EUROPEAN
COMMISSION

Brussels, 16.4.2013
SWD(2013) 137 final

COMMISSION STAFF WORKING DOCUMENT

Adapting infrastructure to climate change

Accompanying the document

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

An EU Strategy on adaptation to climate change

{COM(2013) 216 final}
{SWD(2013) 131 final}
{SWD(2013) 132 final}
{SWD(2013) 133 final}
{SWD(2013) 134 final}
{SWD(2013) 135 final}
{SWD(2013) 136 final}
{SWD(2013) 138 final}
{SWD(2013) 139 final}

COMMISSION STAFF WORKING DOCUMENT

Adapting infrastructure to climate change

Accompanying the document

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

An EU Strategy on adaptation to climate change

Contents

1. INTRODUCTION

This staff working document accompanies the Communication "An EU strategy for adaptation to climate change". Together with the Impact Assessment, it provides further background material supportive of the narrative and arguments put forward in the Communication. It also presents, for some areas, an outline of actions that the Commission will be undertaking, as announced in the Communication.

1.1. Scope of this paper

Section 4.3 of the Communication stresses that due to the long life span of much of our infrastructure and its great economic value, preparedness for current and increasing future impacts of climate change over the life time of infrastructure is critical.

Left unmanaged, climate change may significantly affect the operational, financial, environmental and social performance of large fixed assets and infrastructure. This paper presents the contribution of the European Union to climate change adaptation in selected infrastructure sectors. It covers **energy and transport infrastructure** as well as **buildings** in the EU – sectors which were given priority for adaptation policy mainstreaming in the 2009 White Paper on Climate Change Adaptation.[1] The paper also discusses the instruments and financing provided by the European Union to make Europe's infrastructure more climate resilient.[2]

Adapting infrastructure to climate change is a fast-growing, global business in which European know-how and experience could open up new economic opportunities. By promoting public and private investment in climate-resilient buildings and in smart, upgraded and fully interconnected transport and energy infrastructure, EU climate action makes an important contribution to delivering growth and jobs in Europe. In line with Europe 2020, it simultaneously contributes to progress towards more sustainable transport and a secure and clean energy market.

1.2. Definition

The term "infrastructure" usually refers to physical assets in a wider range of policy areas, including communications, emergency services, energy, finance, food, government, health, education, civil protection, transport or water. Buildings, from private households to schools or industrial installations, are the most common type of infrastructure and the basis for human settlement. In addition, network infrastructure is crucial for the functioning of today's economy and society, notably infrastructure for energy (e.g. grids, power stations, pipelines), transport (fixed assets such as roads, railways or airports), ICT (e.g. data cables) and water (e.g. water supply pipelines, reservoirs, waste water treatment facilities). They are sets of interconnected networks

---

[1] White paper *Adapting to climate change: towards a European framework for action*, COM (2009) 0147 final, Brussels.
Further infrastructure sectors (e.g. water or ICT infrastructure) will be addressed in the implementation phase of the EU adaptation strategy from 2013 on.

[2] The forthcoming Communication from the Commission on *Green Infrastructure* will provide additional information on how "green" infrastructure can contribute to the resilience to "hard" infrastructure.

which facilitate the production and distribution of goods and economic services, and form the basis for the provision of basic social services.

Overall, there are many interdependencies between the infrastructure sectors and failure in one area can quickly lead to cascade failure. Energy, water, ICT and transport infrastructure are also often co-located (e.g. power cables laid below roads and beside communications cables, adjacent to water and gas mains and above sewers), especially in urban areas. Extreme weather events could conceivably affect (or disrupt) all of these infrastructure assets simultaneously[3],

All types of infrastructure have an enormous value, both directly as a capital asset and indirectly as an essential element contributing to a productive economy.[4] However, costs for non-operation or disruption can differ significantly, depending on the type and sector: While damage to a local public building usually only has local economic impact, damage to energy transmission infrastructure can potentially have wider, macro-economic consequences.

1.3. Risks and opportunities

Climate change already has far-reaching impacts on infrastructure and can put their operation and reliability partially at risk. This trend is likely to accelerate in the coming decades (see chapter 2). Main **threats to infrastructure** assets include damage or destruction caused by extreme weather 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 on operating costs, including effects in temperate and/or permafrost. Some infrastructure may not be affected directly but be unable to operate if physical access or services to it (such as electricity and ICT) are disrupted.

The need for **infrastructure investment** over the coming decades is enormous (see chapter 5.2). Climate change does not alter this need but may increase its costs[5]. Climate change may also affect where infrastructure is built and how it is designed and operated. There will also be a need for additional infrastructure, dedicated to climate protection, such as improved sea defences and flood protection, interconnections in water supply, as well as retro-fitting to improve resilience of existing infrastructure.

