s Water Resources (EC, 2012m). The Communication suggests as a key action at EU level to develop CIS guidance on natural water retention measures with the WFD implementation process. This guidance will help to increase the inclusion of natural water retention measures in the programmes of measures for river basins Europe-wide. The Blueprint also addresses climate change as a major issue and therefore it is assumed the issue of adaptation will be included in the guidance as well. It will not only influence the next programming cycle of the WFD, but it could also be used by agriculture and rural development administrations when developing their agri-climate-environmental measure packages in the next rural development programmes period in 2014.

The upcoming Commission proposals for the 2014-2020 Multiannual Financial Framework (MFF) envisions a 20% of the EU budget for climate mainstreaming in the MFF, which – if carried out – would support the implementation of adaptation measures in the water sector, including especially green infrastructure. Furthermore, the proposed CAP regulation for 2014-2020 has introduced some new articles that could enhance green infrastructure in Europe in the next programming period. The greening provision (supporting ecological focus areas and permanent grassland) as well as the continued support of agri-climate environmental measures support farmers to carry out green infrastructure measures that could address a range of pressures, like soil and wind erosion, water quality, biodiversity etc. The proposal also contains some articles – like before – that may be counterproductive, e.g. modernisation of agriculture holdings could results in more intensified agriculture, and could prevent farmers from offering land for permanent changes such as wetland creation of afforestation. Nevertheless, support for green infrastructure has strengthened through the proposal but it remains to be seen what the final regulations looks like after discussions with the Member States and the European Parliament.

Currently, the Commission is finalising a new guidance document on how to address the impacts of climate change within Natura 2000 sites. Green infrastructure is considerably promoted under nature policy. Although these developments signifies a strong commitment to mainstreaming climate change, the Habitats and Birds Directive can only support green infrastructure to a certain extent given the Directives' geographic limitations. The Habitats Directive focuses on priority habitat areas, not priority areas where climate change represents an eminent problem. The percentage of land under Natura 2000 protection varies from Member State to Member State, with the lowest share around 8% in the UK and the highest share around 36% in Slovenia (2011 data from EC Natura 2000 barometer). As such, nature policies are not necessarily able to target climate change impacts specifically given their limited scope.

In May 2011 the EC adopted the Biodiversity Strategy (EC, 2011b), which, among others, states that by 2020 green infrastructure should be established and Action 6 emphasizes the need to develop a Green Infrastructure Strategy by 2012. To this end a working group was established to take the Strategy forward. Nevertheless, it is not clear whether a concrete Strategy will be published by the end of 2012. More likely, a paper will be published fully defining green infrastructure, as the Commission believes this is a crucial step before a Strategy can be developed. As such, it is not certain when a green infrastructure Strategy will be published, the extent to which it will support (through mandatory or voluntary means) projects financially and administratively and whether green infrastructure projects will increase as a result.

6.5.3 Policy options addressing problem 5

6.5.3.1 Mainstream climate change into EU wide standards

Description of the option

This option would consist out of three parts:

- Launch of a mandate on EUROCODES to develop a technical report analysing and providing guidance for potential amendments for EUROCODES with regard relevant impacts of future climate change.
- Issue an official request (Mandate) to CEN-CENELEC to integrate adaptation in the CEN-CENELEC guide 4 - Environmental Guide. The Environmental guide supports to assess sustainability during the development and amendment of standards. It assesses the impact from a product/process on its environment following a life cycle approach.

- Develop with CEN-CENELEC and stakeholders a roadmap to map and prioritise relevant standards for transport infrastructure, energy infrastructure and buildings. The roadmap will be issued in the form of a two-step mandate: the first phase is to identify and prioritize relevant standards; the second phase focusses on how to change these standards and might include necessary (research) to incorporate adaptation to climate change into standards.

Assessment of the option

The assessment of the option will cover to phases: Phase 1 covers the preparatory works to amend a standard and the CEN environmental guide. Phase 2 assesses the impacts if a standard is amended.

Phase 1: Preparatory works

Maintenance of the EUROCODES is an essential activity to preserve their credibility, integrity and relevance, as well as to ensure that they do not contain errors. The Work Programme foresees different activities for the short term, medium term and long term. Long-term activities (more than 5 years) deal with matters relating to development of new items (e.g. advice on making buildings more tolerable against acts of malicious damage). A mandate on EUROCODES to develop a technical report analysing and providing guidance for potential amendments for EUROCODES with regard relevant impacts of future climate change can be considered as such an long term activity due to the technical complexity and the high uncertainties in climate projections.

The current guide provides a useful tool to address environmental issues for revision of existing standards or development of new standards. To avoid any administrative burden and because of the link between climate and environmental issues, the best option would be to integrate climate adaptation directly into the current Guide 4 and not to develop a new one. For adaptation/climate proofing to be covered by the guide, it should also assess the impact of the environment on a product/process. Life-cycle thinking currently applied would also be relevant for adaptation, as that would prescribe consideration of climate change risks in all product development cycles from initial product development to raw material sources, to production processes to use and disposal options.

The roadmap to map and prioritise relevant standards for transport infrastructure, energy infrastructure and buildings will require a huge effort. According to CEN/CENELEC, indicatively 500-1000 relevant transport standards need to be mapped. The time for carrying out this mapping exercise is assumed to take at least 1-2 years[297]. For the energy sector, no figures of potential standards to be reviewed have been found.

[297] Cf. Minutes "Workshop on climate change adaptation and standards in the European Transport sector, 18 June 2012 in Brussels. Available in the Background Report, Part II.

For all three parts of the option the majority of the work has to be shared between EU level and Member States. A detailed cost estimate to carry out this work was not possible but main costs would relate to working time for dozen of national experts from EU 27 will be involved over several years.

Uncertainty in climate modelling and potential lack of data/information in climate impacts for specific regions will make the amendment of any standard a difficult exercise.

Developing this guidance will likely trigger the need for innovation and research. This will stimulate the creation or maintenance of jobs in the area of research. However, the amount of generated jobs cannot be estimated at this stage.

Due to the processes required for carrying out this option increased awareness of climate change within the standardisation bodies could be expected. This might lead to a more detailed discussion when reviewing standards or developing new ones. This might also trigger mainstreaming climate change adaptation for standards which are at the national level.

Direct environmental impacts are not expected.

<u>Phase 2: Amendment of certain standards and applying the modified guidance document</u>

If standards are amended the main benefit would result in a higher climate resilience of infrastructure. This relates to reduction of climate-related damages to or/and destruction of infrastructures and decreased need for maintenance, repair and/or reconstruction of infrastructures. As EUROCODES are mandatory the impacts can be expected to be higher than for all other standards which remain to be voluntary. For the development of new standards the uptake of the modified environmental code will be the determining factor.

Also increased supply security and reliability of transportation lines and facilities (energy, transport, water) for the functioning of the EU Internal Market; avoiding economic costs in case of interruptions (e.g. electricity transmission and distribution) can be expected.

The IPPC report (IPCC, 2011) defines the enforcement of building codes as a low-regrets measure that can reduce exposure and vulnerability to hazards and change. Examples for the benefits of these measures are:

- For municipal governments, adoption of building codes in hurricane-prone areas reduces damages by US$ 108 (84€) per square meter for homes built from 1996 to 2004 in Florida (Kunreuther, et al, 2009).
- According to the Coleman, 70% of the losses associated with Hurricane Alicia (Louisiana, Texas) and up to 40% of the losses associated with Hurricane Andrew (Bahamas, Florida) were due to poor building code enforcement.

- In the context of the Hurricane Katrina (South of the United States) a study of residential wind damage showed that “economic losses, could be reduced by estimated 65 percent if the buildings in the affected area had protected building openings, improved roof-deck connections, and improved roof-to-wall connections. That would have meant a reduction from $4.8 billion to $1.7 billion (€3.7 billion to €1.4 billion). (Cobb, n.y)

- Studies of disasters from 1994’s Northridge earthquake (Southern California, US) to 2005’s Hurricane Katrina demonstrate that effective building-code enforcement reduces loss in catastrophic events (Cobb, n.y).

- A 2005 study conducted by a council of the National Institute of Building Sciences concluded that funds directed toward hazard mitigation before an event reduce losses by almost four dollars for every dollar spent. The federal government supports that concept with pre-disaster grants to communities that effectively institutionalize natural hazard mitigation strategies in their building-code adoption and enforcement (Cobb, n.y).

- A study done for the Institute for Business & Home Safety (IBHS, n.y.) found that losses from Hurricane Andrew (south Florida in 1992) caused more than $20 billion (€15,5 billion) in insured damage, would have been reduced by 50 percent for residential and by 40 percent for commercial properties if they were built in accordance with Florida’s 2004 statewide building code. Another IBHS study following Hurricane Charley (Florida) in 2004 found that modern building codes reduced the severity of losses by 42 percent and loss frequency by 60 percent (IBHS, n.y).

However, enforcement of building codes by municipalities is highly variable and becomes a limiting factor in disaster risk management and adaptation. Poverty, increased urbanization, and extreme climate events limit the capacity to initiate planned livelihood adaptations at the local scale (IPCC, 2011).

Only a limited quantification of these benefits is possible as shown for the option “impose mandatory requirements in terms of resilience of current and future infrastructure projects”. However in most cases the benefits outweigh the costs.

Uncertainty in climate modelling and potential lack of data/information in climate impacts for specific regions will make the amendment of any standard a difficult exercise. There is a risk that certain amendments will lead to overshooting the target and therewith unnecessary costs.

Standards considering climate change risks might lead to increased resource consumption (e.g. thicker steal)[298]. Research on change in constructions and on new materials might help to reduce these negative environmental impacts.

Some respondents of the public consultation stated that ‘Adaptation should be included in relevant national building codes and Eurocodes to ensure that future constructions resist the consequences of climate change. In addition, standards for assessment of sustainability of buildings such as CEN/TC 350 standards should take into account adaptation to climate change as an aspect of sustainability’. Also from the stakeholder workshops, the stakeholders involved supported an EU approach on adaptation in order to integrate adaptation into existing key standards concerning long life cycles.

6.5.3.2 Impose mandatory requirements in terms of resilience of current and future infrastructures

Description of the option

Instead of working together with the industry on standards, a legal proposal could be launched which obliges infrastructure developers in Europe to take into account certain climate scenarios when retrofitting or building new infrastructure. This legal proposal could include certain 'standards' as mandatory requirement to be adhered to when building roads and energy transmission lines. The legal proposal would also force Member States to retrofit existing transport and energy infrastructure until 2040.

Assessment of the option

Altvater et al. (2011b) assessed the economic costs and benefits of certain adaptation options in the energy and transport sector. The study highlights various uncertainties in relation to the assessments but concludes the following:

- Adaptation measures (securing local distribution networks and national transmission networks from storm damage, additional annual maintenance costs of existing transmission and distribution networks due to higher vegetation, and annual investment costs for additional networks (transmission and distribution) due to electricity demand triggered by supplemental cooling) to enhance the energy infrastructure in the EU and make it more resilient towards storm damages and demand-induced overloads in transmission lines are expected to be at some € 500 to 650 million per year until 2020[299]. The benefits are estimated at € 130 million to € 6,500 million per year, with a best-guess estimate of € 870 million per year. While both the cost and benefit estimates are fraught with uncertainties, it seems more likely that the benefits exceed the costs than that the opposite is true.

[298] This concern was expressed in a stakeholder meeting with CEN/CENELC.
[299] Cost estimations are based on the IPCC emission scenarios A1FI and B1.

- The investment costs for better heat-resistant asphalt have been estimated between 2,9 and 8,9 billion Euros per year for public roads. The highest investment costs are assessed for Germany, France, United Kingdom and Poland. The benefits are estimated between 1,8 and 2,5 billion Euros per year for passenger travel and approximately 183 million Euros per year for freight transport. In comparison to the benefits, this implies that, if the costs are at the lower end of the estimated range, benefits and costs would be almost equal. It is more likely though that the costs of the measure would exceed the estimated benefits. It has to be kept in mind that the estimated benefits only measure the benefits of avoided delays and detours in terms of saved travel time. Thus, they only represent a share of the overall benefits: for instance, the avoided costs of road accidents have not been counted, and neither have the avoided maintenance and repair costs for fixing heat-induced damages to the road surface.

- The investment costs of better drainage systems with a higher capacity are between 50 and 240 million Euros per year for public roads. The highest costs are assessed for France, Germany and United Kingdom. The benefits of this measure are estimated between 19 and 57 million Euros per year. Keeping in mind that the benefit estimate only captures part of the overall benefits, there is no guarantee that the benefits of the measure will exceed its costs. If the costs are at the lower end of the estimated range, and the benefits at the upper end, there is a chance that the measure will deliver a net benefit. If the costs are at the upper end of the estimated range, they will exceed the benefits – at least that share of the benefits that was quantified above.

- The estimated operating costs for rail track buckling in the form of costs induced by speed restriction that could prevent derailments. The operating costs for speed restrictions due to track buckling are estimated to range from 59 million to 260 million Euros per year for EU-27 according to different values for delay minutes. The benefits are estimated to fall within a range of 90 million to 537 million Euros per year. It is therefore likely, but not certain that the benefits of the measure would exceed the costs. If the total costs are at the higher end of the projected range, but the benefits at the lower end, it is also possible that benefits may exceed the total cost.

Considering the high uncertainty in the calculations for most of the adaptation measures the benefits are expected to outweigh the total costs.

Major effects on employment would not be expected from the measure, if it is assumed that the upgrading of infrastructures (e.g. heat resistant asphalt or improved drainage capacity) is integrated into the regular reinvestment cycle. In this case, there would be no substantial effects, since the required labour input does not differ. This would be different if existing infrastructure was retrofitted before the end of its economic life span; but this would also incur significantly higher cost than anticipated in this estimation.

The development and construction of new, more robust pylons and overhead lines, but also the development of more resilient grid layouts can help to promote the diffusion of European technologies. The EU industry is a main producer of technologies for energy infrastructure (EC, 2010m). Many countries outside the EU are also facing the challenge of installing electricity networks that are better-adapted to climate change and that meet the needs of changing generation patterns, which potentially increases the demand for European technologies and expertise in the world market. The investment need in this sector would have also a positive impact on small and medium enterprises (SMEs) in the fields of construction, mechanical engineering and business services (EC, 2010n).

Negative environmental impacts during the construction phase are not anticipated: compared to normal renewing works, the construction of heat-resistant road surfaces or increased drainage capacity does not create significantly different environmental impacts. Retrofitting transmission lines can affect agricultural activities including irrigation, aerial spraying, wind breaks and future land development. The placement of pylons on agricultural land can create problems for turning field machinery, lead to the compaction of soils, damage drain tiles, obstruct moving irrigation systems and interfere with a future consolidation of farm fields (PSCW, 2009; BDEW, 2011; Vattenfall Europe, 2005). For underground cables, a corridor of at least four metres width is required, with only low vegetation and without trees. Extensive excavation work and soil movement occurs during the construction of underground cables (BDEW, 2011; Schering, 2009). The excavation work is followed by long-term impacts on soil. Since underground cables produce heat, they may exacerbate droughts in drying out the soil, with adverse effects on the vegetation and agriculture (Vattenfall Europe, 2005; Gouda, et al, 1997). The costs of underground cabling exceeds the costs of overhead lines by a factor of 5 to 21 (highly dependent from local circumstances)[300] and it is thus not feasible to replace overhead lines in the high voltage transmission grid to a large extend. However, the low and medium voltage distribution grid in urban areas is already underground to a large extend in most cities of western and central Europe, which has improved the resilience of urban distribution grids.

The political acceptability of this option is considered to be low due to a high level of uncertainty:

- The uncertainty in climate projections and regional impacts are still quite high (cf. chapters 3.1.1 to 3.1.3). Therefore, the level of adaptation and in some cases also the direction of impacts (more floods, less floods) cannot be clearly estimated;
- The costs and benefits cannot be clearly estimated due to uncertainty mentioned above. This is in particular true for the regional level, which is in the case of transport responsible for maintaining large parts of the infrastructure.

[300] https://online.tugraz.at/tug_online/voe_main2.getvolltext?pCurrPk=33553

However from the public consultation it came clear that 65.84% of respondents consider ‘improving the climate resilience of infrastructure investments’ as being ‘more relevant’ or ‘highly relevant’ for strengthening the adaptive capacity of the private sector.

6.5.4 Effectiveness, efficiency and coherence of the options addressing problem 5

The two options will contribute to the making the EU territory and key vulnerable sectors more resiliant. However, the options are subject to different uncertainties. For the CEN-CENELEC guidelines, the impact will depend on the level of uptake. Mainstreaming climate change into EUROCODES and other CEN-CENELEC standards will only bring effective impacts if finally standards are amended to reflect the potential impacts from climate change. This is, however, a difficult task as climate change impacts are not detailed known in many regions. These uncertainties related to climate change are also an issue if a more mandatory approach is followed and requirements are imposed for future and current infrastructure. The magnitude of reducing the impacts will also depend on the number of standards modified. However, assuming the case that the private sector accepts these new standards, the adaptive capacity and climate impact preparedness and responses in the private sector will be strengthened.

Both options might contribute to the objective of “Better informed decision making” as they might lead to the new research and closing knowledge gaps. The amended environmental guide for standards could also be used to disseminate good practice of infrastructure related adaptation.

The efficiency of options varies widely. There is not a lot of experience out there on mainstreaming climate change into standards to improve climate resilience of potentially impacted infrastructure in Europe. In the case of mandatory retrofitting existing infrastructure, the benefits will outweigh the costs. However, the assessments of costs and benefits are related to a high level of uncertainty (e.g. amount of infrastructure affected by a certain climate threat), which might change this positive ratio.

The options on CEN-CENELEC standards (incl. EUROCODES) are both in line with internal market objectives of the EU. Standardisation is seen as a significant contributor to the completion of the Internal Market in the context of 'New Approach' legislation[301], which refers to European standards developed by the European standards organisations. Also the proposal for the 7EAP argues that infrastructure will need to be compatible with nature protection and climate adaptation needs and obligations.

[301] http://ec.europa.eu/enterprise/policies/single-market-goods/regulatory-policies-common-rules-for-products/new-legislative-framework/index_en.htm

6.5.5 Comparative table of the options addressing problem 5

The options are not contrasting or alternative options and could also be combined (e.g. making a certain standard mandatory. None, one or all could be taken forward; however, the second option is not recommended due to high uncertainties.

The following table compares and summarises how the options contribute to the effectiveness of achieving the operational objectives of the strategy and to the overarching objectives of improving efficiency and coherence.

Table 49: Comparative table of the options addressing problem 5

Options	Economic, social, and environmental impacts	Effectiveness			Efficiency	Coherence	Acceptability
		Objective 1: Better informed decision making	Objective 2: Increasing the resilience of the EU territory	Objective 3: Increasing the resilience of key vulnerable sectors			
No policy change		0	0	0	0	0	0
Mainstream climate change into EU wide standards	++ (low costs and a high potential to improve climate resilience of	+ (might trigger new studies, triggers cooperation among MS)	≈to++/? (might mainstream climate change into construction, transport and energy sectors	≈to++/? (strengthens adaptive capacity and climate impact preparedness and responses in the private sector)	++(standards cover most of the potentially impacted infrastructure in Europe)	++ (Internal Market, the 7EAP, white paper on Transport)	++ (high acceptance as discussed during stakeholder workshops)
Impose mandatory requirements in terms of resilience of current and future infrastructure projects	+(even if this option brings high costs, the benefits achieved outweigh them)	+ (might trigger new studies, triggers cooperation among MS)	≈to++/? (will mainstream climate change into construction, transport and energy sectors	+/? (might trigger a discussion on adaptation in the private sector	?(there are several uncertainties related to this option, so efficiency cannot be ensured)	++ (Internal Market, the 7EAP, White paper on transport)	? to - -(there are several uncertainties related to this option, which affect acceptability negatively)

Magnitude of impact as compared with the baseline scenario (the baseline is indicated as 0): ++ strongly positive; + positive; – – strongly negative; – negative; ≈ marginal/neutral; ? uncertain; n.a. not applicable

6.6 Problem 6: Capture the potential of the market

6.6.1 Problem definition

Climate change exposes the private sector to a range of risks to their operation, profitability and growth opportunities. The impacts from these risks may be systemic (at the whole economy level); sector / industry-wide or company-specific. The private sector is diverse and no assessment of the risks faced by business can be applied to every situation. Risks will vary depending on the business size, its structure, activities and geographical level of operation (global, national, local).

The EU's business enterprises generate in excess of 12 trillion Euros in GDP, exports of more than 1.5 trillion Euros producing a wide range of products, goods and services ranging from primary agricultural products to high tech consumer goods. Some or all of this production is potentially threatened by the impacts of climate change. In most cases impacts are predicted to hamper rather than completely destroy production and distribution of production. However, the scale of potential impact is enormous and touches on every aspect of business activity across all Member States. On the other hand, climate change could also lead to economic benefits. Almost 80% of citizens believe that actions to tackle climate change could boost the economy and create jobs (Eurobarometer, 2011b).

Markets operate most efficiently when actors have good (perfect) information and respond appropriately to this information. At present the private sector faces significant risk enumerated below which arise because private sector entities are unable to assess and respond to risks either because of a lack of publicly available information or the search costs of becoming better informed are relatively high. The risks presented by climate change to the private sector include (cf. also chapter 3.6):

- Physical *risks* to a company's assets or to the public infrastructure.
- *Supply chain / logistical risks.* This includes the costs and availability of raw materials, and other sources of disruption to supply chains.
- *Financial risks*. Climate change may affect companies' access to capital, as investors become more aware of climate change impacts and the need for adaptation. Debt financing may be harder to attract or more expensive for companies that are seen to be at "high risk" of climate change impacts (as businesses with operations, employees and supply chains in developing countries will be).
- *Market demand risks*. In the face of climate change, certain products and services will become more or less relevant and more or less effective requiring businesses to adapt to new market demand drivers in order to remain competitive. The change in products / services as a result of climate change combined with increased energy prices is identified as the main Overall, the impact of climate change on consumer's

behaviour is largely unknown but companies which are able to adapt to changes in demand can turn this risk into new business opportunities. Examples of such an approach are provided in the 2011 OECD report (Agrawala, et al, 2011).

- *Regulatory and legal risks*. As countries adapt to climate change, they will likely use a range of regulatory tools to better manage their natural resources and reduce their disaster risk. For example, they may enact new land use or zoning regulations, or new building codes. They may put more stringent limits on water use and irrigation. Governments are increasingly requiring companies to disclose their climate risks and adaptation efforts.

- *Indirect economic costs* may also occur through reduced workdays and productivity as a result of more severe weather events.

These risks can be characterised as market failures arising from lack of information and asymmetric information which mean that the market fails to take proper account of the risks of climate change and less adaptation is undertaken than would otherwise be desirable.

These are all serious risks which could impact negatively on individual businesses and the EU economy as a whole. The cost of inaction is likely to be high This has been recognised in the Adaptation White Paper which stated that decreasing the vulnerability of the economy is a key convergence area between adaptation policy and the Lisbon strategy

Surveys provide information on how businesses perceive these risks: according to a 2010 UNEP's survey of 72 companies (UN Global Compact, et al, 2011) that responded to the Caring for Climate survey, their main concern relates to supply chain and physical risks (increasing cost of natural resources, raw materials; water scarcity; energy security) i.e. direct risks.

SMEs are likely to be more affected than larger firms. SMEs often face financial limitations, i.e. a lack of venture capital to start a promising business (Butzengeiger-Geyer, et al, 2011).

Low lying regions may be most exposed to risks from sea level rise but all regions are potentially impacted by different aspects of climate change impacting on water availability, forest fires, flooding and other disruptive weather events.

While opportunities for new jobs or securing existing jobs, products and services undoubtedly exist as a result of adaptation, it is likely that the main impacts on businesses will result from the need to adapt their existing processes and products. This makes it very difficult to quantify the benefits from adaptation.

A short, targeted questionnaire was distributed to 43 private sector stakeholders in the following sectors: agriculture, construction, energy, transport, finance, insurance and organisations representing the interest of SMEs. The assessment of policy options for the private sector is informed by the results of this questionnaire, as well as a review of relevant literature and wider consultation responses, one respondent stated that technological risk was one of the top three barriers to adaptation: they stated "*promotional banks can and do provide long-term financing solutions for investments in climate protection projects. Depending on the specific project there might be technological risks, either due to investments in new developed (and therefore riskier) technologies and/or investments in existing technologies which do not pay an appropriate return because fast technological progress can supersede existing technologies only a few years after the investment decision.*"

Information problems and uncertainty

Of those who responded to the questionnaire, lack of information was identified as the most important barrier to adaptation. The lack of accurate and reliable information hinders the uptake of adaptation investment because of a lack of awareness of climate-change related risks in the first place and even when awareness exists, the inability to model the risks and their impacts satisfactorily in order to inform investment decisions. Lack of awareness of climate change-related risks was ranked the second top barrier to adapting to climate change, followed by the short versus long timescales associated with climate change. This is explained in more detail in chapter 4.5. The informational problems are broadly characterised as being one of these types of problems:

- Lack of information, uncertainty and modelling tools.
- Lack of awareness of climate change-related risks.
- Short-term versus long-term horizons.

Policy and regulatory failures

Regulation can explicitly compel companies to take adaptation into account. However, while regulation can promote adaptation, inconsistencies in regulation or uncertainty about the future regulatory environment can be a cause of uncertainty to companies and may even be a barrier to implementing adaptation.

Externalities

A key barrier to private sector investment in actions design to address climate change and other environmental issues is the existence of externalities. This means that those who pay for adaptive responses will not be the only ones to reap benefits. Conversely it can also mean that by not adapting to climate change they generate damages which affect people / businesses beyond themselves.

Negative externalities related to pollution, resource depletion, loss of biodiversity etc. are not captured in market prices, leading market failure and the over production of environmentally damaging outputs. Positive externalities from the restoration of the environment, reduction of emissions, reduced water use are not fully captured by the organisation which invests in actions. In doing so, externalities distort economic activities against the environment on both sides.

6.6.2 No policy change

In the absence of EU action there is an expectation that the gap between those organisations able and willing to take adaptation actions and those left behind will grow. Some of the largest trans-national corporations, and those in certain sectors, have begun to appreciate the potential threat and opportunity presented by climate change. However by 2020 large sectors and a great many small and medium sized enterprises will be unable to make the necessary adaptation measures making them increasingly vulnerable to the effects of unavoidable climate change. In the absence of measures from the EU this gap will widen – creating market obstacles for those left behind.

There is evidence of on-the-ground adaptation (e.g. PwC, 2010; UK Trade and Investment, 2011; Agrawala, et al, 2011) but this is mainly from multi-national corporations and there is little evidence of adaptation in SMEs. Indeed only 24% of respondents to the consultation exercise indicated that EU action within the industry and SME sector was relevant or highly relevant to improve Europe's resilience to the adverse effects of climate change. 29% of respondents were neutral, 13% of respondents did not believe industry and SMEs were relevant and 10% had no opinion. This suggests that with no further action, multi-national companies rather than SMEs would continue to be the drivers of adaptation.

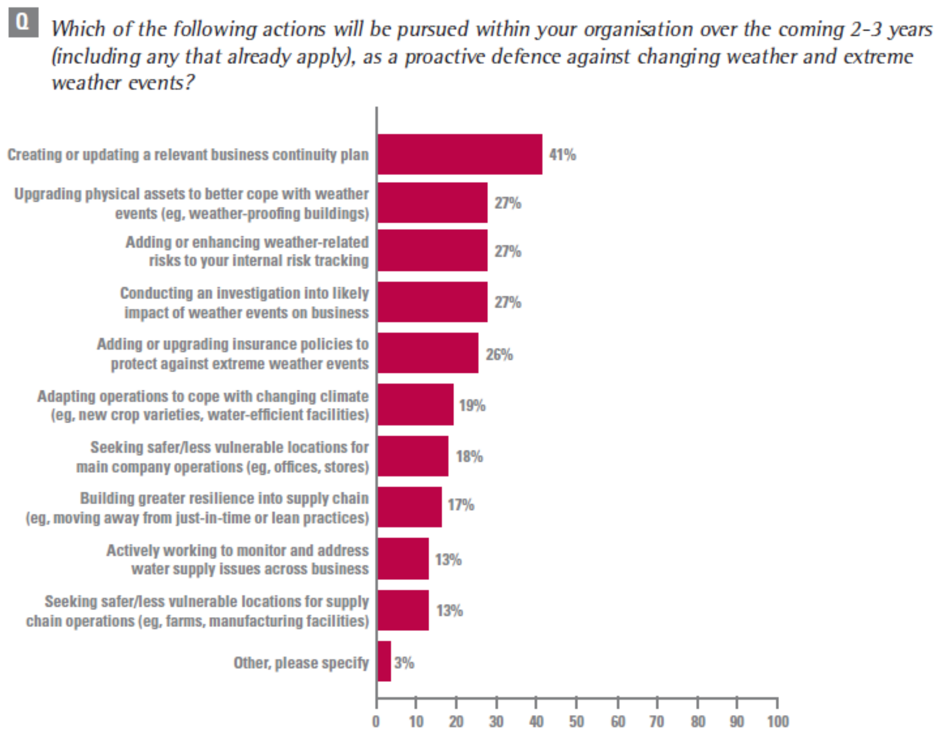
Firms are investing more to protect themselves. Much of this takes the form of updating business continuity plans, or upgrading risk trackers (cf. Figure 64). But around one in four firms is either upgrading their existing physical assets, for example by weather-proofing buildings, or taking out new insurance policies. Around one in five businesses plan to adapt their operations better to deal with such changes, such as adopting new crop varieties or more water-efficient facilities (UK Trade & Investment, 2011).

In a review of existing European National Adaptation Strategies (NAS), there was very little consideration of the role of the private sector in adapting to climate change. Four of the nine NAS reviewed included discussion on the role of insurance, but this was limited. Only the NAS for Malta contained a concrete action relating to the role of insurance: “the Malta Resources Authority will steward discussion amongst stakeholders to identify suitable mechanisms and instruments that will ensure that the insurance market remains sustainable in the event of increasing unpredictability of climate change impacts on various sectors in Malta.”

In light of this, it is likely that Member States require further guidance and assistance from the EU on how to stimulate the private sector into action on adaptation; combined with help to engage the finance and insurance sectors on adaptation. In the Communication for the

Blueprint (EC, 2012m), guidance for taking advantage of payment for ecosystem services in the context of green infrastructure projects has been promoted as an action to support the Water Framework Directive. Without further action, progress among Member States is likely to be slow and fragmented.

Figure 64: Actions to be pursued by organisations over the coming 2-3 years to protect against changing weather and extreme weather events (UK Trade & Investment, 2011)



With no (new) action, large businesses are likely to continue with a piecemeal approach to adaptation and SMEs are not likely to step up their adaptation action. The impact of climate change on Europe and the rest of the world will accelerate and businesses will not be ready and able to reduce their vulnerability and seize the opportunities that adaptation presents. There are strong arguments for a joined up approach, facilitated by the European Commission, to harness the opportunities and reduce the risks of climate change facing the private sector, particularly SMEs.

6.6.3 Policy options addressing problem 6

6.6.3.1 Engage with commercial banks

Description of the option

Adaptation financing is required for national adaptation planning and implementation, impacts and vulnerability research, disaster risk management and technology development and transfer. Financial institutions and banks can play a critical role in financing adaptation interventions, provided that the necessary structural investments and policy frameworks are in place. The aim of this policy option is to better understand the current status of adaptation action in commercial banks, and to develop the evidence base to help formulate a strong policy framework which facilitates greater investment in climate resilience.

Currently access to substantial upfront investment is recognised as a key barrier for climate-resilient investments in the private sector (e.g. UN Global Compact, et al, 2011; Agrawala, et al, 2011). From a company's perspective (in particular SMEs) short term costs and impacts on cash flows are generally more pressing than long term benefits (PwC, 2010). Five out of seven respondents to the private sector questionnaire identified access to finance as a key barrier in adapting to climate change. One commercial bank stated "*climate change might have a (negative) impact on the asset side of the balance sheet of financial institutions (e.g. through its impact on credit portfolios), especially long-term assets and/or derivatives*". A respondent from the insurance sector stated "*the financial risks of climate change are significant for insurers. Increasing claims costs must ultimately lead to increasing premiums, which in turn can generate reputational risk*."

In addition to the problem of capital generation, it is important to ensure that policy, institutional, technological, behavioural and technical skill barriers are removed to redirect existing and planned capital flows from traditional high-carbon to low-emission climate-resilient investments. Removal of these barriers can complement and maximise the impact of capital finance such as concessional loan finance (UNDP, 2011).

Addressing access to finance was identified as a significant issue by 63% of respondents to the consultation exercise. 62% of respondents also said that lack of available funding for adaptation measures was a significant or very significant barrier preventing the economy from becoming more climate resilient.

Current EU funds are not sufficient for climate resilient investment (European Parliament, 2010)[302] therefore there is a need to leverage funding from commercial banks. Currently there are international private sector initiatives aiming to mobilise funds from within the

[302] The European Parliament voted in June 2010 on the 2009 White paper (EC, 2009a) in: CER (2011) The European & rail sector's perspective: an increased interest for Climate Change Adaptation. Adapting Rail Infrastructure to Climate Change, UIC, Paris, 19 October 2010.

private sector for adaptation, e.g. Adaptation Private Sector Initiative[303] which aims to catalyse private sector contributions to and involvement in adaptation and the UNFCCC Green Climate Fund[304], which is designed to support adaptation and mitigation in developing countries, with a target for developed countries to mobilise $100 billion a year in public and private finance by 2020. There are no similar initiatives at the EU level.

While there is an evidence base on the role of public banks (e.g. European Investment Bank) in adapting to climate change, less is known about the role of commercial banks. Therefore this option seeks to engage directly with commercial banks through a workshop which provides an opportunity to a) review what adaptation-related actions are currently being taken, if any; b) review existing structures for risk assessment, e.g. is climate change risk and adaptation taken into account when applying for a loan; c) raise awareness of adaptation and initiate dialogue with stakeholders and facilitate cross-organisation working where possible; and d) motivate commercial banks to consider mobilising funds and sharing best practice with other commercial banks (where it does not compromise banks' competitive edge).

The success of the option could be measured through a status report on adaptation action being taken by commercial banks (valued in EUR); formal and informal networks and partnerships forged by banks and finance institutions; potential/actual value of financial assistance available for adaptation/climate resilient investments; types of investments to be funded.

Assessment of the option

The option identified here is a first step in engaging with financial institutions and the banking sector to promote climate resilient investments; therefore the implications are likely to be relatively limited as this is only part of the solution.

The total (one-time start-up costs and operating) cost of this option relates to organisation and delivery of a workshop for half/one day, as well as post-workshop analysis and taking forward actions/recommendations. In relation to the impact of gathering commercial banks, the cost will be minimal. The key economic impacts are likely to be very modest.

The option is unlikely to have direct, immediate economic impacts. However as a result of increased awareness of climate change adaptation and new forged relationships between Member States, in the mid to long term, the option could lead to increased mobilisation of funding for climate resilient investments, as well as improved access to finance through a wider range of financial instruments on the EU market.

[303] http://unfccc.int/adaptation/nairobi_work_programme/private_sector_initiative/items/4623.php
[304] http://gcfund.net/home.html

Small businesses face the biggest constraints limiting the type and scale of adaptation actions they can take (as do many businesses in developing countries) (PwC, 2010). Engaging with financial institutions and the banking sector to promote climate resilient investments is likely to help SMEs to overcome financial barriers by allowing SMEs to adapt their operations and/or respond to new market demands by investing in product / service development. It is also important to bear in mind that adaptation measures should not increase red tape for SMEs.

The option is not expected to have any significant social impacts. There is unlikely to be any direct implication for employment, however, if engagement is successful there might be a demand for people with relevant skills and expertise to take investments forward (e.g. climate change adaptation generalists, as well as specialist jobs such as seed biotechnologists, engineers, climate modellers, and flood planners) (UK Trade & Investment, 2011). The option will facilitate discussion between commercial banks across Member States and with European institutions, thereby helping to build new relationships and encourage cooperation on the topic of climate resilient investment.

This option will have very few/no direct, immediate environmental impacts. In terms of its contribution to adaptation, direct impacts are not likely to be felt until funding is mobilised and adaptation actions have been taken. Even then, it could be a number of years before benefits are experienced.

The option will have very few direct economic, social or environment impacts as this is only a first step in engaging with commercial banks to promote climate resilient investments and therefore only part of the solution. However it is an important step to take in order to assess the state-of-play of adaptation in commercial banks, as well as in forging relationships, raising awareness and sharing knowledge of adaptation within the sector where this does not compromise a bank's competitive edge.

The option is fully in line with the proposed 7EAP which calls in article 3 that "public authorities at all levels shall work with businesses and social partners, civil societyand individual citizens in implementing this programme".

6.6.3.2 Explore market based approaches

Description of the option

Mandatory regulations can be a blunt, cumbersome and expensive instrument. For this reason, policy makers have been looking at more cost-effective ways to alter how businesses produce and individuals consume. Market-based instruments (MBIs) can provide such solutions. MBIs can take many forms including: taxes, charges, subsidies, marketable (or tradable) permits, deposit/refund systems and fines, payment for ecosystem services, property rights and habitat banking.

Instruments can be thought of as falling into one of two types; instruments with positive incentives (“carrots”) to provide the public good of adaptation (i.e. “promotion of adaptation”). Options including negative incentives (”sticks”) such as taxation of risky activities will face higher political opposition. It is assumed that Tax reductions can only be applied on the national rather than as the international level. This option therefore considers the need for further exploration of possible market based interventions in three areas; i) Payments for ecosystem services ; ii) Removing harmful subsidies and iii) State aid.

Payments for ecosystem services

One specific promising measure for further study is *Payments for ecosystem services,* (discussed in more detail in chapter 3.6.3.2) e.g. for the protection of forests and wetlands, these can mobilize adaptive activities indirectly through the remuneration of certain land uses. Adaptive land uses such as providing flood plains or soft landscaping for improved drainage could be rewarded or at least recognised within the valuation of ecosystems. The effectiveness of this approach is perhaps limited by the scope of application for adaptation compared to the potential to make use of ecosystem service valuations across a much wider field of beneficial services. The potential for double counting or double paying for ecosystem services needs to be avoided and suitable systems need to be in place to maintain the integrity of such a system. Costs are unclear, but transaction costs could be substantial.

Removing harmful subsidies

Some subsidies for the industrial, transport, agriculture and energy sectors can be environmentally harmful because they promote the use of polluting or energy-intensive products or processes. They can also introduce distortions in the Single Market. A combination of an Environmental Tax Reform with a reduction of Environmentally Harmful Subsidies is commonly referred to as an Environmental Fiscal Reform.

Under the public consultation “Contradictory requirements from different EU policies” and their corresponding “Harmful subsidies” came up a few times as well as an additional barrier.

With this in mind, potentially adaptation-harmful subsidies should be identified and screened out at EU and national level (e.g. state aid). However it is unlikely that any subsidies are harmful per se. In fact many are potentially very useful to support adaptation if they can incorporate climate resilience; however in some cases there is the potential for them to have negative impacts. (one such example might be the effect of reduced taxes on domestic electricity encouraging the use of air conditioning rather than other adaptation actions (because of the relative change in price).

State aid

State aid has a critical role to play in eliminating subsidies which exacerbate climate change risks – and equally in supporting subsidies which exploit the opportunities. State aid rules help governments assess the effectiveness of proposed subsidy measures, and help channel funds to where they are the most necessary and can deliver the most benefit to taxpayers[305].

The environmental aid guidelines constitute one of the instruments to implement the environmental aspects of the energy- and climate change-related targets decided by the European Council, and it is recommended that climate change adaptation is incorporated into the revised guidelines. The environmental aid guidelines already refer to the “polluter pays” principle. It is recommended that an official request is made by DG CLIMA to include climate change risk and adaptation in the environmental aid guidelines. The environmental aid guidelines are due to be revised in 2013 which coincides with the implementation of the European Adaptation Strategy.

As an example, “*reduced vulnerability to climate change’* or *‘increased resilience to climate change’* might be suitable assessment criteria/objectives to include in the revised environmental aid guidelines. Discussions between DG CLIMA and DG COMP/DG ENV should also cover the potential to include adaptation in the Regional Aid guidelines, Research, Development and Innovation guidelines and Agriculture and Forestry guidelines.

Assessment of the option

The possibility to use MBIs for adaptation has not so far been widely explored and there is therefore limited evidence of their effectiveness or applicability (Butzengeiger-Geyer, et al, 2011; Kiem & Austin, 2012). As such data and information on the details of the policy option are limited so the assessment is mainly top-level and qualitative.

The key economic impacts are dependent on the nature and choice of instruments adopted. Market based instruments for ecosystem services may have some economic impact on local areas where a payment is made but as suggested this would need to be done as part of a wider system of ecosystem service payments. The economic impact of this is therefore likely to be low, but has not been studied in detail.

MBIs have proven that they can provide firms with an incentive, in the longer term, to pursue technological innovation to further reduce adverse impacts on the environment (“dynamic efficiency”). They encourage businesses to innovate and increase productivity by becoming more efficient and less polluting, contributing to long-term and self-sustaining solutions which are suited to the long timescales associated with climate change adaptation.

MBIs may generate revenues for the government, which can be used to fund further adaptation action.

[305] Joaquin Almunia European Commissioner for Competition, State aid and Subsidies in the European Union 9 th Global Forum on Competition Paris 18 February 2010. SPEECH/10/29. http://europa.eu/rapid/pressReleasesAction.do?reference=SPEECH/10/29&format=HTML&aged=0&language=EN&guiLanguage=en

Where adaptation is linked to the reduction of resource use, market mechanisms have already been applied to optimize resource utilization, e.g. in the case of tradable water access rights (Cantin, et al, 2005). Kiem & Austin (2012) examined the social, economic, and environmental costs and benefits of water trading, and uses insights from this as to the implications of using 'market-based' instruments (MBIs) for climate change adaptation. As an example, water trading has potential as a climate change adaptation strategy with many benefits experienced in previous and current versions of water trading. Yet there are also significant limitations and the people and industries that are negatively impacted by water trading are hit hard. These social impacts and limitations of water trading have not been thoroughly investigated and are not well understood. In addition there are uncertainties about the impact of water trading on the environment, and regarding MBIs as an adaptation tool more widely, in unit costs.

Predictability of adaptation achievement is important in all options: measurability of adaptation achievements has to be given in case of ex-post payments or issuance of certificates. This means that the level of adaptation units (e.g. lives or Euro) would need to be monitored and compared with a hypothetical baseline.

The issues of predictability and measurability are not trivial for adaptation policies. Measuring and verifying may include high transaction costs, which can be a major hurdle for market-based instruments (Stavins, 2003).

A further technical precondition is the availability of different unit costs (Stavins, 2003). Market mechanisms are only expedient if costs to achieve adaptation units differ. This precondition is easily met: Economics of Climate Adaptation (ECA, 2009) show that cost-benefit ratio differ considerably among projects.

Once these main technical preconditions are met, and the following governing functions have to be assigned to existing or newly established institutions: allocation of funding, verification, issuance of certificates, disbursement of funds, appeal procedures, enforcement of rules, establishment of trading platforms and anti-fraud mechanisms.

There are not expected to be any significant social impacts, except possibly in terms of employment although this would be in the long-term and indirectly i.e. through the investments it would enable.

Environmental impacts are likely to be limited although the use of ecosystem service payments would potentially have additional habitat creation benefits.

In particular removing harmful subsidies is also mentioned as a future action under the proposed 7EAP (priority 6).

Respondents to the public consultation were asked to rate actions the EU should take – including emphasizing the role of market-based instruments- to help strengthen the adaptive capacity of the private sector. 53% of respondents ranked 'emphasising the role of market-based instruments' as being either medium or highly relevant for supporting adaptation actions in the private sector. Moreover, when asked to write in additional issues that should be covered by the EU Adaptation Strategy, a few business oriented respondents mentioned the need to strengthen cooperation between insurers and policymakers by encouraging market-driven initiatives.

6.6.3.3 Legislative actions asking all companies to undertake risks assessments along their supply chains

Description of the option

This option seeks to integrate climate change impacts into risk management and other strategic planning activities within private sector organisations. This mandatory approach should help organizations to improve the identification of opportunities and threats in relation to climate change adaptation. It should also enforce an effective allocation and use of resources for risk treatment. Adequately implemented, this option should lead to enterprise risk management providing a holistic approach to address the major climate change needs across business units and functions, thus ensuring that climate change adaptation is aligned with an organisation's business strategy. Organizations should also be able to compare their risk management practices with an EU wide recognised benchmark, providing sound principles for effective management and corporate governance. If risks are identified and included in strategies, it is assumed that there is no requirement to take adaptation measures to reduce the risks identified.

Companies are required to certify their internal risk assessments by external private auditors, which need accreditation at a central European body. Certifications would be renewed every five years or in the case of changes in production or reallocation of the business.

A potential entry point is the ISO 31000:2009[306], which provides principles, a framework and a process for managing any form of risk in a transparent, systematic and credible manner within any scope or context. It can be used by any organization regardless of its size, activity or sector. Another option would be that the Commission develops its own approach.

Assessment of the option

Under this option, investment costs for businesses and for the European Commission can be expected. The costs for the Commission would relate to the development and negotiation of a legislative act and to the establishment of the central auditing body. However, these costs can be reduced if those that want to register have to pay a registration fee.

When assessing the total costs of this option for companies, two main aspects have to be considered: the one-time cost for carrying out the assessment and the potential savings for

[306] http://www.iso.org/iso/home/standards/management-standards/iso31000.htm and http://www.iso.org/iso/home/news_index/news_archive/news.htm?Refid=Ref1586

reducing the risk of potential impacts and damages. However, these costs would only occur if the costs of adaptation measures outweigh the potential damage costs.

The operating cost for the certification process along with the requirements set out by ISO 31000 would mainly relate to acquiring of specialised skills (training of staff), technologic tools and the external certification. The one-time cost for the first certification are estimated between 4.000 Euros for companies with an annual turnover less than 125.000 and 6.000 Euros for companies larger than an annual turnover of 625.000 Euros[307]. The businesses that are expected to be most impacted are SME's, which usually don't have the skills internally, nor the finances to pay external consultants to help them with the first risk assessment and the certification.

The total costs for minimising the risk will clearly depend on the specific situation and the vulnerabilities and cannot be estimated at this stage.

The impacts of this option would also have different results for primary, secondary and the tertiary sector.

For the primary sector the situation can be considered as extremely diverse. In the case of agricultural production, such risk assessments seem to be extremely difficult and would represent an additional administrative burden. This would be the particular case for small farmers, which are proposed to be exempted from certain CAP requirements[308] because of the administrative burden. For other suppliers, such as water and energy providers, the assessment could bring benefits as it would identify the detailed risks from climate change, triggering the uptake of adaptation measures.

For businesses in the secondary sector the burden for carrying out the assessment is clearly dependent on the size of the company. Small companies might have a higher burden than larger companies that already apply risk assessment procedures in other contexts (e.g. financial risk assessments, assessments of risks of pollution) or environmental performance schemes (e.g. EMAS).

For European businesses that are covered by the tertiary sector, impacts of climate change would clearly affect their supply chain (e.g. energy supply) or their offices, but in terms of adaptation they would mainly depend on activities set by their service providers (e.g. energy company or office owner). For this type of business such a mandatory risk assessment would clearly raise awareness but not necessary trigger adaptation measures.

The benefits of being certified are:

- Minimise loss – by having an effective risk management system in place one can reduce the chance of incidents occurring and the financial loss that comes with them.

[307] Cf. for example http://www.qmsuk.com/iso-31000/costs.php
[308] Cf. small farmers scheme under the CAP.

This is a particular issue for all businesses that have to deal with the Directive 2004/35/EC on environmental liability with regard to the prevention and remedying of environmental damage (EC, 2004b).

- The assessment allows management to work confidently knowing that there is a framework in place to assess potential risks and to mitigate or avoid them. By introducing this knowledge into business decisions there is a chance to improve the organisations' performance in a range of areas such as health and safety performance.

- Common risk identified by a sector or by different businesses in the same region could be addressed in a common manner, resulting in cost savings due to the economy of scale.

In order to help businesses that don't have the finances or skills, public authorities could put in place support services:

- In order to limit the impacts on consumers' prices, the implementation of subventions might also be needed. Funding for such is not foreseen so far and might conflict with state aid rules.

- If the results of the assessment have to be made publicly available, there might be implications on the stock market that cannot be foreseen. These implications might lead to a relocation of businesses to less risky areas, thus creating negative economic consequences for the region and reducing the financial and human power to invest in adaptation measures (second order impacts). The impacts on the insurance market cannot be foreseen, but it could be assumed that high risk businesses would have to pay increased premiums or lose their coverage.

- Carrying out risk assessment does not necessarily lead to taking adaptation measures [include examples from flooding]. So it cannot be guaranteed that such a mandatory assessment would reduce vulnerabilities.

It can be assumed that this option will create a significant level of jobs, as new auditing bodies will be needed. The overall number of jobs created will depend on the detailed specifications.

Direct environmental impacts are not expected; however, indirect environmental improvements can be expected due to higher awareness and the removal of potential risks (e.g. reallocation of storage places within flood plains).

6.6.4 Effectiveness, efficiency and coherence of the options addressing problem 6

The proposed options are assumed to realise positive effects, although there are potential costs associated with their implementation. These costs will fall on the private sector and on Member States; however the actual anticipated costs are uncertain. The general expectation is that future costs associated with no action/business as usual are likely to be very substantial and are expected to more or less increase on an annual basis as the likelihood, magnitude and consequences of extreme weather events increase.

Policy option 1, engaging with financial institutions and the banking sector to promote climate resilient investments, is likely to have a strong positive impact on each of the objectives (although the impact on increasing the resliance of the EU territory is less certain). Increased engagement within the sector will raise awareness of adaptation and there is likely to be a cascade effect with financial institutions and banks communicating adaptation-related information with their customers and supply chain partners. This will contribute to improved knowledge and will facilitate cooperation. Capturing the potential of the market is a fundamental objective of this policy option therefore a strong positive impact on the key vulnerable sectors can be expected, however this is a first step action and the immediate impacts are likely to be relatively limited. This option can be seen as preparing the ground for developing a policy framework to facilitate greater long-term investment in climate resilience.

The effectiveness of policy option 2, promoting the use of market based instruments and removing harmful subsidies, is less certain. The possibility to use market based instruments for adaptation has not so far been widely explored, and there is limited evidence of their effectiveness or applicability. Indeed, impacts will vary according to the market based instruments used. The acceptability of market based instruments is deemed largely positive, as they provide companies with an incentive to innovate, increase productivity and reduce environmental impacts. However, market based instruments may not always reach the most vulnerable and may even intensify inequality as poorer (and, therefore more vulnerable) citizens become less capable of converting income into opportunities. As a result, the most vulnerable places (typically those with lower adaptive capacity) may not be able to exploit market based instruments.

The impacts of the third option, legislative actions for risk assessments of private companies, are also quite uncertain as carrying out a risk assessment does not necessarily lead to adopting adaptation measures, however it will increase understanding of opportunities and threats arising from climate change (improved knowledge), and align these with existing business processes and strategies (mainstreaming). Overall however the effectiveness of the option is not yet clear. Acceptability is assumed to be low as additional administrative and financial burden might be feared by SMEs.

6.6.5 Comparative table of the options addressing problem 6

The options are not contrasting or alternative options. Overall, from the point of view of efficiency, effectiveness, coherence and acceptability all policy options are an improvement on business as usual (no policy change). This will be particularly true if the anticipated harmful effects of unavoidable climate change accelerate over time. None, one or all of the options could be taken forward.

Table 50: Comparative table of the options addressing problem 6

Options	Economic, social, and environmental impacts	Effectiveness			Efficiency	Coherence	Acceptability
		Objective 1: Better informed decision making	Objective 2: Increasing the resilience of the EU territory	Objective 3: Increasing the resilience of key vulnerable sectors			
No policy change	0	0	0	0	0	0	0
Engage with commercial banks	≈ (mostly indirect impacts on social, environmental and economic issues)	+ (financial institutions and banks might communicate adaptation-related information with their customers and supply chain partners)	? to + (mainly indirect impacts/increase resiliance resulting from meeting the other two objectives	++ (facilitate long-term investment in climate resilience)	++ (as the bank sector plays a major role in financing)	+ (coherent with the 7EAP)	++ (stakeholder consulation showed a high interest in this option)
Explore market based approaches	≈ to ++ (depending on the definition and application of the market based approaches)	? (depending on the addition research carried out, will foster the cooperation between different authorities but also with the private sector))	- to ++ (will depend on the definition and application of the market based approaches)	- to ++ (will depend on the definition and application of the market based approaches)	+ to ++(depending on the definition and application of the market based approaches)	+ (coherent with the 7EAP and other EU environmental legislation (e.g. WFD))	+ to ++ stakeholder consulation showed a medium to high interest in this option)

Options	Economic, social, and environmental impacts	Effectiveness			Efficiency	Coherence	Acceptability
		Objective 1: Better informed decision making	Objective 2: Increasing the resilience of the EU territory	Objective 3: Increasing the resilience of key vulnerable sectors			
Legislative actions requiring companies to undertake risks assessments along their supply chains	≈ to+(cost savings if adaptation measures are implemented; job creation for certification; no social and environmental impacts are expected).	+ (the detail reported will provide a clear picture on private sector progress on adaptation).	+(due to increased awareness on adaptation, mainstreaming will be fostered).	? to ++(has the potential to improve climate resilience if the option is taken up in a broader sense and adaptation actions are implemented).	? (risk assessments do not necessarily trigger uptake of adaptation measures. If adopted the cost for the measure can be less than the cost of potential damage).	+ (EU Directive 2004/35/EC on environmental liability (EC, 2004b))	- to -- (due to additional administrative and financial burden).

Magnitude of impact as compared with the baseline scenario (the baseline is indicated as 0): ++ strongly positive; + positive; – – strongly negative; – negative; ≈ marginal/neutral; ? uncertain; n.a. not applicable

7 MONITORING AND EVALUATION

The following sections suggest monitoring and evaluation options including progress indicators for the Strategy's three specific objectives as set out in chapter 5 (Better informed decision making; Increasing the resilience of the EU territory and Increasing the resilience of the key vulnerable sectors), and a monitoring system to track overall progress. The indicators suggested are suitable for use independently of the specific policy options selected and are designed to be able to undertake a thorough mid-term evaluation of the progress of the EU Adaptation to Climate Change Strategy in 2017.

7.1 Monitoring and evaluation process and system over the duration of the strategy

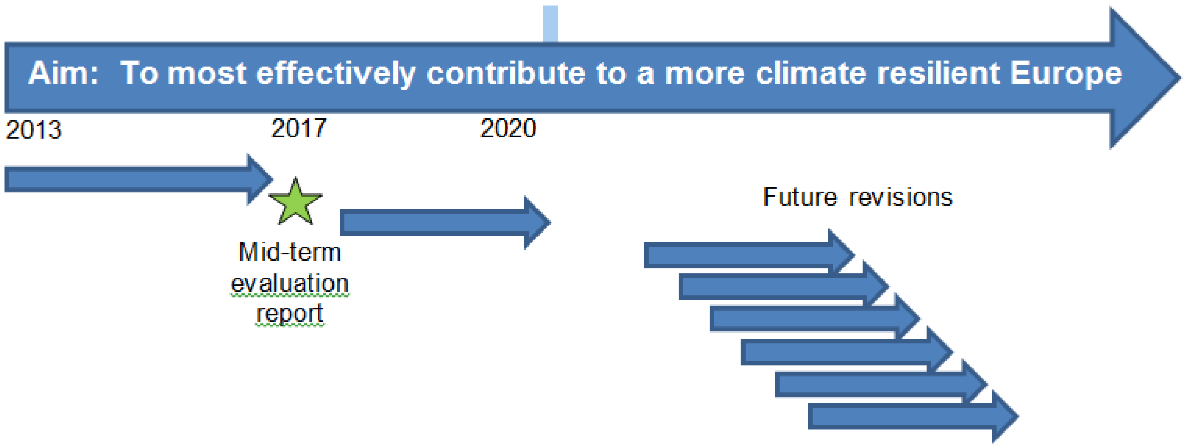
The monitoring and evaluation process has three main elements:

- Publication of relevant information on Climate-ADAPT;
- Reporting under Art 16 of the proposal revising the monitoring mechanism established under Decision No 280/2004/EC of the European Parliament and of the Council (EC, 2004a) by replacing that Decision. The proposal introduces a new reporting requirement for adaptation requesting Member States to report to the Commission by 15 March each year information on their implemented or planned actions to adapt to climate change, in particular, on national or regional adaptation strategies and on adaptation measures. This information shall include the budget allocation by policy sector and, for each adaptation measure, the main objective, the type of instrument, the status of implementation and the climate-change impact category (such as flooding, sea level rise, extreme temperatures, droughts, and extreme weather events) (EC, 2011a/a);
- By 2017, the Commission will publish a report in 2017 on all indicators mentioned below. The aim is to look at the achievements over the first five years of the strategy as part of the mid-term evaluation, and this can be used as the evidence base to inform the revision of the strategy.

The indicators below might be assessed differently in terms of timing and need to be coordinated with other monitoring activities.

The current timeline over which the Strategy will be monitored is from 2013 to 2020. These timeframes present a challenge for monitoring and evaluating adaptation, which has a much longer term perspective. While the strategy covers a fixed period of time, its ambitions and aim are not limited to this timescale. In order *to "most effectively contribute to a more climate resilient Europe"*, adaptation must be considered an ongoing process that will continue into the future (and across any future iterations of the strategy). So while we can monitor progression towards achieving the strategies' objectives via the specified indicators against the specific objectives set out in chapter 7.2, the dynamic and ongoing nature of the adaptation process must also be recognised. Figure 65 illustrates the timeline involved for the strategy. Suggested indicators under each objective are presented as well as a proposal for a monitoring system (cf. chapter 7.3). It is important to note that the indicators in chapter 7.2 might be assessed differently in terms of timing and need to be coordinated with other monitoring activities.

Figure 65: Timeline for the strategy and its evaluation



7.2 Suggested indicators

The following indicators are proposed to monitor the progress:

7.2.1 Objective 1: Better informed decision making

Indicator 1A) Take-up of Climate-ADAPT

This indicator allows tracking the dissemination of currently available information on climate change impacts and adaptation options.

- What is available now? The number of visitors to the site including the countries they represent (from Google Analytics) and the pages most visited. The EEA has already started to closely monitor the usage of Climate-ADAPT and could continue in this context;
- What information is needed by 2017? The number of 'passive' visitors vs. 'active' visitors (who register, repeat visit and upload information) and the development of Climate-ADAPT "personas" of the registered users (as used to understand the users of the EEA's WISE platform) will provide more in-depth information on the users. In addition to this an independent assessment on how Climate-ADAPT has evolved in terms of content, which databases have been connected and what metadata has

been made available would allow a full assessment of the available information on climate change impacts and adaptation options.

- Who should report? EEA.

Indicator 1B) Monitor the implementation of research activities on adaptation and research dissemination

This indicator is designed to track the research (e.g. knowledge gaps, dissemination activities).

- What is available now? The number of LIFE+ projects and HORIZON 2020 projects on adaptation (and other research streams such as the JRC projects) and the amount spent for service contracts relevant for adaptation The JRC budget is known and could be used.

- What information is needed by 2017? The ratio of number and Euros spent on LIFE+ and HORIZON 2020 projects on adaptation (and other research streams) across vulnerable regions, sectors and the issues covered by the research, distinguishing what has been spent on developing models/scenarios, assessing impacts, measures and dissemination types (as per the critical knowledge gaps identified; cf. Annex 8).

  To track the dissemination of adaptation research, the Climate-ADAPT calendar can be utilised to count the number of adaptation events, training and workshops. This and the gaps across the regions, sectors and issues can be identified to inform the State of European Adaptation report under the wider monitoring and evaluation process (cf. chapter 7.1).

  An update of the Climate-ADAPT research projects template, and guidance on value calculation, may be needed to identify the value of the adaptation projects or the adaptation part of wider projects.

- Who should report? EEA, Commission Services, Joint programing initiative.

Activities should be co-ordinated with the monitoring process under HORIZON 2020.

7.2.2 Objective 2: Increasing the resilience of the EU territory

Indicator 2A) Commission-funded cross-border/multi-MS projects on adaptation

Tracking EC support in facilitating and helping coordinate the development of adaptation strategies at all levels, and the inclusion of cross-border considerations will be carried out by monitoring Commission-funded cross-border/multi-MS projects on adaptation.

- What is available now? Number of Commission-funded cross-border/multi-MS projects on adaptation projects underway obtained by monitoring cross-border examples/items available on Climate-ADAPT and the CIRCLE-2 InfoBase[309] (which specialises in capturing these types of projects).

- What information is needed by 2017? Composite of Euros spent on cross-border/multi-MS projects on adaptation projects against the number of countries/regions involved (including Outermost Regions). Information on projects funded by the Cohesion fund, Interreg and the agricultural fund will be available on an annual basis, and in 2017 information will be submitted specifically on climate change that can be used to inform the mid-term evaluation of the strategy. An update of the Climate-ADAPT research projects template may be needed to identify the countries and value of the projects.

- Who should report? Commission Services.

Indicator 2B) Cross-border/Transnational, national, regional and city adaptation policies published

To track EC support in promoting adaptation action at sub-EU level an indicator for adaptation policies published is needed.

- What is available now? List of NAS, city and cross-border/transnational activities, Information on the regional level is patchy (for details on adaptation activities on these levels cf. chapter 3.3).

- What information is needed by 2017? Number of national (as a priority), cross-border/transnational, regional and city adaptation policies published and reported on Climate-ADAPT. Also a comparison between the current preliminary assessment on national adaptation strategies (NAS) and the status in 2017 should be carried out. Issues should cover e.g. sectoral coverage, financing, level of national achievements, transboundary considerations and actions, level of ambition. If a legal proposal is made for mandatory adaptation strategies, or a decision on the EU Mechanism on Monitoring and Review (MMR) is made including adaptation then this indicator would need to be revised accordingly.

- Who should report? Member States, cities, regions via EEA collation of reporting.

[309] http://infobase.circle-era.eu/

Indicator 2C) Uptake of adaptation measures in Member State policies

To track MS policies with regard to the uptake of adaptation measures a specific “mainstreaming” indicator is suggested.

- What is available now? Analysis of available NAS (cf. chapter 3.3.2) and information on national adaptation efforts provided on Climate-ADAPT.
- What information is needed by 2017? A review of MS uptake of adaptation measures in national policies, including the number of guidelines developed, and identification of new adaptation initiatives from Cohesion, CAP, Blueprint etc. as asked for by the United Nations Framework Convention on Climate Change (UNFCCC). The next EU communication is required in Jan 2014 and can be used for this analysis, and in 2017 the EC can report on the types of integration achieved.
- Who should report? Member States (the role of the ASG in this context should be discussed) with support of the EEA.

7.2.3 Objective 3: Increasing the resilience of key vulnerable sectors

Indicator 3A) EC policy integration

An indicator on EC policy integration will be used to track consistent and comprehensive mainstreaming of climate change adaptation considerations in key vulnerable sectors that are closely integrated at EU level through common policies.

- What is available now? List of policies, legal acts and standards which are already considering climate change adaptation (cf. also chapters 3.3.1 for EU level adaptation efforts and 3.5 for the policy context across sectors).
- What information is needed by 2017? Comparison of number and sectoral coverage of policies, legal acts and standards covering adaptation in 2013 and the situation in 2017.
- Who should report? Commission Services. For standards, also MS and CEN/CENELEC, DG MOVE, DG ENER. The role of the ASG in this context should be discussed.

Indicator 3B) Awareness and capacity of private sector

An indicator will monitor the private sector adaptive capacity and climate impact preparedness in terms of increasing resilience.

- What is available now? The number of Climate-ADAPT users and case studies from private sector (also on CIRCLE-2 InfoBase[310]). Questionnaire analysis from six private sector organisation carried out under the support to the development of the strategy project (for results cf. Background report to the IA, part II).What information is needed by 2017? Gathering information on private sector awareness and capacity from setting up regular business and climate change adaptation surveys of Enterprise Europe Network members (which focuses on SMEs) through such mechanisms as Eurobarometer[311] special surveys, and collating the climate risk survey as part of the annual Carbon Disclosure Project[312] surveys of the world's largest companies, as well as the grants under LIFE+ given for private sector initiatives.

- Who should report? Private sector networks.

Indicator 3C) Market based instruments for adaptation

An indicator on the available market based instruments (MBIs) for adaptation at EU level will be used to track the available MBIs, their uptake and implementation.

- What is available now? Status of water pricing in 2009/10 within the EU

- What information is needed by 2017? By 2017 the Commission should have an overview of the available market based instruments and their implementation that will be revised for assessment and use in the mid-term evaluation.

- Who should report? DG ENV as regard to water pricing and Payment for Ecosystem Services (PES).

[310] http://infobase.circle-era.eu/
[311] http://ec.europa.eu/public_opinion/index_en.htm
[312] https://www.cdproject.net/

7.3 Proposal for a monitoring system for the EU Adaptation Strategy

The monitoring process which we describe in this chapter uses a combined traffic light and numerical scoring approach set in the context of the principles of indicator development.

There are two stages in the monitoring system.

Stage 1: Categorise progress

Progress in each line of action under each indicator can be classified into one of 4 categories:

- **Not yet started** (red) for lines of action where there has been no action or progress.
- **Underway – limited progress** (amber) for those where work has started, e.g. lead organisation or DG identified but limited progress has been achieved
- **Underway – substantial progress** (yellow) for those where work has started and substantive progress made, e.g. interim deliverables, tangible outputs or outcomes although some work still to be completed
- **Complete (kept under review)** (green) all planned actions have been undertaken

Adaptation must be a continuous process, so while individual lines of action may be completed (e.g. a final report delivered, series of capacity building events held) there is a need to keep these areas under review throughout the lifetime of the Strategy. Annual reporting on some indicators will allow a more detailed assessment to be made and potentially a trend to be identified at the end of the first five years, but just because the mid-term review is carried out does not mean it should no longer be reviewed. New information or insight gained from the assessment of status against each indicator as the Strategy progresses may highlight a need for further work or revisions under some lines of action against each indicator. New additional lines of action are likely to be required to report against indicator, or indeed new indicators may be required, to support the ongoing achievement of the Strategy's objectives under future iterations of the Strategy.

Stage 2: Determine cumulative score for each Objective

A simple scoring system can used to aggregate the lines of action against each indicator to determine progress against each of the Strategies four Objectives. A numerical score is assigned to each line of action according to the categorisation under Stage 1.

- Not yet started = 0
- Underway (limited progress) = 1
- Underway (substantial progress) = 2
- Complete (under review) = 3

For each Strategy Objective, the scores for all relevant lines of action against each indicator (as indicated in Table 51) are simply summed together, and presented as a percentage of the total potential score for each Objective. Table 51 provides an illustrative worked example for one of the objectives of the EU Adaptation Strategy.

Table 51: Worked example for monitoring system, applied to the better informed decision making objective.

Objective 1	**Better informed decision making**			
Indicator	**Lines of action**	**Reported by**	**Assessment**	**Score**
1A) Take up of Climate-ADAPT	The number of visitors to the site including the countries they represent (from Google Analytics) and the pages most visited. The EEA have already started to closely monitor the usage of Climate-ADAPT and could continue in this context.	EEA	**Underway (substantial progress)**	**2**
	The number of 'passive' visitors vs. 'active' visitors (who register, repeat visit and upload information) and the development of Climate-ADAPT "personas" of the registered users (as used to understand the users of the EEA's WISE platform) will provide more in-depth information on the users.	EEA	**Not yet started**	**0**
	In addition to this an independent assessment on how Climate-ADAPT has evolved in terms of content, which databases have been connected and what metadata has been made available would allow a full assessment of the available information on climate change impacts and adaptation options.	EEA	**Not yet started**	**0**
1B) Monitor the implementation of research activities on adaptation and research dissemination	The number of LIFE+ projects and HORIZON 2020 projects on adaptation (and other research streams such as the JRC projects) and the amount spent for service contracts relevant for adaptation The JRC budget is known and could be used.	EEA, Commission Services, Joint programing initiative	**Underway (limited progress)**	**1**

Objective 1	**Better informed decision making**			
Indicator	**Lines of action**	**Reported by**	**Assessment**	**Score**
	The ratio of number and Euros spent on LIFE+ and HORIZON 2020 projects on adaptation (and other research streams) across vulnerable regions, sectors and the issues covered by the research, distinguishing what has been spent on developing models/scenarios, assessing impacts and measures (as per the knowledge gaps identified by the support to the development of the strategy project).	EEA, all DG´s, Joint programing initiative	**Not yet started**	**0**
	To track the dissemination of adaptation research, the Climate-ADAPT calendar can be utilised to count the number of adaptation events, training and workshops.	EEA	**Not yet started**	**0**
Overall score			**3**	
Overall score as a percentage of the total potential score			**17%**	

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9 ANNEXES

Annex 1 – Glossary

1 General terms with regard to climate change

Abrupt climate change

The nonlinearity of the climate system may lead to abrupt climate change, sometimes called rapid climate change, abrupt events or even surprises. The term abrupt often refers to time scales faster than the typical time scale of the responsible forcing. However, not all abrupt climate changes need be externally forced. Some possible abrupt events that have been proposed include a dramatic reorganisation of the thermohaline circulation, rapid deglaciation and massive melting of permafrost or increases in soil respiration leading to fast changes in the carbon cycle. Others may be truly unexpected, resulting from a strong, rapidly changing forcing of a nonlinear system.

Adaptation

Adaptation is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation. There are different ways in which adaptation can be framed; an inventory has been made by the Dutch Climate Changes Spatial Planning research programme.

Adaptive capacity (in relation to climate change impacts)

Adaptive capacity describes the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. Adaptive capacity can be framed in many different ways; an inventory has been made by the Dutch Climate Changes Spatial Planning research programme.

Baseline/reference

The baseline (or reference) is the state against which change is measured. It might be a 'current baseline', in which case it represents observable, present-day conditions. It might also be a 'future baseline', which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines.

Climate

Climate in a narrow sense is usually defined as the 'average weather', or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classical period of time is 30 years, as defined by the World Meteorological Organization (WMO).

Climate change

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which defines 'climate change' as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. Climate change can be framed in different ways; an inventory has been made by the Dutch Climate Changes Spatial Planning research programme.

Climate (change) scenario

A plausible and often simplified representation of the future climate, based on an internally consistent set of climatologically relationships and assumptions of radiative forcing, typically constructed for explicit use as input to climate change impact models. A 'climate change scenario' is the difference between a climate scenario and the current climate.

Climate sensitivity

In IPCC reports, equilibrium climate sensitivity refers to the equilibrium change in the annual mean global surface temperature following a doubling of the atmospheric equivalent carbon dioxide concentration. Due to computational constraints, the equilibrium climate sensitivity in a climate model is usually estimated by running an atmospheric general circulation model coupled to a mixed-layer ocean model, because equilibrium climate sensitivity is largely determined by atmospheric processes. Efficient models can be run to equilibrium with a dynamic ocean. The effective climate sensitivity is a related measure that circumvents the requirement of equilibrium. It is evaluated from model output for evolving non-equilibrium conditions. It is a measure of the strengths of the climate feedbacks at a particular time and may vary with forcing history and climate state. The climate sensitivity parameter (units: °C (W m–2)–1) refers to the equilibrium change in the annual mean global surface temperature following a unit change in radiative forcing. The transient climate response is the change in the global surface temperature, averaged over a 20-year period, centred at the time of atmospheric carbon dioxide doubling, that is, at year 70 in a 1 % yr–1 compound carbon dioxide increase experiment with a global coupled climate model. It is a measure of the strength and rapidity of the surface temperature response to greenhouse gas forcing.

Climate system

The climate system is defined by the dynamics and interactions of five major components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere. Climate system dynamics are driven by both internal and external forcing, such as volcanic eruptions, solar variations, or human-induced modifications to the planetary radiative balance, for instance via anthropogenic emissions of greenhouse gases and/or land use changes.

Climate variability

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Cost-benefit analysis

Monetary measurement of all negative and positive impacts associated with a given action. Costs and benefits are compared in terms of their difference and/or ratio as an indicator of how a given investment or other policy effort pays off seen from the society's point of view.

Disaster

A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources. Comment: Disasters are often described as a result of the combination of: the exposure to a hazard; the conditions of vulnerability that are present; and insufficient capacity or measures to reduce or cope with the potential negative consequences. Disaster impacts may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation.

There are different ways in which disasters can be framed. See for example an inventory made for the disaster reduction community.

Disaster risk

The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period. Comment: The definition of disaster risk reflects the concept of disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socio-economic development, disaster risks can be assessed and mapped, in broad terms at least.

Disaster risk management

Disaster risk management stands for a systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster. Comment: This term is an extension of the more general term "risk management" to address the specific issue of disaster risks. Disaster risk management aims to avoid, lessen or transfer the adverse effects of hazards through activities and measures for prevention, mitigation and preparedness. There are different ways in which risk management can be framed. See for example inventories made for the disaster reduction community or for the Dutch Climate Changes Spatial Planning Programme.

Disaster risk reduction

The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

Emission scenario

An emission scenario is a plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g. greenhouse gases, aerosols), based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change) and their key relationships. Concentration scenarios, derived from emission scenarios, are used as input to a climate model to compute climate projections. In IPCC (1992) a set of emission scenarios was presented which were used as a basis for the climate projections in IPCC (1996). These emission scenarios are referred to as the IS92 scenarios. In the IPCC Special Report on Emission Scenarios (Nakicenovic, et al, 2000) new emission scenarios, the so-called SRES scenarios, were published, some of which were used, among others, as a basis for the climate projections presented in TAR-IPCC (IPCC, 2001) and 4AR-IPCC (IPCC, 2007a, b, c).

Extreme weather event

An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. Single extreme events cannot be simply and directly attributed to anthropogenic climate change, as there is always a finite chance the event in question might have occurred naturally. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g. drought or heavy rainfall over a season).

Global warming

Global warming refers to the gradual increase, observed or projected, in global surface temperature, as one of the consequences of radiative forcing caused by anthropogenic emissions.

Greenhouse effect

Greenhouse gases effectively absorb thermal infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus, greenhouse gases trap heat within the surface-troposphere system. This is called the greenhouse effect. Thermal infrared radiation in the troposphere is strongly coupled to the temperature of the atmosphere at the altitude at which it is emitted. In the troposphere, the temperature generally decreases with height. Effectively, infrared radiation emitted to space originates from an altitude with a temperature of, on average, – 19 °C, in balance with the net incoming solar radiation, whereas the Earth's surface is kept at a much higher temperature of, on average, + 14 °C. An increase in the concentration of greenhouse gases leads to an increased infrared opacity of the atmosphere, and therefore to an effective radiation into space from a higher altitude at a lower temperature. This causes a radiative forcing that leads to an enhancement of the greenhouse effect, the so-called enhanced greenhouse effect.

Greenhouse gas (GHG)

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Hazard

A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Likelihood

The likelihood is described as an occurrence, an outcome or a result, where this can be estimated probabilistically.

Maladaptation

Action or investment that enhances vulnerability to climate change impacts rather than reducing them. E.g. in the face of rising sea-levels it would be maladaptive to build new key infrastructure on a shallow coastline (UKCIP).

Measures

Adaptation measures are technologies, processes, and activities directed at enhancing our capacity to adapt (building adaptive capacity) and at minimising, adjusting to and taking advantage of the consequences of climatic change (delivering adaptation).

Mitigation

An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies and measures to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks. Examples of mitigation measures are renewable energy technologies, waste minimization processes and public transport commuting practices, etc.

Natural hazard

Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Prevention

Prevention is an outright avoidance of adverse impacts of hazards and related disasters. Comment: Prevention (i.e. disaster prevention) expresses the concept and intention to completely avoid potential adverse impacts through action taken in advance. Examples include dams or embankments that eliminate flood risks, land use regulations that do not permit any settlement in high risk zones, and seismic engineering designs that ensure the survival and function of a critical building in any likely earthquake. Very often the complete avoidance of losses is not feasible and the task transforms to that of mitigation. Partly for this reason, the terms prevention and mitigation are sometimes used interchangeably in casual use.

Projection

The potential evolution of a quality or set of quantities, often computed with the aid of a model. Projections are distinguished from predictions in order to emphasise that projections involve assumptions — concerning, for example, future socio-economic and technological developments, that may or may not be realised — and are therefore subject to substantial uncertainty.

Resilience

Resilience describes the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change. There are different ways in which resilience can be framed; an inventory has been made by the Dutch Climate Changes Spatial Planning research programme.

Risk

Risk is a combination of the probability of an event and its negative consequences. Comment: This definition closely follows the definition of the ISO/IEC Guide 73. The word "risk" has two distinctive connotations: in popular usage the emphasis is usually placed on the concept of chance or possibility, such as in "the risk of an accident"; whereas in technical settings the emphasis is usually placed on the consequences, in terms of "potential losses" for some particular cause, place and period. It can be noted that people do not necessarily share the same perceptions of the significance and underlying causes of different risks. There are different ways in which risk can be framed. See for example inventories made for the disaster reduction community or for the Dutch Climate Changes Spatial Planning Programme.

Scenario

A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a narrative storyline.

Socio-economic scenarios

Scenarios concerning future conditions in terms of population, gross domestic product and other socio-economic factors relevant to understanding the implications of climate change.

Threshold

A threshold is a level of magnitude of a system process at which sudden or rapid change occurs. A point or level at which new properties emerge in an ecological, economic or other system, invalidating predictions based on mathematical relationships that apply at lower levels.

Uncertainty

An expression of the degree to which a value (e.g. the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgement of a team of experts.

Vulnerability

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. There are different ways in which vulnerability can be framed; an inventory has been made by the Dutch Climate Changes Spatial Planning research programme.

2 Specific terms relating to social issues

Well-being

The term "well-being" is defined in notoriously large numbers of ways.

In the context of the project "Well-being 2030" an attempt was taken to define well-being.It is considered as "life satisfaction" and "the presence of positive feelings", which are both highly subjective and hardly measurable at all. The project then goes on by giving recommendations for the social policy in Europe up to 2030 based well-being as described by:

- income
- employment
- health
- education

Social Protection

Social protection, as defined by the United Nations Research Institute for Social Development, is concerned with preventing, managing, and overcoming situations that adversely affect people’s well-being (UNRISD, 2010).

Social cohesion

In EU context the term social cohesion is used to mean "common minimum social standards" with the main financing mechanism being the European Social Fund. The indicators for social cohesion (from EUROSTAT) are:

- poverty
- unemployment
- inequality of income distribution

So it is mainly used to denote the lessening of the social differences between the different Member States. In the context of adaptation it is more important to look at inequalities between social groups than between countries, therefore this term as described above has only a limited use.

Nevertheless, traditionally in research "social cohesion" is used with a wider meaning like „diverse aspects of the dynamics of social relations, such as social exclusion, participation and belonging".

Social inclusion

in EU context has been used to mean:

- gender equality
- promotion of the integration and participation of all into economic and social life.

Special focus is on vulnerable groups- the disabled, ethnic minorities, immigrants.

Social harmony

Social harmony is a general term used widely in everyday language. It originates from Confucianism philosophy.

In the report it is currently used to group those social aspects that ensure peaceful and fair co-habitation of different social groups, namely aspects of crime and conflict, social cohesion and inclusion.

The term, however, is not an official term in EU context.

Annex 2 – Climate change damage costs overview

Table 52: Climate change damage costs overview table (based on Altvater, et al, 2011; updated February 2013)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Integrated economic impact	Changes in global GDP no and forever due to climate change	Global	From now on	- 5 % to - 20% GDP per year	Stern (2006)
	Economic impact on European economy	Europe	2080	- 0.83% GDP	ClimateCost Watkiss et al. (2011)
Soils and land use	NA**	NA	NA	Erosion due to sea level rise is included in coastal area part	NA
Agriculture	GDP losses and benefits (A1B scenario)	Northern Europe	2080	0.46% GDP	ClimateCost Watkiss et al. (2011)
	GDP losses and benefits (A1B scenario)	Central Europe North	2080	- 0.02% GDP	ClimateCost Watkiss et al. (2011)
	GDP losses and benefits (A1B scenario)	Central Europe South	2080	- 0.11% GDP	ClimateCost Watkiss et al. (2011)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Agriculture	GDP losses and benefits (A1B scenario)	Southern Europe	2080	- 0.68% GDP	ClimateCost Watkiss et al. (2011)
	GDP losses and benefits (A1B scenario)	UK and Ireland	2080	0.07% GDP	ClimateCost Watkiss et al. (2011)
	Changes of Gross Agricultural Product (GAP)	OECD – Europe	2.5 °C global temperature rise	0.55%GAP without adaptation 2.09% GAP with adaptation	Tol (2002)
	Changes of Gross Agricultural Product (GAP)	Central and Eastern Europe and the former Soviet Union	2.5 °C global temperature rise	0.94%GAP without adaptation 2.65%GAP with adaptation	Tol (2002)
Forestry	Impact of climate change on forestry	OECD – Europe	1 °C global temperature rise	134 million USD per year	Tol (2002)
	Impact of climate change on forestry for a 1 °C global temperature rise	Central and Eastern Europe and the former Soviet Union	1 °C global temperature rise	- 136 million USD per year	Tol (2002)
Biodiversity	Impact of climate change on natural ecosystems	OECD – Europe	1 °C global temperature rise	- 14.7 million USD per year	Tol (2002)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Biodiversity	Impact of climate change on natural ecosystems	Central and Eastern Europe and the former Soviet Union	1 °C global temperature rise	- 5.4 million USD per year	Tol (2002)
Fisheries	Damage due to decline Gross revenues	World	NA	decline in current gross revenues of up to 50% (about $80 billion per year) from the world's fisheries caused by severe climate change and overfishing	World Bank (2010)
Water	Expected impacts on overall economic activity due to river floods	Northern Europe	2080	- 0.02% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to river floods	UK and Ireland	2080	- 0.01% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to river floods	Central Europe North	2080	- 0.02% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to river floods	Central Europe South	2080	- 0.03% GDP	ClimateCost Watkiss et al. (2011)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Water	Expected impacts on overall economic activity due to river floods	Southern Europe	2080	- 0.02% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to river floods	Europe	2080	- 0.02% GDP	ClimateCost Watkiss et al. (2011)
	Expected additional economic damage costs as a result of floods in river systems under A1B scenario	Europe	2020s	20.4 billion € per year climate and socio-economic change; 9.0 B€/yr. marginal climate change impact (undiscounted)	ClimateCost Feyen & Watkiss (2011)
	Expected additional economic damage costs as a result of floods in river systems under E1 scenario	Europe	2020s	14.6 billion € per year climate and socio-economic change; 5.4 B€/yr. marginal climate change impact (undiscounted, no adaptation)	ClimateCost Feyen & Watkiss (2011)
	Expected additional economic damage costs as a result of floods in river systems under A1B scenario	Europe	2050s	45.9 billion € per year climate and socio-economic change; 18.9 B€/yr. marginal climate change impact (undiscounted, no adaptation)	ClimateCost Feyen & Watkiss (2011)
	Expected additional economic damage costs as a result of floods in river systems under E1 scenario	Europe	2050s	41.7 billion € per year climate and socio-economic change; 20.3 B€/yr. marginal climate change impact (undiscounted, no adaptation)	ClimateCost Feyen & Watkiss (2011)
	Expected additional economic damage costs as a result of floods in river systems under A1B scenario	Europe	2080s	97.9 billion € per year climate and socio-economic change; 50.1 B€/yr. marginal climate change impact (undiscounted, no adaptation)	ClimateCost Feyen & Watkiss (2011)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Water	Expected additional economic damage costs as a result of floods in river systems under E1 scenario	Europe	2080s	68.2 billion € per year climate and socio-economic change; 30.6 B€/yr. marginal climate change impact (undiscounted, no adaptation)	ClimateCost Feyen & Watkiss (2011)
	Economic impact (agriculture and energy) of the drought in the Ebro river basin (Spain)	Ebro river basin (Spain)	2005	Direct loss of gross added value: € 482 million Indirect loss of production: € 377 million.	Pérez y Pérez & Barreiro-Hurlé (2009)
Energy	Investment costs (cooling systems) and additional electric generation costs due to cooling	Europe	2050	Investment 8.4 billion € Generation 7.3 billion € per year	ADAM, Jochem et al. (2009)
	Additional energy saving due to 4 % °C temperature rise in 2050	EU27+ Norway and Switzerland	2050	- 27.5 billion € per year	ADAM, Jochem et al. (2009)
	Additional spending for electricity generation on annual basis	Greece	2080	170-770 million € per year	Mirasgedis et al. (2007)
	Associated costs for energy demand (electricity) as a result of temperature rise as a percentage of GDP	Finland Germany Spain	2020	Finland: - 0.35% GDP Germany: - 0.07% GDP (coal), - 0.05% GDP (oil and gas) Spain: 0.22% GDP, 0.16% GDP (gas)	Pilli-Sihvola (2010)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Energy	Potential and average changes in income	Large nuclear plant in Central Europe	increase of river temperature (1 – 5°C) and a decrease of stream flow (10%-50%)	Average - 80 million € per year Potential - 110 million € per year	Förster & Lilliestam (2009)
	Expected impacts on overall economic activity due to climate change impacts on energy demand. A1B climate change scenario	Northern Europe	2080	- 0.39% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to climate change impacts on energy demand. A1B climate change scenario	UK and Ireland	2080	- 0.10% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to climate change impacts on energy demand. A1B climate change scenario	Central Europe North	2080	- 0.44% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to climate change impacts on energy demand. A1B climate change scenario	Central Europe South	2080	- 0.04% GDP	ClimateCost Watkiss et al. (2011)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Energy	Expected impacts on overall economic activity due to climate change impacts on energy demand. A1B climate change scenario	Southern Europe	2080	- 0.44% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to climate change impacts on energy demand. A1B climate change scenario	Europe	2080	- 0.27% GDP	ClimateCost Watkiss et al. (2011)
	Decrease in heating energy consumption	OECD – Europe	1 °C global temperature rise	- 13.1 billion USD per year	Tol (2002), after Downing (1995, 1996)
	Decrease in heating energy consumption	Central and Eastern Europe and the former Soviet Union	1 °C global temperature rise	- 46.0 billion USD per year	Tol (2002), after Downing (1995, 1996)
	Increase in cooling energy consumption	OECD – Europe	1 °C global temperature rise	20.2 billion USD per year	Tol (2002), after Downing (1995, 1996)
	Increase in cooling energy consumption	Central and Eastern Europe and the former Soviet Union	1 °C global temperature rise	18.6 billion USD per year	Tol (2002), after Downing (1995, 1996)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Energy	Overall costs of climate change on electricity sector in Europe	EU27	2080	49 billion € per year of which 13 billion is related to the grid and the rest to production	Rademaekers et al. (2011)
Transport and infrastructure	Costs of weather events for the transport system (transport mode and infrastructure)	EU	Current	Road: €1.8 B/year Rail: €0.3 B/year Air: € 0.4 B/year	Enei et al. (2011) Weather project
Industry and tourism	Changes in tourism expenditures receipts at annual basis	Northern Europe	2080	0.3 – 2.4 billion € per year	PESETA, Ciscar et al. (2009)
	Changes in tourism expenditures receipts at annual basis	British Islands	2080	0.5 – 3.4 billion € per year	PESETA, Ciscar et al. (2009)
	Changes in tourism expenditures receipts at annual basis	Central Europe North	2080	0.4 – 2.3 billion € per year	PESETA, Ciscar et al. (2009)
	Changes in tourism expenditures receipts at annual basis	Central Europe South	2080	0.6 – 5.0 billion € per year	PESETA, Ciscar et al. (2009)
	Changes in tourism expenditures receipts at annual basis	Southern Europe	2080	- 1.7 to - 12.8 billion € per year	PESETA, Ciscar et al. (2009)
	Changes in tourism expenditures receipts at annual basis	Europe	2080	0	PESETA, Ciscar et al. (2009)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Health	Heat waves, damages related to additional deaths with acclimatisation	Europe	2020	2 – 4 billion € per year	PESETA, Ciscar et al. (2009)
	Heat waves, damages related to additional deaths with acclimatisation	Europe	2080	8 – 81 billion € per year	PESETA, Ciscar et al. (2009)
	Heat waves, damages related to additional deaths without acclimatisation	Europe	2020	13 – 30 billion € per year	PESETA, Ciscar et al. (2009)
	Heat waves, damages related to additional deaths without acclimatisation	Europe	2080	24 – 180 billion € per year	PESETA, Ciscar et al. (2009)
	Economic valuation of cold-related deaths, benefits from avoided deaths without decline in sensitivity of mortality to cold	Europe	2020	24 – 109 billion € per year	PESETA, Ciscar et al. (2009)
	Expected impacts on overall economic activity due to temperature increase impacts on outdoor labour productivity. A1B climate change scenario	Northern Europe	2080	0.01% GDP	ClimateCost Watkiss et al. (2011)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Health	Expected impacts on overall economic activity due to temperature increase impacts on outdoor labour productivity. A1B climate change scenario	UK and Ireland	2080	0.02% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to temperature increase impacts on outdoor labour productivity. A1B climate change scenario	Central Europe North	2080	-0.07% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to temperature increase impacts on outdoor labour productivity. A1B climate change scenario	Central Europe South	2080	-0.17% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to temperature increase impacts on outdoor labour productivity. A1B climate change scenario	Southern Europe	2080	-1.12% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to temperature increase impacts on outdoor labour productivity. A1B climate change scenario	Europe	2080	-0.33% GDP	ClimateCost Watkiss et al. (2011)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Coastal areas	Sea Flood Costs (IPCC A2 scenario)	Europe	2020	6.0 billion € per year (without adaptation) 1.1 billion € per year (with adaptation) Adaptation costs 1.0 billion € per year	PESETA, Ciscar et al. (2009)
	Expected impacts on overall economic activity due to coastal flooding. A1B climate change scenario	Northern Europe	2080	-0.01% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to coastal flooding. A1B climate change scenario	UK and Ireland	2080	-0.03% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to coastal flooding. A1B climate change scenario	Central Europe North	2080	-0.06% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to coastal flooding. A1B climate change scenario	Central Europe South	2080	-0.01% GDP	ClimateCost Watkiss et al. (2011)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Coastal areas	Expected impacts on overall economic activity due to coastal flooding. A1B climate change scenario	Southern Europe	2080	-0.01% GDP	ClimateCost Watkiss et al. (2011)
	Expected impacts on overall economic activity due to coastal flooding. A1B climate change scenario	Europe	2080	-0.03% GDP	ClimateCost Watkiss et al. (2011)
	Salinity Intrusion Costs (IPCC A2 scenario)	Europe	2020	0.6 billion € per year	PESETA, Ciscar et al. (2009)
	Salinity Intrusion Costs (IPCC A2 scenario)	Europe	2080	1.1 billion € per year	PESETA, Ciscar et al. (2009)
	Migration costs	Europe	2020	0.3 million € per year (without adaptation) 0.2 million € per year (with adaptation) Adaptation costs 1.0 billion € per year	PESETA, Ciscar et al. (2009)
	Migration costs	Europe	2080	25.2 billion € per year (without adaptation) 20 billion € per year (with adaptation) Adaptation costs 2.6 billion € per year	PESETA, Ciscar et al. (2009)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Coastal areas	Annual costs (salinization, moving and land loss) for Europe under A1B scenario	Europe	2020	5.2 (5.0-5.6) billion per year; Socio-economic and climate change together, no discounting, no adaptation 2.4 (2.2-2.7) B€/yr. marginal effects climate change signal only	ClimateCost Brown et al. (2011a)
	Annual costs (salinization, moving and land loss) for Europe under E1 (2°C) scenario	Europe	2020	5.6 (5.2-5.8) billion per year; Socio-economic and climate change together, no discounting, no adaptation 2.8 (2.3-2.9) B€/yr. marginal effects climate change signal only	ClimateCost Brown et al. (2011a)
	Annual costs (salinization, moving and land loss) for Europe under A1B scenario	Europe	2050	10.6 (9.9-11.7) billion € per year Socio-economic and climate change together, no discounting, no adaptation 6.2 (5.5-7.3) B€/yr. marginal effects climate change signal only	ClimateCost Brown et al. (2011a)
	Annual costs (salinization, moving and land loss) for Europe under E1 (2°C) scenario	Europe	2050	11.7 (11.1-12.5) billion € per year Socio-economic and climate change together, no discounting, no adaptation 6.7 (6.0-7.5) B€/yr. marginal effects climate change signal only	ClimateCost Brown et al. (2011a)

Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Coastal areas	Annual costs (salinization, moving and land loss) for Europe under A1B scenario	Europe	2080	25.4 (19.3-37.2) billion € per year Socio-economic and climate change together, no discounting, no adaptation 18.4 (12.4-30.2) B€/yr. marginal effects climate change signal only	ClimateCost Brown et al. (2011a)
	Annual costs (salinization, moving and land loss) under E1 (2 °C temperature rise)	Europe	2080	17.4 (15.8-20.1) billion € per year; Socio-economic and climate change together, no discounting, no adaptation 10.4 (8.9-13.1) B€/yr. marginal effects climate change signal only	ClimateCost Brown et al. (2011a)
	Monetary damage caused by flooding, salt intrusion, land erosion and migration	Europe	2100	17 billion USD/year	Hinkel et al. (2010)
	Impact of sea level rise	OECD – Europe	1 meter sea level rise	1.7 billion USD per year	Tol (2002)
	Impact of sea level rise	Central and Eastern Europe and the former Soviet Union	1 meter sea level rise	0.5 billion USD per year	Tol (2002)

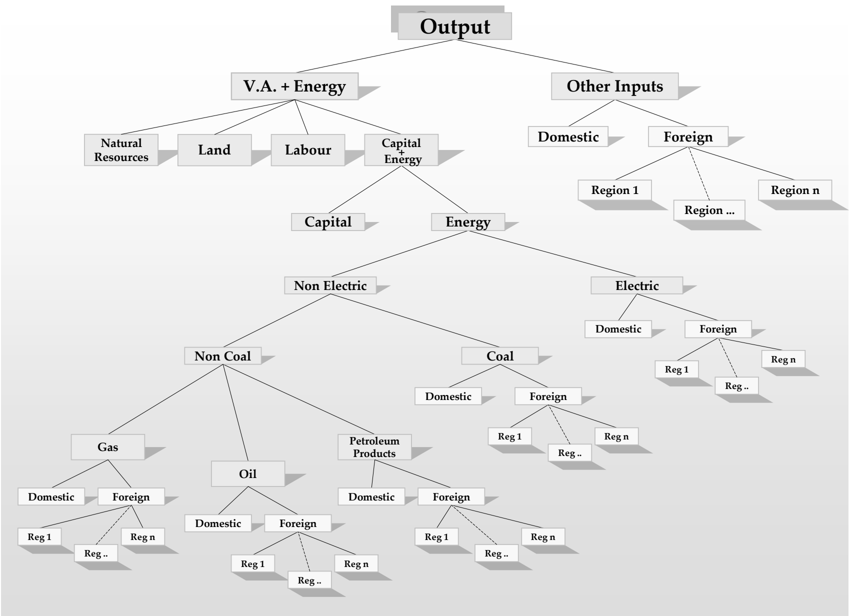
Sector	Indicator	Geographical cover	Time frame or other indicator	Economic impact	Literature
Urban areas	NA	NA	NA	Economic impacts are described in above sections. Especially river floods, coastal areas, health and energy are relevant for cities. However damages are not yet calculated for individual cities	NA

Annex 3 – The ICES model

1 Model description

As in all CGE models, ICES makes use of the Walrasian perfect competition paradigm to simulate market adjustment processes, although the inclusion of some elements of imperfect competition is also possible. Industries are modelled through a representative firm, minimizing costs while taking prices as given. In turn, output prices are given by average production costs. The production functions are specified via a series of nested CES functions. Domestic and foreign inputs are not perfect substitutes, according to the so-called "Armington" assumption (Figure 66).

Figure 66: Nested tree structure for industrial production processes of the ICES model

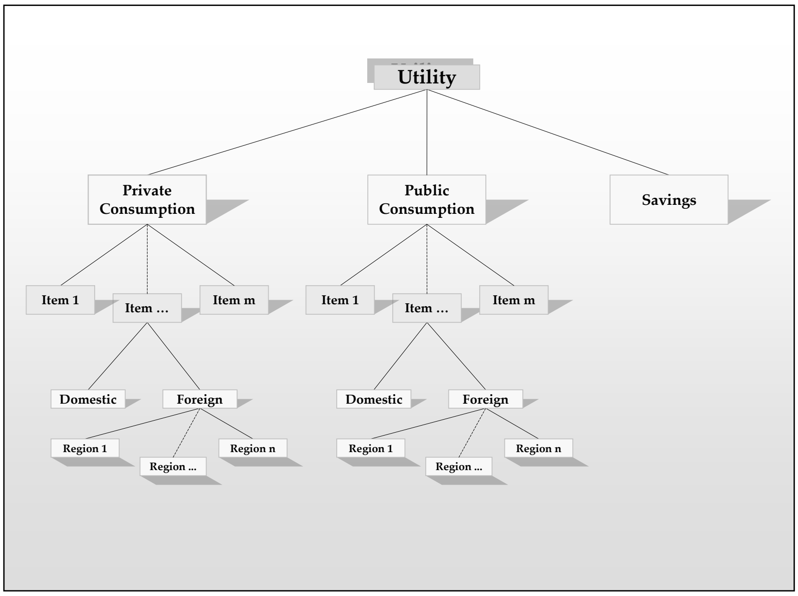


A representative consumer in each region receives income, defined as the service value of national primary factors (natural resources, land, labour, capital). Capital and labour are perfectly mobile domestically but immobile internationally. Land and natural resources, on the other hand, are industry-specific. This income is used to finance three classes of expenditure: aggregate household consumption, public consumption and savings. The expenditure shares are generally fixed, which amounts to saying that the top-level utility function has a Cobb-Douglas specification.