Making infrastructure resilient to climate change is an important and early adaptation challenge. This might not come cheap as infrastructure adaptation usually dominates adaptation cost estimates.[6] It also requires sophisticated decision-making, given how

---

3 Royal Academy of Engineering (2011), "Infrastructure, Engineering and Climate Change Adaptation – ensuring services in an uncertain future", London.

4 HM Government (2011), "Climate Resilient Infrastructure: Preparing for a Changing Climate", London.

5 European Policy Center (2012), "The climate is changing – is Europe ready? Building a common approach to adaptation", *EPC Issue paper* No. 70, Brussels. The report argues that while the World Bank points out that the cost of adapting to climate change, given the baseline level of infrastructure provision, is no more than 1–2 percent of the total cost of providing that infrastructure, the costs of adaptation within infrastructures can be high, and thus it is important to ensure that investments are smart, cost-effective and far-sighted.

6 Fankhauser, S. (2010), "The costs of adaptation", *Wiley interdisciplinary reviews: climate change*, John Wiley & Sons, Ltd., 1 (1), pp. 23-30.

little we know about future climate effects at the regional level.[7] However, starting this process is important, including at the earliest planning stages. Infrastructure assets are long-lived and have the potential to lock in development patterns for a long time.[8]

Changes towards more climate resilient infrastructure investments present some specific **challenges**. First, they often have higher up-front capital costs, even if their climate resilience makes them more profitable over the lifetime of the infrastructure. Second, investors may calculate an additional risk premium for projects to develop climate resilient infrastructure, due to the uncertainty surrounding the implications of climate change in the long run. Third, ecosystems provide some critical services (for example, well-functioning natural habitats on coasts or in floodplains protect against extreme weather events). Investing in protecting these habitats can be less costly than developing or adapting man-made infrastructure, but market structures or incentives are not yet sufficiently implemented to make such investments always profitable.

However, addressing climate risks in investment and operating/management decisions can not only mean avoiding costs at a later state but also opening up new **economic opportunities**.[9] Adapting infrastructure to climate change impacts presents opportunities if early action is taken and expertise developed. This includes new skills and technologies as well as additional adaptation capacity to enable infrastructure to be adapted such as new engineering practices or IT-based technology. What is a risk for city planners, utility firms, businesses and homes, can in turn be an opportunity for those who build and maintain infrastructure. This know-how and expertise can also be an important asset in global competition and be exported to other parts of the world.

From a territorial perspective, the **urban dimension** of infrastructure adaptation is crucial. As a large share of important, often closely inter-linked infrastructure is concentrated in Europe's cities, urban adaptation has to deal with a large number of multiple, cross-sectorial issues in infrastructure development and operation.

2. IMPACTS OF CLIMATE CHANGE ON INFRASTRUCTURE

The severity of climate impacts on infrastructures will vary across the EU according to individual locations and their geophysical risk exposure, the existing adaptive capacity and resilience, and the level of regional economic development. Long- and medium term climatic trends (e.g. increasing average temperatures, modified rainfall patterns) and an inherently rising frequency of extreme weather events impact differently from site to site. Climate impacts not only show regional and seasonal patterns (e.g. North/South, winter/summer) but also differ between territorial settings (e.g. urban/rural/coastal). Therefore, adapting infrastructure usually requires a complex, site-based analysis of different trends and impact patterns.

---

[7] Ranger et al. (2010), "Adaptation in the UK: a decision-making process", *Policy Brief*, Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy, September.

[8] World Bank (2010), *Economics of Adaptation to Climate Change, Synthesis report*, http://climatechange.worldbank.org/sites/default/files/documents/EACCSynthesisReport.pdf

[9] UK Trade & Investment (2011), *Adapting to an Uncertain Climate: A World of Commercial Opportunities,* Economist Intelligence Unit, The Economist, London.

2.1. Trends and patterns

The impacts of climate change vary considerably across Europe, in terms of the regions, territories and sectors affected.[10] The warming of the earth has far-reaching consequences on several climatic parameters, triggering changes in precipitation and temperature patterns, changes in intensity and frequency of extreme weather events (e.g. extreme precipitation, heat waves, cold spells, storms), sea level rise and changing wind patterns.[11] All of these climate phenomena may impact on the stability and the functioning of infrastructure. Therefore they also need to be considered when making climate-resilient investment decisions for new infrastructure and upgrades of existing infrastructure.

The location of an infrastructure, together with the adaptive capacity of local businesses, governments and communities, usually determines an asset's climate sensitivity and vulnerability. This vulnerability to various climate parameters is also strongly sector-specific and closely linked to the technology used for construction and operation (e.g. less precipitation causing decreased efficiency of hydro-power plants).

Climate change will also affect the environmental and social systems around infrastructure assets and their interactions with these systems. For instance, reductions in rainfall may affect the availability and quality of water resources on which industrial assets depend. At the same time, farmers may find they need to irrigate crops for the first time in response to rising temperatures and lower rainfall. Such changes may create competition and could potentially lead to conflict. This highlights the importance of thinking in an integrated, cross-sectoral way to consider climate risks and resilience[12].

2.2. Territorial aspects

Europe is characterised by a great territorial diversity. Questions related to the resilience of infrastructure are usually closely linked to (local or regional) territorial conditions. In addition to global trends and different seasonal and regional patterns, territorial aspects form an additional layer which determines the vulnerability of a given location. This site can be part of different territorial categories at the same time (e.g. urban area in a coastal zone) – a factor which can emphasise certain impacts (e.g. heat island effect combined with heat waves in cities) or lead to deviations from more general regional patterns (vulnerability "hotspots", e.g. high risk-exposure of mountainous villages in an otherwise low-risk region).

Coastal cities and adaptive responses: the example of Hamburg (D)

Recent sea level rise projections taking into account the impact of artic ice melt suggest that increases of between 0.9 to 1.6 metres above the 1990 level could be expected by 2100. These increased sea levels have the potential to interact with storm surges to present a serious flood threat to Europe's coastal area, where large cities and urban centres are located. Cities along the coast of the Netherlands, Germany, Belgium and

[10] EEA (2010), *The European environment – state and outlook 2010*, Copenhagen.

[11] Altvater, S.; van de Sandt, K.; Marinova, N.; de Block, D.; Klostermann, J.; Swart, R.; Bouwma, I.; McCallum, S.; Dworak, T.; Osberghaus, D. (2011a), *Assessment of the most significant threats to the EU posed by the changing climate in the short, medium and long term – Task 1 report*. Ecologic Institute, Berlin.

[12] Approaches such as Integrated Water Resources Management or integrated urban development can help to facilitate this integrated thinking. See, for instance, http://www.gwp.org/The-Challenge/What-is-IWRM/ and http://www.future-cities.eu.

northern Italy are most likely to be significantly affected.

As a response, and already facing increasingly significant impacts of climate change, many cities on (or near) the coast are acknowledging their need to adapt. The metropolitian region of Hamburg, for instance, has put climate adaptation already into action. Its geographical position makes it especially prone to storm floods and risk of inundation. Moreover sea level rise is affecting the level of the river Elbe and its tidal system. In 2007 Hamburg experienced flooding due to storms and high tides on the German coast, raising the river Elbe by 3.5 metres. Hamburg's Climate Action Plan for 2007-2012 therefore included a series of concrete adaptation measures, such as coastal flood defences, water management, inland flood protection, as well as adaptive measures for waterways, urban and landscape planning, transport infrastructure. Adaptation considerations were also integrated in the urban planning of the 'HafenCity' – a newly developed, inner-city district in the port area.

The following sections explain four categories of territories in which climate impacts on infrastructure is expected to be most significant.

2.2.1. Cities and urban areas

Cities are sensitive to many impacts, especially extreme weather events. Due to the concentration of population, physcial assets, and socio-economic activities, cities play an essential role in providing infrastructure to citizens. Many climate impacts are acceleratated or accentuated in built up areas which can create unique microclimates in terms of temperatures, wind and precipitation (e.g. urban heat island effect).

Challenges to operating infrastructure under changing climate conditions include a.o. coping with potentially higher operating temperatures during summer (with an increasing frequency and intensity of heat waves), protecting built environments against floods or ensuring water and energy supply during consumption peaks (e.g. cooling in "hotter" summers, heating in "colder" winters). City dwellers may also be particularly susceptible to vulnerabilities in ageing infrastructure. This includes drainage and sewer systems, flood and storm protection assets, transportation systems, and energy supply.

Urban sprawl and an unbroken trend to soil sealing can have additional negative externalities, for instance a lack of flood areas. In Europe at least 1,000 km^2 of land – more than the size of the city of Berlin – are converted for new infrastructure annually[13].