Public consumption is split in a series of alternative consumption items, again according to a Cobb-Douglas specification. However, almost all expenditure is actually concentrated in one specific industry: non-market services.

Private consumption is analogously split in a series of alternative composite Armington aggregates. However, the functional specification used at this level is the Constant Difference in Elasticities form: a non-homothetic function, which is used to account for possible differences in income elasticities for the various consumption goods (Figure 67).

Figure 67: Nested tree structure for final demand of the ICES model



Investment is internationally mobile: savings from all regions are pooled and then investment is allocated so as to achieve equality of expected rates of return to capital.

In this way, savings and investments are equalized at the world, but not at the regional level. Because of accounting identities, any financial imbalance mirrors a trade deficit or surplus in each region.

The recursive-dynamic engine for the model can replicate dynamic economic growths based on endogenous investment decisions. As standard in the CGE literature the dynamic is recursive. It consists of a sequence of static equilibria (one for each simulation period which in the present exercise is the year) linked by the process of capital accumulation. As investment decisions which build regional capital stocks are taken one year to the other, i.e. not taking into account the whole simulation period, the planning procedure is “myopic”. Two factors drive endogenously investment and its international allocation: the equalization of expected rate of return to capital and the international GDP differentials. In other words, a country can attract more investment and increase the rate of growth of its capital stock when its GDP and its rate of return to capital are relatively higher than those of its competitors.

2 Impacts assessed, data and sources used in the ICES model

The inputs to the CGE exercise derive from the results of a set of bottom-up partial-equilibrium exercises performed within different EU FP projects and other research initiatives referenced in Table 53.

Table 53: Impact types and source studies for the ICES CGE modelling exercise

CC IMPACT	Source Model	Reference project	Reference publication
Sea-level rise	DIVA	ClimateCost[313]	Vafeidis et al. (2008)
Tourism flows	HTM	ClimateCost	Bigano et al. (2007)
Crops' productivity	ClimateCrop	ClimateCost	Iglesias et al. (2009); Iglesias et al. (2010)
Residential energy demand	POLES	ClimateCost	Criqui (2001); Criqui et al. (2009)
River floods	LISFLOOD	ClimateCost	van der Knijff et al. (2010); Feyen (2009)
Health	n.a.	PESETA[314]	Ciscar et al. (2009)
Fishery		SESAME[315]	Cheung et al. (2010)
Ecosystem		n.a.	Manne & Richels (2005); Warren (2006)

These allow to physically quantifyinging climate change consequences on sea-level rise, energy demand, agricultural productivity, tourism flows, river floods, health, fishery and ecosystem. All the studies, except those on floods and health, have a global coverage. The majority of them are based on a geographic information system. When this is the case, results have been aggregated to match the geographical resolution of the CGE exercise.

The major characteristics of the individual input studies are summarised below. The reader interested in further details is directly addressed to the specific researches.

Estimates of coastal land loss due to **sea-level rise** derive from the FP7 project ClimateCost and are based upon the DIVA model outputs (Vafeidis, et al, 2008). DIVA (Dynamic Integrated Vulnerability Assessment) is an engineering model designed to address the vulnerability of coastal areas to sea-level rise. The model is based on a world database of

[313] http://www.climatecost.cc/
[314] http://peseta.jrc.ec.europa.eu/
[315] http://www.sesame-ip.eu/

natural system and socioeconomic factors for world coastal areas reported with a spatial resolution of 5°. The temporal resolution is 5-year time steps until 2100 and 100-year time steps from 2100 to 2500. Changes in natural as well as socio-economic conditions of possible future scenarios are implemented through a set of impact-adaptation algorithms. Impacts are then assessed both in physical (i.e. sq. Km of land lost) and economic (i.e. value of land lost and adaptation costs) terms and are available for the regional detail of the ICES CGE model used in this exercise.

Changes in **tourism flows** induced by climate change derive from the FP7 project ClimateCost and stem from simulations based on the Hamburg Tourism Model (HTM) (Bigano, et al, 2007). HTM is an econometric simulation model, estimating the number of domestic and international tourists by country, the share of international tourists in total tourists and tourism flows between countries. The model runs in time steps of 5 years. First, it estimates the total tourists in each country, depending on the size of the population and of average income per capita; then it divides tourists between those that travel abroad and those that stay within the country of origin. In this way, the model provides the total number of holidays as well as the trade-off between holidays at home and abroad. The share of domestic tourists in total tourism depends on the climate in the home country and on per capita income. International tourists are finally allocated to all other countries based on a general attractiveness index, climate, per capita income in the destination countries, and the distance between origin and destination.

Changes in average **crops' productivity** per world region derive from the FP7 project ClimateCost and are based upon the ClimateCrop model (Iglesias, et al, 2009; Iglesias, et al, 2010). Crop response depends on temperature, CO_2 fertilisation and extremes. Water management practices are also taken into account. Integrating spatially all these elements the model estimates climate change impacts and the effect of the implementation of different adaptation strategies.

Responses of **residential energy demand** to increasing temperatures derive from the FP7 project ClimateCost and are based upon the POLES model (Criqui, 2001; Criqui, et al, 2009). It is a bottom-up partial-equilibrium model of the world energy system extended within ClimateCost to include information on water resource availability and adaptation measures. It determines future energy demand and supply according to energy prices trend, technological innovation, climate impacts and alternative mitigation policy schemes. The present version of the model considers both heating and cooling degree-days in order to determine the evolution of demand for different energy sources (coal, oil, natural gas, electricity) over the time-horizon considered.

Data on climate change impacts on **river floods** derive from the FP7 project ClimateCost and are based upon results from the LISFLOOD model (van der Knijff, et al, 2010; Feyen, 2009). This is a spatially distributed hydrological model embedded within a GIS environment. It simulates river discharges in drainage basins as a function of spatial information on topography, soils, land cover and precipitation. This model has been developed for operational flood forecasting at European scale and it is a combination of a grid-based water balance model and a 1-dimensional hydrodynamic channel flow routing model. The LISFLOOD model can assess the economic loss in the EU27 countries per different macro-sectors: residential, agriculture, industry, transport and commerce together with the number of people affected. The role of climate change and of economic growth in determining the final losses can be disentangled. Differently from other impact studies, LISFLOOD is an EU model, thus the Non-EU regions remain outside the scope of its investigation.

Climate-change induced **changes in global catch potential** derive from the FP6 SESAME project and are based upon Cheung et al. (2010). They applied an empirical model (Cheung, et al, 2008a) that predicts maximum catch potential depending upon primary production and distribution range of 1066 species of exploited fish and invertebrates. Distribution of each species on a 30' latitude 30' longitude grid is derived from an algorithm (Close, et al, 2006) including the species' maximum and minimum depth limits, northern and southern latitudinal range limits, an index of association with major habitat types and known occurrence boundaries as input parameters. Future changes in species distribution are simulated by using a dynamic bioclimate envelope model (Cheung, et al, 2008b und 2010). First, the model identified species' preference profiles with environmental conditions. Then, these are linked to the expected carrying capacity in a population dynamic model. The model assumes that carrying capacity varies positively with habitat suitability of each spatial cell. Finally, aggregating spatially and across species, the related change in total catch potential can be determined.

Health impacts of climate change in the EU derive from the PESETA study (Ciscar, et al, 2009). Heat and cold-related (cardiovascular and respiratory) additional or avoided deaths per thousand for different degrees of warming (1 °C, 2.5 °C, 3.9 °C and 4.1 °C above pre industrial levels) in five European regions (British Isles, Northern Europe East, Northern Europe West, Southern Europe East and Southern Europe West) are estimated. The study emphasizes that the decrease in cold related mortality outweighs the increase in heat related mortality however at a diminishing rate with increase in temperature. Therefore the net reduction in mortality is higher in lower temperature increase than in high temperature increase scenarios. To match the PESETA geographical detail with the higher detail of the present study it is assumed that the change in mortality rate remains the same across those countries part of the same PESETA EU macro-region.

Table 54: Heat-related and Cold-related mortality changes - projections for 2 °C and 4 °C temperature increase. Source: Peseta Project (Ciscar, et al, 2009)

	2 °C			4 °C		
	Heat-related	Cold-related	Net effect	Heat-related	Cold-related	Net effect
Austria	13.6	-16.0	-2.4	31.0	-38.0	-7.0
Belgium	9.6	-11.2	-1.6	21.5	-25.5	-4.0
Czech Republic	13.6	-16.0	-2.4	31.0	-38.0	-7.0
Denmark	6.4	-6.4	0	12.0	-12.0	0
Finland	6.4	-6.4	0	12.0	-12.0	0
France	13.6	-16.0	-2.4	31.0	-38.0	-7.0
Germany	9.6	-11.2	-1.6	21.5	-25.5	-4.0
Greece	8.8	-22.4	-13.6	18.0	-50.5	-32.5
Hungary	13.6	-16.0	-2.4	31.0	-38.0	-7.0
Ireland	3.2	-21.6	-18.4	7.5	-52.5	-45.0
Italy	8.8	-22.4	-13.6	18.0	-50.5	-32.5
Netherlands	9.6	-11.2	-1.6	21.5	-25.5	-4.0
Poland	9.6	-11.2	-1.6	21.5	-25.5	-4.0
Portugal	8.8	-22.4	-13.6	18.0	-50.5	-32.5
Spain	8.8	-22.4	-13.6	18.0	-50.5	-32.5
Sweden	6.4	-6.4	0	12.0	-12.0	0
United Kingdom	3.2	-21.6	-18.4	7.5	-52.5	-45.0
RoEU	9.6	-16.8	-7.2	20.5	-38.0	-17.5

Note: change in death rate per 100,000 population per year. Positive sign means a rise in mortality. A negative sign represents a decrease.

To estimate the **non-market ecosystem loss** component, a Willingness To Pay (WTP) approach has been used. In principle, an elicited WTP to avoid a given loss in ecosystems should encompass all their non-market values and therefore reasonably approximate the lost value in case they are not protected[316]. This is for instance the methodology used in the MERGE model (Manne & Richels, 2005) where the WTP to avoid - and thus the ecosystem losses related to - a 2.5°C temperature increase above pre-industrial levels is 2% of GDP when per capita income is above $ 40,000 US 1990[317]. The implicit (and heroic) assumptions are that the WTP is reasonably close to what actually is paid and that this is roughly sufficient to preserve ecosystems and their services in a world warming moderately. Given the focus of the present research, the proxy for WTP/ecosystem damages in the EU is the EU country expenditure on environmental protection (Table 55). This value encompasses activities such as protection of soil and groundwater, biodiversity and landscape, protection from noise, radiation, along with more general research and development, administration and multifunctional activities. Differently from Manne & Richels (2005), the present study is slightly more conservative and assumes that the observed expenditure relates to protection against 2°C warming. Then to link average per capita environmental expenditure and per capita income in non EU countries the logistic function proposed by Warren et al. (2006) is used:

$$WTP_{n,t|t=2.°C} = \gamma \Delta T^{\varepsilon}{}_{n,t|t=2°C} \frac{1}{1+100e^{(-0.23*GDPn,t|t=2°C/POPn,t|t=2°C)}} \qquad (1)$$

To calibrate γ the EU is the reference. γ is thus set to give exactly 0.6% of GDP when per capita income is $28,780 (and ΔT=2°C) which are respectively 2001 total EU environmental expenditure and per capita income.

[316] In practice the limitations of this approach are well known and many criticisms are raised against WTP and other stated preference approaches. However, the usual response is that in the end, they represent the only viable way to capture existence values.

[317] The 2% figure was the US EPA expenditure on environmental protection in 1995.

Table 55: WTP for ecosystems protection related to a temperature increase of 2°C (% of regional GDP)

Country / Region	WTP (% of regional GDP)
Austria	0.76
Belgium	0.58
Czech Republic	0.62
Denmark	0.66
Finland	0.58
France	0.54
Germany	0.60
Greece	0.67
Hungary	0.70
Ireland	0.88
Italy	0.86
Netherlands	1.52
Poland	0.30
Portugal	0.57
Spain	0.35
Sweden	0.34
United Kingdom	0.49
RoEU	0.21
RoOECD	0.43
CHIND	0.06
TE	0.10
RoW	0.01

As shown, the reference WTP value used for rich countries crucially determines the final results. For instance Nordhaus & Boyer (2000) estimate an annual willingness to pay to avoid the disruption of settlements and ecosystem associated with a 2.5°C increase in global average temperature to about $67 per household (2006 values). Hanemann (2008) revised Nordhaus and Boyer's estimates for the United States almost doubling them to $120 (in 2006 values). Using the EU values as the benchmark for calculations gives lower damages than in the MERGE model, but anyway higher than in Hanemann (2008) and Nordhaus & Boyer (2000). This also emphasises the large uncertainty when assigning an economic value to non-market impacts. Table 55 also demonstrates that a WTP approach tends to produce higher evaluations for non-market ecosystem losses in high-income countries, although ecosystem/biodiversity richness is highly concentrated in developing countries.

Among all the above mentioned studies, those deriving from the ClimateCost project estimate impacts which are roughly consistent with a +2 °C warming in 2050. The same holds for the impact assessment on fishery performed within the SESAME project. This is indeed the warming estimated in the A1B IPCC SRES scenario, reference for both projects. The Health analysis in PESETA addresses impacts for different degrees of warming: 1 °C, 2.5 °C, 3.9 °C, and 4.1 °C. The ecosystem impact assessment refers originally to a 2 °C warming.

In the present analysis impacts are economically assessed for a 2 °C and 4 °C warming scenarios. For simplicity both are assumed to occur in 2050.

In the case of flooding, sea-level rise, tourism, and health, the respective impact estimations are available also for the 4 °C temperature increase. In the case of ecosystem changes the reduced-form formula used allows a straightforward computation of losses for the 4 °C. Unluckily no information is currently available from the surveyed studies to quantify 4 °C impacts on energy demand and crops productivity. In the first case it is for simplicity assumed that the relation between temperature and energy demand is linear. Therefore impacts double in the 4 °C scenario. Concerning agriculture, it is assumed that when impacts on crops' productivity in the 2 °C scenario are negative, they remain negative also in the 4 °C and perfectly proportional to the temperature increase. When they are positive, they still increase linearly with temperature, but just until a temperature threshold of 3 °C and then, albeit remaining positive, they start to decline. The 3 °C temperature threshold derives from inspection of the literature placing between 2.5 °C and 3 °C the peak CO_2 fertilization effect which can benefit especially crops at the medium-high latitudes, where EU region is by and large located.

3 Climate change impacts implementation into the ICES-CGE model

To determine with a CGE model the economic consequences of the different impacts assessed, these need to be firstly translated into changes in economic variables existing in the model.

Therefore:

Land losses to sea-level rise have been modelled as percent decreases in the stock of productive land and capital by country/region. Both modifications concern variables, land and capital stocks, which are exogenous to the model and therefore can be straightforwardly implemented. As information on capital losses is not available, we assume that they exactly match land losses[318].

Changes in regional **households' demand for oil, gas and electricity** are modelled as changes in households' demand for the output of the respective industries.

Changes in **tourists' flows** are modelled as changes in (re-scaled) households' demand addressing the market services sector, which includes recreational services. In addition, changes in monetary flows due to variations in tourism demand are simulated through a direct correction of the regional incomes.

Impacts on **agriculture** are modelled through exogenous changes in land productivity. Due to the nature of source data, land productivity varies by region, but is uniform across all crop types present in ICES.

With reference to **river floods**, to account for economic damages affecting the agricultural sector we impose an equal-value reduction in regional land stock, while, when other sectors are involved, an equal-value reduction in sectoral capital productivity. With regard to people affected, this is accommodated in the model by reduction in labour productivity. This is computed relating people affected to the total regional population and assuming that the average loss of working days is one week.

Changes in **labour productivity** are also the channel to account for **health impacts**. Lower mortality translates in an increased labour productivity which is one on one proportional to the change in the total population. The underlying assumption is that health impacts affect active population, disregarding the age characteristic of cardiovascular and respiratory diseases.

Impacts on **fishery** are modelled as a decreased productivity of the natural resource input used by the fishing sector. In ICES there are four sectors using natural resources as a production factor: coal, oil, gas, timber and fishery.

[318] We could have avoided including capital losses, however they are an important part of sea-level rise costs therefore we prefer to have a rough even though arbitrary estimation of this component rather than none. We are not including displacement costs.

Impacts on **ecosystems** are modelled as a loss in the physical capital stock. In ICES the capital stock does not enter directly in the production function, rather capital services do. Nonetheless in the model there is a one on one relation between capital stock and capital services as any change in the former implies an equal change in the latter. The assumption made thus, is that ecosystems offer a set of support services to the production activity which are all embedded in capital services. When ecosystem deteriorates, its production support services deteriorates and thus (through deterioration of the capital stock) capital services deteriorate.

As can be noted, two broad categories of impacts can be distinguished in the abovementioned list. The first, relates to the supply-side of the economic system, affects exogenous variables in the model - stock or productivity of primary factors - and thus can be easily accommodated. Impacts on sea-level rise, agriculture, floods, ecosystems, fishery and human health belong to this category. They do not require any substantial change in the basic structure of the model to be implemented.

The second affects changes in the demand side. Impacts on tourism and on energy consumption are of this kind. This implies to intervene on variables which are endogenous to (i.e. output of) the model. The technicality involved is more complex than in the case of exogenous variables and consists in the following procedure. The computed percentage variations in the demands have been imposed as exogenous shifts in the respective demand equations. The implicit assumption is that the starting information refers to partial equilibrium assessment thus with *all prices and income levels constant*. The model is then left free to determine the *final* demand adjustments. Modification in demand structure imposes however to comply with the budget constraint, so we compensated the changed consumption of energy and tourism services with opposite changes in expenditure for all the other commodities.

Table 56 to Table 61 summarize the results of all this procedure presenting the computed inputs for the ICES CGE model necessary to run the climate-change simulations.

Table 56: Demand-side impacts: 2° C temperature increase, ref. year 2050

	Demand-side Impacts				
	Energy			Tourism	
	Gas	Oil Products	Electricity	Mserv Demand	Expenditure*
Austria	-0,13	0,58	-0,12	1,61	1,29
Belgium	-0,16	0,46	0,15	-0,17	-0,40
Czech Republic	0,16	1,47	-2,62	0,47	0,09
Denmark	-0,48	0,07	2,95	1,12	0,75
Finland	-1,32	-0,17	-0,44	5,15	2,61
France	0,34	1,12	0,14	-0,43	-6,75
Germany	-0,69	-0,07	-0,25	1,26	9,90
Greece	3,48	-0,14	11,42	-2,13	-2,26
Hungary	2,50	3,83	6,92	-0,43	-0,41
Ireland	-0,88	-0,02	1,17	-0,12	-0,08
Italy	-0,19	0,70	15,22	-0,96	-17,05
Netherlands	-0,47	0,36	2,20	0,28	0,41
Poland	-0,30	0,60	-1,67	0,71	0,53
Portugal	-0,17	0,31	10,91	-2,72	-2,63
Spain	-0,40	0,31	17,52	-2,26	-17,61
Sweden	-1,42	-0,27	0,59	4,00	4,39
United Kingdom	-0,49	0,42	0,44	1,28	12,67
RoEU	0,28	1,27	2,17	0,28	0,26
RoOECD	0,88	1,60	6,94	3,04	297,28
CHIND	2,24	2,83	6,52	-2,81	-102,28
TE	0,17	2,18	-2,94	4,66	31,90
RoW	-0,36	0,89	9,32	-2,40	-212,60

Note: *US$ billion

Table 57: Supply-side impacts (1): 2° C temperature increase, ref. year 2050

	Supply-side Impacts (1)				
	SLR	**Fishery**	**Agriculture**	**Ecosystems**	**Health**
	Land and K Stock	**Fish Stock**	**Land productivity**	**K Stock**	**L Productivity**
Austria	0	*n.a. -> 0*	7,63	-0,13	0,0024
Belgium	-0,00390	0,21	-3,79	-0,12	0,0016
Czech Republic	0	*n.a. -> 0*	-3,95	-0,10	0,0024
Denmark	-0,00369	7,87	20,35	-0,15	0
Finland	-0,00008	14,86	31,33	-0,11	0
France	-0,01929	0,27	-5,36	-0,11	0,0024
Germany	-0,01706	*n.a. -> 0*	-0,77	-0,12	0,0016
Greece	-0,00145	0,14	-20,88	-0,13	0,0136
Hungary	0	*n.a. -> 0*	3,33	-0,13	0,0024
Ireland	-0,00540	-1,43	-2,11	-0,22	0,0184
Italy	-0,00552	-12,37	-9,27	-0,19	0,0136
Netherlands	-0,13763	7,79	0,08	-0,29	0,0016
Poland	-0,00040	7,65	-1,76	-0,07	0,0016
Portugal	-0,01128	3,80	-15,70	-0,11	0,0136
Spain	-0,00147	-6,49	-17,71	-0,06	0,0136
Sweden	-0,00007	10,96	28,59	-0,08	0
United Kingdom	-0,00344	1,84	5,12	-0,12	0,0184
RoEU	-0,00515	2,28	-0,90	-0,04	0,0072
RoOECD	-0,15174	6,34	-2,87	-0,08	*n.a. -> 0*
CHIND	-0,13254	-2,02	0,30	-0,02	*n.a. -> 0*
TE	-0,09475	2,95	-4,14	-0,07	*n.a. -> 0*
RoW	-0,11420	-4,21	-7,30	0,00	*n.a. -> 0*

Table 58: Supply-side impacts (2): 2° C temperature increase, ref. year 2050

	Supply-side Impacts (2)					
	Floodings					
	Agriculture (land stock)	Residential (K prod.)	Transport (K prod.)	Commerce (K prod.)	Industry (K prod.)	Population (L prod.)
Austria	-0,009131	-0,635930	-0,005735	-0,000753	-0,002799	0,001251
Belgium	-0,015736	-0,048307	-0,003496	-0,005481	-0,019250	0,001245
Czech Republic	-0,000834	-0,112179	-0,002207	-0,003253	-0,009282	0,000482
Denmark	-0,000044	0,000435	0,000018	0,000015	0,000132	0,000000
Finland	-0,009900	-0,212826	-0,007250	-0,004996	-0,007816	0,001105
France	-0,001524	0,018805	0,000825	0,000173	0,000944	0,000452
Germany	0,001652	0,004830	0,000533	0,000093	0,000691	0,000167
Greece	-0,002600	-0,030850	-0,000498	-0,000283	-0,002170	0,000305
Hungary	-0,008180	-0,297233	-0,007311	-0,001823	-0,005408	0,000319
Ireland	-0,011957	-0,205516	-0,006128	-0,000513	-0,000307	0,000227
Italy	-0,014730	-1,340414	-0,003075	-0,000960	-0,004711	0,000839
Netherlands	-0,008952	-0,021213	-0,000869	-0,000062	-0,000342	0,001168
Poland	0,005314	0,032759	0,000609	-0,000186	-0,000677	-0,000008
Portugal	-0,011786	-0,010840	-0,001154	-0,000127	-0,000446	0,000082
Spain	-0,014978	-0,105708	-0,001926	-0,001412	-0,004107	0,000424
Sweden	-0,001952	-0,063190	-0,001366	-0,000526	-0,001764	0,000081
United Kingdom	-0,037875	-0,377944	-0,011255	-0,003419	-0,024845	0,000918
RoEU	-0,006674	-0,352415	-0,005959	-0,003333	-0,008521	0,000968
RoOECD	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
CHIND	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
TE	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
RoW	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0

Table 59: Demand-side impacts: 4° C temperature increase, ref. year 2050

	Demand-side Impacts				
	Energy			Tourism	
	Gas	Oil Products	Electricity	Mserv Demand	Expenditure*
Austria	-0,27	1,21	-0,26	4,24	4,90
Belgium	-0,34	0,95	0,31	0,37	0,59
Czech Republic	0,33	3,07	-5,48	2,06	0,55
Denmark	-0,99	0,15	6,17	2,87	2,77
Finland	-2,76	-0,36	-0,91	12,74	9,33
France	0,71	2,34	0,29	-0,01	-0,30
Germany	-1,45	-0,14	-0,52	3,30	37,33
Greece	7,26	-0,29	23,83	-3,39	-8,16
Hungary	5,21	7,99	14,44	-0,30	-0,66
Ireland	-1,84	-0,04	2,44	0,27	0,11
Italy	-0,39	1,46	31,76	-1,30	-52,11
Netherlands	-0,98	0,76	4,60	1,17	2,46
Poland	-0,63	1,25	-3,49	1,49	1,60
Portugal	-0,35	0,65	22,78	-3,98	-8,70
Spain	-0,84	0,65	36,57	-3,08	-54,21
Sweden	-2,96	-0,57	1,23	9,65	15,28
United Kingdom	-1,01	0,87	0,93	2,65	37,69
RoEU	0,58	2,66	4,53	1,82	2,46
RoOECD	1,83	3,34	14,49	7,22	1018,28
CHIND	4,68	5,91	13,61	-4,37	-358,91
TE	0,35	4,55	-6,13	14,61	144,42
RoW	-0,75	1,87	19,45	-3,98	-794,71

Note: * US$ billion

Table 60: Supply-side impacts (1): 4° C temperature increase, ref. year 2050

	Supply-side Impacts (1)				
	SLR	Fishery	Agriculture	*Ecosystems*	*Health*
	Land and K Stock	Fish Stock	Land productivity	*K Stock*	*L Productivity*
Austria	0	*n.a. -> 0*	6,51	-0,52	0,0070
Belgium	-0,01351	0,44	-9,29	-0,47	0,0040
Czech Republic	0	*n.a. -> 0*	-9,70	-0,38	0,0070
Denmark	-0,01164	16,42	17,35	-0,59	0
Finland	-0,00026	31,01	26,72	-0,44	0
France	-0,09245	0,57	-13,14	-0,46	0,0070
Germany	-0,05916	*n.a. -> 0*	-1,89	-0,49	0,0040
Greece	-0,14124	0,29	-51,19	-0,52	0,0325
Hungary	0	*n.a. -> 0*	2,84	-0,54	0,0070
Ireland	-0,45826	-2,99	-5,18	-0,90	0,0450
Italy	-0,02250	-25,81	-22,72	-0,75	0,0325
Netherlands	-0,50368	16,26	0,07	-1,17	0,0040
Poland	-0,06546	15,96	-4,33	-0,26	0,0040
Portugal	-0,06294	7,93	-38,49	-0,44	0,0325
Spain	-0,02724	-13,54	-43,43	-0,24	0,0325
Sweden	-0,00019	22,86	24,38	-0,31	0
United Kingdom	-0,35276	3,83	4,36	-0,46	0,0450
RoEU	-0,08152	4,75	-2,20	-0,15	0,0175
RoOECD	-0,38697	13,24	-7,03	-0,34	*n.a. -> 0*
CHIND	-0,63032	-4,21	0,25	-0,06	*n.a. -> 0*
TE	-0,27001	6,15	-10,14	-0,28	*n.a. -> 0*
RoW	-0,24184	-8,78	-17,89	-0,02	*n.a. -> 0*

Table 61: Supply-side impacts (2): 4° C temperature increase, ref. year 2050

	Supply-side Impacts (2)					
	Floodings					
	Agriculture (land stock)	Residential (K prod.)	Transport (K prod.)	Commerce (K prod.)	Industry (K prod.)	Population (L prod.)
Austria	-0,019844	-1,351235	-0,012211	-0,001854	-0,006816	0,002273
Belgium	-0,043552	-0,101259	-0,006539	-0,009657	-0,034333	0,001879
Czech Republic	-0,003306	-0,297799	-0,005237	-0,007026	-0,019762	0,000842
Denmark	-0,004319	-0,031111	-0,000603	-0,000121	-0,000440	0,000072
Finland	-0,018154	-0,411370	-0,014361	-0,008443	-0,013213	0,001746
France	-0,014930	-0,136315	-0,008830	-0,001716	-0,008446	0,001177
Germany	-0,005323	-0,006574	-0,000632	-0,000087	-0,000772	0,000424
Greece	-0,005643	-0,094077	-0,001396	-0,000721	-0,005516	0,000442
Hungary	-0,017378	-0,582444	-0,011749	-0,003160	-0,009341	0,000772
Ireland	-0,035354	-0,614801	-0,018013	-0,001521	-0,001024	0,000623
Italy	-0,030584	-2,954311	-0,006971	-0,002166	-0,010472	0,001318
Netherlands	-0,062254	-0,109728	-0,004355	-0,001034	-0,005382	0,002099
Poland	0,010549	0,077988	0,001652	-0,000182	-0,000619	-0,000069
Portugal	-0,010016	-0,018937	-0,001490	-0,000196	-0,000763	0,000096
Spain	-0,015747	-0,125104	-0,002292	-0,001702	-0,004995	0,000467
Sweden	-0,002559	-0,095156	-0,002931	-0,001439	-0,004791	0,000095
United Kingdom	-0,100310	-1,021074	-0,028817	-0,008138	-0,057809	0,002078
RoEU	-0,008616	-0,461287	-0,008151	-0,004495	-0,011618	0,001208
RoOECD	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
CHIND	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
TE	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
RoW	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0

Form a quick inspection of the inputs, sea-level rise and ecosystem effects entail unambiguous negative impacts in all the countries/regions considered; the same for flooding;

whereas net health impacts of climate change are everywhere positive. Tourism is positively affected by climate change in Northern European countries, where warming increases climatic attractiveness, and negatively affected in Southern European countries, becoming “too hot”. Both climate change consequences on crops and the fish stock productivity are mixed depending on the country. In general crops productivity tend to benefit from climatic change, trough positive temperature and CO_2 concentration-fertilization effect, in Centre-North EU and to decrease in the South. Reduced catches affect mainly Mediterranean countries, primarily Italy and Spain, whereas Greece is almost unaffected. On the contrary Northern EU fishery is apparently advantaged by climatic change. Electricity consumption with the only exceptions of Austria, Finland, Czech Republic, Germany and Poland is expected to increase in the EU for the prevalence of a cooling effect, i.e. more air conditioning in the summer. In gas and partly oil product demand there is a prevalence of “minus signs” as a consequence of the warming effect: less energy used to warm in the winter. Note that when demand side impacts are concerned (tourism and energy), these imply by construction a re-composition rather than a shrinking/expansion of agents demand as their total budget is unaltered. Accordingly, it is very difficult to assess since the beginning if the final consequences are positive or negative for the economic system.

Annex 4 – The improved AD-WITCH model

1 Model description

The modelling tool used in the present analysis is an improved version of the AD-WITCH model (Bosello, et al, 2011; Agrawala, et al, 2010b, 2011a) whose main features are summarised below[319].

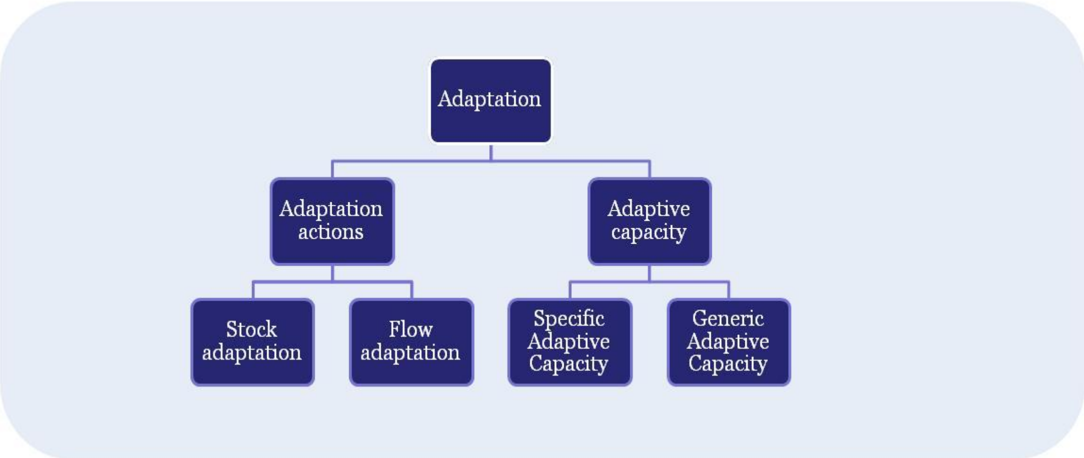
AD-WITCH builds on the WITCH model (Bosetti, et al, 2006, 2009), of which it shares the main characteristics. It is an intertemporal, optimal growth model in which forward-looking agents choose the path of investments to maximise a social welfare function subject to a budget constraint. A reduced-form global circulation model links emissions from industrial activities to temperature increase. On its turn temperature increase translates in GDP losses via a reduced-form climate change damage function. The model can be solved in two alternative game theoretical settings. In the non-cooperative one, the twelve model regions[320] behave strategically with respect to all major economic decision variables – including adaptation and emission abatement levels. This yields a Nash equilibrium, which does not internalise the environmental externality. The cooperative setting describes a first-best world, in which all externalities are internalised, because a benevolent social planner maximises a global welfare function[321].

In AD-WITCH, adaptation response is modelled as a set of control variables chosen optimally together with all the other controls, namely investments in physical capital, R&D, and energy technologies. The large number of adaptive responses that exist has been aggregated into four macro categories: generic and specific adaptive capacity-building, anticipatory and reactive adaptation.

Generic adaptive capacity building captures the link between the status of the development of a region and the final impact of climate change on its economic system (Parry, et al, 2007; Parry, 2009). Specific adaptive capacity building accounts for all investments dedicated to facilitate adaptation activities (e.g. improvement of meteorological services, of early warning systems, the development of climate modelling and impact assessment etc.). Anticipatory adaptation gathers all the measures where a stock of defensive capital must already be operational when the damage materialises (e.g. dike building). By contrast, reactive adaptation gathers all actions that are put in place when the climatic impact effectively materialises (e.g. use of air conditioning) to accommodate the damages not avoided by anticipatory adaptation or mitigation.

[319] The interested reader is addressed directly to Agrawala et al. (2011) for further detail.
[320] Western Europe (), Latin and Central America (LACA).
[321] AD-WITCH, as well as the WITCH model, features technology externalities due to the presence of Learning-By-Researching and Learning-By-Doing effects. The cooperative scenario internalises all externalities. For more insights on the treatment of technical change in the WITCH model see Bosetti et al. (2009).

Figure 68: The adaptation tree in AD-WITCH.



In the original framework developed for AD-WITCH (Bosello, et al, 2010a, 2012) the choice between different adaptation types is organized by a nested sequence of CES functions. In a first node it is possible to choose between investment in adaptation actions and/or building adaptive capacity. Within adaptation actions, meanwhile, it is possible to choose between stock/proactive and flow/reactive adaptation. These are considered to be substitutes. Adaptive capacity is then composed of generic and specific adaptive capacity, also considered to be substitutes. Both generic and specific adaptive capacities improve the effectiveness of adaptation.

A first novelty of the present analysis is the specification of generic capacity. It is treated as endogenous and its parameterization follows Yohe & Tol (2002), even though some sensitivity has been done on the basis of Alberini et al. (2006).

Yohe & Tol (2002) estimate an equation where the dependent variable is the natural logarithm of people affected (normalized with population size in 1995) by natural disaster in the period 1990-2000. Alberini et al. (2006) estimate an equation where the dependent variable is country I's deaths in extreme weather events per million people in year t, panel of data from over 100 countries covering the years 1990-2003. Two specifications are considered. The first uses an adaptive capacity index (constructed by Alberini herself and based on experts' judgments). The second uses POLITY2 in place of the index. Such a variable proxies adaptive capacity capturing institutions, political processes, the government's willingness to provide assistance in case of natural disasters and social capital, even though imperfectly. Used estimates are reported in Table 62.

Table 62: Estimates of the relationship between generic adaptive capacity and its drivers

	Yohe & Tol (2002) (Central Case)	Alberini et al. (2006) (Cap Index)	Alberini et al. (2006) (POLITY2)
GDP per capita (a)	-1.02	-0.08847	-0.10339
Population density (b)	0.24	0.000379	0.000727

Generic capacity building is linked to per-capita GDP by a factor of (roughly) one while the exponent associated to population density is 0.24. Hence, generic capacity has been modelled as follows:

$$GCAP_{n,t} = [\, Y_{n,t}/L_{n,t} \,]^{1.02} * [\, L_{n,t}\,/WPOP_t \,]^{(-0.24)} \quad (1)$$

where $Y_{n,t}$ is country's n GDP; $L_{n,t}$ represents regional population and $WPOP_t$ is global population.

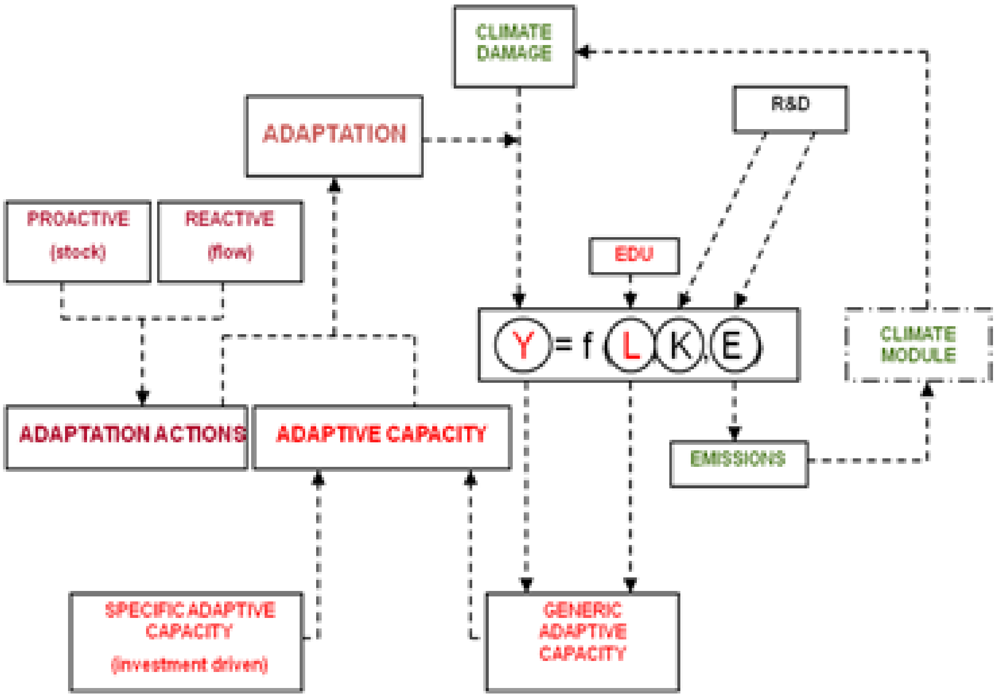
On its turn, specific adaptive capacity building is investment driven, thus it accumulates over time according to:

$$SCAP_{n,t} = (1-\delta) * \, SCAP_{n,t-1} + \, I\_SCAP_{n,t} \quad (2)$$

where $I\_SCAP_{n,t}$ represents new investments in specific capacity while the stock depreciates at a rate δ.

A second novelty is a partly endogenous treatment of economic growth based on Carraro, et al. (2009). In the model, GDP is partly driven by the stock of human capital and knowledge. Regions can decide to invest also in these sectors to stimulate economic growth. Since generic capacity is linked to per capita GDP, the stock of human capital and the stock of knowledge ultimately affect the adaptive capacity (cf. Figure 69).

Figure 69: General description of the model



As it can be seen in Figure 69, the output of the production process is a unique final good produced by means of three inputs: capital, labour and energy.

$$Y(t) = H(t)\{[AK(t)K(t)]^{\rho} + [AL(t)L(t)]^{\rho} + [AE(t)E(t)]^{\rho}\}^{1/\rho} \quad (3)$$

The coefficients (Ai with $i = K, L, E$) that pre-multiply the three inputs capital, labour and energy (K, L, E), describe the productivity of the singular production factor, whereas neutral technical change is described by H. In particular $\rho = (\sigma - 1)/\sigma$ where σ is the elasticity of substitution.

When technical change is endogenous, factor productivity at time t depends on factor productivities at time $t - s$, for all $s = 1, \ldots, t$, and on its specific technological driver. Following Carraro & De Cian (2009), innovation ($R\&D$) better explains the dynamics of capital and energy productivities, while human capital (HK) is the main driver for labour productivity advancements. Hence, endogenous factor-augmenting technical progress may be expressed as follows:

$$AK\ (t) = AK_0\ R\&D^{\chi_K} \quad (4)$$

$$AE\ (t) = AE_0\ R\&D^{\chi_E} \quad (5)$$

$$AL\ (t) = AL_0\ HK^{\chi_L} \quad (6)$$

The equations (4), (5), (6) indicate that the evolution of the productivities of capital, energy and labour is related to their respective technology drivers according to the parameter χ_i with $i = K; L; E$, which are the factor elasticities with respect to endogenous technology drivers. Once the endogenous dynamics of the factor productivities have been formalised, it is possible to investigate whether the technology drivers, i.e. human capital and innovation expressed as the stock of R&D, are energy-saving or energy-using. When a stabilisation policy is implemented, the behaviour of the technology drivers with respect to the use of the energy input will be determinant for the allocation of resources towards either R&D investments or education. The parameters linking factor productivity with endogenous technological drivers have been estimated by Carraro & De Cian (2009) using the Feasible Generalised Least Square Estimator. The estimation results indicate that all the three elasticities are positive and statistically significant; hence, factor productivities come as the result of an endogenous process. In particular, the central value of the elasticity of capital productivity with respect to generic knowledge has been estimated to be equal to 0.28 (χ_K), while the same parameter regarding the contribution of human capital to labour productivity and the effect of total R&D for energy productivity are, respectively, 0.17 (χ_L) and 0.59 (χ_E). Using these estimates it turns out that human capital is energy using, while knowledge is energy-saving (Carraro, et al, 2009).

2 Incorporating adaptation as a policy variable in the AD-WITCH model

In what follows, a more detailed representation of the adaptation modelling framework used in AD-WITCH will be presented. In the model, the damages that will be experienced in absence of adaptation, i.e. gross damages (GD), are exponentially linked to temperature changes (T):

$$GD_{j,t} = \alpha_{0,j} T_t + \alpha_{1,j} T_t^{\alpha_{2,j}}$$

$$\mathrm{GD}_{j,t} = \alpha_{0,j} \mathrm{T}_t + \alpha_{1,j} \mathrm{T}_t^{\alpha_{2,j}}$$

(A1)

where the subscript *j* represents the region and the subscript *t* the time period.

When adaptation is undertaken, the level of damage is reduced, leaving to a residual damage (RD). Residual damages are directly linked to gross damages and inversely to the achieved level of adaptation (ADAPT) according to the following function:

$$RD_{j,t} = \frac{GD_{j,t}}{1 + ADAPT_{j,t}}$$

$$\mathrm{RD}_{j,t} = \frac{\mathrm{GD}_{j,t}}{1+\mathrm{ADAPT}_{j,t}}$$

(A2)

According to the functional form, residual damages approaches zero when total adaptation reaches infinity, while residual damages are equal to gross damages in the case in which no adaptation is undertaken. In such a way, the fraction by which the gross damages can be reduced is limited to the interval of 0 to 1. Moreover, adaptation shows a decreasing marginal damage reduction: the more adaptation is used the less effective additional adaptation will be.

The net damage (ND) is the damage in the presence of adaptation, and it is given by the sum of adaptation costs and residual damage. Expenditure in adaptation is made by the whole of flow adaptation actions (FAD), stock adaptation (SAD), and in specific adaptive capacity (SAC).

Flow adaptation entails simultaneous costs and benefits. Stock adaptation instead is created with investments in adaptation (IA). Hence, the law of motion for adaptation stock is:

$$SAD_{j,t+1} = (1-\delta) SAD_{j,t} + IA_{j,t}$$

$$\mathrm{SAD}_{j,t+1} = (1\text{-}\delta)\mathrm{SAD}_{j,t} + \mathrm{IA}_{j,t}$$

(A3)

Where δ is the capital depreciation rate (10% in AD-WITCH). The build-up for specific adaptive capacity is also based on the accumulation investments in specific adaptive capacity (IAC), which depreciates at a 3% rate.[322] Adaptation costs are thus given by:

AC = FAD + IA + IAC (A4)

Flow adaptation and investment in stock adaptation are aggregated together to adaptation actions (ACT) using a Constant Elasticity of Substitution (CES) function:

$$ACT_{j,t} = \beta_{1,j}(\beta_{2,j}FAD_{j,t}{}^{\rho} + (1-\beta_{2,j})SAD_{j,t}{}^{\rho})^{\frac{\beta_3}{\rho}}$$

$$ACT_{j,t} = \beta_{1,j}\left(\beta_{2,j}FAD_{j,t}^{\rho} + [(1-\beta]_{2,j})SAD_{j,t}^{\rho}\right)^{\frac{\beta_3}{\rho}} \quad \text{(A5)}$$

Furthermore, adaptation actions are part of a bigger nest in which they are combined with adaptive capacity building. Adaptive capacity is also derived as a CES combination of specific (SAC) and generic (GAC) adaptive capacity:

$$AC_{j,t} = (\varphi_j SAC_{j,t}{}^{\gamma} + (1-\varphi_j)GAC_{j,t}{}^{\gamma})^{\frac{1}{\gamma}} \quad AC_{j,t} = \left(\varphi_j SAC_{j,t}^{\gamma} + [(1-\varphi]_j)GAC_{j,t}^{\gamma}\right)^{\frac{1}{\gamma}}$$

(6)

Finally, adaptation actions and adaptive capacity building are combined to form total adaptation, also with a CES function:

$$ADAPT_{j,t} = (\mu_j ACT_{j,t}{}^{\gamma} + (1-\mu_j)AC_{j,t}{}^{\gamma})^{\frac{1}{\rho}} \quad ADAPT_{j,t} = \left(\mu_j ACT_{j,t}^{\gamma} + [(1-\mu]_j)AC_{j,t}^{\gamma}\right)^{\frac{1}{\rho}}$$

(7)

In absence of empirical estimates for the elasticities, the values have been chosen to reflect substitutability between the different adaptation types. The elasticity of substitution in AD-WITCH is 1.2, with an exponential parameter ρ equal to 0.2. This is due to the fact that the stock and flow adaptation actions are part of a bigger nest in the AD-WITCH model. Specific and generic adaptive capacities are assumed to be gross complements with an elasticity of substitution equal to 0.2. Adaptive capacity building and adaptation actions are instead assumed to be gross substitutes and have an elasticity of substitution of 1.2.

[322] Direct stock adaptation is comparable to building or adapting infrastructure so it is a capital-intensive activity which is assumed to depreciate at a rate close to that of physical capital. Specific adaptive capacity instead is assumed to depreciate at a lower rate because it has a knowledge component that is therefore closer to human capital, which depreciates at a lower rate.

The model has been calibrated on the basis of Nordhaus & Boyer (2000), Agrawala & Fankhauser (2008) and UNFCCC (2007). The calibration point corresponds to an increase in temperature equal to 2.5°C, which is supposed to happen between 2060-2065 Protection levels, damage costs and adaptation costs calibrated and those reported by the literature are depicted in Figure 70, Figure 71 and Figure 72 respectively. Figure 73 reports the resulting adaptation cost/effectiveness curves for the AD-WITCH model regions.

Figure 70: Protection Level for the reference case in the calibration point, when temperature increase 2.5°C above pre-industrial levels, which occurs between 2060 and 2065

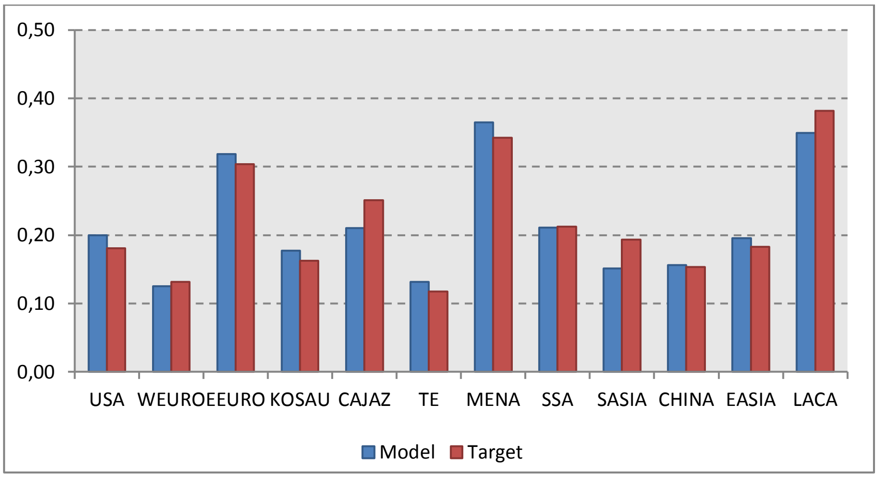


Figure 71: Protection Costs + residual damages for the reference case in the calibration point, when temperature increase 2.5°C above pre-industrial levels, which occurs between 2060 and 2065

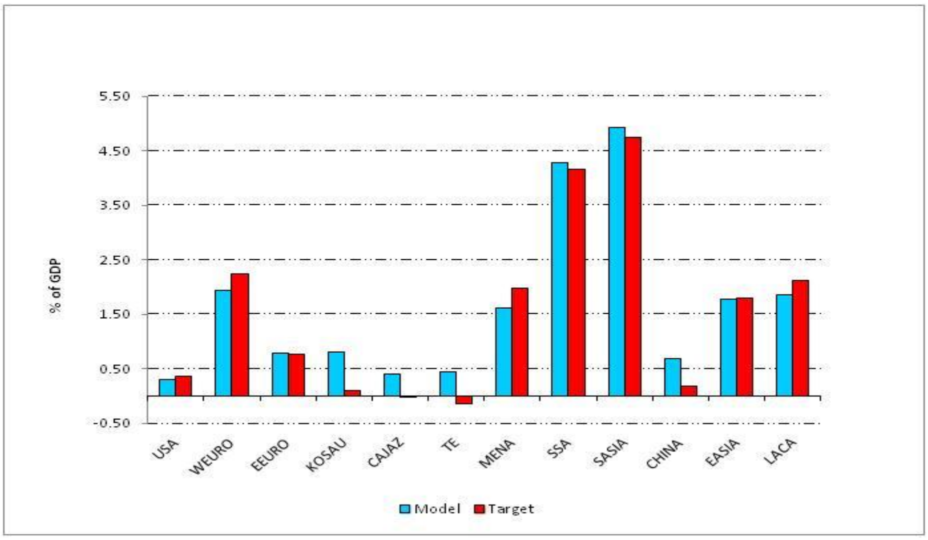


Figure 72: Protection Costs for the reference case in the calibration point, when temperature increase 2.5°C above pre-industrial levels, which occurs between 2060 and 2065

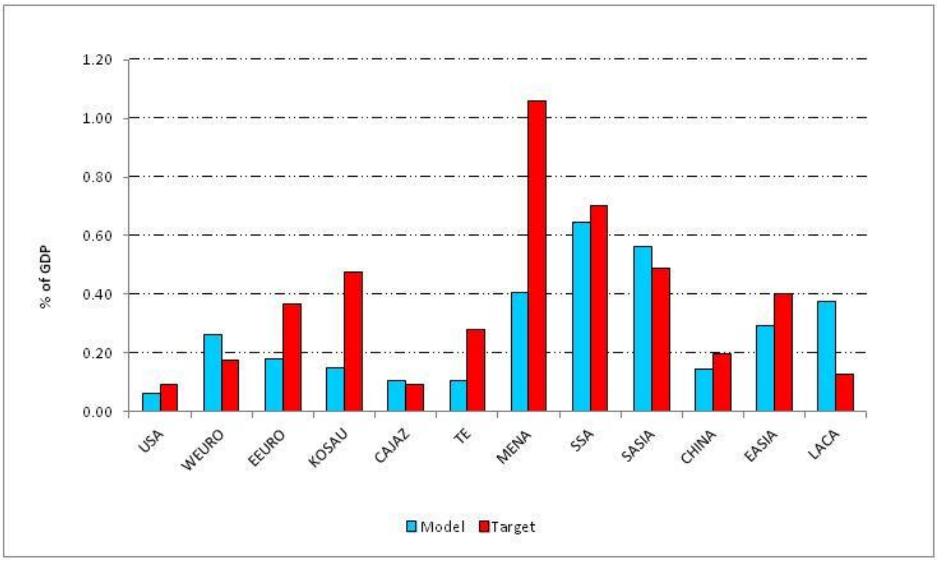
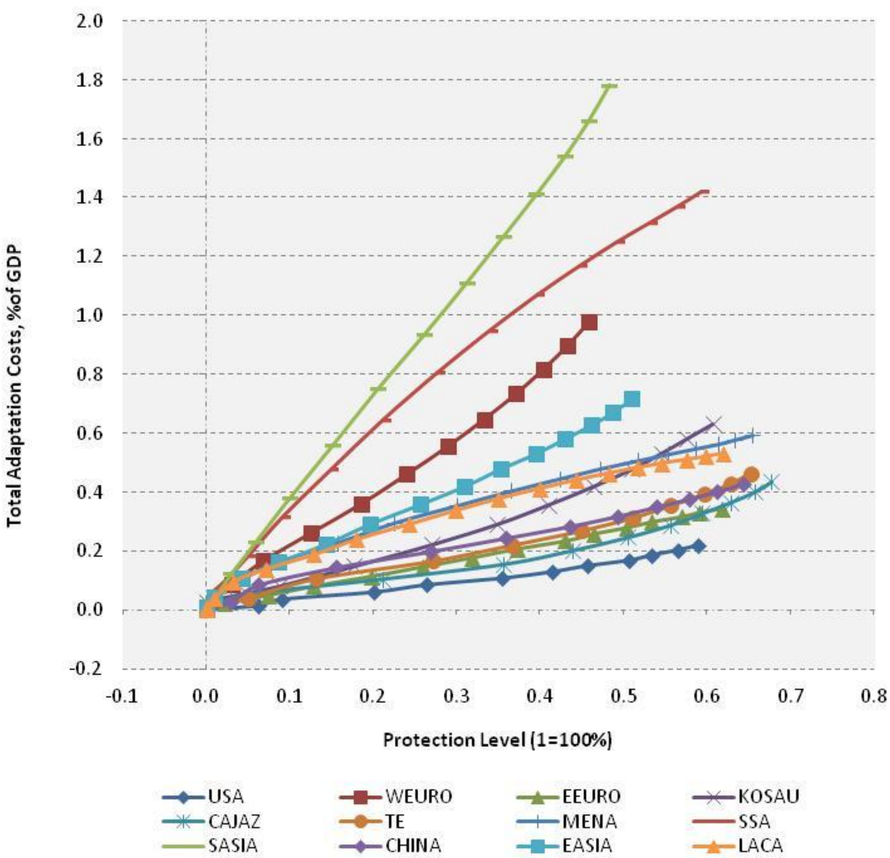
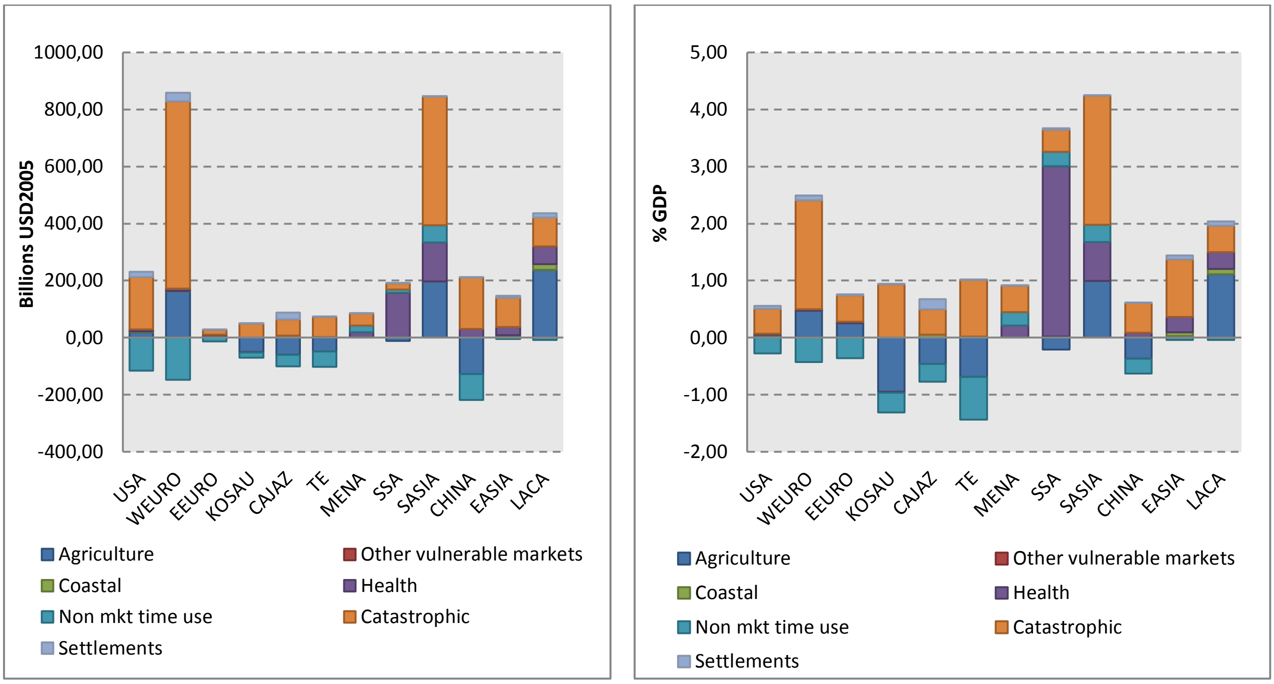


Figure 73: Adaptation cost/effectiveness curves for the AD-WITCH model regions



To conclude, damages differentiated for categories and for regions are represented in Figure 74.

Figure 74: Damages at the calibration point: absolute values (left) and percentage of GDP (right).



The calibration process results in region-specific estimates for the parameters described in section 2 and reported in Table 63.

Table 63: Parameters of adaptation and damage functions (calibrated values)

	USA	WEURO	EEURO	KOSAU	CAJAZ	TE	MENA	SSA	SASIA	CHINA	EASIA	LACA
α_0	-0.0021	-0.0025	0.001	-0.007	-0.007	-0.008	0.002	0.0015	0.0004	-0.0045	0.001	-0.002
α_1	0.0014	0.0044	0.0014	0.0043	0.004	0.004	0.0035	0.0105	0.0105	0.003	0.0028	0.0105
α_2	2	2	1.8	2	2	2	1.6	1.6	1.8	2	2	1.1
μ_2	0.0001	0.01	0.0001	0.01	0.0001	0.2	0.3	0.315	0.3	0.15	0.25	0.3
φ_2	0.3	0.5	0.1	0.1	0.9	0.00001	0.00001	0.1	0.2	0.0001	0.1	0.2
β_1	5.7	0.85	50	22	18	42	24	14	2.1	3.8	8	7
β_2	0.5	0.5	0.6	0.6	0.5	0.5	0.6	0.6	0.6	0.4	0.4	0.4
β_3	1	1	1	1	1	1	1	1	1	1	1	1

3 Extended modelling results – world

Figure 75: Composition of climate change costs World: BaU Default scenario.

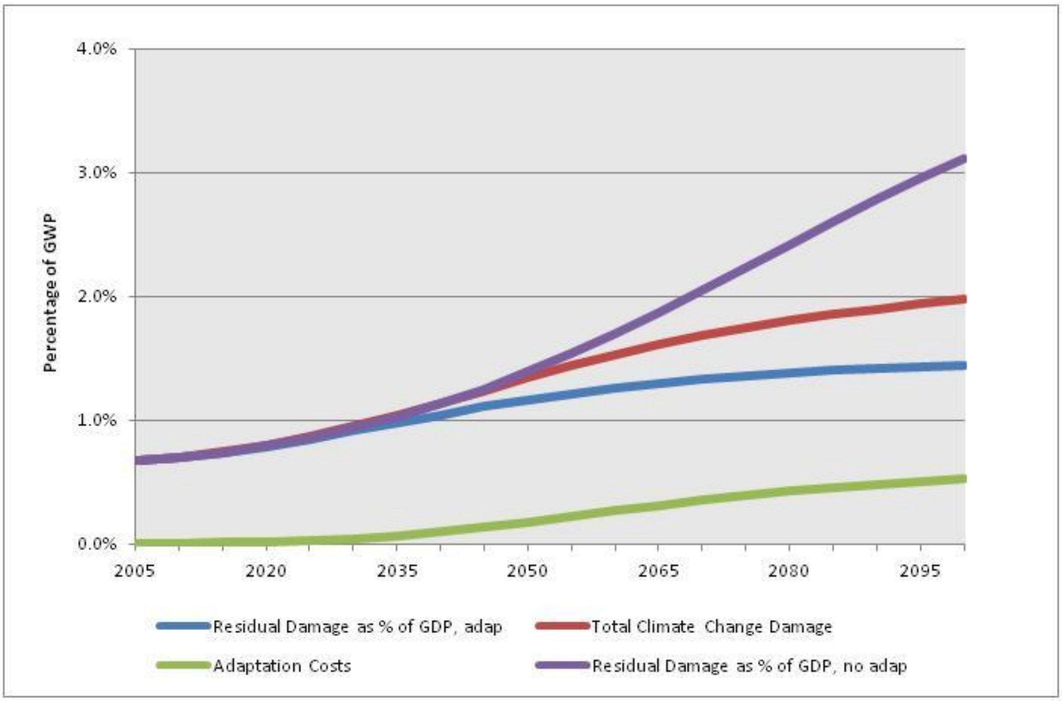


Figure 76: Capacity and adaptation activities World: BaU Default Scenario

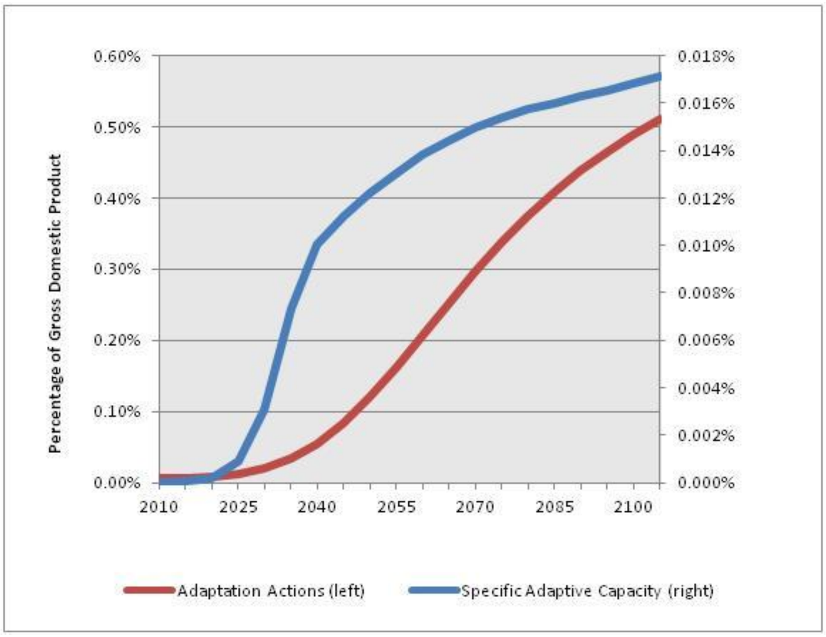


Figure 77: Composition of adaptation expenditure World (% of GDP). BaU Default. Reactive and Anticipatory Adaptation to be read on the left axis, Specific Capacity on the right axis.

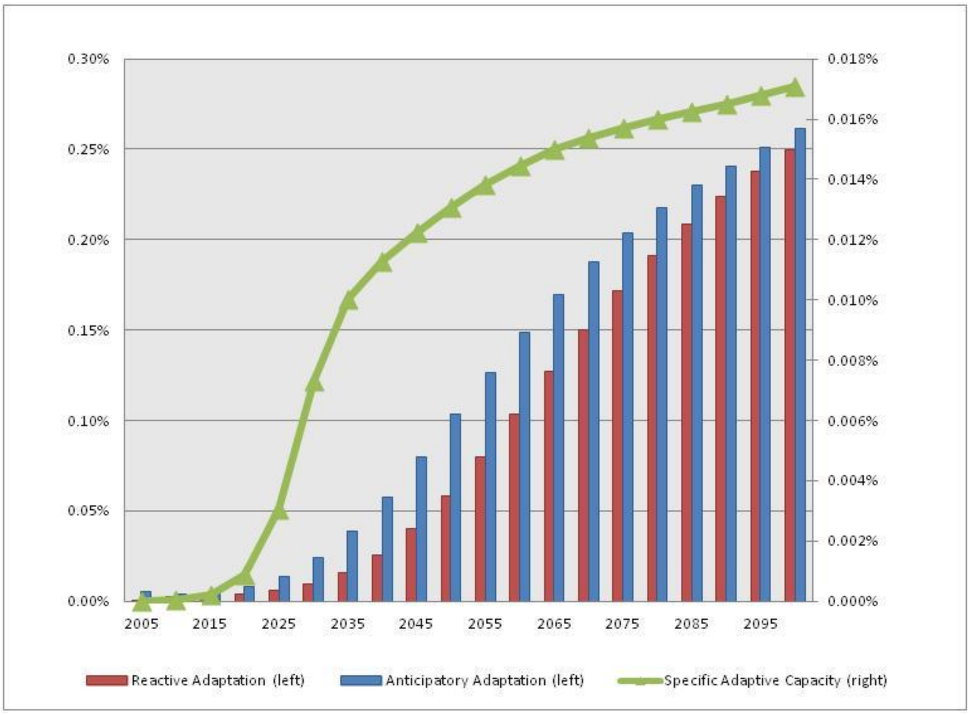


Table 64: Composition of adaptation expenditure World (2005 US$ Billion): BaU Default

	Anticipatory Adaptation	Reactive Adaptation	Specific Adaptive Capacity	Total
2010	2.25	1.35	0.02	3.62
2030	26.26	10.12	7.98	44.36
2050	192.76	109.14	24.44	326.34
2100	1071.77	1021.97	70.07	2163.81
2010-2100 Discount rate 3%	4432.68	3403.46	432.37	8268.51
UNFCCC (2007) reference year 2030	8-130			49-171

Figure 78: Figure A2.4. Residual Damage, World: Billion USD2005 (left) and % of GDP (right).

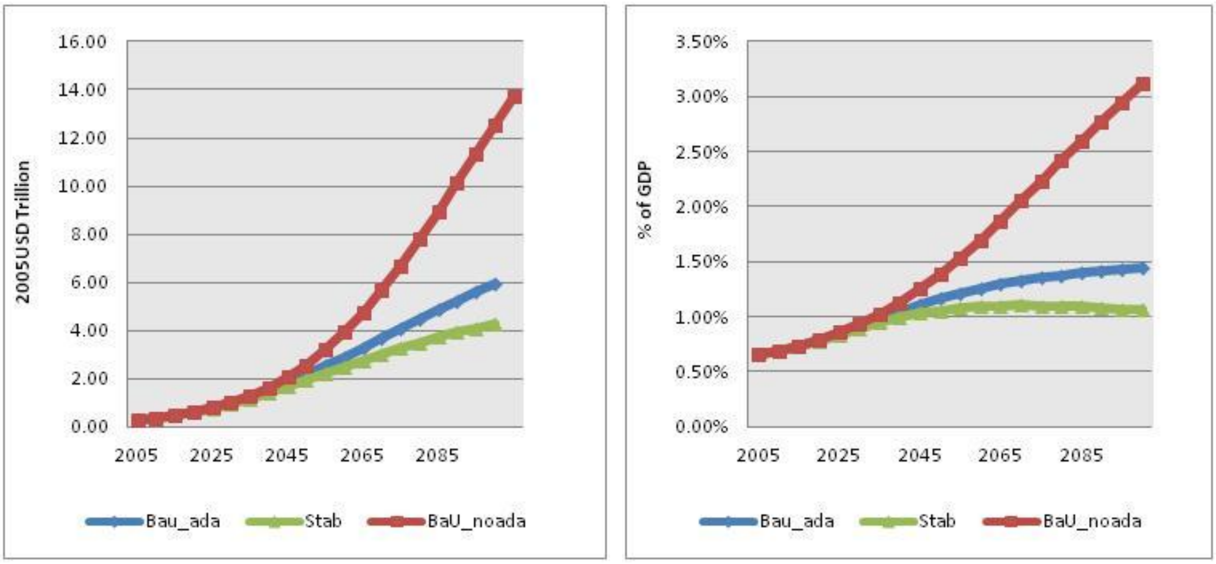


Figure 79: Adaptation Costs, World. % of GDP.

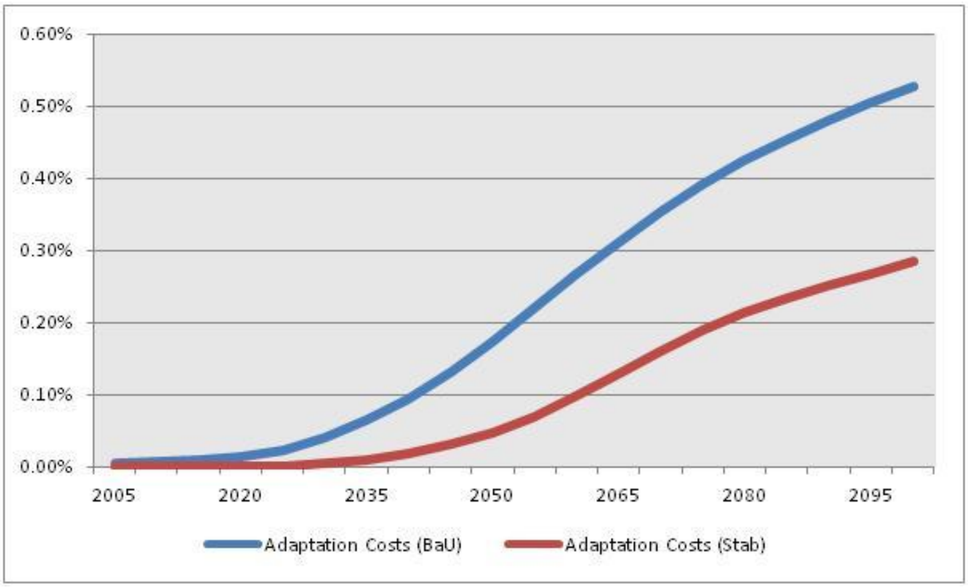
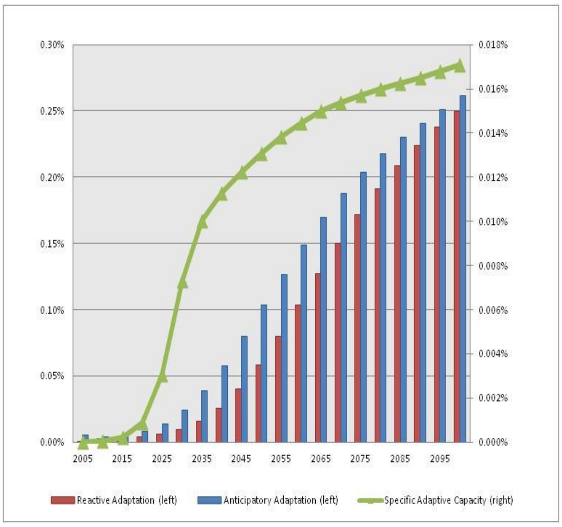


Figure 80: Composition of adaptation expenditure. World (% of GDP). BaU Default (left) and Stab (right).



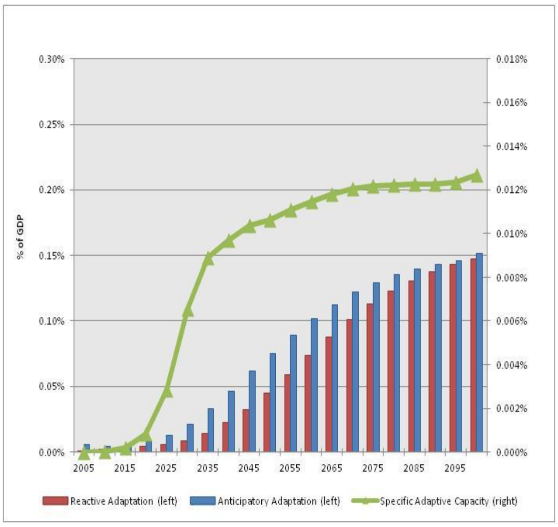


Table 65: Composition of climate change policy expenditure World (2005 US$ Billion): Stab Scenario

	Anticipatory Adaptation	Reactive Adaptation	Specific Adaptive Capacity	Mitigation Costs
2010	0,0	0,0	0,0	78,9
2050	61,1	27,7	13,2	242,4
2100	606,4	543,7	50,1	623,6
2010-2100 Discount rate 3%	2011,6	1440,4	256,4	9227,5

Annex 5 – Relevant climatic drivers and their potential impacts in regard to environmental, economic and social issues per policy area/sector

The following tables summarise relevant climatic drivers and their potential impacts in regard to environmental, economic and social issues per policy area/sector addressed for the EU Adaptation Strategy. The tables also provide information on the level of agreement and evidence.

1 Agriculture

Table 66 (Altvater, et al, 2011a) summarises relevant climatic drivers and their potential impacts in regard to environmental, economic and social issues. It also provides information on the level of agreement and evidence.

Table 66: Climatic drivers and their potential impacts on agriculture

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Rising air temperatures and CO_2 concentrations	Lengthened growing seasons Decreasing cold spells Extended periods without frost	2050	Northern Europe	Northwards movement of suitable zones for crops, e.g. cereals Increased need for fertiliser and pesticides	Increased crop productivity, thus increased yields (up to 30% in 2050, depending on the crop). 30- 50% increase in area suitable for maize production in 2100 Changes in optimal farming systems	Increasing rural incomes Relocation of farm processing industry	Medium/ high	Maracchi et al. (2005); Olesen & Bindi (2004); Falloon & Betts (2010); Iglesias et al. (2009)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Rising air temperatures and CO_2 concentrations	Increased production	2080	Northern Europe		Rise of 0.8 – 1.1 % of GDP		Low	Ciscar et al. (2009)
Rising air temperatures and CO_2 concentrations	decreased production	2080	Southern Europe		Fall of up to 1.3 % of GDP		Low	Ciscar et al. (2009)
Rising air temperatures and CO_2 concentrations	decreased production	2080	Europe		-6to -18% of GDP under SRES A2		Low	Fischer (2005)
Rising air temperature by 2.5 °C global temperature rise	Increased production	Unclear as the study summarises several studies	OECD-Europe		Plus 0.55%GAP without adaptation Pus 2.09% GAP with adaptation		Low	Tol (2002)
Rising air temperature by 2.5 °C global temperature rise	Increased production	Unclear as the study summarises several studies	Central Europe and the former Soviet Union		Plus 0.94%GAP without adaptation Pus 2.65% GAP with adaptation		Low	Tol (2002)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Rising atmospheric CO_2 concentrations	Potential increase in CO_2 fertilization by plants	2100	Whole of Europe		Increased crop productivity	Increasing rural incomes	High/ high	Olesen & Bindi (2004); EC (2009a); Maracchi et al. (2005);
Rising air temperatures Decreased precipitation	Droughts Heat stress of livestock	2050	Mediterranean and Southeast Europe	Desertification in dry areas- Major Soil degradation- Major Increasing demand for water for crop irrigation (up to 10%) in southern regions Increasing demand for irrigation for fruit and vegetables in Northern Europe	Yield decline up to 30%, depending on the crop Need for new varieties and cultivation methods Reduced reproduction and milk production dairy cows Reduced pig fertility Need for climate regulation technologies	Increasing competing claims for water Loss of rural income Land abandonment	Medium/ high	Falloon & Bets (2010); Maracchi et al. (2005); Iglesias et al. (2009)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Rising air temperatures Increased precipitation	Pests and diseases		Northern Europe	Increased use of pesticides may lead to environmental pollution	Production losses Increased costs of pesticides Costs for research& development to mitigate pests and diseases (major)	Increased risk of health problems Loss of rural incomes	Medium/ medium	Olesen et al. (2011); Iglesias et al. (2009)
Rising air temperatures and raising CO_2 emissions Increased precipitation	Increased or decreased production	2020/2030	Europe		See main text below		high	Donatelli et al. (2012)
Increased number and intensity of wind and precipitation	Severe storms	2050	Europe	Increased erosion rates	Disruption of crop production Greater yield variability	Damage to properties	Medium/ medium	Maracchi et al. (2005); Iglesias et al. (2009)

2 Forestry

Table 67 (Altvater, et al, 2011a) summarises relevant climatic drivers and their potential impacts in regard to environmental, economic and social issues. It also provides information on the level of agreement and evidence.

Table 67: Climatic drivers and their potential impacts on forestry

Climatic driver or social economic driver	Sub-threat or *opportunity*	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Rising air temperatures Rising atmospheric CO_2 concentrations	Changing biomes distribution Decreased period with frozen soils and snow cover	2050- 2100	Enlargement of climatic zone suitable for boreal forest by 150- 550 km Extension of growing season and higher photosynthesis in northern latitudes Growth of forest in mountainous areas currently limited by temperature	Changing tree species distributions in Northern Europe Northwards and upwards (mountains) expansion of broadleaved deciduous species Increasing threats for specialized plant communities Thermophilic plant species become more common, while cold-tolerant species	Higher timber yields in northern latitudes (e.g. 8-20% increase depending on climate scenario and species) Limited accessibility of forest areas outside the frost period	Increasing incomes in forestry sector in Northern Europe	Medium/ Medium	EC (2006k); Maracchi et al. (2005); Lindner et al. (2010)

Climatic driver or social economic driver	Sub-threat or *opportunity*	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
				decline In large areas of Western and Central Europe, indigenous conifers may be replaced by deciduous trees chance of tree species influences the quality of water				
Rising air temperatures Rising atmospheric CO_2 concentrations	Productivity and market changes	1 °C global temperature rise and CO_2 fertillization	OECD-Europe		134 million USD per year		Low	Tol (2002)
Rising air temperatures Rising atmospheric CO_2 concentrations	Productivity and market changes	1 °C global temperature rise and CO_2 fertillization	CEE&fSU		- 136 million USD per year		Low	Tol (2002)

Climatic driver or social economic driver	Sub-threat or *opportunity*	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Rising air temperatures Decreased precipitation	Droughts	2050	Decreased productivity in Central and Southern Europe due to decreased summer precipitation Increased fire risk in Southern and Central Europe, particularly in difficult to combat mountainous terrain Decreased tree growth in Mediterranean mountain ranges, the Alps and Carpathians	Desertification in dry areas- Major Soil erosion due to fires which enhance hydrophobicity and reduce plant regeneration- Major	Decreased forest productivity (e.g. 4- 16% production losses in Germany for dry scenario)- Major Increased fire events will reduce wood production and decrease timber values- Major	Increasing competing claims for water Temporal replacement of inhabitants	Medium/ Medium	Maracchi et al. (2005); Lindner et al. (2008); Lindner et al. (2010)

Climatic driver or social economic driver	Sub-threat or *opportunity*	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Rising air temperatures Increased precipitation	Pests and diseases	2100	Throughout Europe: Survival of exotic species in west, south and Central Europe, pest and pathogen development in East Europe, expansion of insect herbivores and fungal diseases in Northern, Central and Western Europe	Increased abundance of exotic species may lead to competition with indigenous species Increased loss of natural vegetation (major) Increased use of pesticides may lead to environmental pollution	Production losses (major) Increased costs of pesticides Costs for research& development to mitigate pests and diseases (major)	Increased risk of health problems	Medium/ Medium	Maracchi et al. (2005); Lindner et al. (2008); EC (2010f)

Climatic driver or social economic driver	Sub-threat or *opportunity*	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Increased number and intensity of wind	Severe storms		Northern, Western and Central Europe.	Loss of natural habitat Increased erosion rates Decreased water quality due to suspended materials	Yield reductions in recoverable timber (major) Increased costs of unscheduled thinning and clear-cuttings Problems in forestry planning	Damage to properties	Low/ Low	Maracchi et al. (2005)

3 Transport

Table 68 (Altvater, et al, 2011a) summarises relevant climatic drivers and their potential impacts in regard to environmental, economic and social issues. It also provides information on the level of agreement and evidence.

Table 68: Climatic drivers and their potential impacts on transport

Climatic driver or social economic driver	Sub-threat/opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Changes in temperature	Lower damage to roads and railways in winter, higher in summer	Gradually increasing 2020	Europe-wide	NA	Increased monitoring and maintenance	Choice of different transport mode by public; more risky driving	Low/low	Swart & Biesbroek, (2008); Haurie (2009); Jochem & Schade (2009)
	Thawing of ice roads and permafrost leads to road and rail instability	2020	Northern Europe (Arctic) and Alpine region	Erosion	Maintenance cost	Isolation of communities	Medium/medium	Jochem & Schade (2009)
	Ice free shipping	Long-term 2080	Northern Europe (Arctic)	Pollution if accidents	Positive	Employment (+)	Medium/low	Swart and Biesbroek, (2008); Haurie (2009)

Climatic driver or social economic driver	Sub-threat/opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Change in precipitation	Inland shipping problems due to low water levels	Gradually increasing 2020	Major rivers	Move to less eco-efficient transport modes	Increased freight prices and move to other modes minor	Employment (-) major	High/medium	Koetse & Rietveld (2009)
	Flooded roads, tunnels, railways	Gradually increasing 2020	Europe-wide	NA	Disrupted economic activity minor	Traffic disruptions, inconvenience	Medium/low	Swart & Biesbroek (2008); Haurie (2009)
	Overloaded storm water disposal system	Gradually increasing 2020	Europe-wide	Pollution of surface waters	Small minor	inconvenience	Medium/low	Swart & Biesbroek (2008); Haurie (2009)
Changing wind patterns	Damage by high winds (railways)	Unknown	Europe-wide, coastal areas	NA	Losses due to runway closure minor	inconvenience	Low/low	Swart & Biesbroek (2008); Haurie (2009)
	Changed runway availability airports	Unknown	Europe-wide, coastal areas	NA		inconvenience	Low/low	ICAO (2010)

Climatic driver or social economic driver	Sub-threat/opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Rising sea levels, **combined with** **storm surges**	Flooding coastal roads, port facilities	Gradually increasing 2050	coastal areas	Pollution of sea water and beaches	Damage, economic disruption major	safety	Low/low	PRC (2009)
Weather extremes	Floods, droughts, precipitation, storms, etc	Current	EU	NA	Road: €1.8 B/year Rail: €0.3 B/year Air: € 0.4 B/year		Low/Medium	Enei et al. (2011)

4 Construction and buildings

Table 69 (Altvater, et al, 2011a) summarises relevant climatic drivers and their potential impacts in regard to environmental, economic and social issues. It also provides information on the level of agreement and evidence.

Table 69: Climatic drivers and their potential impacts on construction and buildings

Climatic driver or social economic driver	Sub-threat	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	References
Changing precipitation patterns	Fluvial/urban drainage flooding	2020	Cities on rivers and cities with inadequate drainage systems	Pollution (waste dumps, gas stations)	Through physical damage to buildings Maintaining infrastructure	Water safety of inhabitants Maintaining infrastructure	Medium/low	Schauser et al. (2010)
	High snow load	2020	Mountain areas, Northern Europe		Through physical damage to buildings Maintaining infrastructure	Safety problem Maintaining infrastructure		Strasser (2008)
	Building and infrastructure subsidence and landslides	2050	Mountain areas	NA	Through physical damage to buildings Maintaining infrastructure	Safety Maintaining infrastructure	Medium/low	Infrastructure Canada (2006)

Climatic driver or social economic driver	Sub-threat	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	References
	Water scarcity, drought and implications for water resources	2020	Southern Europe	Limitations for green roofs	Internal water use limited. Subsidence of clay-rich soils and peat soils causing foundation damage[323]	NA	Medium/medium	Schauser et al. (2010)
Temperature increases	Heat/ cold related deaths	2050	Improving in NE, deteriorating in SE	NA	Decreased labour productivity, higher costs for cooling, Increased costs for emergency/medical services/supplies	Health impacts	Medium/medium	EEA (2010a); Ecorys (2011)
	Diseases (vector and water-borne diseases)	2050	Europe-wide	NA			Medium/low	EEA (2010a)
	Air quality and health	2020	Europe-wide, notably south	NA			Medium/low	EEA (2010a); Andersson & Engardt (2010)

[323] http://www.ecn.ac.uk/iccuk/indicators/12.htm

Climatic driver or social economic driver	Sub-threat	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	References
Sea level rise	Sea level rise and storm surge flooding Salt water intrusion	2080	Coastal cities	Pollution (waste dumps, gas stations)	Through physical damage to buildings Maintaining infrastructure Higher maintenance/upgrading for/of protective installations	Water safety of inhabitants Maintaining infrastructure	Medium/low	Schauser et al. (2010)
Extreme events (storms)	Direct wind storm damage	2080	Europe-wide, coastal areas	NA	Physical damage to buildings Maintaining infrastructure	Inconveniences by service disruption of electricity and water	Low/low	Carmin & Zhang (2009)
	Disruption of power, communication, or other services	2050	Europe-wide, coastal areas	NA			Low/low	Carmin & Zhang (2009)

5 Energy

The following tables provide a summary on future climatic pressures which may affect the energy system negatively (based on Altvater, et al, 2011a).

Table 70: Transmission and distribution infrastructure

Type	Climatic pressures	Risk	Time frame of expected impact	Area mainly affected
Primarily electrical transmission and distribution networks	Extreme high temperatures	Decreased network capacity	Medium negative (2025) to extreme negative (2080)	EU-wide
	Snow, icing, storms	Increased chances on damages to energy networks/blackout	medium negative to low positive (2050)	NW-EU
	Heavy precipitation	Mass movements (landslides, mud- and debris flows) causing damages	Time frame, magnitudes and frequencies uncertain	Especially mountain-ous regions

Type	Climatic pressures	Risk	Time frame of expected impact	Area mainly affected
Primarily Transmission networks (oil and gas)	Melting permafrost	Ties of gas pipelines in perma-frozen ground cause technical problems (this is touching only arctic supply pipelines and not the East-West gas pipelines, since the latter ones are not grounded in permafrost)	Low for 2025 and gradually increasing	Arctic Eurasia
	Higher Temperatures	Reduced throughput capacity in gas pipelines	Low for 2025 and gradually increasing	EU-wide
Primarily Storage and Distribution	Storms in connection with high tides and SLR	Threats to refineries and coastal pipelines due to SLR/high tide/storms	Low for 2025 and gradually increasing	Coastal regions

Table 71: Energy supply[324] and demand

Type	Climatic pressures	Risk	Time frame of expected impact	Area mainly affected
Hydropower, large-scale (down-stream facilities)	Decreased glacial run off (mid- to longterm) Extreme low rivers and stream flows during drought periods	Increased chance on shortage of hydropower supply in summer at downstream (pluvial-regime fed) stations	Medium negative (2025; 2080) to high negative (2080)	EU-wide
Hydropower, small scale (upstream/alpine)	Increased glacial run-off in the short run	Loss of "buffer capacities" for summer droughts in the mid and long run due to losses in glacier volumes	Short term: positive, mid- to long term: high negative (with individual glacial volumes, regional climates and thus different time scales)	Mainly Alps and Scandinavia
Solar energy (PV and thermal)	Increasing temperatures	Loss in solar cell effectivity due to higher ambient temperatures	Medium (2050) and long-term (2080) negative	EU-wide
Solar energy (PV and thermal)	Cloudiness	For some regions with high potential (and existing capacities) a decrease in cloudiness seems likely	Highly uncertain: medium negative (2025), no information for 2080 (depending largely on the uncertain climate parameters irradiation and cloudiness	Southern Europe: positive
	Solar irradiation	Inverse proportional to cloudiness		Northern Europe: negative (highly uncertain)

[324] All relevant electricity production supplies are examined here. Biomass (not yet important as electricity producer) can be regarded as part of 'Thermal power'. The climate risks on the supply of biomass are highly uncertain, regionally diverse and do not show a clear signal across Europe.

Type	Climatic pressures	Risk	Time frame of expected impact	Area mainly affected
Thermal power plants (incl. nuclear)	Water temperature increase	Lower CARNOT efficiency due to higher ambient and cooling water temperatures	Medium negative (2025) to extreme negative (2080)	EU-wide
	Floods	Risk of flood damages due to location of most thermal facilities at water bodies (rivers)		
	Extreme low water flows	Reduced cooling water availability		
Wind power generation	Storm frequency (not severity, since facilities are capable to handle highest wind speeds)	Wind power generation has to be turned down beyond certain wind speed thresholds in order to avoid overheating/overload of distribution systems	Referring to climate model outputs, future storm frequencies are highly uncertain, but might increase in North and Baltic Sea (where offshore wind power generation is concentrated)	North Sea and Baltic Sea regions
	Melting inland glaciers and water expansion due to temperature increase	SLR (only in very few offshore cases and considering high SLR scenarios)	Long term (2080) negative	

Type	Climatic pressures	Risk	Time frame of expected impact	Area mainly affected
Reduction of electricity demand by consumer (through self-supply of e.g. small PV units)	Higher temperatures	Reduced PV efficiency	Highly uncertain	cf. solar energy
Passive heating (geothermal)	Altering precipitation regime	Fluctuating groundwater levels	Unpredictable	Regions with sensitive aquifers
Energy demand	Higher temperatures	High AC demand in summer; high cooling demand by food industry	Short term medium to long term strong negative (i.e. raise in electricity demand in summer season)	EU-wide
		Low heating demand in winter	Positive (for both cf. studies by Dolinar et al. (2010) for Sl, Mirasgedis et al. (2007) for GR and Christenson et al. (2006) for CH)	
	Droughts	High energy demand by pumping for irrigation	Low negative	Southern and Eastern Europe

6 Soil

Table 72 (Altvater et al. 2011a) summarises relevant climatic drivers and their potential impacts in regard to environmental, economic and social issues. It also provides information on the level of agreement and evidence.

Table 72: Climatic drivers and their potential impacts on soil

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Rising atmospheric CO_2 concentrations Rising temperatures Changing frequency and intensity of rainfall events	Increase in soil carbon content Increase in decomposition rates with 15- 45% Increase in soil moisture deficits	2100	Especially northern latitudes European shrub lands: ranging from 40% increase or 30% decrease in soil respiration rates Erosion in Mediterranean and Mountainous areas	Positive feedback to the climate system in the long term Desertification, removal and redistribution of soil carbon			Low/ Low	Schils et al. (2008)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Rising air temperatures Changing frequency and intensity of rainfall events Types of land use, vegetative cover and land management	Soil erosion	2050	Increase of 80% erosion risks in agricultural areas, especially in those areas already affected by erosion Wind and water erosion in southwest Europe Mountainous areas in Central Europe	Desertification in dry areas - <u>Major</u> Removal and redistribution of soil carbon	Increased land degradation Increase investments in erosion prevention measures	Decreased rural incomes	Medium/ Medium	Schils et al. (2008); EEA (2007b); Kirkby et al. (2004)
Rising sea level Temporal low river discharges	Salinization	2100	Coastal areas	Altered soil quality Changing natural vegetation towards more salt-tolerant species	Reduced crop yields Technological development	Reduced incomes Cultivation of more salt-tolerant crops	Low/ low	EEA (2007)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Heavy rain fall events Increased temperatures	Landslides	2100	Very local effects	Soil loss in case of shallow landslides Soil transfer Changing soil structure, bulk density, water permeability and retention capacity Increasing vulnerability to erosion and compaction	Reduced crop yields	Damage to properties	Low/ Low	Ecklemann et al. (2006)

7 Biodiversity

Hodgson et al. (2009a) undertook a systematic review, synthesis and analysis of published reports, information and data relating to the observed and projected impacts of climate change in Europe, with a particular focus on the species and habitats in the EU 27 Member States.

Table 73: Overview of observed and projected impacts of climate change on biodiversity

Impact category	Alpine	Atlantic	Black Sea	Boreal	Conti-nental	Macaro-nesian	Mediterra-nean	Panno-nian	Steppic
Physical effects									
Increase in sea level and coastal flooding	N/A	OE MP		CM		OE			
Increase in annual average temperature	OE MP	OE MP	OE	OE MP	OE	OE MP	OE MP	OE MP	
Increase in extreme weather events		OE MP		MP	OE			MP	
Increased drought	OE MP	OE	OE		OE	OE MP	C MP	OE MP	
Increased precipitation, run-off and flooding	OE MP		OE	OE MP	OE				
Change in snowlines and duration	OE MP	MP							OE
Increased carbon dioxide		OE MP		OE MP		OE			
Increased forest fire	OE MP			OE	CO				
Increased disease and infestation	OE MP			OE MP					
Increased rate of change in temperature	OE								
Shifts in water quantity and quality			OE		OE				OE
Decreased river discharge			OE MP						
Increased biomass and carbon sequestration				OE MP	OE MP				
Decreased plant productivity						OE			

Impact category	Alpine	Atlantic	Black Sea	Boreal	Conti-nental	Macaro-nesian	Mediterra-nean	Panno-nian	Steppic
Increased humidity						OE MP			
Increased Ocean acidification						OE			
Effects on biodiversity and ecosystems									
Altitudinal movement of plants/animals/habits	OE MP	MP			OE MP	OE			
Latitudinal movement of plants/animals/habits		OE MP		MP	OE MP				
Seasonal changes in plants		OE							
Changes in limiting resources							OE		
Increase in species richness	OE MP			OE MP			OE		
Earlier life cycle events		OE	OE	CO				CO	
Decreased life cycle events						OE	OE		
Longer growing season		OE	OE	OE	OE				
Range contraction and extinction	OE MP				OE MP	OE	OE		
Gain in climate space	OE MP	OE MP		MP	OE MP	OE			
Loss in climate space	OE MP	OE MP			OE MP	OE			
Loss of glacial extent	OE								
Land use constraints		OE							
Breeding decline and sea level rise		OE							
Increase in species competitive advantage					OE		OE		
Increased invasive species					OE				
Loss of wetlands						OE	OE		

Impact category	Alpine	Atlantic	Black Sea	Boreal	Conti-nental	Macaro-nesian	Mediterra-nean	Panno-nian	Steppic
Decoupling of species interactions		OE						MP	
Increased species mixing									
Vulnerability									
Identification of vulnerable species and/or habits	OE	OE MP	MP	OE MP	OE	OE	MP	OE	
Identification of resilient species and/or habitats								OE MP	
KEY Observes evidence exists and showing impacts - **OE** Model projection exists and showing impact - **MP** Contradiction in observed literature - **CO** Contradiction in modeled literature **CM** Not applicable **N/A**									

8 Health

Table 74 (after Altvater, et al, 2011a; adjusted in May 2012) summarises relevant climatic drivers and their potential impacts in regard to environmental, economic and social issues. It also provides information on the level of agreement and evidence.

Table 74: Climatic drivers and their potential impacts on Health

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Temperature increase	Temperature Rise and heat waves (heat related deaths) Drought Heat stress of livestock	From 2020 it can be an important problem. It is uncertain how this will develop in the future, because of the role of acclimatisation and the uncertainty of the progress of the rise of temperature	Europe, but the most severe in Southern and Central Europe	Increased risk of food and water shortages and water- and food-borne diseases	With acclimatisation 2020: 2 – 4 billion 2080: 8-80 billion Without acclimatisation 2020: 13 – 30 billion 2080: 50 - 180 billion	Premature deaths on a population of 500 million With acclimatisation 2020: 4.000 2080: 0 – 70.000 Without acclimatisation 2020: 25.000 2080: 50.000 – 160.000	Medium/high, numbers are uncertain	Ciscar et al. (2009) CEHAPIS (2012, DRAFT)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Cold spells	Temperature Rise and cold spells reduction	From 2020 an important benefit, due to reduction in death related to cold spells and increased temperature	Europe, but the North benefits the most. Small benefits in Southern Europe	Not available	Benefits 2020: 30 -80 billion	Fall of deaths on a population of 500 million 2020: 50.000 – 100.000 2080: 100.000 – 250.000 Acclimatisation is not taken into account	Medium/high, numbers are uncertain	Ciscar et al. (2009) PESETA (2009) CEHAPIS (2012, DRAFT)
Health related risks floods and storms	Extreme rainfall, Glacial melt and sea level rise resulting in: river flooding and coastal flooding Storms	2080-2085 2060-2011	River flooding: Central Europe and regions and the British Isles Coastal flooding: British Isles, Central Europe North and Southern Europe regions Considerable geo-graphic variability, largest loss ex-pected for Denmark and Germany		UK Environment Agency estimated that the impacts on public health (including school education) accounted for about 9 per cent (£287 million) of economic costs. £260 million of this comprises the mental health cost associated with	Direct impacts through deaths and injuries: 250.000 to 400.000 additional people per year in Europe by the 2080 for river flooding Without adaptation: 775.000 to 5.5 million people effected by coastal flooding by 2085 With adaptation: 22.000 to 40.000	Medium/high	Jonkman & Kelman (2005); UNEP/AMAP (2011); CEHAPIS (2012, DRAFT)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
					flooding based on estimates of people's willingness to pay to avoid exposure to the distress caused by flooding No health economic specific data available	Indirect impacts through physical trauma, heart attack and electrocution. Long term mental illness and infectious diseases Contamination with persistent organic pollutants (POPs) and heavy metals, especially long-range chronicle contamination of water bodies, ground water and food chain Depending on the wind speed, elderly people and cyclists could be blown down, high side vehicles can become unstable, serious incidents occur, dangerous to stay outside, trees fall down, building and		

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
						structure damage		
Vector-borne diseases (e.g. Lyme borreliosis, malaria, leishmaniasis, Rift Valley Fever, bluetongue)	Temperature, changing precipitation patterns (etc.) change the distribution, seasons of activity and population size (differs for every disease)	From 2020	Europe, but Southern Europe has higher chances since they already occur or are being (re)introduced In case of Lyme borreliosis: spread into higher latitudes	Not available	In the developing world, malaria control costs are estimated at around US$ 1 to US$ 2 per capita per year until 2015 (not considering climate change)	Low because the general high characteristics of the European health care are expected to limit the risks of introducing vector borne diseases. The Lyme disease is mentioned as one of the main risks for Europe Effects on animal health and future diseases transmitted by wildlife and changes in the known ranges of virus distribution	High/high	Hunter & Bouzid (2010) CEHAPIS (2012, DRAFT) Semanza & Menne (2009) Kovats et al. (2003)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Food-borne and water-borne diseases	Temperature rise, higher water temperatures, droughts and extreme rain events		Areas with inadequate water systems Throughout Europe for swimming water	Decrease of water quality Increased use of pesticides may lead to environmental pollution	The annual costs of diarrhoeal diseases for Europe for the years 2000-2030 are estimated to reach US$ 12-205 million for diarrhoea (stabilization of GHG emissions at 550 ppm), US$ 12-270 (stabilization at 750ppm) and US$ 12-260 for unmitigated emissions 5-30% of increase of number of cases with 1°C increase of temperature 20.000 cases in 2020	Risks on facially polluted drinking and swimming water, cholera and Cyanobacteria Spread of infectious diseases by waterfowls due to changes in flyways Changes in the migration ranges can spread certain infectious fish diseases € 70-139 million by 2040 for salmonelloisis (annual estimated loss)	High/high	Senhorst & Zwolsman (2005) Hunter & Bouzid (2010) CEHAPIS (2012, DRAFT) Olesen et al. (2011)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Health related risks fires	Droughts and heat waves	Cf. soil and land use section	Cf. soil and land use section	Loss of forest and farmland	Estimated costs related to decreased health and well-being during the 7-day wildfire are between US$ 9 and US$ 12 million	Direct impacts through deaths and loses (food and property) and a chronic reduction of the lung function	Medium/high	UNEP (2006) Guha-Sapir et al. (2012) CEHAPIS (2012, DRAFT)
Air quality, allergens	Temperature rise, changing precipitation and wind patterns lead to an altered spatial and temporal pattern of allergens and to increased allergenicity	From 2020	Europe	Not available	Health costs are high	Not available	Medium/high	WHO (2010e)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environmental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Air quality, pollution	Temperature rise and heat waves increase ground ozone and main pollutant levels in the atmosphere	From 2020, both frequency as intensity will increase	Complex and region specific. This depends on climate and population characteristics. But cities and Southern Europe are expected to be vulnerable	Not available	Air quality is negatively influenced by emissions	Increased respiratory and cardio events and diseases	High/ high	WHO (2010e)

9 Inland water

Table 75 (Altvater, et al, 2011a) summarises relevant climatic drivers and their potential impacts in regard to environmental, economic and social issues. It also provides information on the level of agreement and evidence.

Table 75: Climatic drivers and their potential impacts on inland water

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environ-mental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Precipitation, cryosphere changes	Floods	1996	Unevenly distributed though EU. The British islands and Central, Eastern and Southern Europe are the most vulnerable	n.a.		194.000 people in EU affected		Ciscar et al. (2009) Current situation
		2080		n.a.	7,728 Additional expected damage (million/y)	276.000 additional people in EU affected		Ciscar et al. (2009): 2.5° B2HadAM3h
		2080		n.a.	11,469 Additional expected damage (million/y)	318.000 additional people in EU affected		Ciscar et al. (2009): 3.9° A2HadAM3h

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environ-mental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
		2080		n.a.	8,852 Additional expected damage (million/y)	251.000 additional people in EU affected		Ciscar et al. (2009): 4.1° B2ECHAM4
		2080		n.a	15,032 Additional expected damage (million/y)	396.000 additional people in EU affected		Ciscar et al. (2009): 5.4° A2ECHAM4
Precipitation	Floods (1-in 100y flood	2025	40% more areas in most of Europe and more than 80% of NUTs-2 areas in UK, Western France, Belgium, Netherlands, Western Germany, Finland, Portugal and Spain will be flooded	n.a.			high	Flörke et al. (2011), Economy first

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environ-mental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
	Floods (1-in_100y flood	2050	Lower bound of projections: 20% to 40% of the area of UK, Ireland, and Norway Upper bound of projections: severe floods in more than 80% of the area of UK, Western France, Belgium	n.a.	4914.7 $ Million of additional direct economic losses induced by flooding due to climate change or 0.006 GDP losses induced by flooding due to climate change equal to 1147.8 $ Million	302,400 additional people affected by flooding (if no change in current protection levels) in the EU	high	Flörke et al. (2011), (the figures are an average calculated across the 4 different SCENES scenarios)
Precipitation	Floods	Baseline (1961-1990)	EU27		5.5 billion AED	167,000 EAP	low	Feyen & Watkiss (2011)
	Floods	2020 (A1B)	EU27		20 billion EAD Climate change alone: 9 billion EAD		low	Feyen & Watkiss (2011)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environ-mental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
	Floods	2050 (A1B)	EU27		46 billion EAD Climate change alone: 19 billion EAD	300,000 EAP	low	Feyen & Watkiss (2011)
	Floods	2080 (A1B)	EU27		98 billion EAD Climate change alone: 50 billion EAD	360,000 EAP	low	Feyen & Watkiss (2011)
	Floods	2020 (E)	EU27		15 billion EAD Climate change alone: 5 billion EAD		low	Feyen & Watkiss (2011)
	Floods	2050 (E)	EU27		42 billion EAD Climate change alone: 20 billion EAD	300,000 EAP	low	Feyen & Watkiss (2011)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environ-mental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
	Floods	2080 (E)	EU27		68 billion EAD Climate change alone: 30 billion EAD	360,000 EAP	low	Feyen & Watkiss (2011)
Water use (withdrawals)	Water scarcity	2005			609 km^3		high	Duel & Meijer (2011)
		2025 – 2050			+ 19%			Duel & Meijer (2011)
		2025 – 2050			+ 24% + 40 %			Duel & Meijer (2011)
		2025 – 2050			- 26 %			Duel & Meijer (2011)
		2025 – 2050			-26 % -62 %			Duel & Meijer (2011)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environ-mental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Water use	Water scarcity, annual	2050	Western and Eastern Europe		Almost double increase in Western and Eastern Europe		medium	Flörke et al. (2011), EcF
	Water scarcity, annual	2050	Western and Eastern Europe		About four time decrease in West Europe, three times in East and North and two times in South		medium	Flörke et al. (2011), SuE
	Water scarcity, annual	2050	Western and Eastern Europe		About 60 % increase in Western, Eastern and North Europe, slight decrease in Southern Europe,		medium	Flörke et al. (2011), EcF

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environ-mental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
	Water scarcity, annual	2050	Southern and Western Europe		Almost 3 times decrease in Southern and Western Europe		medium	Flörke et al. (2011), SuE
Water availability	Water scarcity	2005	Mediterranean, Eastern Europe		100 – 1000 mm			Duel & Meijer (2011)
	Water scarcity		Mediterranean, Eastern Europe		- 50%		high	Duel & Meijer (2011)
	Water scarcity, annual	2050	Southern Europe		No significan changes in averages, about 11 % decrease in Sothern Europe		high	Flörke et al. (2011)
	Water scarcity, summer	2050	Most of Europe		Average decrease of about 13 %		high	Flörke et al. (2011)

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environ-mental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
Water availability	Drought	2005	Ebro river Span		Direct costs: 482 million Euro Indirect costs: 377 million €	Loss of 11,275 jobs	High	Pérez y Pérez, & Barreiro-Hurlé (2009)
WaterStress	Water scarcity, annual	2050	Southern Europe most affected		10% of Europe		high	Flörke et al. (2011), baseline
	Water scarcity, annual	2050	Southern Europe most affected		25% of Europe		high	Flörke et al. (2011), EcF
	Water scarcity, annual	2050	Southern Europe most affected		5% of Europe		high	Flörke et al. (2011), SuE
	Water scarcity, summer		Southern Europe most affected		Slight decrease in affected area in Southern and Western Europe, large (>40 %) decrease in affected area Eastern Europe		high	Flörke et al. (2011), SuE

Climatic driver or social economic driver	Sub-threat or opportunity	Time-frame	Area affected	Potential environ-mental impacts	Potential economic impacts	Potential social impacts	Level of agreement and evidence	Reference
	Water scarcity, summer	2050	Southern, Western Europe most affected		25 % more water stressed area in Southern Europe, 3 times increase of water stress area in Western Europe		high	Flörke et al. (2011), EcF E

Annex 6 – Case studies on jobs and employment

In the following the observable and expected effects of climate change and adaptation policies on enterprises and employment is explored on a set of ad-hoc chosen case studies that draw on ongoing research in the Po river basin. The analysis is completed by literature review of comparable studies conducted elsewhere.

Agriculture

Raising temperature and increased inter-annual and seasonal variability of rainfall, with extreme events such as heat waves and droughts occurring more frequently will affect crop yields, food production and prices, trade flows, and viability of farming and employment (EC, 2009n).

The agricultural output in the Po River Basin District (P-RBD) accounts for 35% of the national production. The agricultural sector generates an added value of about 7.7 billion €/year (~1.2% of the total added value produced in the basin).

Table 76: Irrigation boards and managed agricultural land in the Po River Basin District (RBD-P). (Source: INEA, 2011)

Hydrographical district	Irrigation boards	Agricultural land (ha)	Irrigable Surface (ha)	Irrigated Surface (ha)
Emilia Romagna	4	1,156,642	353,864	132,142
Lombardy	14	943,435	349,776	349,118
Lombardy – Emilia R.	2	284,068	145,772	87,710
Piedmont	35	1,693,079	315,334	275,180
Piedmont – Lombardy	1	210,000	137,343	127,722
Trentino	25	24,166	2,982	2,926
Valle d'Aosta	159	176,767	20,836	9,069
Po River Basin	**240**	**4,488,157**	**1,325,907**	**983,867**

The Sixth National Agricultural Census (ISTAT, 2010) sheds light on the transformation of the agricultural sector. Between 2000 and 2010 the number of agricultural and zoo-technical enterprises declined by 32.2 per cent, whereas the Farm Agriculture Surface (FAS) and Utilised Agricultural Area (UAA) was reduced by 8 and 2.3 per cent respectively; the average size of farms on the other hand increased by 44 per cent. Partly, this trend reflects with some delay, similar tendencies that were observed in other EU Member States.

Table 77: National Agriculture Census 2010: number of enterprises, utilised and total agriculture area (hectares). (Source: ISTAT, 2000; ISTAT, 2009; ISTAT, 2011)

REGION	Enterprises		Δ	UAA		Δ	TAA		Δ
	2010	2000	%	2010	2000	%	2010	2000	%
Piedmont	66,930	106,969	-37.4	1,048,350.45	1,068,872.59	-1.9	1,364,088.61	1,459,224.20	-6.5
Valle D'Aosta	3,520	5,981	-41.2	55,384.41	71,120.32	-22.1	119,140.27	158,249.88	-24.7
Lombardy	54,107	71,350	-24.2	984,870.55	1,039,592.36	-5.3	1,228,274.57	1,350,853.87	-9.1
Emilia Romagna	73,441	106,363	-31	1,066,773.17	1,129,317.92	-5.5	1,364,698.74	1,462,984.91	-6.7
ITALY	**1,630,420**	**2,405,453**	**-32.2**	**12,885,185.90**	**13,183,406.76**	**-2.3**	**17,277,022.97**	**18,775,270.66**	**-8**

The average farm/cultivated area is 52 and 46 ha respectively. Irrigation networks, mainly open channels, extend over more than 11.000 km. The prevailing irrigation method is furrow irrigation (>50%). The permeable substrates induce high infiltration losses (51.7 per cent). The main characteristics of the irrigation network in the Po River Basin District (RBD-P) are shown in Table 78.

Table 78: Irrigation infrastructure typologies in the RBD-P. (Source: INEA, 2011)

District	Type of use (in km)		Type of infrastructure (km)					Total (km)
	Irrigation	Multiple	Open channel	Artefact	Aqueduct	Pressurised	Other	
Emilia Romagna	224	805	762	45	8	25	189	1,029
Lombardy – Emilia R.	150	295	434	1	-	10	-	445
Lombardy	1,357	1,996	3,078	83	18	173	2	3,353
Piedmont – Lombardy	-	1,894	1,889	-	4	1	-	1,894
Piedmont	3,001	588	2,663	258	19	234	415	3,589
Trentino	55	-	3	5	-	46	-	55
Valle d'Aosta	939	28	359	305	4	295	4	967
Po River Basin	5,727	5,605	9,188	697	53	784	610	11,332

In terms of employment, the agriculture sector is facing a decreasing trend of employment throughout Europe. As highlighted by Eurostat (EUROSTAT, 2010), between 2000 and 2009, the sector employment decreased by 25 per cent in the EU27, the equivalent of 3.7 million full time jobs. The decrease is greater in the 12 New Member States, which recently joined the European Union (-31 per cent), while it is relatively lower in the EU15 (17 per cent). Within the Union, the highest reduction was recorded in Estonia (-55 per cent), while the lowest in Greece (-3 per cent). Among the Member States with the highest level of employment in the agriculture sector, Italy recorded an overall loss of 16 per cent, France and Spain 17 per cent, Poland 11 per cent and Romania 41 per cent (EUROSTAT, 2010).

Concerning the Po River Basin, the employment reduction trend is even greater than the National trend. In the Emilia Romagna region for example, the agriculture sector offers now some 200,000 jobs, down by 50,000 (19.7 per cent) compared to 2000. In the same period, the higher qualified jobs increased by 42 per cent, whereas lower qualified jobs declined between 28 and 74 per cent, depending of the educational level. The farm holder is typically a man aged 53. Farm labour needs are mainly satisfied by permanent staff (99 per cent) and only in 25 per cent of the cases workers are the holders' family members. In the Lombardy region on-farm jobs declined by 14.2 per cent, in the Piedmont region by 29.6 per cent and in the Valle d'Aosta region by 33.2 per cent. Considering the major regions of the Po River Basin, during the last decade (2000-2010), total job losses account for around 135,000 employees, some 22 per cent of agriculture sector's total work force in the area.

Table 79: Own elaboration on the National Agriculture Census 2010. (Source: ISTAT, 2000; ISTAT, 2010)

Region	Jobs		Variation		Working days		Variation	
	2010	2000	Δ	%	2010	2000	Δ	%
Piedmont	142,340	202,076	-59,736	-29.6	18,596,933	24,300,444	-5,703,511	-23.5
Valle d'Aosta	8,248	12,341	-4,093	-33.2	803,869	1,227,930	-424,061	-34.5
Lombardy	132,003	153,902	-21,899	-14.2	19,146,199	22,600,027	-3,453,828	-15.3
Emilia Romagna	201,852	251,476	-49,624	-19.7	19,092,317	25,931,213	-6,838,896	-26.4
Po River Basin*	**484,443**	**619,795**	**-135,352**	**-21.8%**	**57,639,318**	**74,059,614**	**-16,420,296**	**-22.2%**

* above mentioned Regions only

Triggered by the 2000-2001 and 2003 drought events in Italy, the efforts intensified to achieve a more efficient use of water in agriculture. The National Irrigation Plan 2007-2010 (NIP), a part of National Water Infrastructure Plan (MPAAF, 2010), compelled the regional administrations to identify priority for interventions to increase the efficiency of the irrigation system. NIP comprises an intervention plan worth of 1.1 billion Euro of which some 770 million Euro are designated for the regions of central and northern part of the country and some 330 million Euro for the southern part of the peninsula and the islands (MPAAF, 2010). The intervention includes typically restoration and efficiency increase of the reservoirs and water storage systems; completion of the upstream part of the water provision infrastructures; restoration of the damaged part of the aqueducts, measures aimed to avoid unauthorised withdrawals and reduce losses due to evaporation; renovation of the water distribution network; renovation of measurement and monitoring systems; utilisation of the purified urban wastewater for specific cultures.

In the Emilia Romagna Region (RER), the NIP interventions set to restore, maintain and improve the irrigation systems with an investment of almost 125 million Euros. As of September 2011, the rate of completion of the planned interventions reached a value of 67.63 per cent (MPAAF, 2010). The interventions include the renovation of the water distribution system of the Molato Dam; enhancement of the pumping capacity from the Po river; implementation of pressurised irrigation networks; infrastructures aimed at the increase of the Canal Emiliano Romagnolo water uses and finally, and the renovation of the irrigation network. With consideration to the NIP plan and other sources, the regional Emilia Romagna Water Protection plan foresees a total public irrigation investment of 283 million Euros for the whole region, which includes functional rehabilitation (110.5 millions) and completion/extension of the irrigation network (172.5 millions).

In the Lombardy Region, water for irrigation is mainly diverted from the rivers originating from the major lakes of the area. The irrigation system is fed for 97 per cent with surface water, 3 per cent with underground water (MPAAF, 2010). The irrigation network is extremely complex and it covers the entire territory of the region with more than 4.000 km of canals, 60 per cent of them are used for irrigation and land reclamation. NIP investment plan for the Region aims to restore, maintain and improve the irrigation systems in Lombardy, with an investment of around 92 million Euros. On September 2011, the rate of completion of planned work reached a value of 79.73 per cent (MPAAF, 2010). Main interventions are represented by the extension of the irrigation network; increasing of the pumping capacity to respond to the increasing water requirements and the creation of infrastructures aimed at the reuse of water for irrigation.

The irrigation system in the Piedmont Region is divided into three areas with specific characteristics in terms of organisation, infrastructures and water resources availability. The water abundant plain area including the provinces of Vercelli and Novara is modelled around the cultivation of the rice, crop characterised by the large water requirements. Here the infrastructural network is largely developed and exploited. The plain area between the provinces of Turin and Cuneo is characterised by the presence of a large number of small irrigation boards. The irrigation is mainly ensured by the exploitation of the underground aquifers. The area between Alessandria and Tortona is characterised by water scarcity, lack of infrastructures and inefficient water management. Here, the irrigation is mainly ensured by private wells. In the Region, around 50 per cent of the irrigation demand is satisfied through the diversion of surface water: 80 per cent of these resources are used in the area located north of the Po river. The irrigation network is represented mainly by open air canals: the rate of evaporation and irrigation network losses is very high (MPAAF, 2010). For the Region, NIP investment plan aims to restore, maintain and improve the irrigation systems with an investment of around 124.5 million Euros. On September 2011, the rate of completion of the planned works in the Region reached a value of 89.64 per cent (MPAAF, 2010). The main intervention has been represented by the restoration of the irrigation network and the implementation of sprinkler irrigation facilities.

The following table reports the state of the art of the irrigation investment plan updated to September 2011.

Table 80: National Irrigation Plan for the Regions of Italy centre and north. (Source: MPAAF, 2010)

Region	Investment (Euro)	Revised Investment (Euro) *	Investment Paid (Euro)	Rate of Completion
Bolzano Province	10,952,086.06	9,718,189.14	9,718,189.14	100%
Emilia Romagna	**124,546,921.60**	**113,135,551.58**	**76,517,836.61**	**67.63%**
Friuli V. Giulia	76,325,274.18	75,211,091.62	62,140,151.69	82.62%
Lazio	37,074,069.60	33,745,108.23	21,630,670.77	64.10%
Liguria	11,440,000.00	10,135,744.97	9,761,040.51	96.30%
Lombardy	**92,165,768.50**	**78,938,734.76**	**62,940,016.79**	**79.73%**
Marche	41,312,213.90	28,583,894.53	30,820,152.58	100%
Piedmont	**124,546,921.60**	**105,354,518.52**	**94,443,646.73**	**89.64%**
Tuscany	29,457,837.04	27,109,305.88	9,329,370.18	34.41%
Umbria	89,448,485.42	89,446,485.42	30,283,606.39	33.86%
Valle d'Aosta	**3,500,000.00**	**2,014,633.38**	**2,014,633.38**	**100%**

Based on the estimates of the National Authority for Public Works (NAPW, 2010), the expected employment potential for the construction industries generated by the above mentioned investments, including direct and indirect effects in the major Regions of the Po River Basin, namely Lombardy, Piedmont, Emilia Romagna and Valle d'Aosta, amount to 5,600 to 7,500 jobs. These estimations are based on the empirical evidence showing that the labour component of the investment accounts to ca. 30 per cent: For 1 billion euro invested in structural measures some 8,000 jobs are created. The indirect effects on the satellite industries are estimated to 50 to 100 per cent of direct effects. In total, the employment potential of public investments in structural measures amounts to 12,000 to 16,000 jobs per 1 billion public investments (NAPW, 2010). It should be highlighted here, that the potential employment opportunities are related to short-medium terms jobs, which normally belongs to non-agriculture sectors, like construction and services. Maintenance related job opportunities related to new irrigation infrastructures are not considered because of their negligible impact to the sector.

The medium to long term on-farm employment demand for operation and maintenance is estimated using the Farm Accountancy Data Network (FADN) data collection tool established in order to evaluate the income of agricultural holdings in the EU. It consists of annual micro-economic surveys carried out by Liaison Agencies in each Member State on a rotating panel of “commercial” farms.

Using the FADN the following section analyses the impacts of droughts on agricultural employment, considering as case study agriculture in the Po Basin in the period 2003-07. We focus our attention on a bordered area of the Basin, located in the administrative territory of the Emilia Romagna region, and consider changes in the employment level, measured as the total amount of hours of labor per hectare. This variable is regressed against the main factors that could influence its value, such as climatic aspects, soils characteristics, farm’s specialization level, physical and economic farm’ dimensions, irrigation quota, irrigation system, and so on.

We choose to implement a panel data analysis for the following reasons: 1) to model differences in behavior across individuals and, indirectly, consider adaptation strategies actuated by the Po Basin farmers to face weather fluctuations in the short period; 2) to consider annual fluctuations and estimate a direct relationships between the dependent variable and the annual value of climatic variables; 3) to capture annual changes and, at the same time, to compare effects of the different drought events occurred in the Basin in the period 2003-07.

We estimate different un-balanced panel data models, relaxing gradually OLS hypothesis and taking into account both the effect of the explanatory variable when it changes between and within farm. We estimate models robust respect to heteroskedasticity, applying the Huber and White procedure.

<u>Model specifications:</u>

Literature suggests different approaches to analyse un-balanced panel data set (Greene, 2002). A standard specification of the model is the following:

$$Y_{it} = \beta_i + \sum_{j=2}^{J} \beta_j X_{jit} + \sum_{p=1}^{P} \gamma_p Z_{pi} + \sum_{d=1}^{D} \delta F_d + \varepsilon_{it} \qquad (1)$$

where Y is the dependent variable and the X_j and Z_p are respectively the observed and un-observed explanatory variables. The indexes i and t refer to the unit of observation and to the time, while F_d represents a set of dummy variables, one for each time period except for the reference one. ε_{it} is a disturbance term, assumed to satisfy the usual regression model conditions.

Z_{pi} are un-observed explanatory variables and isn’t possible to have information on their values. Assuming $\alpha_i = \sum_{p=1}^{P} \gamma_p Z_{pi}$ it represents the individual-specific un-observed (time invariant) effect. The presence of this element causes OLS inefficient estimates and invalid standard errors, either if it is correlated or not with X_{jit}.

To estimate the model, a first possibility is that αi equals to zero, in the luckily case that X_{jit} captures all the relevant characteristics of the individual. In this case α_i can be dropped. Consequently, the model can be fit estimating a pooled OLS regression. Another option is to estimate a between effect panel data model. This approach modeled the mean response, where the means are calculated for each of the units. In this case it is assumed that the mean of the α_i term is zero, but the individual terms are not necessarily zero. This model answers the question about the effect of an explanatory variable when its value changes between farms. These results can usefully be compared with those obtained estimating a fixed effect regression which, instead, answers the question about the effect of an independent variable when its value changes within farm. The fixed effect regression assumes that the un-observed effect is correlated with the observed explanatory variables. In the within groups-fixed effect regression the un-observed effect disappear because in this approach the model explains the variations about the mean of the dependent variable in terms of the variations about the means of the explanatory variables for the group of observations relating to a given individual[325]. This model gives an estimate of the so-called "intra-class correlation" (ρ), that represents the ratio of variance due to differences across individuals.

The estimates of the standard errors obtained by the aid of the above estimators are consistent even if the residuals are heteroskedastic. To avoid this possibility, Huber and White's robust estimators have to be implemented (Huber, 1967; White, 1980).

In this study we consider as dependent variables the employment level, measured in terms of total hours of labor per hectare.

<u>Data source:</u>

To analyse the drought impacts on agricultural employment we use the panel data from the Italian Farm Accountancy Data Network (FADN). The FADN is a data collection tool for evaluating income in agricultural holdings in the EU. It consists of annual micro-economic surveys carried out by Liaison Agencies in each Member State on a rotating panel of "commercial" farms. The information collected for each sampled business takes into consideration approximately 1,000 variables described in a specific questionnaire called Farm Return. Collected information refers to physical and structural data (location, crop areas, livestock numbers, labour force, etc.) and economic and financial data (value of production of the different crops, stocks, sales and purchases, production costs, assets, liabilities, production quotas and subsidies etc.).

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[325] However, also both the constant term and the variables constant for each individual disappear. Another disadvantage is that variations respect to the mean is smaller vs the variations of each variable, and this can give a rise in imprecise estimates. In fact precision in OLS estimates depends on the mean square deviations of the explanatory variables being large in comparison with the variance of the disturbance term. Finally there is a higher loss in degrees of freedom, proportionally to the numbers of individuals.

From the Italian FADN database for the years 2003-07 we identify an un-balanced panel data of 1,123 farms. From FADN information on the type of farming[326] we built dummy variables grouping specialized farms devoted to crops, fruits and vegetables cultivations or devoted to livestock. As it concerns the farm's economic dimension, we measure this variable in terms of European Size Units (ESU)[327].

Concerning market effects we use prices index published by the ISMEA (2007, 2009), while as in concerns climatic aspects we associate to each farm weather variables using original data recorded by the local meteorological stations and provided by the ARPA Emilia Romagna bureau. In particular, we analyse data on total daily precipitation and on minimum and maximum daily temperature, and for each station we account the values of the annual total precipitation and of the annual total degree-days. The last climatic variable is defined as "the sum of degrees above a lower baseline and below an upper threshold during the growing season" (Schlenker et al., 2006). According with literature, we set the lower and the upper thresholds, respectively, to 8°C and 32°C. Using this variable in our model, instead the annual average temperature, we can account for the effect of temperature on plant growth in term of cumulative exposure to heat. As agronomic studies suggest, in fact, plant growth is partially no-linear in temperature (Mendelshon & Dinar, 2009)[328]. Weather variables are associated to each farm by multiple regression models, where the value of the dependent variable measured by each station is regressed against latitude and longitude (UTM format), altimetry and year[329]. Climatic variables are then calculated for each farm selected by the Italian FADN database. Moreover, we build also some dummy variables to select farms that in the period 2003-07 were real affected by drought events. Comparing the annual value of precipitation and degree-days for the years 2003, 2006 and 2007 with the long run averages measured in the periods 1951-2008 for precipitation and 1977-2008 for degree-days, in fact, it is possible to select farms affected by droughts, that are those for which precipitations was below the long average and in the same time degree days was above.

[326] The type of farming is established according with the concept of Standard Gross Margin (SGM),that is the value of output from one hectare, or from one animal, minus the cost of variable inputs required to produce that output. A three-year average is calculated, to avoid bias caused by fluctuations in production and/or in prices. To determinate the Type of Farming (TF) the value of SGM coming from each farm is compared with the SGM farm's total value. The farm is classified as "specialist" if the contribute of a particular type of farming exceeds 2/3 of the total farm's SGM. Consequently the TF is a proxy of the farm's specialization and different schemes of classification are adopted, each one based on a code with different levels of detail.

[327] One ESU is equal to 1,200 EUR/ECU of the Standard Gross Margin (SGM). SGM is the value of output from one hectare, or from one animal, minus the cost of variable inputs required to produce that output. A three-year average is calculated, to avoid bias caused by fluctuations in production and/or in prices.

[328] We try to take into account in our models also the real length of growing season measured in terms of total number of days, in one year, with temperature included in the interval 8-32°C, but it is un-significant.

[329] In the studied area, according with the ISTAT bureau classification, fall 27 agricultural districts called agrarian regions. Given that different stations fall in different agricultural districts, we also consider the panel nature of the data estimating for each climatic variable a fixed effect specification. However, these models do no better-fit data then the pooled OLS specifications that consequently we prefer to predict climatic variables at farm level.

Results:

In the following models we hypothesize that the employment level, measured in terms of the logarithm of the total hour of labor per hectare depends on: annual weather scenario and occurrence of drought events; farm's specialization; physical and economic farm's dimensions; irrigation regime, source and system; soil characteristics; field fragmentation and market effects.

We adopt the following estimators: Pooled Ordinary Least Squares (OLS), Between Effect (BE), Fixed Effect (FE). The first and the third models are estimated applying the Huber and White's heteroskedasticity robust estimator.

Focusing on the results, estimated signs are coherent with expectations for all model specifications. Considering between variations (BE), droughts imply a decrease on the employment level (p-value equal to 6%; marginal value equal to -0.0263 hours per hectare)[330]. However, considering with-in variations, drought event occurred in 2003, 2006 and 2007 do not imply a significant change in the employment level, as showed by the insignificance of the dummy variables used in the FE model specification to select farms affected by drought in those years.

Pooled OLS specification shows a significant drought effect for the year 2007. Farms affected in that year by drought show a decrease of the employment level respect to those un-affected (marginal value: -0.0107 hours per hectare).

Moreover, the level of employment decreases if annual precipitations increase (marginal value equal to -2.3626 and to -1.6603 hours per hectare respectively for the BE and FE models) and, oppositely, rises if the annual total degree-days increase (for this variable marginal effect ranges between -3.0811 ÷ -3.0795 hours per hectare).

The degree of employment depends also positively on specialization on fruits and vegetables productions (not for the FE model that estimated an un-significant coefficient for this variable) and for farms devoted to livestock, while is negatively influenced by crops cultivation.

The marginal value of the variables "specialization on crops productions" and "been a farm devoted on livestock" depend heavily on the model specification, ranging respectively between -0.2043 ÷ -0.0358 hours per hectare and between 0.0470 ÷ 0.1643 hours per hectare. "Specialization on fruits and vegetable productions" show more stable estimations of the marginal value that in this case ranges between 0.0819 ÷ 0.0974 hours per hectare, respectively for the pooled OLS and the BE specification.

The physical dimensions show apparently an incoherent (negative) sign (marginal value: -0.6654 ÷ -0.1727 hours per hectare). This result plausibly reflects the condition that farms with higher physical dimension are those with higher surfaces cultivated with forages and

[330] In the sample there are not farms that was affected by droughts in all the events happened in the period 2003-07. Consequently, was not possible to account for the cumulative effect of droughts.

pastures that, consequently, present minor labours requirements compared to other farms' typology (for example horticulture or livestock). Our hypothesis on a quadratic relationship between the level of employment and the farm's cultivated surface is confirmed. In fact, the coefficient of surface squared is statistically significant and shows a u-shaped function. The farm' s economic dimension, measured in terms of ESU, shows a negative effect on the level of employment, probably because bigger farms present a higher mechanization level and consequently need less hours of labour then those with lower dimensions (marginal value equal respectively to -1.3530, -1.4613 and -0.6146 hours per hectare for the following specification: OLS, BE and FE). Low fertile soils need more hours of labour (margin value: -0.0173 hours per hectare), such as farms with fragmentized fields (margin value: -0.2861 ÷ -0.2362 hours per hectare), while a farm with fields' prevalently flat show, on average, an increase of the employment level (margin: 0.1202). Variables connected to soil characteristics and field fragmentation are not present in the FE model specification. In fact, both these variables such as those connected to irrigations, are time-constant and consequently are automatically removed from the model. The estimated sign of the ratio seasonal/total workers show the negative impact (margin value: 0.06 ÷ 0.07) of this variable on the employment level. As for the irrigation methods, irrigation quota presents a positive effect on the employment level. The marginal value is relevant, ranging between 0.08 and 0.10 hours per hectare respectively for OLS and BE specification. Irrigation system is un-significant in all model specifications, and if water is distributed by collective organizations this has a negative effect on employment level, marginally equal to – 0.03 ÷ -0.04 hours per hectare. FE specification shows a significant and negative market effect both for output and wages prices. For these variables margins equal respectively to -2.2897 and -0.8177 hours per hectare.

Water supply and sanitation

Climate change will have a discernible impact on water supply and sanitation (Downing, et al, 2003; EEA, 2009). Residential water demand, both in- and outdoor, is likely to increase (EEA, 2008). Changes to river flows and groundwater recharge rates are likely to affect potable water supply. Under drought conditions, when water resources are at a minimum and the adverse environmental impacts of abstraction are at their peak, even a small increase in household demand can exacerbate the impacts of drought (EEA, 2009).

Climate change will affect water industry in multiple ways: The infrastructure vital to services, and the further treatment that will be required to meet quality standards. Reservoirs will be affected in terms of operation, quantity, quality and structure. Lower river flows will reduce the dilution of wastewater effluent. Additional treatment will be needed to meet higher standards. Colour and odour problems will result from higher temperatures and more intense rainfall events.

Presently, the water sector in Europe has an annual turnover of about 100 billion Euro (EC, 2011g), about a third of which is spent on building new and maintain existing infrastructure. The sector provides 600,000 direct jobs in water utilities alone, more are development of products, techniques and services that promote the efficient use of water, reuse resources from waste water and save or even generate energy from waste water. Globally the development of the water infrastructure system will require substantial investments in the future. Ashley & Cashman (2006) estimated the global annual expenditure on water and wastewater services in 772 billion USD by 2015 and 1038 billion USD by 2025. The same source estimates for Italy 16.83 billion USD by 2015 and 25.23 billion USD by 2025. Other sources, such as Hughes et al. (2010), estimated the economic and engineering cost of climate change adaptation for the water service industry in the OECD countries. According to their estimations, Western Europe will require a total of 110 billion USD for the period 2010-2050, for the engineering cost only. Hughes et al. (2010) calculated that the economic adaptation, using economic instruments such as water tariff policies instead of engineering investments, will reduce adaptation costs by 87 billion USD. Considering also the avoided engineering cost, the total saving from economic instrument adaptation is estimated as 197 billion USD for the period 2010-2050 in the Western Europe OECD area.

Focusing on the Italian water sector, the reform of the public water supply and sanitation (WSS) service set off in 1994 had helped to modernise WSS, and reduce fragmentation in both service provision and water tariffs in place. The reform also reduced the number of water utilities in the market. For example, between 2001 and 2010, the number of water utilities operating in the Region Emilia Romagna decreased from 157 to 18.

Whereas until 1994 the water infrastructure had been built exclusively using public money, the reform set for a private participation in the water service delivery. Yet the reform however has not managed to ensure the necessary level of investments for the extension and the modernisation of water infrastructures. The WSS sector suffers from insufficient investments (Massarutto, et al, 2011). The average annual per capita investment in water supply and sanitation services in 2007 amounted to 37.00 Euro (min-max range 19-117 Euro) (CONVIRI, 2008). Most of the investments (57 per cent) is designated for new infrastructure, whereas improvement in the existing infrastructure only accounts for 37 per cent. The new investments are financed predominantly from the collected revenues (46 per cent) and public transfers (21 per cent). Own capital investments and loans are represented by 11 per cent and 14 per cent respectively (EPI-WATER, 2011).

The case study selected for this document explores the effects of increased investments into water infrastructure, full cost recovery of water services and water resource efficiency policies in selected water service area situated in the Emilia Romagna Region (RER). In each water service area (called *ambito territoriale ottimale* ATO), the water supply and sanitation services are commissioned to one or more water utility for the period up to 30 years. In the case of ATO Bologna the service is commissioned until 2021 to HERA Group S.p.A; ATO Ferrara water service is commissioned until 2024 to HERA Group S.p.A. and CADF S.p.A. (Regione Emilia Romagna 2006b). The two largest water service providers in RER (Hera and Iren) are multi-utility corporations with large turnover. Business diversification influence positively company’s ability to access credits. Table 81 and Table 82 show the planned investments in the ATO Ferrara and ATO Bologna.

Table 81: Actual and planned investment in ATO Ferrara. (Source: ATO 6 Ferrara (2007))

	HERA	CADF	TOTAL
Population (2006)			353.304
Aqueduct length (km)	2.420	2.264	4.684
Sewage system length (km)	928	905	1.833
Investments 2005-2007 (Euro)	25.872.000	14.039.041	39.911.041
Investments 2008-2012 (Euro)	53.074.000	20.100.000	73.174.000
Investments 2012-2024 (Euro/year)	10.000.000	4.300.000	14.300.000

Table 82: Actual and planned investment in ATO Bologna. (Source: ATO Catchment Area Plan)

	HERA
Population (2008)	960,343
Aqueduct length	8,801 km
Sewage system length	3,504 km
Investments 2004 – 2006	82,000,000 €
Investments 2007 – 2009	108,000,000 €
Investments beyond 2010	194,720,565 €

Water tariffs are designed to recover full financial costs of the WSS service, that is investment costs, operational and management costs, and administrative and support costs (Folifac and Gaskin, 2011). Ambiente Italia (2001) estimated employment potentials of public investments in the water sector. Table 83 summarises the employment potential based on long term empirical evidence in water sector for different type of investments.

Table 83: Employment potential arising from investments in the WSS

Source	Activity	Employment potentials per 1 billion USD invested in public works		
		min	average	max
PERI, 2009	drinking water	12,805		17,761
PERI, 2009	waste water	12,805		17,761
PA Consulting, 2009	water infrastructures	20,000		27,000
ARA-AWE, 2008	water losses control		20,571	
	HE toilet rebate programme		18,750	
	HE toilet direct install programme		19,770	

The employment potential ranges from 12,805 to 27,000 jobs per billion USD invested. These estimations include direct, indirect and induced effects on the labour market. Generally, it can be estimated that the effects are spread over a wide range of economic sectors. In terms of employment, AmbienteItalia (2011) estimates that the construction sector absorbs around 56 per cent of direct and indirect employment opportunities, while the industry and service sectors absorb 11 and 33 per cent respectively. This proportion moves to higher values for the services sector (around 48 per cent) considering the induced effects only.

Based on these estimates, we conclude that planned investments 2010-2024 in the provinces of Ferrara and Bologna in RER, the employment opportunity created by interventions in the domestic water sector amounts to 5,000 (4,694) and 10,000 (9,898) jobs (cf. Table 84).

Table 84: Estimated employment potential arising from the planned investments in the WSS

	ATO 6 Ferrara		ATO 5 Bologna
	Per year	2012-2024	2010 - 2020
HERA	10	120	195
CADF	4	52	
Total	14	172	195
Employment min	183	2,197	2,497

	ATO 6 Ferrara		ATO 5 Bologna
	Per year	**2012-2024**	**2010 - 2020**
Employment max	386	4,633	5,265

Energy generation

Changes in climate will have a distinct influence on runoff regimes and on water balance (IPCC, 2007c; Bates, et al, 2008). There is evidence that river regimes will shift to higher runoffs in winter and lower in other seasons (EEA, 2007a; Bates, et al, 2008). These changes will affect thermoelectric and hydro power plants depending on water as cooling substance. The more frequent and intense drought spells will affect electric-power reliability.

The 890 or so hydroelectric plants installed on the Po River and its tributaries generate on average 20 billion kWh/year (~48% of the installed hydropower in Italy). Additional 400 thermoelectric plants generate around 76 TWh every year, accounting for ca. 31 per cent of the national thermo-electric production. During the spring and the summer of 2003 and 2006-2007 severe droughts afflicted Northern Italy, including the otherwise water abundant river basin Po. The state-of-emergency (SoE) has been declared by the Italian Prime Minister in 2003 and then again in 2006 and 2007. The drought impacted all water use sectors, including thermoelectric production.

In June 2003, several power plants were undergoing maintenance work off-grid when temporarily decline of imported energy triggered a partial blackout in the North East of Italy. Some non-critical users were disconnected from the service provision as foreseen by the Electricity System Security Emergency Plan. The emergency highlighted the vulnerability of the national energy system (AdBPo, 2006).

In July, the Porto Tolle thermo-electric power plant (PTPP), that supplies the North-East Italy with electricity, was temporarily turned off as a result of low river flow and insufficient availability of water for cooling purposes in the downstream part of the Po river. Situated in Polesine Camerini (Rovigo province, downstream part of the basin), PTPP is one of the largest thermo-electric power plant in Italy. Installed capacity of the 4 units of the plant reaches 2,640 MW. Some 8 per cent of the national electricity is produced by this plant.

The water concession of the PTPP allows a withdrawal of 80 m^3/sec when the river flow exceeds 460 m^3/sec. The concession is reduced to 40 m^3/sec with a flow ranging from 380 and 460 m^3/sec, allowing the plant to work with only 2 units. The concession does not allow any withdrawal when the river flow falls below 380 m^3/sec. The concession takes into account the environmental flow and the quantity of “thermal pollution” of the river from which the derivation is authorised. Under persistent conditions of low river flow, the operators are obliged to reduce the withdrawal, leading to temporary reduction or suspension of the electricity production.

In July 2003, the river flow settled constantly under the 380 m³/sec threshold for almost the whole month. This would have caused the suspension of the abstraction licence but the Veneto Regional Council enacted a regulation allowing the PTPP to maintain the production of all 4 units with no reduction of permitted water withdrawal. The regulation meant to ensure the energy security of the country. Thanks to the drought mitigation measures implemented by the Po River Basin Authority, the water flow increased and reached 412 m³/sec by the end of July, further increasing to 450 m³/sec one week later (Dipartimento della Protezione Civile, 2003).

In 2005, the company owning Porto Tolle power plant submitted a project to change the production process using coal instead of oil for the combustion: total investment for the renovation of the plant was estimated in around 3 billion Euro. The plan included a modification of the cooling system. It has been proposed to change the original open-loop fresh water cooling system with a more efficient closed-loop seawater cooling system. This solution has been designed to protect the plant from the risk of drought events, mitigating the impacts and the potential impacts registered during the event occurred in 2003 (Giunta Della Regione Emilia – Romagna, 2003).

We estimated that out of the expected 3 billion-worth investment, the cost of installing the new cooling system would range approximated between 15 and 25 Million Euro. Based on the employment estimates of public investment in infrastructure (AmbienteItalia, 2011), we estimate that the intervention on a single thermoelectric power plant would create up to some 250 additional jobs. Only a small part would translate into a long term employment. The maintenance of the closed cooling system using sea water is more labour intensive. The extrapolation of the insights from this case to the whole river basin is not easy, the conversion costs and thus investment needed depend on the specific typology of the plants that are not disclosed by the utility.

Adopting the most efficient technologies available, a power plant, using open-loop fresh water cooling system, requires water for around 3.5 – 4 m³/h per MW installed. A typical 2 units thermal power plant with an installed capacity of 1,000 MW (2 x 500) registers water requirements for around 4,000 m³/h. Around 3,500 m³/h of the total are used for cooling purposes (Central electricity authority, 2012). As consequence, it is possible to highlight that about 80 per cent of the water is required for the cooling system (Central electricity authority, 2012). A small fraction of the withdrawn water is actually consumed: typically less than 5% (Ecologic, 2007).

Close-loop evaporative cooling systems have far lower requirements on water withdrawal but consume up to twice as much water as open-loop cooling systems (DOE, 2006). A greater deployment of dry cooling - that is plants with cooling towers cooled by air - can reduce the water demand but also the plant efficiency: the yearly plant output can be reduced by as much as 2 per cent compared with evaporative closed-loop cooling (DOE, 2006). This also means that more fuel is needed to deliver the current energy supply and that more emissions are released. The total costs of dry-cooled systems are also up to 16 per cent higher than evaporative closed-loop cooling, depending on the local climate (California Energy Commission, 2002).

In case of water scarcity the most important data to be taken into consideration are represented by the water requirements of the thermal power plant. In this case, the comparison of the withdrawals needed for an open-looped cooling system plant are up to 6 times higher than the ones required by a dry cooled plant. Dry cooling systems, as such, are costly technologies and are not comparable to wet cooling system on techno-economic considerations. However, for sites where adequate quantity of water is just not available, dry cooling system offers possible solution for power plant installation with much reduced water requirement (Central electricity authority, 2012).

In the Po river Basin, as reported above, more than 400 thermal power plants use freshwater for cooling purposes. Almost 45% of the installed capacity is concentrated in 8 plants, reaching a cumulative value of 8,755 MW (AdBPo, 2006). The substitution of the open-looped cooling system with a more efficient technology could allow a reduction in the water withdrawals up to 80%.

The introduction of the close-looped cooling system, has a variable cost dependent on the characteristics of the power plant. However, a study conducted by the California Energy Commission in 2002, estimated the cost of intervention in a range variable from US$ 8 to 12.5 (around 6.5 to 10 Euro) per kW installed (California Energy Commission, 2002).

The implementation of the intervention required for the adaptation to climate change in this sector could be estimated in an amount ranging from 60 to 90 million Euros, taking into consideration only the main thermal power plants located in the Po river basin. The mentioned investment for this adaptation strategy could bring large possibilities in terms of job creation, up to 900 (AmbienteItalia, 2011), but, at the same time, the perspective of protecting the existing technology for energy generation could deprive of consistent investments the research on new technologies. A different alternative source, able to ensure the same level of electricity production of the actual thermal power plants, could create a consistently larger possibility of additional employment.

Annex 7 – Adaptation options per policy area/sector

1 Agriculture

1.1 Technical measures for adaptation

Beside the measures already proposed under the new CAP proposal; water is an essential factor for agricultural production all adaptation measures in the water sector, which have an impact on agriculture and are not mal-adaptation should be considered. Further changes in farm management will be required in many places. The issue of genetic modified crops as a potential adaptation option need to be discussed within society considering also the potential risk. Also the new development of environmental friendly pesticides to avoid large scale diseases needs to be discussed. Cooling of stable also might be considered, however should also be assessed from a climate mitigation point, due to the high energy consumption required.

1.2 Potential of the market for enhancing the EU's resilience to climate change

The Commission (DG AGRI and JRC) has conducted a lot of work on EU agricultural insurances over the last years. A short summary can be found in the IA annex on risk management[331] accompanying the CAP legislative proposals[332]. The OECD (from JWP on Agriculture and environment) will release soon a paper on risk management strategies in agriculture within the context of climate change. Conclusions are interesting, such as, according to cases, agricultural insurances might not be an optimal economic instrument to maintain agriculture revenues (too costly) and diving adaptation in a context of climate change. So, we don't need to reinvent the wheel.

1.3 Building capacities

Follow the proposed actions set out in the EU Innovation Partnership for agriculture (EC, 2012f).

[331] http://ec.europa.eu/agriculture/analysis/perspec/cap-2020/impact-assessment/annex6_en.pdf
[332] http://ec.europa.eu/agriculture/cap-post-2013/legal-proposals/index_en.htm

2 Forestry

2.1 Technical measures for adaptation

In 2008 a list of adaptation measures has been developed in a study (EC, 2008c) of the European Forest Institute (EFI) for the European Commission. This list was discussed and amended by the working group and covers the following aspects:

- Forest regeneration
- Tending and thinning of stands
- Harvesting
- Forest management planning
- Silviculture and forest protection
- Biotic and abiotic damages
- Forest fires
- Wind
- Infrastructure and transport
- Nurseries and tree breeding
- Further adaptation options in risk management and policy

The full list of measures can be found in EC (2010f) and needs to be adapted to the natural conditions of the stand taking into account cost-effectiveness and environmental side impacts.

2.2 Potential of the market for enhancing the EU's resilience to climate change

Based on the before mentioned stakeholder meeting the potential of market forces is seen as follows:

- The sector has some specificities that makes the use of insurance more difficult in the sector. The demand is also considered to be limited (Holthausen & Baur, 2004).
- The role of payments for ecosystem services (e.g. for providing protection to settlements) should be assessed and strengthened. However the details on how to do this and for which services need further investigations.

2.3 Building capacities

Based on the before mentioned stakeholder meeting capacity building should focus on:

- Information exchange between different forest owners on how to adapt to climate change.
- It is important to increase the awareness on adaptation at the local level. This should be mainly done due to the use of advisory services and the creation of local forest organisations (co-operations). Such organisations are seen as a suitable entry point for increasing awareness about EU policies in general but also for adaptation in particular. For larger companies it is also important to create a business case for adaptation.

However, when doing so it is important to keep in mind that there is an overflow of information at all levels. This makes it difficult to draw attention of the sector on adaptation. It is also important that forest management can have different objectives also economic ones. This should be considered when trying to convince forest managers to take actions in the area of adaptation to climate change.

3 Transport

3.1 Technical measures for adaptation

A. Technical measures for **RAIL**

- Use materials for new or upgrades of rail infrastructure which better cope with summer heat to prevent track buckling (e.g. endless welding of rails to eliminate the risk of rail buckling; Doll, et al, 2011)
- Check existing air conditioning systems in trains and adopt them to higher temperature (cf. summer 2010 in Germany) (Savonis, et al, 2008) and humidity
- Improve air conditioning for signals in case of heat waves (Savonis, et al, 2008)
- Improve system to warn in case of rail buckling and update dispatch centers, crews and stations (Savonis, et al, 2008)
- Increase in monitoring of land slopes (TRB, 2008; Nolte, 2008)
- Install early warning systems which can shut down the train service in case of floods (Lindgren, Jonsson and Carlsson-Kanyama 2009; Nolte, 2008)
- Use sensor technology to track the condition of infrastructure and implement reporting system (The Royal Academy of Engineering, 2011)
- Strengthened earthwork to reduce embankment instability due to moisture fluctuation caused by wetter winters and drier summers (HM Government UK, 2011; Nolte, 2008; RSSB, 2003)
- Monitoring wind speeds and install wind alarms for overhead line system based on real time monitoring (Nolte, 2008)
- Design structures (bridges, signs, overhead cables, etc.) for more turbulent wind conditions (Savonis, et al, 2008)
- Develop rolling stock further to cope with falling ice
- Select suitable vegetation near the rail corridor to reduce risk of fire, falling trees (Doll, et al, 2011)

B. Technical measures for **ROAD**

- Identify and implement cost-effective means of retrofitting existing infrastructure (e.g. roads, tunnels, bridges) and equipment (in particular buses and coaches) to more extreme climatic conditions (e.g. technical flood protections) (Cochran, 2009; HM Government UK, 2011)

- Develop new, heat-resistant paving materials (Doll, et al, 2011)
- Improvement in pavement technology, for instance compact asphalt ("hot on hot technology") (Doll, et al, 2011)
- Design electronic equipment (e.g. telematic systems for traffic signals) that is more resistant to heat (Doll, et al, 2011)
- Use higher dimensions of drainage systems and materials that can be easier inspected and maintained (Doll, et al, 2011)
- Consider sea level rise in the design of long-life structures (Youman, 2007)
- Link road infrastructure with other transportation modes to enhance resilience (Taylor, 2011)
- Stipulate monitoring of land slopes and floods (Nolte, 2008)
- Enhanced vegetation control along roads (Doll, et al, 2011)
- Install early warning systems in case of extreme events (e.g. floods, storms) (Knoflacher, 2010)

C. Technical measures for **AVIATION**

- Build longer runways at high-altitude or hot-weather airports, if feasible (Ang-Olson, 2009, Savonis, et al, 2008)
- Update gate-based cooling systems due to temperature increase (Ang-Olson, 2009)
- Install redundant systems (e.g. navigation equipments) (Ang-Olson, 2009)
- Install protective structures/dikes to protect runways or raise existing dikes (Ang-Olson, 2009, Savonis, et al, 2008)
- Consider sea level rise in the design of long-life structures (Youman, 2007)
- Improve early warning systems in case of extreme events (Savonis, et al, 2008)

D. Technical measures for **SHIPPING**

- Improve or develop monitoring system, e.g. for river depth information or sea level rise (van der Toorn, 2010; ECCONET, 2012c)
- Improve and maintain fairway conditions in a good navigational status, as required by the AGN agreement (ECCONET, 2011; 2012a; 2012b) (bfg, via donau and NEA)[333]
- Improve weather forecast systems (UK's Transport Research Laboratory)
- Consider sea level rise in the navigation and design of long-life structures (e.g. dock and wharfs) and retrofit facilities (Savonis, et al, 2008; Youman, 2007)
- Consider climate change conditions in the design procedures of ships (DNV 2009)
- Install protective structures/dikes or raise existing dikes to protect ports (Ang-Olson 2009; Savonis, et al, 2008)
- Elevate bridges and other structures (Savonis, et al, 2008)
- Find alternate navigation routes (van der Toorn, 2010)

E. Technical measures for **URBAN TRANSPORT**

- Compose asphalt roadway of light-coloured aggregate and/or binder producing high solar reflectance index (SRI) values in order to reduce the heat it generates (GRaBS project) and plant roadside vegetation to decrease the exposure of roads to heat
- Use porous asphalt, which is standard asphalt concrete mixed without fine particles and with low binder content to leave space for water to drain through to an open-graded stone bed to reduce run-off into the sewer system and the likelihood of puddles or slick or icy surface conditions (GRaBS project)
- Link road infrastructure with other transportation modes and adud alternative paths (parallel structures) to enhance resilience (Taylor, 2011)
- Link green infrastructure network, which is a set of connected green spaces (GRaBS project)
- Install air conditioning and cooling systems through retrofitting in urban tramways and metros (sustainable cooling schemes for the London underground and railway

[333] European Agreement on Main Inland Waterways of International Importance (AGN); http://www.unece.org/fileadmin/DAM/trans/conventn/agn.pdf

network) and reduce the temperatures of buses (e.g. controlled air-cooling systems, better windows, white roofs, insulated roofs and side panels, controlled heating systems)

- Intensify maintenance of relevant waterways and assess the likeliness of constraints on urban waterway usage and plan for alternatives

3.2 Potential of the market for enhancing the EU's resilience to climate change

One consideration might be the inclusion of climate impacts into Eurocodes, especially into the diverse EN 1991, which deal with certain parameters like wind or snow loads as well as into the Technical Specifications for Interoperability (TSI) of railways (mainly with respect to early warning and contingency planning in case of extreme events/traffic interruptions). A link shall also be established to the German BMBF-funded project INFRANORM[334] which has the goal to develop DIN specifications for the protection of traffic infrastructures.

On diverse national levels already now different additional standards have to be applied. The disadvantageous value is generally applied for calculations in order to be on the safe side.

The project ECCONET dealt with the identification and analysis of the following adaptation options addressed to inland waterways transport issues which would mainly rest with the private sector:

- technical changes of the fleet (vessels),
- changes in operation of the fleet
- changes in logistic solutions
    - increasing the payload of a ship keeping the main dimensions (L x B x T) unchanged (lightweight structures)
    - reducing the number of days per year when the navigation of a ship is physically not feasible (e.g. by installing retractable tunnel aprons, adjustable blisters)
    - upgrading of smaller, less low-water-sensitive vessels from only daytime- and semi-continuous operation-mode to continuous operation-mode and thereby increasing the annual number of operating hours of these vessels
    - co-operation with the railway mode in order to shift parts of the IWT-transport-volume in low water periods to the railway mode

[334] http://www.bmbf.de/de/13086.php

- implementation of a larger number of smaller, less low-water-sensitive vessels

They conclude that in regards to fleet and transport systems, certain adaptation measures are considered as promising approaches. Nevertheless, further elaborations have to be carried out in order to investigate the advantages of these measures and their effectiveness when implemented.

Standards and regulations for RAIL

- Higher standards of rail used to prevent track buckling in increased temperatures (HM Government UK, 2011)
- Modify standards for bridges to be able to cope with higher temperatures (e.g. to avoid thermal expansion) (Doll, et al, 2011)
- Modify standards for air conditioning systems in trains and for signals to be better adopted to higher temperature
- Modify standards to improve the stability of slopes (Doll, et al, 2011)
- Upgrading drainage system to better meet the requirements in case of extreme precipitation (The Royal Academy of Engineering, 2011; TRB, 2008; Nolte, 2008)
- Modify standards for height of dams and flood barriers due to expected increases in rainfall intensity and duration (especially in winter) (ARISSC; Nolte, 2008)
- Restriction of development in floodplains (TRB, 2008)

Standards and regulations for ROAD

- Modify standards for road materials (e.g. pavement, embankments) to be able to cope with higher temperature and extreme precipitation events (Youman, 2007)
- Modify standards for bridges to be able to cope with higher temperatures (e.g. to avoid thermal expansion) (Doll, et al, 2011)
- Modify technical standards for height of dams and flood barriers due to expected increases in rainfall intensity and duration (Nolte, 2008)
- Modify standards to improve the stability of slopes (Doll, et al, 2011)
- Upgrade drainage system to better cope with intensive precipitation events (UK's Transport Research Laboratory)

- Design structures (e.g. bridges, anchorage of traffic lights and signs) for more turbulent wind conditions (Savonis, et al, 2008; Knoflacher, 2010)
- Restrict development in flood-prone areas to major roads (UK's Transport Research Laboratory)

Standards and regulations for AVIATION

- Modify surface materials of runways to be able to cope with higher temperature and extreme precipitation events (Youman, 2007)
- Modify standards for gate-based cooling systems taking summer heat into account
- Upgrade drainage system to better cope with intensive precipitation events and storm water runoffs (UK's Transport Research Laboratory; Ang-Olson, 2009)
- Design structures (e.g. terminals, navigation equipment, signage) for more turbulent wind conditions (Savonis, et al, 2008)

Standards and regulations for SHIPPING

- Regulate the number and weight of barges in case of low river discharge (van der Toorn, 2010)
- Modify technical standards for height of dams and flood barriers due to expected increases in rainfall intensity and sea level rise (Nolte, 2008)
- Design harbor infrastructure (e.g. docks, wharves, terminals) stronger to protect it from storm surge and wave damage (Savonis, et al, 2008)

Standards and regulations for URBAN TRANSPORT

- Explore more resilient design standards (Eurocodes), urban drainage and materials for infrastructure construction; may be needed to withstand higher temperatures and expected increase in rainfall intensity
- Minimise the need for road infrastructure through compact urban planning and provide sufficient redundancy to allow for alternative ways of passage, when obstruction occurs
- Develop joint adaptation action plans in vulnerable urban areas (risk mapping) with clearly assigned responsibilities for all participating parties (GRaBS project)

3.3 Building capacities

RAIL

- Adaptation measures should be incorporated into the routine maintenance processes and the lifecycle replacement of assets in particular rolling stock. Some major infrastructure may require significant investment to meet adaptation requirements; new infrastructure will need to be built consistently with adaptation requirements (The Royal Academy of Engineering, 2011)
- Systematic mapping and monitoring of different types of climate threats, vulnerabilities and their consequences on the existing infrastructure (e.g. development of a Climate-Rail - risk map) should be performed in order to guide the implementation of adaptation measures (Lindgren, Jonsson and Carlsson-Kanyama 2009; UIC, 2011; Nolte, 2008; RSSB, 2003). Vulnerability hot spots can be detected in regard to e.g.
    - Summer heat (overheating)
    - Floods
    - Storms
    - Mass movements
- Create a central asset database for all relevant kinds of railway infrastructure assets with detailed information about the current general and maintenance standard (UIC, 2011).
- Provide information (e.g. impact maps, good practice examples) and easy access to information to the national railway operators in Europe (e.g. communicate results from research projects such as ARISCC)
- Development of emergency plans/ crisis management plans in case of heat waves, floods, storms, etc. including replacement modes (Cochran, 2009) (cf. Action 23 of the White Paper on Transport concerning Mobility Continuity Plans; EC, 2011v)
- Develop check lists for the EU national railway operators to assess vulnerability and possible adaptation options
- Develop methodologies for climate proofing to rail companies

ROAD

- Increase understanding of how materials react to higher temperature and intensive precipitation and the thresholds at which deterioration or disruption occurs (research) (UK's Transport Research Laboratory; Cochran, 2009)
- Enhance methods of maintenance in order to address extreme fluctuations in temperature
- Identify the likely risks of climate change for roads (e.g. degradation of permafrost) and the specific areas of vulnerability (UK's Transport Research Laboratory)
- Identify and prioritize critical network “nodes” for immediate attention and reinforcement (detect vulnerability hot spots) (Cochran, 2009)
- Develop climate change strategies and actions plans for local authorities and operators
- Provide sea level rise maps (Youman, 2007)
- Recognize current operational practices and approaches to ensure that existing road infrastructure is functioning properly within changing climatic conditions (Cochran 2009; HM Government UK, 2011)
- Assist State and local governments and private infrastructure providers to incorporate climate change into their long-term capital improvement plans, facility designs, maintenance practices and operations (TRB, 2008)
- Provide advice for reviewing and revising road regulations of Member States and existing incentives with consideration of expected climate changes (HM Government UK, 2011)
- Provide information (e.g. vulnerability maps, good practice examples) and easy access to information to the National Ministries of Transport and to operators
- Create crisis management plans, including replacement modes, secondary itineraries and temporary network shutdowns, in preparation for the potential increase in frequency and intensity of extreme weather events (Knoflacher, et al, 2010)
- Provide real-time communication and information to help manage recovery and emergencies, including providing information about road closures, traffic conditions, alternative routes and early warning systems on adverse weather (Gledhill & Low, 2010)
- Develop check lists for vulnerability assessments supporting the National Ministries of Transport

- Publish guidelines for responsible Ministries and road operators to take climate change into account in connection with construction and operation (HM Government UK, 2011)

AVIATION

- Assess how temperature increases may affect aircraft takeoff performance capabilities and payload requirements, and address any such increases in the context of current runway utilization and future runway design (Savonis, et al, 2008)
- Identify the critical concerns and screen risks for airports in the light of climate change projections to determine whether, when, and where projected climate changes might be consequential; detect vulnerability hot spots (Savonis, et al, 2008)
- Consider not only vulnerability of the aviation sector but include other related infrastructure, e.g. surface access to airports (Gledhill & Low, 2010)
- Recognize current operational practices and approaches to ensure that existing infrastructure is functioning properly within changing climatic conditions (Cochran, 2009; HM Government UK, 2011)
- Airport infrastructure typically undergoes regular upgrades, replacement and maintenance. Depending on these cycles, introduce adaptation measures to incorporate enhanced levels of resilience according to the latest science (Gledhill & Low, 2010)
- Provide information (e.g. vulnerability maps, good practice examples) and easy access to information to operators
- Create crisis management plans, including replacement modes, secondary itineraries and temporary network shutdowns, in preparation for the potential increase in frequency and intensity of extreme weather events
- Publish guidelines for operators to take climate change into account in connection with construction and operation (HM Government UK, 2011)
- Develop check lists for vulnerability assessments

SHIPPING

- Carry out risk-analysis for ports by simulating different scenarios of likely impact to identify how vulnerable a port is to such risks (detect vulnerability hot spots) (Becker, et al, 2011)

- Address climate change in existing management plans such as port strategic plan, and in the operational practices and approaches (Becker, et al, 2011)
- Produce sea level rise maps (Youman, 2007)
- Increase understanding of climate change and Waterborne transport by providing funding for research
- Provide information (e.g. vulnerability maps, good practice examples) and easy access to information to operators
- Create crisis management plans, including replacement modes, secondary itineraries and temporary network shutdowns, in preparation for the potential increase in frequency and intensity of extreme weather events
- Publish guidelines for operators to take climate change into account in connection with construction and operation (HM Government UK, 2011)
- Develop check lists for vulnerability assessments

URBAN TRANSPORT

For urban transport, many of the adaptation options above should be considered. The following options are specifically addressed to urban areas.

- Inform transport planning and operations that they need to take current and future climatic changes into account. This means that new tools, such as regional climate scenarios, vulnerability and risk assessments need to be integrated
- Develop recommendations to urban transport, which provides scope for a rational use of private cars (Europe at a crossroads – The need for sustainable transport)
- Develop Practitioners' guides for climate proofing for urban transport planning

4 Construction and buildings

4.1 Technical measures for adaptation

Firstly, as climate change is a long term problem and buildings will function on average 70 years, climate-proofing of new developments is important. A building strategy should consider the extreme scenarios as these define the parameters for engineering specifications. There is a need for guidance on taking into consideration projected future extreme events (not the standard of the past which is common).

Specific technical measures to prevent flooding and overheating of buildings can be taken at two levels: the building level and the project or spatial level. The project/spatial level has to be taken into account in an early stage for new developments, and the local government has an important role.

Technical measures in new buildings against flooding, to be applied in cities and in flood-prone areas (van de Ven, et al, 2009):

- Minimum elevation of a building above street level of, for example, 20cm, so that the streets will drain excessive water while buildings remain dry;
- Building ground floors of water resistant materials;
- Putting electricity, communication networks and other water-sensitive installations on the first floor, or, at the least, not in a basement;
- Enabling shutting off sensitive appliances in case of flooding.

These measures can be expensive, especially the third option, since everything above ground level is the space that is actually rented/sold. Considering that installations also need more protection in general (fire resistant walls, insulation in case of leaks of oil tanks, etc.) the rentable space would be significantly reduced; also in case of earthquakes these installations would be less protected. The additional costs in flood-prone areas should be weighed against building outside of flood-prone areas where ground prices may be higher.

In existing buildings, the following flood-proofing measures are possible:

- Ask inhabitants to avoid soil sealing in their garden;
- The ground floor can be furnished in a more flood-proof way, for example, with a tile floor instead of wood.

Technical measures at the level of new projects /spatial level against flooding (van de Ven, et al, 2009):

- Green infrastructure such as green roofs, parks and ponds provide buffering capacity for flash floods;
- Adapting drainage systems to compensate for peaks, for example, with underground water storage facilities;
- Build streets and public spaces with additional buffering/ drainage capacity for extreme events;
- Build public transport and main traffic roads at higher level;
- Separate systems for rainwater drainage and wastewater transport, to prevent flooding with waste water;
- No storage of toxic materials in flood-prone zones;

Technical measures in existing buildings against overheating (Foundation Building Research website http://www.sbr.nl/, Ministry of interior, 2011):

- Mobile shading structures, preferably on the outside of the building;
- Reducing heat producing equipment (LED lighting, passive lighting such as skylights, energy saving equipment;
- Green roof or façade provides cooling through evaporation and limits uptake of solar radiation.
- Discouraging energy consuming air conditioning because it adds heat to a city

In new buildings, the following measures are possible against overheating:

- Isolation for winter circumstances will prevent cooling in summer time; Since thermal insulation is placed on the outside of the building (envelope) it is not only preventing heat to pass from indoor to outdoor, it also prevents wall materials to heat up and pass the stored heat to the inside of a building. It should be compensated with sufficient passive ventilation possibilities, otherwise cooling is not possible without air conditioning;
- Passive cooling through a heat pump system;
- Building materials with high albedo (light colours, reflective materials).

Technical measures at project/spatial level against overheating (Foundation Building Research website http://www.sbr.nl/; Hebbert & Webb, 2011):

- Green infrastructure such as street trees and parks provide cooling;

- Orientation of buildings towards sun matters for limiting entrance of solar radiation;
- Create urban ventilation corridors;
- Neighbourhood detention ponds and wetlands which collect storm water.

4.2 Potential of the market for enhancing the EU's resilience to climate change

Designing and building climate proof houses can give architects and project developers a competitive advantage. Important aspects during the construction phase are design flexibility, suitability of materials used and a skilled workforce (Dlugolecki, et al, 2009). Thereafter sound standards of upkeep and maintenance must be observed. The Dutch company Dura Vermeer has been active already in designing floating houses[335]; in Hamburg[336] and in the UK flood proof houses are being researched[337]). Similar developments are possible in the directions of low-energy houses and urban heat-proof houses.

However, due to the long life span of buildings and civil engineering works as well as the large number of small and medium enterprises and micro enterprises, the construction sector traditionally is relatively slow to introduce innovations at a large scale. If climate change is not taken into account already at the design stage, (unaware) buyers might have to face later adaptation costs, keeping in mind that later adaptations will most likely not achieve similar gains. Therefore, it is advisable to innovate building practices as soon as possible. New standards may be a way to achieve this, although some years of experimentation may be needed before new technologies settle down.

Extreme events like flooding and heavy precipitation are expected to increase, but there is uncertainty about the frequency. Insurance may be a more cost-efficient solution that prevention of damage due to these extreme events. British Insurance companies will only insure newly built homes and buildings if they had a 1 in 200 chance of flooding each year. If the risk was greater, insurance companies would need evidence that additional measures were taken to protect against flooding, such as putting the electric wiring at a higher level[338]. Considerations for insurances in the construction sector:

- Insurers must engage in construction projects early to ensure that planning and design addresses climate risks, especially when developments are planned in hazardous zones,

[335] http://inhabitat.com/dutch-floating-homes-by-duravermeer/
[336] http://www.iba-hamburg.de/expertinnen.html
[337] http://www.bris.ac.uk/civilengineering/research/water/projects/bhs_folder/flood_proof_house/
[338] http://www.london.gov.uk/media/press_releases_london_assembly/insurance-costs-worry-homes-thames-gateway

- Insurers should collaborate with governments to make flood-resilient construction mandatory in new developments, and after major flood damage, and aim for sustainable solutions to flood risk, such as water management schemes, sustainable drainage systems (SUDS), resilient domestic construction and demountable defences,

- Insurers should identify high-hazard categories, e.g. construction industry professions, and require policyholders to undertake regular climate change risk assessments, both on a business-wide basis and for specific projects (Dlugolecki, et al, 2009).

Further options comprise:

- Promote a climate-proof guarantee and certification system for housing developers

- Arrangements for insurance / compensation

- Adapt building regulations with clear performance levels for prevention of overheating and robustness against flooding, landslides, etc. (This is a shared responsibility of project developers and local governments, depending on the scale of a project)

Provide financial incentives for improving the performance of buildings and civil engineering works for climate resistance (comparable if not even compatible with the approach for energy efficiency, accessibility, etc.). Finally, we want to consider the effects of adaptation to climate change on employment in the construction sector. There are few studies available on the relation between adaptation and employment in general. The adaptation of existing urban structures and of additional infrastructure for adaptation (for example, additional drainage capacity for extreme events) could generate additional employment. Especially flood prevention measures along large rivers and seas could generate thousands of additional jobs during the construction phase and an unknown (but smaller) number of jobs for maintenance.

4.3 Building capacities

- Provide information and access to information to Member States, municipalities and construction authorities as well as construction companies (e.g. through the Adaptation Clearing House for Europe).

- Connect spatial planning practices with water management in legislation, to enhance shared responsibility for water proof building projects,

- Improve awareness and provide training for civil engineers for climate resistance of buildings and civil engineering works,

- Enhance awareness of citizens of potential risks of climate change, to create a climate-aware housing market;
- Response and relief plans for flooding and heat waves at municipal level;
- Structural evaluation of critical events to promote learning.

5 Energy

5.1 Technical measures for adaptation

There are a lot of chances in the transformation of the energy sector we are currently experiencing that should be capitalised for climate adaptation:

- A new energy mix envisaged in most EU Member States enables ex ante climate proofing of planned new supply facilities;
- Ageing transmission and distribution infrastructure and new infrastructure to be built for connecting newly built energy supply (e.g. offshore wind parks, solar power plants) and to transmit and distribute this electrical energy (e.g. in Germany from north to south) can be climate-proofed ex ante;
- Smart grids and smart metering should be regarded as tools to moderate non-adapted demand peaks for example during prolonged and more frequent summer heat waves.

A. Technical measures for transmission, distribution (including storage)?

- Climate-proof the grid by
    - **Transmission**: Install additional network capacities with special focus on volatile base load countries and regions. Especially regions with high potential and future dependence on non-base load capable renewable energy sources ((e.g. North Africa -> Solar Energy (cf. DESERTEC) or North Sea (offshore wind parks) (cf. ENTSO-E, 2010)) have to be taken into account. [This measure refers to smart grid activities already taking place (cf. e.g. EDSO-SG) which yet do not take into account the threats climate change is posing to the security of supply through the stepwise implementation of the renewable energy goals and are already part in the 10-year network development plan of ENTSO (ENTSO-E, 2010).] Make use of existing power pole infrastructure wherever possible.
    - **Transmission**: Install additional network capacities with special regard on countries and regions with high storage potential (e.g. Norway and Austria -> pumped storage units) (cf. ENTSO-E, 2010) [Yet, water pumping storage capacities have the highest efficiency]. Make use of existing power pole infrastructure wherever possible.
- **Transmission:** Detect vulnerability hot spots (Williamson, 2009) in the overhead transmission (and gas pipeline) networks by monitoring
    - mass movements

- storms
- floods
- overheating.

- **Transmission**: Install underground cables at vulnerability hot spots [expensive, according to ZEW (cf. Altvater, et al, 2011c), costs may exceed 10 times the costs of ordinary overhead transmission, also the conductivity of underground cables is limited due to fast warming and additional cooling facilities necessary]

- **Transmission**: Expand aisles through forests to the degree necessary [controversial, but in some explicitly storm-exposed regions possibly unavoidable]

- **Transmission/Distribution** (depending on the scope of the threat): Put slope stability measures into place (protective forests or technical measures such as terraces and fences)

- **Transmission/Distribution**: Set up early warning systems (Williamson, et al, 2009 and Ebinger, et al, 2011) for energy shortcuts due to
  - high demand (e.g. during heat waves or cold spells leading to overheating of the network due to overuse);
  - extreme events (storm, icing, hail) or periods (droughts lead to low hydropower and usually also wind power, heat waves -> overheating of the transmission cables due to high temperatures).

- **Transmission/Distribution**: (Re-)locate flood-prone transformers and substations to higher/safer ground.

- **Transmission/Distribution**: Support the Establishment of small/regional distribution networks that work independent from large-scale grid infrastructures. Support small and smart projects which go for independent ‘isle solutions’.

Storage:

- Install new storage facilities (pumped storage units) especially in regions with volatile base load (Ibrahim, et al, 2008).

- Explore potential of other storage methods (e.g. H_2 or CH_4) to build up in parallel to expanding renewable energy share (Ibrahim, et al, 2008; URS, 2010).

- Mid-term: Make use and maintain existing gas distribution network for CH_4 transmission and storage, once SABATIER process (‘solar fuel’, or other biochemical methods) reach industrial application/marketability. [currently research is progressing fast on new methods for electrolysis and methanising H_2 and CO_2 to CH_4]

B. Technical measures for supply and demand

Supply:

Water:

- Technically optimize hydropower plants to more frequent and intense extreme events (droughts, floods, erosion/sedimentation) by e.g. build desilting gates to flush silted reservoirs (Williamson, et al, 2009) and adjust upsurge operation (cf. proceedings from Austrian research project DSS_KLIM:EN project[339]).
- Avoid erosion in hydropower catchments by land management and by this decrease the sedimentation in hydro-power plants (Williamson, 2009).
- Install additional capacities (if possible) at increasing (glacial) flow regimes, if increases persist longer than the technical lifetime of the plant (Williamson, 2009).

Wind:

- Increase in efficiency of wind turbines towards more variable wind conditions through adjustments of constructions and power control for wind speeds <5m/s and >15m/s (according to Krohn (2009) wind turbines are currently optimized for wind speeds of around 8m/s).
- Due to the high volatility in wind power generation, combine/connect wind power plants with local storage systems (pumped power units, electrolytic generation of H_2/CH_4 or loading storage batteries) to avoid losses due to network overloads.

Solar:

- Enhance efficiency of PV installations by solar tracking.
- Storm- and hail-proof PV installations (cf. Ebinger, et al, 2011; German NAS, 2008).

Thermal:

- Improve the robustness of mining installations: i. offshore: storms and SLR[340] and ii. onshore: to both flooding and shortage of water needed for mining operations (Williamson, 2009).
- Site power plants in flood-secure places with sufficient cooling water supply (Williamson, 2009).

[339] Final report available at http://ebookbrowse.com/final-dss-klimen-endbericht-pdf-d257150713
[340] Sea Level Rise

General:

- Diversify energy supply to the degree possible.
- Support integrated approaches tackling energy and water supply.

Demand:

Water:

- Promote water saving technologies that are capable to reduce cooling water demands by thermal power plants (e.g. through reuse or partially closed circles) and if ambient temperature scenarios allow, replace water cooling systems with air cooling (Williamson, 2009).

Solar:

- Install decentralized solar-powered air conditioning ('solar cooling'), since energy production of PV units is usually high during heat waves (increased irradiation outweighs high temperatures) to cut demand peaks during heat waves (cf. Ebinger, et al, 2011).

Standards for demand (energy efficiency)

- Set standards for summer proof of buildings (minimization of cooling loads by building related measures like shading devices, thermal storage or ground cooling).
- Set standards for energy efficiency of air conditioning devices.
- Set regulation for air conditioned office buildings to install PV ('solar cooling').
- Set standards for energy efficiency for water pumping (needed for additional irrigation).
- Set up regulation for energy cuts during meteorological extreme events/periods (Ebinger, et al, 2011).

5.2 Potential of the market for enhancing the EU's resilience to climate change

For standards, the smart grid initiative would be one major possibility to introduce new (adapted/climate-resilient) standards.

The classical market based instrument for adaptation in the energy sector is the internal energy market itself as it has the task to accelerate the exchange (transmission and distribution) of energy across the EU. This has to include a safe, secure and stable (and thus also climate-resilient) transmission of energy. To get the internal energy market working and functioning properly, a risk disclosure for energy transmission (i.e. at least a hot-spot mapping of vulnerable transmission infrastructure) is essential.

Further, cooperation with insurance companies seems advisable for awareness campaigns to include climate change considerations in their risk assessments and in determining insurance premiums.

5.3 Building capacities

Transmission

- Foster strong cooperation with the European Transmission Operators via ENTSO-E (mandated by internal energy market directive 2009/72/EC (EC, 2009i)) to climate-proof the transmission network.
- Enhance cooperation of ENTSO-E with small electricity producers to climate-proof the transmission network by better connecting decentralized energy supply facilities to the network.
- Foster the cooperation among the European Electricity Grid Initiative (EEGI), EDSO-SG (the European DSO Association for smart grids), the grids R&D Roadmap 2010-2018 and ENTSO-E's R&D activities towards European smart grid solutions that are not only capable to optimize supply and demand issues but also to allow for emergency switches ('detours for transmission') of the network in case of local/regional disruptions caused by meteorological extreme events.
- Take care for adaptation to be taken into account in further integration of the national networks into a pan-European one i.e. mainstream adaptation into further proceedings of ENTSO, EDSO, ACER, EEGI and the execution of the SET plan.

Supply and Demand

- Set up an EU-wide database of hydropower stations and classify them according to their climate sensitivity (e.g. types: pumped storage, power stations with reservoir, river run-off stations; run-off regime: glacial, nival, pluvial with different vulnerabilities). (cf. proceedings from Austrian research project DSS_KLIM:EN).
- Set up energy-meteorological databases tailoring data needs for the purposes of energy suppliers (e.g. site-specific wind simulations, catchment-specific run-off data, localized solar irradiation data) (cf. Ebinger, et al, 2011).
- Intensify international cooperation in energy policy (cf. SET-Plan) not just with a focus on supply of fossil fuels, but also emphasizing security of energy supply with respect to climate change (the DESERTEC project might serve as nucleus for that).

- Set up overviews of envisaged energy mix 2020 of all EU MS as basis for national climate-proofing and assist EU MS in doing so.

- Explore opportunities to build clusters of energy suppliers (maybe via Eurelectric[341]) that are specialized in certain generation of energy and build European networks for e.g. hydropower, wind and solar suppliers on the vulnerability and opportunities of climate change – this could lead to common approaches for Climate Risk Assessment (CRA) and Management (CRM) for power plants either planned or already operated.

[341] http://www.eurelectric.org/

6 Disaster Risk Reduction

6.1 Technical measures for adaptation

Disaster risk reduction is a well-established field in policy and research, and many technical measures have been developed. For example, the recently published Special Report of IPCC on disaster risk reduction (IPCC, 2012b) contains 140 pages on managing the risks at three levels: local, national and international. Some examples of risk reduction options at the three levels are:

Local level:

- Warning systems
- Land use management: zoning, conservation zones, buffer zones, or land acquisition
- Ecosystem management and restoration: watershed rehabilitation, agro-ecology, and forest landscape restoration
- Post-disaster recovery and reconstruction (preferably in ways that reduce future risk)

National level:

- Early warning systems,
- Health surveillance,
- water supply, sanitation, and drainage systems;
- climate proofing of major infrastructure and enforcement of building codes;
- restoration of degraded ecosystems and nature conservation.

International level:

- strengthen forecasting and warning systems
- emergency response
- diversify agriculture
- promote water conservation
- provide typhoon-resistant housing

6.2 Potential of the market for enhancing the EU's resilience to climate change

Possible joint activities with the private sector are:

- disaster-proofing of investments (climate-proofing investments) on ex ante and ex post conditionality on disaster risk for any investment (in collaboration with DG REGIO);
- innovative financing mechanisms on disaster prevention, taking into account insurance and mainstreaming into forthcoming Green Paper on the prevention and insurance of disasters (in cooperation with DG MARKT).
- insurers can increase awareness and enhance resilience by demanding policy holders to manage their risks. For example, they can make flood-resilient construction mandatory. Insurers can also help small and medium enterprises to adapt to climate change (Dlugolecki, 2009).
- The insurance industry needs to discuss with national governments how to organize flood risk funding: what is public and what is private (Dlugolecki, 2009).
- Large companies are vulnerable to climate change depending on the employment of sophisticated. technologies and the location of their facilities They need to assess climatic risks on a site-specific basis (Dlugolecki, 2009).

A problem with disasters though, is that a disaster is defined as an event that exceeds the normal capacity of emergency services, insurances and private actors to respond. This characteristic may limit the role of insurance companies in disaster response (Dlugolecki, 2009).

6.3 Building capacities

The EU Climate-ADAPT platform[342] and PreventionWeb[343] can build specific synergy to assure that the data and information that will be published at Climate-ADAPT are well disseminated among the CCA and DRR community reached by PreventionWeb and its mailing list.

Still an obstacle for successful cooperation between the DRR and the CCA community is the different terminology. It would be very useful and possibly a prerequisite for stronger DRR-CCA integration to work on a common wording/terminology,

The EC, the Council of Europe, UNISDR and regional platforms such as the European Forum for DRR and their national actors (HFA Focal points, National Platform Coordinators,

[342] http://climate-adapt.eea.europa.eu
[343] www.preventionweb.net

Permanent Correspondents, etc.) should be involved in hosting workshops focusing on specific aspects of CCA and DRR, on a central topic of science/policy interface.

7 Soil

7.1 Technical measures for adaptation

- Soil carbon storage: Peat soils can become a sink for carbon when they are kept in wet conditions; when they are drained, oxidation of peat will increase due to climate change. So the technical option is appropriate water management to preserve peat soils (Kwakernaak, et al, 2010).

- Erosion: commonly used methods to prevent erosion on croplands are contour ploughing (ploughing horizontally), terracing, growing of plants (for example, temporary grasses, permanent crop cover or reforestation), roughening of soil to slow down water flows, wood fibre matting and adding mulch to enhance water absorption by the soil[344]. These well-known practices may become more urgent due to climate change; and vegetation cover may consist of different species.

- Salinization: sustainable water management is the most important option to prevent salinization: no waste of freshwater, no over irrigation. Once the soil has become saline, there are few remedies; although exploring salt tolerant crops is still an option.

- Landslides: May be prevented with proper land management, by taking care of the balance between soil and biotic structures (Restrepo, et al, 2009). In general this will mean reforestation and protection of vegetation on slopes. Other options are not to use steep slopes, drainage ways, natural erosion valleys or slopes with weak soils for building or other human activities.

- Soil sealing: options are to prevent soil sealing (for example, by encouraging development of already used areas such as brownfields; to limit soil sealing (for example, by make hard surfaces permeable with open types of bricks or porous asphalt; or building green roofs); to compensate for soil sealing in other areas (e.g. turning brownfields into parks) (Prokop, et al, 2011).

7.2 Potential of the market for enhancing the EU's resilience to climate change

The private sector is crucial for soil management since most of the land in Europe is private property (EC, 2006a). The majority of the land is owned by farmers. Agriculture is a market that can be stimulated to use soils sustainably. Farmers are especially important for the problems of carbon storage, erosion and salinization.

[344] http://www.landscapeplanet.com/maintenance-1-soil-erosion-prevention.htm, http://www.portlandonline.com/bds/index.cfm?a=101683&c=40879

Other owners are project developers, municipalities and private property owners (industries, governmental services, individual families etc) who can be stimulated to look for ways to cause less soil sealing.

7.3 Building capacities

Capacity building for more sustainable soil management is of crucial importance, considering that soil degradation is already a problem without climate change happening, and considering that most of the land is privately owned. Farmers will be interested in the long term fertility of their land, but may lack the time and resources for sufficient education. Farm advice services under the CAP should address this issue.

For soil sealing the population of stakeholders is different: these are municipalities, project developers, and their activities can be better regulated (Prokop, et al, 2011). For example, spatial planning can direct new developments to already urbanized areas; and when arable land is used, compensation can be demanded.

8 Biodiversity

8.1 Technical measures for adaptation

Climate change highlights the need to manage for the future and adopt an increasingly dynamic approach to the conservation of biodiversity and ecosystem services. Uncertainties surrounding the precise nature of future climate change and its impacts should not delay conservation action. The ability of ecosystems to absorb and recover from change whilst maintaining and increasing biodiversity should be enhanced. In addition to maintaining existing conservation activities, actions to increase ecosystem resilience and accommodate the impacts of climate change on biodiversity and ecosystem services should be considered (Harley & Hodgson, 2008; Smithers, et al, 2008; Silva, et al, 2010):

- Maintain existing conservation activities in protected areas and intervening habitats;
- Reduce sources of stress and harm to biodiversity and ecosystem services not directly linked to climate change;
- Maintain and restore ecosystem function (including at the landscape scale) and, where appropriate and cost effective, relocate and create new habitats;
- Establish buffer zones with ecologically sensitive management regimes around conservation areas;
- Establish networks of interconnected protected areas (terrestrial, freshwater and marine) and intervening habitat (green infrastructure) to increase permeability and aid gene flow;
- Decrease fragmentation and land use intensification, and strengthen ecologically compatible land uses (e.g. agriculture and forestry) that support healthy biodiverse ecosystems and habitat connectivity;
- Plan future conservation areas to ensure that vulnerable species groups and habitats types are protected;
- Consider the role of species translocation and *ex-situ* conservation, especially for threatened species.

Measures to facilitate the movement of species:

- Increase the number of individuals that could disperse and their ability to establish on arrival at sites by enhancing the ecological quality of existing habitats, reducing external impacts (e.g. by establishing buffer zones and controlling pollutant emissions) and managing species populations (e.g. controlling exploitation and impacts of invasive alien species);

- Increase the area of available habitat by restoring degraded habitats and creating new habitat adjacent to existing sites;
- Increase/restore connectivity through landscape-scale conservation measures (e.g. restoring degraded habitats and creating new habitats as 'stepping stones' between existing habitat patches, enhancing the permeability of the wider matrix between habitat patches, and creating habitat corridors to physically link them).

8.2 Potential of the market for enhancing the EU's resilience to climate change

Ecosystem services and their valuation can be linked to a wide range of existing financial tools, such as carbon markets and eco-tourism fees, which attract a wider range of funders, including private finance[345]. These payments, be they government or public, voluntary private or regulation-driven private, can be used to maintain and improve biodiversity and ecosystem services that support climate change adaptation across all sectors that make use of land and natural resources. Ecosystem-based approaches to climate change adaptation and mitigation can offer cost-effective alternatives to technological solutions, while delivering multiple benefits beyond biodiversity conservation.

8.3 Building capacities

Adaptation policy across all sectors and Member States needs to be built on a foundation of healthy and resilient ecosystems. However, different sectors and countries value biodiversity and ecosystem services from the perspective of their own economic, societal and cultural needs and values, with their use of land, water resources and the marine environment often conflicting with the integrity of natural systems. Successful adaptation requires that the conservation of biodiversity and ecosystem services is fully integrated with other land and water management and economic activities. To build capacities and ensure cross-sectoral and cross-border knowledge transfer, it is necessary to (Harley & Hodgson, 2008; Smithers, et al, 2008):

- Strengthen existing relationships and build new partnerships between stakeholders, sectors and Member States;
- Ensure that adaptation policy and practice are integrated across sectors and borders;
- Communicate best practice and exchange information on successful adaptation between stakeholders, sectors and Member States.

[345] http://ec.europa.eu/environment/integration/research/newsalert/pdf/20si.pdf

9 Health

9.1 Technical measures for adaptation

It is important to modernise surveillance with trans-European early warning systems and to install preventive measures, including those focusing on high-risk groups (e.g. elderly, children, pregnant woman) in the population. The EU can capitalise on its science base to build the necessary interdisciplinary linkages – particularly across epidemiology, ecology and molecular biology with the social sciences – to address the current fragmentation in knowledge (recommended by EASAC (2010).

The research study, Mapping Climate Change Vulnerabilities to Infectious Diseases in Europe (Semenza, et al, 2012a), identified shortcomings in institutional capacities to manage climate change vulnerability, which should be addressed in upcoming impact, vulnerability, and adaptation assessments. Based on a survey of all European National infectious disease experts responsible for climate change impacts in their country, institutional improvements are needed for ongoing surveillance programs (83%), collaboration with the veterinary sector (69%), management of animal disease outbreaks (66%), national monitoring and control of climate-sensitive infectious diseases (64%), health services during an infectious disease outbreak (61%), and diagnostic support during an epidemic (54%).

ECDC is in the process of building a resource (The European Environment and Epidemiology Network) for monitoring environmental and climatic precursors of infectious disease outbreaks (Semenza, 2009). The E3 Network aims to integrate and synthesise environmental and epidemiologic information, enabling disease surveillance systems to incorporate and analyse environmental precursors to disease outbreaks, thus preparing public health to meet the challenges of climate change.

The existing infectious disease surveillance systems should be improved specifically for chikungunya fever, dengue fever, Rift Valley fever, Lyme disease, tick-borne encephalitis (TBE), Vibrio spp. (except V. cholera O1 and O139) and visceral leishmaniasis (Lindgren, 2012).

9.2 Potential of the market for enhancing the EU's resilience to climate change

- Opportunities of science in market developments, e.g. vaccine and medication developments (CEHAPIS, 2012, DRAFT),
- Investment in the development of health knowledge provides a return in terms of improvements in health and well-being (CEHAPIS, 2012, DRAFT),
- Macroeconomic effects like health-related productivity of labour force, impact of health and safety measures on the resilience of businesses and public sector activities to disasters (e.g. floods, drought and storms) (CEHAPIS, 2012, DRAFT),

- Proactive research (e.g. on how to influence population behaviour) and health sector action to different sectors will payout in health care savings (CEHAPIS, 2012, DRAFT).
    - The cost of preventive services will vary depending on the measures chosen, and the increased health risk posed by climate change. For example, the cost of preventing water-borne diseases varies whether implementation of water safety plans or promotion of household water treatment is selected. Given that these policies need to be implemented at decentralized level, in all locations where services are currently inadequate to protect individuals from the increased health risks of climate change, these costs vary from moderate to high. Some health sector costs can be recovered from the beneficiaries, in the form of health care user fees or via insurance, and payment of services demanded in the marketplace (CEHAPIS, 2012, DRAFT).

9.3 Building capacities

- Policy leadership, which includes for example advocacy and fund raising, standards, guidelines, surveillance, monitoring and reporting, data compilation and analysis, coordination, declare emergency is needed to deal with the already occurring and coping challenges related to climate change. In general, health policy leadership requires minimal additional resources, as this is already the function of the health sector for which most EU country health ministries are well resourced. (CEHAPIS, 2012, DRAFT).
    - Development of guidance and criteria for case studies could be very helpful to promote national policy making (CEHAPIS, 2012, DRAFT).
    - Develop climate change specific health economic guidelines to ensure robust methods are used (Hutton, 2011) and promote pilot projects in integrating health into adaptation policies and practices.
- Share the economic costs between the EU (e.g. annual budget for research funding) and the Member States (e.g. national health impact assessments, national funding activities) and primary focus might start by addressing particular high potential/impact climate-specific disease burdens (CEHAPIS, 2012, DRAFT).
- Develop and implement national adaptation preparedness and response strategies or action plans with a focus on health (WHO, 2010a) aiming for sustainable health services.
- Information dissemination from trusted institutions can have significant impacts. Evidence from recent outbreaks of infectious disease suggests that care is required in the dissemination about spread and danger of disease (CEHAPIS, 2012, DRAFT).

- Develop the European Information Platform on climate change and health and a European communication strategy (CEHAPIS, 2012, DRAFT).

- Include more information on health and climate change in the EU Climate-ADAPT platform to address the full scale needed of European Member States. This will lead to annual costs of € 250.000, if carried out with the WHO (CEHAPIS, 2012, DRAFT).

- Costs of public information need to be taken into account, especially on messaging, materials for e.g. publications, distribution and transport. Additional positive effects of autonomous and individual actions are possible, like improved health leading to positive effects on production - Awareness campaign involving health institutions, media and other stakeholders (CEHAPIS, 2012, DRAFT).

- Preventive services e.g. promote home water treatment, target high risk groups, improved regulation of piped water supply, indoor spraying, mosquito bed nets, preventive prophylaxis, behavior change and communication, vitamin and mineral supplementation, food fortification, feeding programmes, nutrition education, can be supported (CEHAPIS, 2012, DRAFT).

- For EU countries, the active involvement of non-EU countries in health intelligence will be very important to on the one hand be rapidly informed on new threats and on the other hand to apply joint methodology and tools for cross country comparison. Therefore collaboration with non-EU countries should be strengthened from passive to active sharing mechanisms (CEHAPIS, 2012, DRAFT).

10 Inland water

The forthcoming Commission Communication “blueprint to safeguard Europe’s waters” (EC, 2012m) will propose the following measures also highly relevant to tackle climate change:

- Support to environmental flows through guidance and technical annexes to the WFD
- Support to setting up water allocation mechanisms through guidance and technical annexes to the WFD and support water pricing and water trading.
- Support to drought management through recommendations or an amendment to the WFD or a new directive
- Support natural water retention measures through guidance, a WFD amendment, through rules on CSF funds
- Support water efficiency through performance ratings for buildings or water efficiency requirements
- Reduce leakages by prioritizing CSF funds, through public-private partnership investments, by developing methods to determine the sustainable level of water leakage
- Reducing the barriers to re-using wastewater in agriculture
- Promoting metering by setting criteria for the use of CAP and CSF funds or through amending the WFD
- Guidance on estimating environmental and resource costs of water services
- Improve governance at EU level on water management through introducing peer review process for RBD authorities, introduce legally binding measures or introduce a strong mediation role for the EC

A more detailed list of about 450 technical adaptation (and mitigation) measures that are currently included in the first set of River Basin Management plans is available at Nõges, et al. (2010).

11 Marine and coastal zones

DG CLIMA will support the legal proposal for a Directive of the EU Parliament and of the Council on establishing a framework for Maritime Planning and Coastal Management. The proposal sets the objective of considering climate change adaptation when achieving the Directives overall objective of securing sustainable economic growth of marine and coastal economies.

The development of an inventory of adaptation measure is subject of services contract “ENV.D.2/SER/2012/0037 - Sharing of best practices on Integrated Coastal Zone Management (ICZM), in a context of adaptation to climate change in coastal areas”. First results are expected for 2013.

12 Food security

12.1 Technical measures for adaptation

Cf. adaptation measures for agriculture (Annex 7, section 1).

12.2 Potential of the market for enhancing the EU's resilience to climate change

Water pricing in the agricultural sector

Agriculture is one of the biggest water users in the EU. So water prices in the agricultural sector represent a strong market instrument in this sector. Prices usually reflect i) the amount of money charged for the direct abstraction of water from ground or surface water sources (abstraction tax or fee) or ii) as a charge or tariff for water supply services (abstraction, treatment, transport). It is important to distinguish between water provided and self-supply (abstraction).

Pricing mechanism for practices of self-supply (abstraction)

Self-supply for agricultural purposes (irrigation in particular) is widespread in the EU, often through groundwater abstraction. According to the research, agricultural use (Greece, Malta, Spain, Cyprus, Hungary and the Netherlands) or irrigation (Estonia, Slovakia and Finland) specifically are exempted from abstraction taxes, meaning that the costs of water abstraction are limited to the private on-farm costs and no water price is charged (Bogaert, et al, 2012).

The majority of EU Member States have installed water abstraction taxes / fees for direct water abstractions:

- In Belgium, France, the Netherlands, United Kingdom, Czech Republic, Germany, Finland and Ireland, the tax is payable above a defined threshold. These threshold values are rather low in most countries except for the Netherlands where agriculture is indirectly exempted with thresholds of e.g. 40.000 m³ per year.

- No minimum abstraction quantity stated for Denmark, Italy, Lithuania, Portugal, Bulgaria and Slovenia. It is however unclear if the tax applies to the agricultural sector or for irrigation purposes in all these countries.

Most Member States have installed a flat volumetric tariff based on the quantity of the abstracted and/or permitted volume. Most Member States then further differentiate between groundwater and surface water abstractions (except e.g. Slovenia where the same fee has been installed). In Romania, direct abstractions from groundwater sources are not allowed for irrigation.

Some Member States have developed differentiated tariff systems where the total price depends on more parameters (for example season, area). Generally, there appears to be a lack of incentive elements in the pricing of direct abstractions. Some Member States allow exemptions for agricultural water use or irrigation specifically, also in water stressed areas e.g. in Southern Europe.

Pricing mechanisms for the provision of water (irrigation)

Similar to the water price for direct abstractions, there is a large heterogenity of tariff systems for the provision of water for irrigation or to farmers in general. Public supply services or collective (irrigation) systems set water charges or tariffs in order to recover (a share of) their supply and water management costs. For Europe in general however, as for OECD countries, a common conclusion across countries is that irrigators have been, and still are, heavily subsidised, primarily in terms of insufficient capital cost-recovery (OECD, 2010b). According to the same source, Environmental and Resource Costs (ERC) are hardly paid for by irrigators.

(Flat) volumetric charges are generally applied in Cyprus and Luxembourg. These schemes are based on actual consumption. Some collective systems in Greece, Spain and Italy apply volumetric tariffs, but this is a clear minority. Water must be metered before it can be charged volumetrically. Metering is often obliged for permit holders, though limited evidence on the actual implementation and control at the farm level could be identified. Mixed tariffs are commonly used for the provision of water to farmers. These charges combine area or crop based flat-rate with a volumetric element and are also called two-tiered or two-part tariffs (ENTEC, 2010). According to the results of the OECD questionnaire Austria, Czech Republic, Finland (livestock and dairy farming), Germany, Ireland, Poland and Spain are using mixed tariffs for water supply for agricultural use. No further details on the systems are available there. In Belgium (Flanders), volumetric block tariffs are in place. These (decreasing) block tariffs are combined with a small fixed charge based on diameter of the pipe.

Despite the absence of incentives for sustainable water use resulting from area-based charges, the mechanism is still widely applied for irrigation water use in the EU. An irrigator is then charged according to the area irrigated, the crop cultivated or a combination of the two. Many southern European Member States (Spain, Greece, Italy, France, Malta and to a lesser extent Cyprus) still rely on this pricing mechanism. Area rates can be based on land registry area, irrigated area or a differentiated charge per crop area. The level of the charge still significantly differs between and within Member States.

It can be concluded that there are significant variations in water charges for farmers not only across countries, but also between regions and different water basins within regions. This applies for both the structure of the tariffs and the level of the water price.

13 Other social issues

13.1 Technical measures for adaptation

General

- Technical measures for adaptation for most of the social policy focus areas are relevant insofar as they ensure supply of essential services that are covered within different sectors.
- The options outlined in the subchapters Gender, Ageing population and Social protection, are not technical measures per se, however, they are social measures tightly interlinked with the planning, development, construction, use and maintenance of the technical adaptation measures.

Migration

- Strengthening technical protection measures in migration source countries and assist people in their adaptation (including technical measures such as flood protection, land reclamation, early warning-systems, engineering for more productive land, etc.)

Gender

- Ensure equal opportunities for all genders to participate in the planning, development and set-up of technical adaptation measures, also providing equally fair remuneration for all genders, as well as provide assistance to lessening gender-specific burdens (e.g. by providing child care facilities for working mothers and single parents).

Ageing population

- The design of technical adaptation measures needs to take into account the special needs of the different age groups to be equally accessible and beneficial for all generations.
- Equal job opportunities and salary equality should be provided for suited professionals of all ages in the "green jobs" pool arising from the demand for technical adaptation measures.

Social protection

- The access to and use of technical adaptation measures should be made financially affordable to poor social groups, if necessary by providing financial assistance or concessions.
- The needs of population groups with physical and psychological disabilities need to be considered in the design of technical adaptation measures to ensure benefits to these especially vulnerable population groups. Furthermore, consideration needs to

be given when planning proactive adaptation, whether these population groups would require special technical measures and assistance additional to what needs to be provided to general population.

13.2 Potential of the market for enhancing the EU's resilience to climate change

- Ensuring equal access to insurance and adaptation finance to vulnerable groups.
- Tackling of the private market potential in improving the social realities in Europe through corporate social responsibility initiatives.

13.3 Building capacities

In all social policy areas awareness of social impacts of climate change needs to be raised among the policy-makers on both EU and Member State levels, down to regional and local levels. This includes facilitation of interdisciplinary dialogues, mutual capacity building, shared strategic policy planning processes, exchange of best practices and continuous research and development of integrated policy-making methods.

Annex 8 – Critical knowledge gaps per policy area/sector

1 Agriculture, Rural development

Policy area: Agriculture, Rural development			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	▪ Climatic model limitations ▪ Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing. There is a huge variation in prediction of higher or lower rainfall between climate models (correctly reflecting the uncertainty). Given a soil and a climate, a single crop yield model is poor at predicting yields over the whole of Europe and for climate changes particularly for the full range of crops. Partly it is the need to take account of variety changes and diseases. The target needs to be correct relative expected yields between situations. There is a lack of grass yield models to	MACSUR

Policy area: Agriculture, Rural development			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		predict the yield of grass available to a grazing animal given soil type and depth and climate (altitude) and the associated profitability of grazing livestock enterprises to predict land use Need methods to predict long-term agricultural land use selected by farmers in southern Europe given soil and climate at a location, where the choice is more determined by infrastructure (water) and market.	
Impacts	Environmental Impacts	There is a needed to analyse: i. the impact of extreme events; ii. The impact of climate change on other crops than cereals; and iii. The impact on pasture and livestock production;	
	Social Impacts	Impacts on EU´s Food security and how climate change in the rest of the world can affect European agricultural markets could be better assessed, in particular via changes in food prices, price volatility, or trade patterns; There is a lack of consideration of the impact	Recommendation which launched a Joint Programming Initiative on ‘Agriculture, food security and climate change’, bringing together 20 European countries (see http://www.faccejpi.com/).

Policy area: Agriculture, Rural development			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		of population increase, particularly across the world, on EU food security.	
	Economic Impacts	Comprehensive assessments of the costs of climate change on agriculture in Europe are missing, as well as of the costs and benefits of adaptation	
	Limits in modelling the impacts	Models are often not holistic: increase forestry, increase arable land used for biodiversity, produce bioenergy crops, reduce inputs to crops, reduce ruminants, increase self-sufficiency - cannot all be achieved at the same time.	
Adaptation	▪ Lack of available adaptation benchmark measures ▪ lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness)	The role of innovation in agriculture should also be better considered, as it will influence farmers' adaptive capacity. Additional analysis is needed on the expected changes in farmers' practices in the context of the CAP reform, and in particular on the expected co-benefits from 'greening' the CAP or further decoupling support to farmers.	Parallel on-going study by DG Climate on CAP and Cohesion led by IEEP. Results will be ready first half of 2012

Policy area: Agriculture, Rural development			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures ▪ Residual damages after adaptation measures ▪ Factors determining the adaptive capacity		

2 Disaster Risk Reduction

Policy area: Disaster Risk Reduction			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	▪ Climatic model limitations ▪ Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing	
Impacts	Environmental Impacts		
	Social Impacts		
	Economic Impacts		
	Limits in modelling the impacts		

Policy area: Disaster Risk Reduction			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Adaptation	▪ Lack of available adaptation benchmark measures ▪ Lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures ▪ Residual damages after adaptation measures ▪ Factors determining the adaptive capacity		

3 Forestry

Policy area: Forestry			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	- Climatic model limitations - Uncertainties related to emission scenarios - Missing physical understanding - Land use developments - Changes in demographic development - Changes in technology and technological development - Economic developments - Migrations developments	The role of European forests in the carbon cycle is reasonably understood, probably with the exception of C soil dynamics. However, to what degree management can influence the carbon cycle, under climate change, and how it affects other goods and services e.g. biodiversity remains an important field of research Quantitative data to describe the environmental, ecological and social effects of climate change on the forestry sector are very site-specific due to ecological and socio cultural diversity. Therefore it is difficult to give a generalized overview of these effects at EU-level. Regional studies focussing at the impacts, adaptive capacity and adaptation are necessary. In particular, in the Mediterranean area the counterbalance between water availability and C sequestration is a major gap. Research is particularly required on the identification of vulnerable areas and sites regarding changes of conditions in the future.	

Policy area: Forestry			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		▪ Climatic model limitations ▪ Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing	
Impacts	Environmental Impacts	Only limited broad scale knowledge is available regarding the prediction of impacts of climate change on European forests. The knowledge base needs to be broadened through monitoring, experiments and modelling, including for high temperature increase and water reduction scenarios. Knowledge and predictions need to be regionally specific, and need to address the relation with fire incidence, forest management, and other local factors (including predominant type of forest production, disturbances, pests, genetic resources etc.), and address other values of the forest (e.g. water and biodiversity, social and economic). The knowledge needs to be made available locally, and especially connected to outreach activities. Interactions among the different risks should be taken	

Policy area: Forestry			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		into account, in particular in vulnerable areas. Literature on (northward) spread of pests and diseases is virtually absent. It is unknown if increased growth due to higher CO_2 levels will outweigh drought effects in forest productivity.	
	Social Impacts	The interaction between climate change and land use changes will have a large impact on humans, but it is largely unknown.	
	Economic Impacts	Costs of climate change are not known	
	Limits in modelling the impacts	Information on land use changes, soil characteristics and even ecophysiological responses of species to climate changes are not available for all regions and ecosystems.	
Adaptation	▪ Lack of available adaptation benchmark measures ▪ lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl.	The socio-economic adaptation capacity related to the forest sector has rarely been analysed in the EU. On adaptation of the ecosystem to climate change, and required responses from forest management, specific research is limited so far, partly because the local impacts of	

Policy area: Forestry			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	effectiveness) - Lack of knowledge on the impact of adaptation measures on society and economy - Lack of cost information - Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures - Residual damages after adaptation measures - Factors determining the adaptive capacity	climate change remain uncertain. Adaptation measures need to be designed, tested, and experimented	

4 Biodiversity

Policy area: Biodiversity			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	Note that climate model uncertainty will increase with sophistication and downscaling. Develop range of likely land-cover, land-use and resource-use scenarios. ▪ Climatic model limitations ▪ Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing Take account of the dispersal patterns of species in the evaluation of distribution shifts in response to global drivers	Yes. SCALES Securing the Conservation of biodiversity across Administrative Levels and spatial, temporal, and Ecological Scales (2009–2015, FP7) has a relevant objective to: Assess and model the socio-economic driving forces and resulting environmental pressures (habitat loss and fragmentation, changing climate, disturbance) affecting Europe across scales. This may lead to the development of relevant scenarios. Yes. CLIMSAVE through its Integrated Assessment Platform (IAP) is simulating impacts and vulnerability in Europe and Scotland including linkages and feedbacks between key sectors under different climate and socio-economic scenarios (the latter having been especially developed within the project). Results available late 2012.
Impacts	Environmental Impacts	Monitor direct impacts of climate change and, where possible, indirect impacts (e.g. those associated with land use change) Note that research has focused on direct	Yes. CLIMSAVE is developing an Integrated Assessment Platform (IAP) for Europe and Scotland which includes indirect effects from urban, agriculture, forestry, water and coastal sectors (and their

Policy area: Biodiversity			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		impacts of climate change on biodiversity, particularly changes in species' phenology, distribution and future climate space. However, less is known about impacts on changes in species abundance, species and trophic interactions, species community composition, ecosystem processes and, hence, ecosystem services. Note that there has been limited research on indirect impacts of climate change on biodiversity (i.e. through changes in socio-economic drivers, working practices, cultural values, policies and use of land and other resources - e.g. A-TEAM, ACCELERATES, RegIS). Such research should be a high priority, given that potential scale, scope and speed of indirect impacts could be more damaging than direct impacts and may occur more rapidly than policy-makers can react. Undertake vulnerability assessments of EU species and habitats (notably those associated with the Natura 2000 network).	environmental, social and economic impacts and adaptations) on biodiversity. There is a need to improve the IAP to include dynamic time steps, country-specific parameterisation and other sectors, such as health. CLIMSAVE is also building on the MACIS review (Berry et al., 2008) of how biodiversity will be affected by adaptation (and some mitigation actions in other sectors). Berry, P.M. et al., 2008 Meta-analysis of adaptation and mitigation measures across the EU25 and their impacts and recommendations how negative impacts can be avoided. Available from http://www.macis-project.net/MACIS-Deliverable-2.2-2.3-Oct.2008.pdf Yes. HABIT-Change[346] Minimisation of and Adaptation to Climate change Impacts on BiodiverSity (2010–2013, Interreg IV B, Central Europe has an overall objective to evaluate, enhance and adapt existing management and conservation strategies in protected sites to respond proactively to likely influences of climate change that threaten habitat integrity and diversity. A monitoring concept is being developed to detect changes caused

[346] http://www.habit-change.eu/

Policy area: Biodiversity			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		Establish possible impacts of invasive alien species. Identify impacts of all sectors on biodiversity. Identify trade-offs between different ecosystem services under different environmental and socio-economic drivers of change across a range of scales.	either by human activity or climate change effects, which may contribute to closing this knowledge gap. It is intended to provide valuable information for administrations of nature protected areas, and will look at strategies for transnational cooperation. No, but opportunity to build upon methods developed by Sajwaj *et al.* (2009) and Harley *et al.* (2010).
	Social Impacts		
	Economic Impacts	Estimate economic value of dependencies of all sectors on biodiversity. Identify opportunities and threats for all sectors of their impacts and dependencies on biodiversity in relation to their ability to adapt to climate change	Yes. EcoSpace[347] – Spatial-Dynamic Modelling of Adaptation Options to Climate Change at the Ecosystem Scale (2010-2015, FP7) may reduce the economic impacts knowledge gap as it will look at the application of an ecosystem services approach to analyse adaptation options, the integration of complex ecosystem dynamics and societal impacts, and the spatially explicit modelling of economic benefits supplied by ecosystems.

[347] http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_RCN=11624250

Policy area: Biodiversity			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	Limits in modelling the impacts	The past may not be an analogue of the future. Species distribution data only relates to presence of species not to their absence. Species distribution models should take into account the dispersal ability of species and impacts from land use change scenarios as well as climate change. There is a lack of data on species abundance. It is not possible to assess ‘risk’, as probability that certain states or outcomes that may occur cannot be precisely known. In relation to ‘direct’ impacts of climate change on biodiversity, uncertainty will remain over what will happen to which species, where and by when, inter-specific interactions that will occur, and consequences for habitats, ecological processes and ecosystem services.	No but EMMA[348] –Evolution Meets MAcroecology (2012–2012, FP7) is a project that aims to improve the quality and reliability of species distribution models by bridging the gap between macro-ecological approaches and accumulating evidence of the importance of evolutionary dynamics for species' response to climate change ACCELERATES incorporated dispersal ability and land use change, as well as climate change, in species distribution models (see del Barrio et al., 2006, Environmental Science & Policy, 9: 129-147. CLIMSAVE has incorporated indirect effects from water quantity (inc flooding) and agriculture, but there is a lot of scope to make these links more detailed, which is particularly important at local scales.

[348] http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_RCN=11365954

Policy area: Biodiversity			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		It is not possible to predetermine scope, scale and speed of market forces that will drive land and resource managers to adapt to climate change and result in indirect impacts on biodiversity. Better modelling of indirect effects from other sectors on biodiversity. Better modelling of ecosystem service trade-offs and interactions across scales.	
Adaptation	▪ Lack of available adaptation benchmark measures ▪ Lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do	Undertake an in-depth review of the complete spectrum of EU indicators in relation to the high-level Biodiversity Adaptation Indicator categories (Harley & van Minnen, 2010), and *vice versa*, to identify those relevant by policy area, associated data issues, and where indicators need modification/development. Undertake scenario planning that addresses the range of likely futures in relation to climate and land/resource use, and identify actions that will be beneficial whatever the extent, rate or direction of change. Pilot new approaches through demonstration	Yes – CLIMSAVE explores two adaptation options for biodiversity (i) increasing the size of protected areas (ii) increasing connectivity of protected areas, As well as examining how adaptations in other sectors impact on biodiversity. No, but would build upon Smithers *et al.*, 2012 and related preceding projects Yes. EcoSpace (above) will develop a spatially explicit, dynamic modelling approach for identifying and analysing adaptation strategies for ecosystem management. In particular, the project will develop and

Policy area: Biodiversity			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	exist!) which might help to serve as decision support on setting priority adaptation measures ▪ Residual damages after adaptation measures ▪ Factors determining the adaptive capacity	projects. Assessment of how different adaptation options fair under different scenarios (wind-tunnelling) to highlight the risks, opportunities and dependencies between different options.	apply a general, spatial model to integrate climate change scenarios, ecosystem dynamics, response thresholds, ecosystem services supply and management options.

5 Soil

Policy area: Soil			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	▪ Climatic model limitations ▪ Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing Crop models tend to use very little of the soil information available to model yields and thus ignore root development and the many nutrients available.	
Impacts	Environmental Impacts	A major gap is the lack of understanding and quantification of the impacts of freeze-thaw and drought-rewet events on soil carbon. What is the impact of droughts on erosion and soil cracking? There is a lack of knowledge on the implications of climate-induced changes in	The aim of CARBO-EXTREME (http://www.carbo-extreme.eu/) is to achieve an improved knowledge of the terrestrial carbon cycle in response to climate variability and extremes, to represent and apply this knowledge over Europe with predictive terrestrial carbon cycle modelling, to interpret the model predictions in terms of vulnerability of the terrestrial in particular soil carbon pools and give advice to EU climate and soil protection policies. The project ends 05/2013

Policy area: Soil			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		soil water regime and agronomic timings (planting, harvesting etc) on soil structural degradation and resultant water and pollutant movement to rivers.	
	Social Impacts	Data about the social impacts related to soils and land use are lacking.	
	Economic Impacts	Quantitative data about the costs of climate change related to soils and land use is hardly available.	
	Limits in modelling the impacts		
Adaptation	▪ Lack of available adaptation benchmark measures ▪ lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness)		

Policy area: Soil			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures ▪ Residual damages after adaptation measures ▪ Factors determining the adaptive capacity		

6 Water

Policy area: Water			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	Local data information on water use and flow conditions ▪ Climatic model limitations ▪ Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing --- High-resolution information on current and future extreme precipitation	Yes. CIRCLE-2 MED projects. Results are available at http://www.circle-era.eu/np4/157.html Yes, the ACQWA project should help close some of these gaps. An ACQWA-sponsored paper in the journal "Environmental Science and Policy" (2012) has explored many issues related to data and information gaps in climate-water related issues (Beniston et al., 2012: Obstacles to data access for research related to climate and water: Implications for science and EU policy-making, Env. Sci. & Policy, doi:10.1016/j.envsci.2011.12.002 EUCLIPSE ECLISE
Impacts	Environmental Impacts	Regional occurrence and impacts of floods and droughts Future research is especially needed in	Yes, Interreg IV project "Water scarcity and droughts; coordinated actions in European regions" http://www.watercore.eu/ Results expected by 2013. Yes. CIRCLE-2 MED projects. Results are available at

Policy area: Water			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		terms of water quality (model developments and appropriate measurements). The protection of low flows is seen as the key to achieving “good ecological status”, as required by the WFD, with very limited or no abstraction below Q95. So far, this is an arbitrary threshold, but instead standards should be based on a comparison of observed ecological quality against the degree of alteration to the natural hydrological regime. Models and tools are needed to evaluate adaptation measures quantitatively. What are the feedbacks? There is a need of further research on water-related ecosystem services (monetary and non-monetary). There is a lack of knowledge on the impacts on groundwater systems, especially locally-important aquifers, and river bank filtration (RBF) systems.	http://www.circle-era.eu/np4/157.html

Policy area: Water			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	Social Impacts	Impacts on drinking water supply Research is needed to characterise the relationship in water management between and across governmental, administrative, and private levels (multi-level governance) as a key for policy actions. Considering European, national and sub-national levels for striking a balance between interests, capacities and objectives. Adaptive capacity, together with other related topics such as resilience and coping capacity need a special attention in the further research, however. Costs of floods and droughts Costs of water pollution and damages to aquatic ecosystems	Yes, study by DG ENV “Literature review on the potential climate change effects on drinking water resources across the EU and the identification of priorities among different types of drinking water supplies (ENV.D.1/SER/2011/0037)”. First results expected by 2012.
	Economic Impacts	Better estimates of the economic costs of damage. Improving water governance to reduce risks of rivalries between economic sectors	ACQWA project has the objective of improving knowledge on this, with expected outcomes by mid-2013

Policy area: Water			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	Limits in modelling the impacts	Problems of cross-sectoral data (socio-economic and physical/biological at differing spatio-temporal scales; data formats, etc.) Changes in certain processes most often become vulnerabilities only after passing a certain "tipping point". There is a lack of knowledge on many of these tipping points yet. There is a need for more adequate representation of groundwater systems in hydrological models. There is a need to improve the ability to simulate (and understand) the effects of climate change on river bank filtration (RBF) systems.	
Adaptation	▪ Lack of available adaptation benchmark measures ▪ lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the	Models and tools are needed to evaluate adaptation measures quantitatively. Therefore, research efforts should focus on how to improve the overall performance of one system/region instead of studying the effect of separate measures. This attention should focus especially on the water-energy	Some of the "Impacts" work within the ACQWA project will help provide some concrete results to some of these questions.

Policy area: Water			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures ▪ Residual damages after adaptation measures ▪ Factors determining the adaptive capacity	nexus and on a more systematic mapping of the impact of measures and policies on water management in the agricultural, tourist and domestic sector. Research is needed to analyse conflicts and synergies between different actors and sectors in terms of implementation of adaptation measures. Special attention needs to be paid on further research on scenarios for agriculture-water-energy nexus, as well as on more systematic mapping of the impact of measures and policies in agricultural, tourist and domestic sector on water management. A synchronisation of viewpoints relating to measures is important, i.e. different time-dependent dynamics have to be brought together. For example, long-term projections from climate change impacts, time for project planning and implementation, utilisation, and economic lifetime.	

7 Marine and Coastal zones

Policy area: Marine and Coastal zones			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Uncertainty in downscaling of climate effects to local/regional scales ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	Climate change impacts are certain, but the projections still need to be better understood. For instance there are no sea level projections for the Black Sea. The projections on sea level rise based on the behaviour of polar ice-sheets are still in their infancy. Necessity of better observational data and data access – for improved understanding of on-going changes, to constrain model projections, and for adaptive management Socio-economic change in the coastal zone, including population, economy, land cover in terms of both observations, and credible scenarios	Yes. CIRCLE-2 MED projects. Results are available at http://www.circle-era.eu/np4/157.html ECLISE (regional sea level rise) e.g., Demography projections available from Foresight Migration study (Foresight, 2011)[349]

[349] Foresight, 2011. *Migration and Global Environmental Change*. Final Project Report. Foresight: The Government Office for Science, London, 127pp.

Policy area: Marine and Coastal zones			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		Regional sea level rise estimates still suffer from uncertainties in ice sheet melting and the spatial distribution of SLR Interactions in the food web are hard to predict (e.g. it is unknown how plankton blooms will coincide with growth of larvae and small fish). Climatic model limitations Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing	
Impacts	Environmental Impacts	Lack of information (data), e.g., on historic wetland habitat loss/change	Yes. CIRCLE-2 MED projects. Results are available at http://www.circle-era.eu/np4/157.html
	Social Impacts	Limited ability to quantify future changes in human perception on impacts and adaptation	

Policy area: Marine and Coastal zones			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	Economic Impacts	Limited knowledge about the link between sea temperature increase and fishery and aquaculture. No information (data) on the impact of climate change on employment in coastal regions and maritime sectors (including fishery industry). No assessment of the damage and adaptation costs due to e.g. sea level rise and coastal erosion on port infrastructure and activities. No assessment of the damage and adaptation costs due to increased occurrence of extreme-weather events (e.g. storminess) in coastal areas	
	Limits in modelling the impacts	Uncertainties in impact assessments Limited information (available data) for large scale assessments, e.g., lack of protection data at regional (sub-continental) or European scale Lack of adequate tools to facilitate the appraisal of cross-sectoral adaptation and	

Policy area: Marine and Coastal zones			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		mitigation options, e.g., across multiple water-dependent sectors	
Adaptation	▪ Lack of available adaptation benchmark measures ▪ lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures ▪ Residual damages after adaptation measures	No assessment of the damage and adaptation costs due to increased occurrence of extreme-weather events (e.g. storminess) in coastal areas. Limited ability to characterise in sufficiently appropriate detail the response of coastal systems (and their constituent parts) to climate change drivers and to adaptation initiatives For coasts, adaptation has received more treatment than many sectors, but more detailed assessment are still needed	e.g., The EC-funded FP7 THESEUS project (www.theseusproject.eu

Policy area: Marine and Coastal zones			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	▪ Factors determining the adaptive capacity		

8 Construction/Buildings

Policy area: Constructions/Buildings			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	▪ Climatic model limitations ▪ Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing	
Impacts	Environmental Impacts		
	Social Impacts		
	Economic Impacts	More knowledge is needed on the aggregated cost to buildings from climate change covering all impacts and all Europe, The methods of the ex-ante cost assessments have to be adapted so that	

Policy area: Constructions/Buildings			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		they can take long term use and energy costs into account. A transparent use of up to date climate scenarios must be encouraged,	
	Limits in modelling the impacts		
Adaptation	▪ Lack of available adaptation benchmark measures ▪ lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures	Additional research on possible impacts is needed to be able to develop effective adaptation measures for construction and buildings (including design, building type, water storage and communication infrastructure). The focus shall be placed on indicators and guidance on how to climate-proof (e.g. via a brief climate assessment as a part of the building approval) development's and buildings, from an interdisciplinary perspective, involving inter alia urban planners, urban transport planners, building and water authorities and construction companies.	

Policy area: Constructions/Buildings			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	▪ Residual damages after adaptation measures ▪ Factors determining the adaptive capacity		

9 Transport

Policy area: Transport			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	Vulnerability assessment for different transport modes on European scale for 2030/2050/2100 are lacking. In particular European wide vulnerability hot spot analyses by transport mode Climate change adaptation and aviation needs to be further assessed in detail ▪ Climatic model limitations ▪ Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing 1) Climatic model limitations are always debatable, yet the recent observations	Some results in terms of future vulnerability assessments can be expect by the following projects. Nevertheless, it is not clear if they provide a European overview for various transport modes. ▪ EWENT350: Extreme weather events on EU networks of transport (2010-2012; FP7) Vulnerability, hazard and risk assessment separately for each EU-27 country and transport mode (road, railway, aviation, inland water transportation and short sea shipping) are produced in EWENT project. Results can be found from http://ewent.vtt.fi/deliverables.htm from D5 / Deliverable D5.1 and Risk Panorama ▪ WEATHER[351]: Weather Extremes – Impacts on Transport Systems and Hazards for European Regions (2010-2012; FP7) ▪ ECCONET[352]: Effects of climate change on the

[350] http://ewent.vtt.fi/
[351] http://www.weather-project.eu/weather/index.php

Policy area: Transport			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		support global warming hypothesis. Despite many uncertainties related to the models the warming hypothesis can be taken for granted. The challenge is from thereon to simulate how the warming will otherwise impact our climate and weather conditions, e.g. with respect to extreme weather phenomena. 2) Technological development will not impact in time to change the climatological course, especially thinking of market penetration of these technologies. Otherwise their impact could be radical but the external effects can provide unpleasant surprises (e.g. battery waste of electric vehicles). 3) The unbundling of former public services, such as road, rail and runway maintenance through competitive contracts will create situations where responses to extreme weather events	inland waterway networks (2010-2012; FP7) 1) EWENT's use of six different regional climate models shows the diversity of their results when projections are made to 2040-2070. The mean values of the models suggest some changes, of which the warming effect seems to clearly dominate. Other effects remain much more uncertain, although some indication of extreme phenomena increase is well within expected changes. The warming effect will to some extent increase the likelihood of thunderstorms and phenomena associated with these (wind, rain). See EWENT reports: http://ewent.vtt.fi/Deliverables/D2/ewent_d2%201_18082011.pdf http://ewent.vtt.fi/Deliverables/D3/EWENT_D34_v12_20120209.pdf as well as published reports: http://www.vtt.fi/inf/pdf/workingpapers/2011/W168.pdf https://helda.helsinki.fi/handle/10138/28592

352 http://www.ecconet.eu/

Policy area: Transport			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		can be delayed as the roles and responsibilities are divided through contractual arrangements where extreme events might not be covered. Performance type contracts can mitigate part of this problem. 4) Impacts of migration and ageing of population are not known and they will be of greater magnitude in the future due to demographic change in Europe.	2) EWENT did not touch this question. 3) EWENT project identified the challenges raised by new public management where outsourcing and resource optimisation can lead to suboptimal situations. However, no detailed answers were given / found.
Impacts	Environmental Impacts		
	Social Impacts	1) The preference – if prioritisation is exercised - for either public transport system or private car oriented system in mitigation and adaptation strategies will have an effect on the well-being of citizens with different income levels, i.e. social classes. Public transport emphasising mitigation and adaptation will keep lower income citizens slightly better off. 2) The warming may have drastic impacts in South Europe, if faced in fast pace	EWENT briefly discusses the prioritisation strategies but is unable to provide detailed answers or solutions (such do not exist, of course).

Policy area: Transport			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		and intensely.	
	Economic Impacts	Aggregated cost to transport systems from CC covering all impacts and all Europe First results of economic impacts on transport system are available, but the productive impacts are not known, which result from various impacts of climate change in different economies and different transport modes (aviation – wind, road – ice etc.).	Economic impacts (damage costs) of extreme weather events in the **past** have been assessed (e.g. EWENT, WEATHER) EWENT's cost analysis covered all modes as well as time, accident and infrastructure costs for EU-27. Also the future costs are projected. http://www.vtt.fi/inf/pdf/technology/2012/T36.pdf
	Limits in modelling the impacts	The impact models are limited according to a) scope, b) method, and c) data availability. Framing and scoping of impacts (which are included, which excluded, how far to go with externalities, etc., etc.) will have the most radical impact on results and the results depend on aforementioned criteria. Also the methodological choices (how to value, how to scale values for different countries, etc.) affect results. Finally, the data availability builds a significant barrier and challenge for	EWENT has provided some answers to all the mentioned points and provides probably a benchmark for further studies which are needed of course when more precise analysis with different scopes are needed. EWENT report on costs of extreme weather to European transport system available at: http://www.vtt.fi/inf/pdf/technology/2012/T36.pdf

Policy area: Transport			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		analysis. For example, very little is known about the fact how much extreme weather actually impacts on accidents, time delays and infrastructure costs.	
Adaptation	▪ Lack of available adaptation benchmark measures ▪ lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures ▪ Residual damages after adaptation measures	Costing of adaptation options, e.g. retrofitting railway bridges, usage of more heat resistant rail material, changes in stress free temperature standards for rails, retrofitting train air conditioning systems, climate-proofing of road bridges, etc. Different Member States face different impacts of climate change so there is a need to address what is the total cost (impact) of climate change to transport system in a given country and then assessing the potential ways in which adaptation can reduce the impacts and at what cost. In other words, some of EWENT's results should be downscaled to member state level and analysed with higher resolution, if such an analysis is aspired. Evaluating adaptation benefits and cost of	Effectiveness of different management and policy options will be assessed within EWENT; partly within WEATHER. Results can be expected by summer 2012. EWENT's assessment of effectiveness will be based on cost analysis of extreme events and discuss not only technical choices but how different stakeholders will face their roles and responsibilities in measures of adaptation and mitigation. Deliverables are almost complete (99%) and will be issued in July 2012. Partly topic of ongoing research project (cf. above), but yet no results available No relevant EU-wide research on the way

Policy area: Transport			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	▪ Factors determining the adaptive capacity	residual damage after adaptation Advance development of detection and communication salutation with ICT technology (e.g. damage prevention through early warning) More technical knowledge is particularly necessary to be able to suggest concrete amendments in standards and regulation	

10 Energy

Policy area: Energy			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	Energy demand: future demand peaks during extreme periods (e.g. heat waves, cold spells): Here we have a bunch of publications e.g. on heating and cooling demand in certain regions, but not yet any critical thresholds in terms of system failures (i.e. demand peaks that might cause black outs) Assessing cooling demand for urban agglomerations ('heat island effect') Energy supply: Climate sensitivity of renewable energy supply (in the following order of importance: water, wind, solar/PV, biomass) and thermal power plants including nuclear (e.g. CARNOT efficiency) Mapping hot spots of vulnerable transmission infrastructure (with regard to capacity during climate-triggered demand as well as with	No relevant EU-wide research on the way Numerous regional studies available Is normally done on-site, but there is no European-wide assessment/projection for 'energy climatology' ENTSO and EDSO-smart grids might have studies underway (should be clarified soon), but yet nothing is published ECLISE

Policy area: Energy			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		regard to its physical resistance towards extreme events) Climatic model limitations Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing High resolution information on future precipitation and river discharge for adaptation of hydropower systems and operations. Cooling capacity of energy plants.	
Impacts	Environmental Impacts		
	Social Impacts		
	Economic Impacts	Costing inaction (damages, impacts) and adaptation as well as the net benefits of adaptation Assessing indirect costs of complete energy	no

Policy area: Energy

Category	Subcategrory	Detailed knowledge gaps	Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available
		system failure ('black out')	
	Limits in modelling the impacts		
Adaptation	▪ Lack of available adaptation benchmark measures ▪ lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures ▪ Residual damages after adaptation measures	Priorisation of measures to be set primarily on the basis of cost/benefit analysis: Costing of adaptation options, e.g. hardening of transmission infrastructure, climate proofing (future) energy mix by ensuring sufficient supply of renewable energy sources or keeping (old) power station at stand-by, cutting-off climate-triggered demand peaks,... + Evaluating adaptation benefits and cost of residual damage after adaptation Technical know-how must be incorporated to be able to suggest concrete amendments in standards and regulations	No and must thus be done together with key players

Policy area: Energy			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	▪ Factors determining the adaptive capacity		

11 Health

Policy area: Health			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	Lack of consistent and comparable epidemiological studies to provide the basis for a more robust set of temperature-mortality exposure-response functions applicable across Europe (Watkiss et al., 2009). Health effects of mitigation and adaptation in other sectors ▪ Climatic model limitations ▪ Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing	No relevant EU-wide research on the way
Impacts	Environmental Impacts	Possible interactions between climate and air pollution, particularly the potential rates of ground level formation of ozone in summer and health effects Other analysis of the urban effects of heat related impacts (e.g. taking account of the	Partly covered by EUROSUN, (results available since 2010) and ICEPURE (results by 2012) Partly from PHEWE (results available);

Policy area: Health			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		urban heat island effects which are not fully represented within the models), and additional impacts that may result from longer periods of extreme high temperatures (heat waves) (Watkiss et al., 2009), Further analyses of other food borne disease in addition to salmonella	
	Social Impacts	Hot-spot-regions (e.g. specific cities) should be identified in order to plan adaptation in areas where it is most needed Current national and subnational capacities for addressing the health and environmental risks (WHO 2010a), The identification of vulnerable groups and subregions	No relevant EU-wide research on the way Start to enhance capacities within CLIMATE-TRAP project
	Economic Impacts	Costing of the risks (e.g. through water and vector borne diseases, extremes other than heat waves) and opportunities, including the health costs of inaction (WHO 2010a, Hutton	Information from PESETA are available and will be updated by summer 2012

Policy area: Health			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		2011),	
	Limits in modelling the impacts		
Adaptation	▪ Lack of available adaptation benchmark measures ▪ Lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures		

Policy area: Health			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	▪ Residual damages after adaptation measures ▪ Factors determining the adaptive capacity		

12 Social issues

Policy area: Social issues			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	▪ Climatic model limitations ▪ Missing physical understanding Feedback of clouds in climate change. This currently limits our ability to predict climate change due to anthropogenic forcing	
Impacts	Environmental Impacts		
	Social Impacts	Social impacts of climate change in Europe are little understood. Gaps in social impacts of the respective areas are outlined in all other tables. Additionally to those, there is a need to: improve the knowledge on how vulnerable are the most vulnerable and what are the	FP7 FUTURESOC project will assess the likely consequences of future climate change on future human wellbeing (has global and developing world focus).

Policy area: Social issues			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		inequalities in adaptive capacity in Europe by carrying out adaptive capacity evaluations and comparisons of the different groups of society in the EU assess the climate change impacts on poverty rates in Europe Carry out Europe-wide assessment of the relationship between social deprivation and exposure to physical climate change impacts (e.g. living in flood-prone areas, areas more vulnerable to heat-waves, water scarcity, etc.) better understand the social consequences of internal and external environmental migration on the host communities (e.g. in relation to access and quality to resources, public services, impacts on access to jobs and levels on communal tensions and conflicts) evaluate the economic cost aspect of food security in Europe analyse the quality of green jobs created through climate action and how that compares to the quality of jobs lost due to	http://cordis.europa.eu/projects/rcn/90065_en.html Results expected in early 2014. CLIMSAVE (FP7) is looking at adaptive capacity and coping capacity at the European level Census 2011 data will provide insight into the levels of homelessness in Europe. Will be published by EUROSTAT.

Policy area: Social issues			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		climate change itself or related climate policies. better understand the climate change impacts on access to leisure, natural sites and spiritual sites and the subsequent impacts on mental and physical health, well-being and social harmony improve knowledge on the climate change impacts on one of the most deprived and vulnerable group of the society, the homeless	
	Economic Impacts	Analysis of economic effects of social impacts of climate change, including: ▪ Economic evaluation of increased crime levels due to higher temperatures ▪ Assessment of the cost to society of forced inter-EU relocation of people due to decreased habitability of certain areas and due to adjustments to job market restructuration ▪ Analysis of the budgetary pressures and economy benefits of increased	

Policy area: Social issues			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
		intra-EU and external migration ▪ The effects on economy of disruptions or reductions caused by climate change to access and quality of health care, education and leisure	
	Limits in modelling the impacts		
Adaptation	▪ Lack of available adaptation benchmark measures ▪ lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools which might help to serve as decision support on setting priority adaptation measures in	Including: ▪ Lack of knowledge on the effectiveness of adaptation measures addressing social impacts of climate change ▪ Lack of understanding of the necessary adjustments in education systems, offer and curricula to increase the adaptive capacity of people ▪ Lack of full understanding of how and to what extent the current social policies of EU, both on national and EU level, influence the adaptive capacity of Europeans ▪ Lack of guidance on the development of strategies to strengthen the social side of adaptive capacity	Climsave: adaptive capacity index based on five forms of capital including social and human capital. D 4.1, D 5.1 www.climsave.eu

Policy area: Social issues			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	regard to social adaptation ▪ Residual damages after adaptation measures ▪ Importance of human and social capital	▪ Lack of knowledge on costs of implementing measures aiming to improve the social determinants of adaptive capacity ▪ Lack of knowledge on importance of human and social capital for coping and adaptive capacity ▪ Lack of data on indicators for human and social capital	

13 Jobs/Employment

Policy area: Jobs/Employment			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments	Jobs and employment markets respond to a number of stimuli including but not limited to technology development, economic development and transformation, demographics, fiscal and employment polices, urbanisation etc. The effects of climate change and mitigation/adaptation policies interplay with these stimuli in multiple ways making it difficult to tease out what the responses of climate (policy) drivers are or will be.	Sectoral studies are available on a regional scale, with different death and depth. Impacts of climate change/policy drivers are better explored for tourism, water supply and sanitation and to some extent agriculture.
Impacts	Environmental Impacts	Secondary impacts of deterioration of ecosystem services on employment and labour demand are neglected.	
	Social Impacts	Impacts of climate change on social organisation and interaction of social structures, and the cumulative impacts of both on jobs and employment	

Policy area: Jobs/Employment			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	Economic Impacts	Economic transformation and labour intensity (especially in long term) of resource efficient economies	
	Limits in modelling the impacts		
Adaptation	▪ Lack of available adaptation benchmark measures ▪ Lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures ▪ Residual damages after adaptation	▪ Only a few studies are available that address the long term, economy-wide effects of climate adaptation policies on labour market including the employment potential and quality. ▪ The tendency of shifting the tax burden from welfare-negative taxes, (e.g. on labour) to welfare-positive taxes, (e.g. on environmentally damaging activities). ▪ Requested skills and quality of employment in medium- to long-term ▪ Indirect and induced (higher order) effects of environmental policies.	

Policy area: Jobs/Employment			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	measures ▪ Factors determining the adaptive capacity		

14 Private market

Policy area: Private market			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments		
Impacts	Environmental Impacts		
	Social Impacts		
	Economic Impacts		
	Limits in modelling the impacts		

Policy area: Private market			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Adaptation	▪ Lack of available adaptation benchmark measures ▪ Lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures ▪ Residual damages after adaptation measures ▪ Factors determining the adaptive capacity		

15 Further knowledge gaps that should be considered

General knowledge gaps			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Climatic driver or social economic driver	▪ Climatic model limitations ▪ Uncertainties related to emission scenarios ▪ Missing physical understanding ▪ Land use developments ▪ Changes in demographic development ▪ Changes in technology and technological development ▪ Economic developments ▪ Migrations developments ▪ Decision-making processes	Lack of knowledge about how adaptation decision-making processes deal with and incorporate uncertainties related with climatic, impacts and socio-economic information	Yes. CIRCLE-2 (FP7) is promoting a Joint Initiative on 'Climate Uncertainties'[353] that will produce a special issue on a peer-review journal and a final publication for decision-makers during 2013.
Impacts	Environmental Impacts Sustainable development goals	Lack of analysis on how different scenarios (e.g. high-end) and tipping points can have an effect on long term sustainability of complex processes both at EU-wide as well as at national-to-local levels.	

353 http://www.circle-era.eu/np4/P_UNCERT.html

General knowledge gaps			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
	Social Impacts Sustainable development goals	Lack of analysis on how different scenarios (e.g. high-end) and tipping points can have an effect on long term sustainability of complex processes both at EU-wide as well as at national-to-local levels.	
	Economic Impacts Sustainable development goals	Lack of analysis on how different scenarios (e.g. high-end) and tipping points can have an effect on long term sustainability of complex processes both at EU-wide as well as at national-to-local levels.	
	Limits in modelling the impacts	Too little integration. By dealing with sector-by-sector approaches, one often loses “the bigger picture”, where impacts from one sector can amplify or attenuate impacts in another sector, in highly non-linear ways. If science persists in addressing impacts only by sector, we are unlikely to make much headway in our understanding of the complexities of cross-sectoral impacts.	

General knowledge gaps			
Category	**Subcategrory**	**Detailed knowledge gaps**	**Ongoing research activity to close the gap (yes/no). If yes, add reference and state when results are expected to be available**
Adaptation	▪ Lack of available adaptation benchmark measures ▪ Lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve. ▪ Lack of knowledge on the impact of the measure on risk reduction (incl. effectiveness) ▪ Lack of knowledge on the impact of adaptation measures on society and economy ▪ Lack of cost information ▪ Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures ▪ Residual damages after adaptation measures ▪ Factors determining the adaptive capacity ▪ Decision-making processes	Lack of knowledge about how adaptation decision-making processes deal with and incorporate uncertainties related with climatic, impacts and socio-economic information. Lack of understanding (and tools) to 'test' on-going efforts on adaptation (e.g. policies, options and measures) against current limits and drivers of adaptation and high-end scenarios (climatic and societal).	Yes. CIRCLE-2 (FP7) is promoting a Joint Initiative on 'Climate Uncertainties'[354] that will produce a special issue on a peer-review journal and a final publication for decision-makers during 2013. The ACQWA project addresses some of these issues. Most results will be available before the completion of the project in September, 2013

[354] http://www.circle-era.eu/np4/P_UNCERT.html

16 Comparision of critical knowledge gaps

The following assesses critical knowledge gaps identified in this report with the knowledge gaps outlined in the Commission staff working document (EC, 2008j).

16.1 Climatic drivers, natural processes and socio economic drivers

The Commission staff working document (EC, 2008j) identified already in 2008 that there was a lack of regional climate change information. It also highlighted that the confidence in projections is not the same for all the variables, space-scale and periods. In terms of physical understanding, the document noted the need of a better understanding of coupled system processes and their feedbacks, but also the need to strengthen climate observations and maintain long term records in order to understand key processes and their feedbacks. A better understanding of the carbon cycle (sources and sinks but also ocean carbon fluxes) is also noted as needed. Finally, it added the need to better understand the links between the Arctic Ocean and the climate system.

The above mentioned issues have been addressed by further research, but still climatic model limitations (e.g. huge variation in predictions between different climate models, lack of local data, lack of models for certain regions i.e. modeling sea level rise in the Black Sea) and a lack of understanding natural processes (e.g. anthropogenic forcing, the carbon cycle, lack of epidemiological studies) exists. The AQWA, CIRCLE-2 MOUNTain[355] and CIRCLE-2 MED[356] projects should help close some gaps in the field of lack of data and information in the water sector. The CARBO-EXTREME project should improve knowledge about carbon-cycle. ECLISE should help for the coastal areas.

The 2008 staff working document (EC, 2008j) also already highlighted the need to better understand vulnerability in the field of land use. This issue still remains and there is a need to identify more precisely the vulnerable areas and the vulnerability of the different sectors (e.g. different transport modes, climate sensitivity of renewable energy supply).

In 2008, the Commission staff working document (EC, 2008j) highlighted the need to integrate medium and long-term uncertainties in climate change projections. Currently the CIRCLE-2 (FP7) project promotes a joint initiative on climate uncertainties[357] that will produce a special issue peer-review journal and a final publication for decision-makers during 2013.

While the classical sequential approach for assessing impacts, vulnerability and adaptation needs was basically (economically, demographically, technologically and policy triggered) SRES scenarios -> radiative forcing -> climate projections (GCMs/RCMs) -> impacts (I), vulnerability (V) and adaptation (A) needs, the community puts forward a parallel approach

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355 http://www.circle-era.eu/np4/CARAmountain1.html
356 http://www.circle-med.net/
357 http://www.circle-era.eu/np4/CARAUncertainties.html

for setting up new scenarios for IVA research, which is considering a much stronger integration of socio-economic pathways and Earth system modeling and – by leaving the sequential approach – allowing feedbacks between them. With respect to IVA, this means that impacts and vulnerabilities (and the adaptation needs thereof) are regarded as a result of climate change but – to a much stronger degree than before – also to so-called Shared Socio-economic Pathways (SSPs) Shared Policy Assumptions (SPAs) which are determining exposure, sensitivity and adaptive capacity – and thus future vulnerabilities.

This much more dynamic view of vulnerability will also help to better address potential costs of climate change, since it opens a range of plausible cost sensitivities – determined by climate change, but also by exposure of climate-sensitive assets and economic activities.

Thus, much more attention should be focused on socio-economic pathways and policies (with and without adaptation) that determine which kind of Europe (which exposures, which sensitivities and adaptive capacities) will be hit by climate change in the forthcoming decades.

The socio-economic aspects

Our future world will be impacted by the direct effects of climate change but also by the evolution of the socio-economic context. It is thus important to have a good knowledge of the socio-economic scenarios to evaluate their impacts on the different sectors.

The commission staff working document (EC, 2008j) mentioned already in 2008 the need to take account of the socio-economic scenarios in the assessment of climate change impacts for the sectors of agriculture and forestry, and health.

Presently some general gaps in this knowledge have been identified, namely: i) Land use developments, ii) Changes in demographic development, iii) Changes in technology and technological development, iv) Economic developments, v)Migrations developments.

More precise in the sector of agriculture, there is a need to find methods to predict long term agricultural land use, what is also important to evaluate the impacts on Biodiversity. There is also missing information about population, economy and land cover in the sector of coastal zone. The transport sector could be impacted by migration and ageing of population but these impacts are currently not known. It could also be impacted by the competitive contracts for infrastructure maintenance what can lead to a delay in responses to extreme climate events. To solve this issue, the effects of performance type contracts should be studied. In the sector of energy, there is a gap in the field of energy demand (demand peaks during extreme periods and cooling demand for urban agglomerations). The sector of job/employment is impacted by a multitude of elements (e.g. technology development, economic development, demographics) what makes it very difficult to have relevant scenarios. To finish, the way climate uncertainties will be taken into account will also have an impact on the different sectors and thus need to be better known.

16.2 Impacts

Environmental Impacts

In 2008, the Commission document (EC, 2008j) already mentioned the need to better address the impacts of climate change on water quality, but also the need of more efforts on the assessment of impacts in the area of health (results of the not yet published CEHAPIS study (CEHAPIS, 2012, DRAFT) will partly close the knowledge gaps, but also identifies areas where more research and effort is needed). Also the need to have more information about floods and droughts impacts in the water sector and about the impacts of extreme events was already identified in the staff working document. It also identified the need to better understand the impacts of ocean acidification.

Over the last years some progress has been made in particular in relation to floods and droughts (e.g. by PESETA, CLIMWATADAPT, LISFLOOD), however some knowledge gaps remain. Especially the improvement of existing early warning systems for heat waves, floods, droughts and forest fires can be an added value and advantage in knowledge, reducing impacts from extreme events and weather pattern.

The first one is the lack of information about the impacts of some scenarios (extreme events for agriculture, droughts for soil, floods and droughts for water. The second one is the lack of information about the impacts of the different scenarios on a specific point (e.g. soil water regime or agronomic timings in the soil sector or water quality in the sector of water).

The Commission staff working document identified already in 2008 that for agriculture and forestry in order to plan future management requirements a better estimation of impacts at finer spatial scales and shorter timeframes are needed. According to the survey conducted there is still a lack of broad scale knowledge in the forest sector in particular about the regional or local level.

There is limited information about indirect impacts (e.g. biodiversity, health sector (traumata after flood events, reduced working ability, workdays and productivity as a result of more severe weather events) or secondary impacts (e.g. deterioration of ecosystem has secondary impacts on employments and labor demand). The CLIMSAVE project is trying to address the issue of the indirect impacts of the different sectors on Biodiversity.

Most important knowledge gaps are climate change impacts on ecosystem services. This is indeed an important problem to be addressed, since its dimension is socio-economic, too. Implications range from the water sector, infrastructure safety to air quality and human health. Integration and coupling of land use and climate change scenarios would provide better insights into future vulnerable ecosystem hot spots.

Social Impacts

Research on social impacts is addressed in various ways in the 2008 Commission Staff working document indicating that research its early stage. The document also mentioned the need to better quantify the impacts of climate change in vulnerable world regions. Over the last years some progress has been made, but there are still some major gaps:

- There is a lack of information on how EU can be affected by the rest of the world (e.g. impacts of climate change and increase of population on food security).
- Social impacts in the fields of soil, drinking water supply and land use change are also missing.
- There is also a need to identify vulnerable groups and sub-regions, evaluate the inequality in adaptive capacities and how vulnerable are the most vulnerable, assess the impacts on poverty rates.
- Adaptation measures themselves have unequal costs and benefits, which might increase social or regional disparities and which need to be further addressed

Some of the issues mentioned are currently subjects to tendering.

Economic Impacts

The Commission staff working document already identified the need of more information about costs of climate change and adaptation, and about inter-sector linkages and identified that this information would be obtained by the development of high resolution climate change impacts studies and large scale quantitative modeling.

Even if in this area some projects have been carried out (e.g. ClimateCost) there is still missing information on disaggregated and sectoral costs of inaction (direct damage costs and indirect costs due to disturbed/interrupted economic activities of system failures). Thus, costs and benefits of adaptation can’t be assessed prior to the assessment of costs of inaction. Elaboration on cost-sensitive climate triggers in all relevant sectors, a better assessment on the exposure of assets and economic activities, their projection and impacts of extreme events as most important cost triggers are urgently needed and would complement Top-Down Integrated Assessment as delivered now by ClimateCosts for some important sectors.

The costs of damages in the sector of water are currently studied by the ACQWA project (expected outcomes by mid-2013). In the sector of transport, they are studied by the project EWENT, and in the sector of Health by the project PESETA (updated in 2012) and CEHAPIS (2012, DRAFT).

It is also needed to better estimate the economic value of interdependencies between the different sectors. This issue is currently studied by the EcoSpace project.

In addition, the Commission staff working document also mentioned the lack of information about the role of the financial flows in the insurance sector, the distribution of damage and repair costs between the different parties affected. It recommended focusing research on coastal protection and monitoring activities. This issue is currently studied by THESEUS (final results for Nov 2013)[358].

Cross sectoral impacts

The Commission staff working document also mentions the need to develop multi-sectorial analysis. With ESPON Climate and the PESETA some progress has been made to develop such multi-sectorial analysis. However, still only a few sectors can be covered at the same time. A major issue in this context is a lack of data availability (e.g. soil characteristics not available for all regions and ecosystems, cross-sectoral data). The CLIMSAVE project could help closing some gaps as it develops linkages between key sectors under different climate and socio-economic scenarios (results available late 2012).

16.3 Adaptation

Adaptation: Knowledge gaps related to adaptation and related measures can be related to:

- Lack of available adaptation benchmark measures
- Lack of practical process knowledge on how to start adaptation processes, where to set priorities and whom to involve.
- Lack of knowledge on the potential impacts of measures on risk reduction (incl. effectiveness)
- Lack of knowledge on the impact of adaptation measures on society and economy
- Lack of cost information for adaptation measures
- Lack of assessment tools (guidelines do exist!) which might help to serve as decision support on setting priority adaptation measures
- Assessment of residual damages after adaptation
- Factors determining the adaptive capacity

The 2008 commission staff working document (EC, 2008j) already mentioned the need to evaluate the impacts and costs and benefits of adaptation measures and to encourage innovation. Some progress has been made, but the quantitative evaluation of adaptation options remains a challenge.

There is a need to better consider the risks, opportunities and dependencies between different options, to have a better knowledge of the impacts of some measures and policies on different sectors (currently studied by the EcoSpace project, and coastal technology options via the THESEUS project), to evaluate adaptation costs and benefits and the costs of

[358] http://www.theseusproject.eu/

residual damages, and to take into account the changes in practices (e.g. CAP reform for the farmers).

There is also a lack of knowledge on long-term adaptation in some sectors and on how adaptation decision-making processes deal with climate change uncertainties. More emphasis is needed in field of climate change adaptation decision-making processes related to adaptation strategies (ongoing work of CIRCLE-2 in the field of adaptation strategies[359] especially related to transnational knowledge sharing and collaboration) and multilevel governance, avoiding mal-adaptation (cf. ongoing work in the RESPONSES and MEDIATION projects). The adaptation process often stops after the generation of good ideas. The conflict between short term and long term goals is identified as the main barrier to implementation of adaptation options. For peoples pensions, long term institutions like saving and pension funds have been invented, but for adapting land use to future climate threats and for securing natural resources for the long term, institutions are still lacking. Also, many laws and regulations miss the capacity to deal with a dynamic and uncertain environment. Research is needed how adaptive management can be supported by the regulatory system and how the adaptation process can be monitored and evaluated.

[359] http://www.circle-era.eu/np4/CARAadaptationstrategies.html

Annex 9 – Integrating adaptation into EU policies

Table 85: Integrating adaptation into EU policies – current state of relevant policy actions and strategies (Source: Report from the Commission to the European Parliament and the Council; Progress towards achieving the Kyoto objectives, Table 15 (EC, 2012n))

Policy issues	Relevant policy actions and strategies
1) Health and social policies	
Develop guidelines and surveillance mechanisms on the health impacts of climate change by 2011	The EU has explored with the WHO and EU agencies means of ensuring adequate surveillance and control of the impact of climate change on health, such as epidemiological surveillance, the control of communicable diseases and the effects of extreme events. The Parma Ministerial Declaration brings new priorities in the environment and health process with one pillar dedicated on protecting health and environment from climate change. The Health Programme of the EU has been the key financing mechanism for projects, setting up networks and initiatives to support the work of the Health Security Committee. Funding of projects to address adaptation to climate change has been foreseen under the work plans for 2009-2011, including: PHASE will provide the public health sector with prevention guidelines to promote resilience and reduce health risk associated to extreme weather events, their environmental consequences and development of tools to select vulnerable subgroups most at risk to specific extreme weather events; CLIMATE TRAP: Impact assessment, surveillance and preparedness guidelines, training, will play a pivotal role in assisting the process of strengthening the implementation of existing warning systems and plans and in strengthening the Health Sector in preparedness in facing the health impact of climate change; HIALINE aims at evaluating the effects of climate diversity and change on airborne allergen exposure, and to implement an outdoor allergen early warning network; EUROSUN aims at monitoring ultra violet exposure in the EU and its effects on incidence of skin cancers and cataracts; EUROMOMO aims at developing and operating a coordinated approach to real-time mortality monitoring across Europe such as pandemic influenza, emerging infections as well as environmental conditions with an impact on public health, i.e. heat waves and cold spells; CEHAPIS: Impact assessment, policy options and indicators on health and climate change aims at providing an evaluation of policy option impacts for successful health adaptation to climate change and monitor trends and policies over time; EDEN (Emerging diseases in a changing European environment) contributed to this effort. Atopica: Atopic diseases in changing climate, land use and air quality. EFSA is developing scientific reports on vector-borne diseases and has already issued a general overview of the geographical distribution of tick species and an update on the role of tick vectors in the epidemiology of African Swine Fever and Crimean-Congo Hemorrhagic Fever in Eurasia.
Development of a new Animal Disease Information System (ADIS)	The development of ADIS will provide better and more comparable epidemiological data to risk managers, enabling them to better identify, evaluate and respond to changing or emerging disease situations.
Develop a new EU Plant Health Law addressing	The EU Plant Health Regime (PHR) concerns pests and diseases that impact on plant production in agriculture, forestry and the natural environment. The regime´s

Policy issues	Relevant policy actions and strategies
phytosanitary consequences of climate change	objective is to contribute through plant health to sustainable production. The evaluation of the PHR has been the starting point for a fundamental review of the regime for addressing the phytosanitary consequences of globalisation and climate change. A legal proposal for the new EU plant health law is foreseen by 2012. CLIMPEST is a project about the establishment of harmful organism due to climate change.
Assess the impacts of climate change and adaptation policies on employment and on the well-being of vulnerable social groups	The social dimension of adaptation policies needs to be pursued within existing EU processes in the social and employment fields, and all social partners need to be involved. ECDC (European Centre for Disease Prevention and Control) is mapping EU vulnerability on climate change and has developed a Handbook for National Vulnerability, Impact, and Adaptation Assessments. Cf. also PHASE project.
Step up existing animal disease surveillance and control systems	The ECDC – as well as EFSA - are conducting many projects which contribute to the strengthening of the knowledge base on climate change health impacts, vulnerability and adaptation, such as setting up of the European Environment and Epidemiology Network, development of a Handbook for National Vulnerability, Impact, and Adaptation Assessments and risk assessment for the water-, food- and vector-borne diseases. Within the frame of the EU Animal Health Strategy (2007-2013) a Commission proposal for a new Animal Health Law is scheduled for adoption by the end of 2012. It will consolidate the exhaustive existing animal health legislation and put more emphasis on preventive measures such as surveillance activities and biosecurity. The rules will be flexible allowing for adaptation of disease control measures to changes in disease patterns including those resulting from climate change.
2) Agriculture and forests	
Measures for adaptation and water management in rural development national strategies and programmes for 2007-2013	The EU regulation on rural development 2007-2013 contains explicit references to the need to anticipate the likely effects of climate change on agriculture. After the "Health check" of the CAP in 2008, additional funds to measures that target new challenges faced by agriculture, such as climate change and the need for better water management, were made available. The revised RD programmes have been approved by the Commission within 6 months and the additional resources used as from 2009. A share of 15% of the new funds made available has been allocated to mitigation and adaptation measures. In addition, some measures aiming at improving water management (22% of funds allocated) and biodiversity (34%) will have some positive impact on adaptation.
Integration of adaptation into 3 strands of rural development, adequate support for sustainable production, contribution of the CAP to the efficient use of water in agriculture	A number of actions with adaptation potential have been programmed by Member States and regions. Almost 70% of the RDP include actions to renovate irrigation equipment to improve the efficiency of water use. Half of the RDP supports waste water treatment installations on farms and water saving production techniques. Around 40% of the programmes also include the development/improvement of farm water storage capacity. Due to the Health Check better water management objectives have been included in the scope of cross compliance with a new GAEC issue relating to protection and management of water.
Examine the capacity of	The Farm Advisory System (FAS) is an important tool to improve farm

Policy issues	Relevant policy actions and strategies
the Farm Advisory System to reinforce training, knowledge and adoption of new technologies that facilitate adaptation	management. It requires national authorities to offer advice to farmers, at least for the rules included into cross compliance. Member States may use the FAS for advising farmers on the respect of standards going beyond cross compliance, e.g., water commitments under agri-environmental measures. RDP provides the possibility to co-finance the setting-up of the FAS and its use by farmers. The Commission proposal for the CAP post-2013 foresees to extend its scope to climate-related aspects, such as information on prospective impacts of climate change in the relevant regions, impact on GHG emissions of the relevant farming practices and on the contribution of the agricultural sector to mitigation.
Update forestry strategy and launch debate on options for an EU approach on forest protection and forest information systems	The 1998 EU Forestry Strategy established a framework for forest-related actions in support of sustainable forest management (SFM) which is currently being revised. A Green Paper on forest protection and forest information (preparing forests for climate change) was adopted in 2010 with a view to strengthening EU action on forest protection and forest information systems; currently a follow-up of the Green Paper on forest protection and information is ongoing. Two ongoing studies will have links to adaptation: "Disturbance of EU forests by biotic agents" and "Influences of EU forests on weather patterns". The EU's rural development policy for the period 2007–2013 provides a basis for the full integration of forestry. In the context of the review of Rural Development Policy post 2013 the further development of the forestry measures will be examined. A new EU Forest Strategy is expected to be adopted in Spring 2013.
European Consortium for Modelling of Air Pollution and Climate Strategy	Linkage of many sectoral models. Baseline and Forecasts on non CO_2 emissions. Providing scientific and economic analyses for the revision of the EU Thematic Strategy on Air and the European Climate Change Programme (ECCP).
LULUCF Accounting tool	Modelling tool for international negotiations on LULUCF CO_2 sink/source.
An analysis of potential and costs of LULUCF use by EU Member States	This study is aimed at developing projections for LULUCF emissions by 2020 and 2030, covering forests, agricultural soils and wetlands. A next step will include policy scenarios deviating from BAU, taking account of the Copenhagen agreement and further policy options to be implemented at EU level. Finally, potential and costs for reducing net emissions from LULUCF will be estimated at Member State level.
Options for including LULUCF in the Community reduction commitment and instruments for increasing GHG mitigation efforts in the LULUCF and agriculture sectors	This study assessed and proposed policy options for including LULUCF in the Community reduction commitment. It presented four options for inclusion and three options for accounting of these options, altogether 12 possible scenarios. However, the accounting scenario was developed prior to the Durban decision on LLULUCF accounting rules, which more or less made several accounting options obsolete. The policy options included no action, inclusion of LULUCF in the Effort Sharing Framework and a separate framework with or without a target. Using this input among other, the Commission developed its proposal for LULUCF accounting rules which are currently in co-decision procedure.
Evaluation of livestock sector's contribution to EU greenhouse gas emissions - phase II	COMPLETED - The objective of the GGELS project was to provide an estimate of the net emissions of GHGs and ammonia (NH3) from livestock sector in the EU-27 according to animal species, animal products and livestock systems following a food chain approach. The project provides a quantification of GHG and NH3 emissions both ex-post for the year 2004 and ex-ante according to the latest CAPRI projections for the year 2020. A new FP7-funded research project AnimalChange

Policy issues	Relevant policy actions and strategies
	will be working on mitigation and adaptation options for livestock.
CC mitigation potential of EU Farm	To better understand the GHG profile of common farm practices in the EU, and how these practices fit into the major farming systems. Understand how changes to these practices can improve the GHG profile. To propose a tentative model for a whole-farm assessment of GHG profile and to understand the potential synergies between the different practices discussed.
Assessing Agriculture Vulnerabilities to design Efficient Measures for Adaptation to Climate Change - AVEMAC	COMPLETED - The objective of the study is to provide an improved estimate of the main vulnerabilities of the European crop productions in the main producing regions in the short and medium term (2020, 2030), assess the possible impacts (at macro level and at micro level using farm type) and adaptation potential in order to define the more efficient adaptation measures to be recommended. The JRC-IES will continue developing expertise to assess potential impacts of climate change on agriculture by developing the current modelling platform. The full report (Donatelli, et al, 2012) is available at: http://ec.europa.eu/agriculture/analysis/external/avemac/index_en.htm.
Identification and Elaboration of Methodology for classification and costing of projects/programmes for adaptation to climate change	To conduct an extensive review of available information on costs of adaptation within the EU (and when appropriate neighbouring countries) and a review of existing methodologies for identifying these costs. To assess and compare such methodologies identifying the methodological and data challenges associated with calculating the expenditure on adaptation. To propose a set of criteria for classifying different projects, programs or budget lines and calculating the expenditure and propose a system to estimate the "adaptation share" for projects not exclusively intended for adaptation. The scope of adaptation options does not include small-scale private autonomous adaptation measures (e.g. farm-level adaptation practices, air conditioning).
Inventory of certification schemes for agricultural products and foodstuffs marketed in the EU member states	COMPLETED - A new inventory compiled (in 2010) counted 441 schemes for agricultural products and foodstuffs marketed in the EU. It provides a broad picture of existing schemes in the EU-27. Voluntary certification schemes for agricultural products provide assurance that certain aspects of the product or its production method, as laid down in a specification, have been observed. (http://ec.europa.eu/agriculture/quality/certification/inventory/inventory-data-aggregations_en.pdf
3) Biodiversity, ecosystems and water	
Explore the possibilities to improve policies and develop measures which address biodiversity loss and climate change in an integrated manner to fully exploit co-benefits and avoid ecosystem feedbacks that accelerate global warming	Climate change was one of the four key policy areas identified in the Communication on "Halting the loss of Biodiversity by 2010 – and beyond" and the Biodiversity Action Plan includes the objective "to support biodiversity adaptation to climate change". The EU Biodiversity Strategy up to 2020 reiterates that biodiversity loss and climate change are intrinsically linked and states that "Ecosystem-based approaches to climate change mitigation and adaptation can offer cost-effective alternatives to technological solutions, while delivering multiple benefits beyond biodiversity conservation". Green Infrastructure is seen as an essential means of integrating biodiversity and climate change adaptation, a Green Paper on Green Infrastructure shall be presented in autumn 2012.

Policy issues	Relevant policy actions and strategies
Develop guidelines and a set of tools (guidance and exchange of best practices) by the end of 2009 to ensure that the River Basin Management Plans (RBMP) are climate-proofed	COMPLETED - The Water Framework Directive provides European countries with a common basis to address water challenges posed by climate change. In particular, the Directive's river basin approach to water management – centred on the establishment and review of river basin management plans every six years, including a Programme of Measures to bring waters to good status, establishes a mechanism to prepare for and adapt to climate change. The first river basin management plans were required by 22 December 2009. The ClimWatAdapt study, completed in 2011 (Flörke, et al, 2011) looked into how key sectors, i.e. agriculture, industry, tourism, can adapt in order to counterbalance the effects of floods, water scarcity, droughts and changes in water quantity and aims to provide a sound basis for the assessment of vulnerability and of adaptation measures in the context of water policy, but also other environmental and sectoral policies.
Ensure that climate change is taken into account in the implementation of the Floods Directive.	Directive 2007/60/EC on the assessment and management of flood risks (EC, 2007f) requires Member States to assess if water courses and coast lines are at risk from flooding, then to map flood risks and to take adequate and coordinated measures to reduce the risk. Work is progressing on a catalogue of good adaptation measures and on the improvement of the information on past floods. Most Member States reported their preliminary flood risk assessments by March 2010. Member States must by 2013 develop flood hazard maps and flood risk maps for areas where potential significant flood risk exists.
Assess the need for further measures to enhance water efficiency in agriculture, households and buildings	The 2007 Communication on addressing the challenge of water scarcity and drought in the EU (EC, 2007h) set out a number of policy options for addressing water scarcity, including the important roles played by water pricing and land use planning in incentivising efficient water use. The Policy Review for Water Scarcity and Droughts will be integrated into the "Blueprint to safeguard European waters" (EC, 2012m) to be presented by the Commission by November 2012. A set of completed studies helped bridging important knowledge gaps as regards water scarcity & droughts in the EU and assessed what measures are needed to improve water efficiency in various sectors: agriculture, buildings, water distribution networks, product labelling.
Explore the potential for policies and measures to boost ecosystem storage capacity for water in Europe	The Water Framework Directive (WFD) (EC, 2000c) will contribute strongly to improving and maintaining ecosystems and works in order to deliver guidance on the relationship between inland river waterways and Natura 2000, selecting best-practice examples for integrated management, combining nature protection, climate change adaptation and transport navigation measures are ongoing. A service contract for the analysis of costs, benefits and climate proofing of natural water retention measures (Stella Consulting, 2012), as part of the "green infrastructure" approach for flood and water scarcity & droughts prevention was completed in April 2012. Modelling of the land use, hydrological, and economic impacts of the natural water retention measures is undertaken by JRC in the context of the impact assessment of the Blueprint Communication, which will address the need and potential options for unlocking the potential of these measures.
Draft guidelines by 2010 on dealing with the impact of climate change on the management of Natura	As the establishment phase is nearing completion the focus is increasingly on the management and restoration of sites in the network, and on its overall ecological coherence. A study on Biodiversity and Climate Change in relation to Natura 2000 (Bertzky, et al, 2010) was conducted. The guidelines on Natura 2000 and climate change will assess current knowledge of risk from climate change to species and

Policy issues	Relevant policy actions and strategies
2000 sites	habitats of EU conservation concern protected by the network, as well setting out on approaches to reduce, mitigate and adapt to such impacts, both within the sites and at broader network level. They will also look at the benefits arising from management and restoration of Natura 2000 sites to climate change mitigation and adaptation. Further assisting guidelines will help dealing with the impact of climate change on the management of Natura 2000. Scheduled issuing autumn 2012.
Explore the potential for policies and measures to boost soil storage capacity for both carbon and water in Erope	The fight against soil degradation and, in particular, the loss of soil organic matter and soil biodiversity, is dealt with via the Soil Thematic Strategy (STS) and the proposed Soil Framework Directive (SFD). CLIMSOIL shows the inter-relationship between soil and climate change and SOCO assessed a range of soil conservation practices, including from the perspective of keeping organic matter levels. Possible ways of strengthening and supporting soil measures within the framework of the CAP will be addressed as part of the post-2013 reform. Guidelines have been produced to provide competent authorities in Member States as well as stakeholders with a useful tool containing relevant information which could be used from awareness raising to planning, from implementing mitigation measures to providing a check-list for development projects. It is based on the approach consisting of limiting, mitigating, and compensating the effects of soil sealing.
4) Coastal and marine areas	
Ensure that adaptation in coastal and marine areas is taken into account in the framework of the Integrated Maritime Policy, in the implementation of the Marine Strategy Framework Directive and in the reform of the Common Fisheries Policy.	When addressing maritime activities from a cross-sectorial perspective, the EU Integrated Maritime Policy provides a comprehensive framework for better understanding the impacts of climate change with coastal and marine areas and to integrate measures on climate change adaptation at EU level. The EU Integrated Maritime Policy is implemented at the level of marine regions and specific Sea Basin strategies have already been developed for the Baltic, the Mediterranean and the Atlantic Sea Basin. The Marine Strategy Framework Directive will facilitate adaptation to climate change by ensuring that climate change considerations are incorporated into Member States' marine strategies while providing a mechanism for regular updating of the marine strategies to take account of new information. The Common Fisheries Policy is currently subjected to a root-and-branch overhaul with a view, in particular, to rebuild stocks to levels capable to produce maximum sustainable yield. Increasing the size of fish stocks and their productivity will make them less vulnerable to external factors like climate change. A more coherent and integrated approach to coastal and maritime planning and management through integrated coastal zone management (ICZM) and maritime spatial planning (MSP) will benefit adaptation in coastal and marine areas. The ICZM Recommendation (2002/413/EC) provides for Member States to take a strategic approach to the management of their coastal zones. The proposal for an EU framework on ICZM and MSP is expected towards the end of 2012.
Develop European guidelines on adaptation in coastal and marine areas	The Commission is committed to developing guidelines on best practice in coastal and marine areas which will contribute to ensuring a coordinated and integrated approach to climate change adaptation in these areas. This could be addressed as part of the EU Communication on a strategy on adaptation to climate change to be adopted in 2013. The guidance will take account of and build on existing studies,

Policy issues	Relevant policy actions and strategies
	research and relevant policy initiatives, in particular the Community strategy on disaster prevention, the Floods directive, the EUrosion study and the study on the Costs of coastal defence and adaptation. OURCOAST is an initiative to support and implement sustainable coastal planning and management. It includes a database of coastal planning and management practices, with a key focus on adaptation to risks and climate change.
5) Production systems and physical infrastructure	
Take account of climate change impacts in the Strategic Energy Review process	The EU's agenda for 2020 has set out the essential first steps in the transition to a high-efficiency, low-carbon energy system. The EU needs to develop a vision for 2050 and a policy agenda for 2030. The fundamental technological shifts involved in decarbonising the EU electricity supply, ending oil dependence in transport, low energy and positive power buildings, a smart interconnected electricity network will only happen with a coordinated agenda for research and technological development, regulation, investment and infrastructure development. In addition, the transition to a high efficiency, low-carbon energy system needs to be promoted not only in Europe but worldwide. The Energy Roadmap towards 2050 was adopted in December 2011.
Develop methodologies for climate-proofing infrastructure projects and consider how these could be incorporated into the TEN-T and TEN-E guidelines and guidance on investments under Cohesion policy in the current period	The ' Green Paper on a secure, sustainable and competitive energy network' (EC, 2008i) was designed to encourage a reflection on how energy networks should develop in the coming years, amongst others, to reflect the new climate change and energy policy. The Commission is currently working on a comprehensive energy infrastructure package. Elements such as increasing resilience of energy transmission infrastructure to cope with extreme weather condition, positioning of over-head power lines, impacts of climate change on LNG infrastructure will be examined in the TEN-E revision process. The TEN-T programme consists of hundreds of projects whose ultimate purpose is to ensure the cohesion, interconnection and interoperability of the trans-European transport network, as well as access to it.
Explore the possibility of making climate impact assessment a condition for public and private investment	In the discussions on the future Cohesion Policy the inclusion of climate proofing as a horizontal condition for all investments is ongoing. Including climate proofing provisions in EU co-financed programmes could be exemplary for national and local public investments and for private sector take-up.
Assess the feasibility of incorporating climate impacts into construction standards, such as Eurocodes	The Eurocodes are currently taken up by Member States and several have already fully replaced their previous national codes with the Eurocodes. In principle Member States are supposed to have the Eurocodes in place since the beginning of 2011.
Develop guidelines by 2011 to ensure that climate impacts are taken into account in the EIA and SEA Directives	The Commission has decided to develop practical guidance and recommendations for integrating climate change and biodiversity into EIA/SEA procedures to assist EIA/SEA practitioners in taking full advantage of EIA and SEA in achieving EU climate change and biodiversity goals. It is expected that the Commission Guidance should be made publicly available by the end of 2012.

Annex 10 – Social impacts of climate change

Social domain impacted	Climate change impact	Specific risk / opportunity
Conflicts, crime	Heat waves	▪ Risk of social unrest, crime, violence, and excessive consumption of alcohol
	Increased heat and drought	▪ Risk of fire from natural causes and arson leading to loss of property, distress and damage to health. ▪ Increasing occurrence of conflicts over water-use
	Floods and storms	▪ Increased risk of social unrest and violence due to disputes over allocation of resources (e.g. water / housing) ▪ Potential for looting ▪ Increased rates of stress and anxiety negatively contributing to social harmony
	Internal and external migration	▪ Risk of intercommunal disputes and violence due to inward migration of people fleeing from climate change impacts in their home countries or vulnerable regions within the country
	Decreased occurrence of cold weather	▪ Reduction in cold-related burglaries
Social cohesion, inclusion	Floods, storms, sea level rise, coastal erosion followed by internal or external migration.	▪ Forced dislocation from family and community through evacuation or migration away from vulnerable areas causing psychological stress and deteriorating pre-existing community structures ▪ Increase of a vulnerable group
	Heat	▪ Increased social isolation
	All impacts	▪ Potential for increased sense of community in face of common risks
Access to and quality of water and sewerage	Reduced rainfall in summer/ droughts	▪ Increased water stress
	Heat	▪ Threat to access to potable water due to potential groundwater contamination, reduced efficiency of treatment, dissolved oxygen depletion and algal blooms in rivers and reservoirs
	Sea level rise	▪ Threat to access to potable water due to saline intrusion of freshwater aquifers
	Heavy rainfall and	▪ Threat to access to potable water from contamination of

Social domain impacted	Climate change impact	Specific risk / opportunity
	flooding	water supplies and disruption of treatment works and supply infrastructure
	Heavy rainfall and flooding	▪ Risk of sewer overflows
	All impacts	▪ Employment and business opportunities in civil engineering and water conservation / efficiency
Food security	Water stress, spread of pests and diseases, soil erosion, waterlogging of soil and storm damage	▪ Reduced availability and increased cost of vegetables and fruit (grown in Europe and imported from abroad ▪ Higher food prices lead to further adverse impacts on well-being, health and education.
	Extreme heat, heavy rainfall and flooding, spread of pests and diseases	▪ Reduced availability and increased cost of animal/dairy products (in Europe and abroad) due to impacts on animal health and increased livestock deaths.
	Droughts, heavy rainfall, rising sea temperatures	▪ Reduced availability and increased cost of fish/shell fish due to adverse impacts on fisheries (in European waters and abroad) such as decline in water quality due to reduced water flows or contaminate run-off, declining fish stocks.
	Heat waves and flooding	▪ Increased incidence of food poisoning
	Longer growing seasons, warmer and wetter climate	▪ Increased availability of locally grown food crops and introduction of new crops. ▪ Rising food process can benefit farmers, who grow food commodities. ▪ Increase demand and prices of agricultural products increases demand for labour.
Access to clean air	All impacts	▪ Decreasing air quality ▪ Growing environmental inequity of low income households being increasingly more exposed to air pollution
Access to and quality of housing and property	Heat	▪ Physical and psychological discomfort in poorly adapted buildings
	Subsidence in very hot weather, floods, high winds and storms, coastal	▪ Damage and loss of residential buildings and their contents, especially those located in vulnerable areas

Social domain impacted	Climate change impact	Specific risk / opportunity
	erosion / sea level rise	
	All impacts	▪ Employment and business opportunities in sustainable construction and design
	Internal and external migration	▪ Pressure on available housing
	Higher ambient temperatures in winter	▪ Reduced need for heating leading to diminishing "fuel poverty"
Access to energy	Heat, floods, storms, heavy rainfall	▪ Disruption to electricity supply, damage to power stations, transmission and distribution systems.
	All impacts	▪ Employment and business opportunities in improving infrastructure, developing decentralised energy supply and energy efficiency
Access to healthcare services	Heat, fires, floods, storms, coastal erosion, sea level rise	▪ Increased demand for healthcare services ▪ Risk of limitations in access to healthcare services due to disruptions to energy supply, telecommunications and transportation
Access to education, training and jobs	Changing weather patterns, spread of pests and diseases, soil degradation, droughts, extreme weather events, floods, storms, impacts on seas	▪ Loss of jobs amongst disadvantaged groups in climate sensitive industries (e.g. agriculture, tourism and fisheries) due to business failure. ▪ Involuntary change of occupation and retraining. ▪ Re-training more difficult at older age.
	Heat	▪ Loss of concentration amongst children and students in education
	Flood and storms, spread of diseases	▪ Loss of pupil/teaching days due to damage to school buildings and increase sick-leaves
	Internal and external migration	▪ Pressure on education services
	All impacts	▪ Opportunities for education, skills and jobs relating to climate change e.g. decentralised energy supply, sustainable construction to improve resilience of buildings, civil engineering, research and innovation.

Social domain impacted	Climate change impact	Specific risk / opportunity
Access to transport, mobility and communication	Heat, fires, floods, storms, coastal erosion, sea level rise	▪ Disruption of transport and communications networks
	Heat	▪ Discomfort on public transport services
	Warmer winters with less ice and snow cover	▪ Reduction in transport delays, disruption and accidents caused by snow and ice conditions
	Dry, warm summers	▪ Greater demand for walking and cycling
Access to leisure/ recreation/ tourism	Warmer winters and less winter precipitation	▪ Loss of tourism based on winter sports relying on snow cover
	Heat	▪ Reduced access to water recreational opportunities due reduced water quality caused by heat ▪ Decreasing suitability of climatic conditions for beach tourism in Mediterranean ▪ Risk of discomfort in poorly adapted leisure/entertainment/sports facilities
	Drought	▪ Loss of utility of ecosystems for tourism due to drier weather
	Floods, storms	▪ Disruption to sports events and recreational activities
	Floods, storms, coastal erosion and sea level rise	▪ Reduced access to leisure, cultural facilities and historic buildings and sites
	All impacts	▪ Less time for leisure due to increased pressures on securing livelihood. ▪ Less disposable income available for leisure, entertainment, due to rising expenses for basic needs and coverage of loss and damage.
	Warmer weather and lengthening of tourism season in Northern Europe	▪ Increase in outdoor recreation, nature tourism and water based activities. Opportunities and job creation for tourism and leisure industry.
Access to and quality of landscapes	Heat, floods, storms, coastal erosion, sea level rise	▪ Reduced access to ecosystems, biodiversity, as well as natural historic and cultural landscapes, green spaces and gardens leading to less health, social and personal

Social domain impacted	Climate change impact	Specific risk / opportunity
and natural sites		development benefits enjoyed through contact with nature
	All impacts	▪ Opportunities for increasing green spaces in urban areas through eco-system based approach to adaptation ▪ Improved access to new habitats created through green infrastructure projects for flood management and similar.
Access to spiritual/religious sites and buildings	Heat, fires, floods, storms, coastal erosion, sea level rise and associated disruption to energy supply, telecommunications and transportation	▪ Risk of limitations in access to spiritual/religious sites and buildings. ▪ Risk of discomfort in poorly adapted spiritual/religious buildings. ▪ Reduced opportunities of migrant integration

(Risk identification based on CAG Consultants (2009), UN (2011), EC (2009c), Pye et al.2(008), stakeholder inputs and own elaboration)

Annex 11 – Social influences on adaptive capacity

Social domain impacted	Social pattern / trend	Specific risk / opportunity
Existing social trends		
Age distribution	Ageing of population	Older people are more susceptible to climate impacts, increasing size of a vulnerable group. Additional burden on working age taxpayers supporting older generations and bearing the cost of adaptation measures.
Poverty	Share of low-income households, people at risk for poverty	Poor people less likely to take adaptive action and have access to insurance. Less likely to cope with hazards and recuperate. Risk of poor households increasingly being located in more vulnerable areas
	Homelessness	Homeless people are more exposed to climatic impacts such as heat, cold and extreme weather events, lack access to resources and information.
Migration, mobility	Internal migration within national borders	Adaptation opportunity for individuals, but may create social tensions and pressure on resources in host location. (cf. Annex 10)
	Free movement of people in EU	Adaptation opportunity for individuals, but may create social tensions and pressure on resources in host location. (cf. Annex 10)
	Immigration from outside EU	Potential rise in illegal immigration enlarging vulnerable and socially deprived group. Can create social tensions and pressure on resources in host location. Additional workforce for green economy.
	Integration	Poorly functioning integration can lead to expansion of a vulnerable group and lead to more social tensions.
	Urbanisation	Leads to more people living in vulnerable areas Increasing social tensions in cities and pressure on resources and infrastructure. Cities as centres for innovation, knowledge creation and sharing, as well as economic activity can significantly contribute to adaptation
Education	Primary and secondary	Potential for awareness raising at an early stage.

Social domain impacted	Social pattern / trend	Specific risk / opportunity
	education	
	Professional and higher education	Potential for training in skills needed for climate resilient economy. Risk of failing to recognise the new set of skills needed, resulting in unemployment.
	Life-long learning	Potential of increasing adaptive capacity through re-training and acquiring additional skills necessary for adaptation.
Unemployment	All unemployment	Less adaptive capacity due to low income. Stress on public finances also needed for adaptive measures. High workforce availability for adaptation jobs.
Gender issues	Gender inequality in income	Due to lower income females are at risk to have lower adaptive capacity
	Gender inequality in education	More women with higher education, thus more likely to have awareness and willingness to take preventive action. Less awareness among males.
	Gender inequality in care for children	There are more single mothers than fathers – particularly vulnerable group with low adaptive capacity.
Disabled and people with poor health		Are more sensitive to climate change impacts on health. Have less mobility, less income, hardships finding employment and participating in social life, may be dependent on help and spend larger proportion of income on essential needs, thus have significantly reduced adaptive capacity.
Adaptation strategies and measures		
Capacity to support vulnerable groups	All trends and climate impacts	Lack of understanding of / expertise in how to increase the adaptive capacity of vulnerable groups.
	All trends and climate impacts	Policy response to climate change ignores the needs/potential contribution of vulnerable groups.

Social domain impacted	Social pattern / trend	Specific risk / opportunity
Participation in climate change adaptation strategies and programs	All trends and climate impacts	Vulnerable groups may be excluded, or less able to participate in decision-making affecting the development of adaptation strategies and measures. Vulnerable groups may be deprived of information on possibilities of participation in adaptation programs, access to funding for adaptation, etc.

Based on CAG Consultants (2009), UN (2011), EC (2009c), Pye et al. (2008)

Annex 12 – The Munich Re weather loss data

Munich Re kindly provided an extract of their archive of extreme events for detailed analysis. The data gave details of 4,110 weather–related incidents at national level over the period 1980-2011. The countries covered were all 27 EU member states, apart from Cyprus and Slovakia, plus Iceland, Liechtenstein, Norway, Switzerland, and Turkey-in-Europe. The data itself is confidential and cannot be reproduced here.

The significant information used for this analysis comprised:

- the date(s) of the event,
- the event type e.g. flood, drought,
- the scale of the event (from 1 'insignificant' to 6 'major catastrophe')
- the country affected (events which affected more than one country had multiple entries in the data table),
- a detailed description of the event e.g. type of damage/sectors affected,
- total damage in US$ (original values),
- insured damage in US$ (original values),

Main Hazard

In many cases an event of a given event type covered a number of types of hazard. For example an event of the type 'severe storm' could include hail damage to crops, flash flooding, and wind damage to infrastructure and buildings. The costs were not split between these. However, insurers could have quite different liabilities to indemnify clients depending on which hazard affected which policies. It was decided therefore to re-allocate the cost of each incident to a definite type of hazard.

By considering the event type, the event description, and the proportion of cost insured, a new indicator was given to each event by Dr Dlugolecki:

F flood

W windstorm

I cold temperature

H hot temperature/drought

This rather crude scheme at least allows a rough analysis in line with the approach that insurers adopt to hazards.

Under-estimation

By comparing the data with other series e.g. the Association of British Insurers data on UK weather losses (1988-2011), which the author has permission to use, it is clear that the Munich Re data is not complete. The omissions are significant in some cases (e.g. for insured subsidence damage to buildings during heatwaves), but as they may affect countries to different degrees, and the comparative national data is restricted to a handful of countries, no attempt was made to fill the lacunae.

What one can say is that this means that the data understates the cost of weather damage, perhaps substantially.

Indexation

The values were indexed to 2011 values by using the official US consumer price index.

Allowing for size of country

To allow for differences in country size, Dr Dlugolecki normalised the loss data, by dividing the cost by the respective national Gross Domestic Product (GDP). The method adopted was to take the average of GDP for 1980, 1990, 2000 and 2010, valued in 2005 US$. The source for GDP was United Nations Statistics Division[360]. In a few cases the 1980 value was not given and it was estimated from other sources. Any effect would be minimal, since the results were used in such a broad way that the effect of any error would be trivial.

Another way of doing this, in non-monetary terms, would be to divide the number of large events in the period1980-2011, by the respective national population. However, this method does not work for small countries. This is because extreme events are also relatively small in terms of the European landmass, and so may completely miss small countries, but hit one or more large countries.

[360] http://unstats.un.org/unsd/snaama/dnllist.asp

Annex 13 – Insurance Company Reporting

There is a move towards broader corporate reporting, beyond the statutory or regulatory minima, primarily concerned with financial performance (UNEPFI, 2007b ; PRI, 2012). This new model includes non-financial 'ESG' issues (environmental, social and governance factors), which are increasingly recognised as significant drivers of corporate performance-even leading indicators , signalling future financial performance.

Voluntary corporate reporting on climate change has become an accepted procedure for major publicly quoted companies in every business sector, in every major world stock exchange, and is particularly strong in Europe (CDP, 2011). Increasingly, investors are calling for mandatory reporting. In a joint statement released on 18 October 2011 a group of 285 institutional investors representing more than $20 trillion in assets stressed the urgent need for policy action on climate change, to transform energy systems, and so ensure the sustainability and stability of the world economic system. Under one of the domestic policy recommendations: "Ensure that effective policies exist" the statement suggests that the policy framework should include corporate disclosure of material climate change-related risks (CERES, et al, 2011).

The generic format for corporate climate risk disclosure is the *Global Framework for Climate Risk Disclosure*. This was adopted on 11 October 2006, by a global partnership of 14 leading institutional investors and other organisations representing trillions in assets, to provide specific guidance to companies regarding the information they provide to investors on the financial risks posed by climate change (CERES, et al, 2006).

Investors require this information in order to analyse a company's business risks and opportunities resulting from climate change, as well as the company's efforts to address those risks and opportunities. The Framework encourages standardised climate risk disclosure to make it easy for companies to provide and for investors to analyse and compare companies.

Investors pledged to use the disclosure framework in engagements with companies and encourage them to use existing reporting mechanisms-including the Global Reporting Initiative, the Carbon Disclosure Project and financial filings with securities regulators-to provide information that meets investors' expectations and serves their analytical needs. They also plan to distribute the framework to securities regulators, investors and leading companies that failed to respond to previous investor requests for information.

The Framework consists of four elements of disclosure: total historical, current, and projected greenhouse gas emissions; strategic analysis of climate risk and emissions management; assessment of physical risks of climate change**; a**nalysis of risk related to the regulation of greenhouse gas emissions

In practice, the key mover on voluntary climate risk disclosure is the Carbon Disclosure Project (CDP), now supported by 655 institutional investors holding US$78 trillion in assets. In 2011, CDP invited nearly 6,000 companies around the world to report on their climate change risks and opportunities, and received over 2,000 replies, making it the largest and oldest global repository of data on corporate climate change risks. However, the focus is on mitigation, rather than adaptation, so that the information is primarily concerned with emissions, and there are no questions specific to insurers.

There is little official guidance on climate risk disclosure from regulators or other public authorities. Notably, in the USA, the Securities and Exchange Commission has issued a guidance note specifying four climate-change-related points that could warrant reporting, as being relevant for future financial performance: Impact of legislation and regulation; International accords (treaties); Indirect consequences of regulation or business trends (legal, technological, political and scientific developments regarding climate change that may create new opportunities or risks; and Physical impacts of climate change (SEC, 2010). However, the choice of what, when and how to report is left to management discretion.

The first statutory reporting on climate change risks occurred in the United Kingdom. Under the Climate Change Act 2008, using the Adaptation Reporting Power (ARP), the Minister for the Environment can require key organisations to report on their status in regards to adaptation (i.e. risk assessment, and plans to handle those risks) The first round of reports for 102 organisations, largely responsible for national infrastructure in the energy, transport and water sectors, was concluded in 2011.

The ARP has proved to be the catalyst for many organisations to begin formally considering their climate change risks and adaptation responses. In particular, it has led to greater visibility of climate change risks at the organisational and board level, and has embedded management of these risks within corporate risk management processes. Many enterprises are now undertaking research into the effects climate change could have on their functions, or taking adaptation actions to prepare for a future climate. Through the process of compiling their report, many organisations engaged with their relevant stakeholders specifically on climate change risks, and worked collaboratively to identify interdependencies between sectors. Similarly the reporting process has resulted in greater awareness of potential barriers to climate change adaptation and suggested ways these barriers can be overcome (DEFRA, 2012).

The emphasis in climate change reporting has been on mitigation, with the focus on trying to acquire information and hard data on historical and future emissions, and strategies relating to products and services in that arena. For insurers, this is less important, the main issue is not emissions, but rather weather impacts on clients and suppliers. Thus the Carbon Disclosure Project has generated little data on adaptation in the insurance sector (Obersteadt, 2012).

As regards the insurance sector itself, again there is little detailed guidance for reporting climate change issues. Insurance is treated as part of the financial sector within the voluntary Global Reporting Initiative (GRI), and while the GRI financial sector guidelines are comprehensive in scope (GRI, n.d.), they are not specific enough to generate useful comparable data.

The United Nations Environment Programme Finance Initiative (UNEP FI) attempted to conduct a survey on adaptation in the insurance industry in 2011, for publication at COP17 in November 2011, but the report has been delayed. UNEP FI's more successful initiative '*Principles for Sustainable Insurance'* is too broad, since it covers a wide range of sustainability issues, founded on a previous report (UNEP FI, 2007) and a subsequent consultation exercise. Furthermore, UNEPFI's insurance membership is relatively few compared to the world population of insurance organisations, and is diffuse globally.

There is one initiative dedicated to best practice on climate change in the insurance industry, Climatewise. Founded in 2007, Climatewise is a voluntary project, but it is small with only 26 members, predominantly UK-based. It asks its members to adopt six principles 1. Lead in risk analysis, 2. Inform public policy-making, 3.Support climate awareness amongst customers, 4. Incorporate climate change into investment strategies, 5. Reduce the environmental impact of their own business, 6.Report and be accountable. The principles are subdivided into 25 sub-principles, which gives some granularity to the information. The fourth annual review report (Climatewise, 2011) provides some interesting information on the state-of-play, but unlike the Carbon Disclosure Project, the information on member performance is anonymised, so that stakeholders and observers cannot engage with them easily.

The most comprehensive initiative on insurance and climate change is the one conducted under the aegis of the National Association of Insurance Commissioners (NAIC) in the USA. Despite many scientific uncertainties NAIC concluded that climate change did pose sufficient material issues for insurers, that regulators needed more information about how the insurers were addressing the challenges (NAIC, 2008). Subsequently, NAIC decided to implement a reporting procedure on insurance and climate change. Although there have been marked differences in how individual States have adopted the measures, some States have made it mandatory, and also made the company reports public. The situation is under review, since such an inconsistent approach is not ideal (Obersteadt, 2012). The survey form is derived from the Carbon Disclosure Project framework, and is shown in Exhibit A1 below.

The initial round of public reports submitted in 2010 was analysed by CERES (Leurig, 2011). The survey found that U.S. insurers' perceptions about and responses to climate

change vary significantly by segment and size, indicating that less aware insurers might perform less well in the face of unexpected impacts and regulations.

Of 88 companies surveyed, making public disclosures, only 11 reported having formal climate change policies, and more than 60 percent of the respondents had no dedicated management approach for assessing climate risk.

None of the 18 non-life companies surveyed had formal climate change policies or explicit board or executive oversight of this key issue, and few insurers provided meaningful information on the potential financial impacts of more volatile weather losses.

The CERES analysis considered seven issues: A) Risk Perception & Management Structure, B) Risk Exposure and Management, C) Financial Effects, D) Loss Modeling, E) Investments,

F) Emissions Management, G) External Engagement. However, the report concluded that the lack of specificity in the NAIC disclosure questions led to responses that are ‘frequently vague and unhelpful, with little consistency in how insurers address major trends, including pricing, modelling and governance.’

The survey is to be repeated again for the 2011 NAIC survey, with a report expected in Autumn 2012.

Exhibit A1

INSURER CLIMATE RISK SURVEY

For Reporting Year 2011

Company Name:			
NAIC No.:		Group No.:	
Nationwide Direct Premiums Written:			
Survey Questions			Comparable Carbon Disclosure Project Questions
1. Does the company have a plan to assess, reduce or mitigate its emissions in its operations or organizations? If yes, please summarize.			Performance Question 21
2. Does the company have a climate change policy with respect to risk management and investment management? If yes, please summarize. If no, how do you account for climate change in your risk management?			
3. Describe your company's process for identifying climate change-related risks and assessing the degree that they could affect your business, including financial implications.			Risks and Opportunities Questions 1-3
4. Summarize the current or anticipated risks that climate change poses to your company. Explain the ways that these risks could affect your business. Include identification of the geographical areas affected by these risks.			Risks and Opportunities Questions 1-3
5. Has the company considered the impact of climate change on its investment portfolio? Has it altered its investment strategy in response to these considerations? If so, please summarize steps you have taken.			Risks and Opportunities Question 3: "Other Risks" Question 6: "Other Opportunities"
6. Summarize steps the company has taken to encourage policyholders to reduce the losses caused by climate change-influenced events.			Risks and Opportunities Questions 4-6
7. Discuss steps, if any, the company has taken to engage key constituencies on the topic of climate change.			Governance Questions 24, 26, 27
8. Describe actions your company is taking to manage the risks climate change poses to your business including, in general terms, the use of computer modeling.			Risks and Opportunities Questions 1-3