With a growing urban population in Europe, city and regional authorities will play an increasingly important role in climate change adaptation in the future. Many European cities have already developed local adaptation strategies, including measures aiming to ensure the future operation of existing urban infrastructure (e.g. cooling in metro-systems or trams) or increasing the share of urban green space. For new infrastructure, examples show that construction codes or planning legislation (e.g. for new residential zones) partially already incorporate climate change parameters.[14]

2.2.2. Coastal areas

Infrastructure in coastal areas as well as off-shore installations (e.g. transmission lines, wind turbines) will be particularly affected by sea level rise (of between 0.18m and 0.58m by 2100),by changes in ocean currents (which could potentially cool the northern

13 COM(2012) 46, 13.02.2012: Report on the Implementation of the Soil Thematic Strategy.

14 Examples from European cities are included on: http://eucities-adapt.eu/

hemisphere by -1.7°C and lead to a significant increase of frost and snow cover) and by coastal erosion (which will be accelerated by sea level rise and an increase frequency of heavy storms). Sea level rise will exacerbate coastal inundation and magnify the effect of storm surges, thus threatening vital infrastructure, settlements and facilities that support the livelihoods of local communities.

Historically, much attention has focused on using hard structures such as seawalls to protect infrastructures and coastlines susceptible to sea level rise. More recently, integrated coastal zone management and ecosystem-based adaptation, including coastal forest rehabilitation or beach dune restoration, have proven to be more suitable frameworks in this respect[15].

A comprehensive analysis of climate impacts in coastal areas and potential further action is discussed in the Commission Staff Working Paper "Climate change adaptation: marine and coastal issues".

2.2.3. Mountainous regions

The functioning of infrastructure in mountainous areas can be increasingly threatened by an increased frequency and intensity of natural hazards (such as landslides, rock falls or floods). Most phenomena are linked to the increasing ambient temperature which leads to a loss of glacier mass and consequent morphological transformations, reduced snow cover, thawing of permafrost and changing precipitation patterns. Climate change is projected to result in later seasonal snow, less snow coverage, earlier wet snow avalanches, and generally shorter snow seasons.

Apart from the physical destruction of (or damage to) infrastructure in risk zones, in particular water cycles are expected to change significantly (e.g. increasing/decreasing water availability for hydropower generators, depending on local and regional conditions). In addition, increasing temperatures and decreasing snow cover will affect regionally economically important winter activities and connected infrastructure (e.g. installations for artificial snow, ski lifts).

Examples show that especially investing in natural solutions to protect infrastructure has a large potential. Approximately 780,000 ha (20 per cent) of Austrian forests are classified as ‘protection’ forests ("Bann- und Schutzwälder"), by the Austrian Forest Act.[16] The primary benefits of these mountainous forests to human society are in particular protection from natural disasters (such as avalanches, mudslides, rock falls) but their benefits cover as well biodiversity enhancement, recreation and tourism.

---

15 EEA (2010), "Thematic assessment Marine and Coastal Environment", *The European environment – state and outlook 2010*, Copenhagen.

16 Mazza L., Bennett G., De Nocker L., Gantioler S., Losarcos L., Margerison C., Kaphengst T., McConville A., Rayment M., ten Brink P., Tucker G., van Diggelen R. 2011. *Green Infrastructure Implementation and Efficiency*. Final report for the European Commission, DG Environment on Contract ENV.B.2/SER/2010/0059. Institute for European Environmental Policy, Brussels and London.

2.2.4. *Outermost regions*

Given their remoteness, insularity, small size and difficult topography and climate, the EU's outermost regions[17] are particularly sensitive to the impacts of climate change. Indeed, these permanent constraints render these regions all the more vulnerable to global climate challenges. While the deterioration of the shoreline and the increase of average temperature represents a common challenge, many other phenomena are linked to specific territorial conditions: Caribbean islands and French Guiana are expected to be hit by increased dryness, more intense cyclones and sea level rise, Macaronesian islands will be particularly threatened by changes in wind and precipitation patterns, and in Réunion rising temperatures will accentuate water scarcity problems.

The outermost regions' particular territorial characteristics (such as being islands, mountainous or coastal locations) and their sensitivity to the impacts of climate change put additional pressure on infrastructure and urban settlements. Flooding, sea-level rise, drought, heat waves or temperature rise will impact spatial planning and development in the OR and all have implications for infrastructure resilience.

Adapting infrastructure: A challenge for the EU's outermost regions

As most of the infrastructure (i.e. energy, water supply, transport and communications) is concentrated along the coastal zones, climate impacts such as coastal erosion, loss of available land area due to sea level rise and increased frequency of extreme weather events such as storms, typhoons and hurricanes pose significant challenges. For example, of the 300 km coastline of French Guiana 45% is currently subject to erosion, 14% in Guadeloupe. Due to their small size economies, remoteness and often fragmented nature of their territories (given some outermost regions are archipelagos), disruption to transportation and communication networks could have a severe impact on vital economic sectors, particularly the food-supply and tourism sectors. For example, in the Canary Islands, tourist infrastructure has spilled over into the coastal areas, with more than 10 million visitors a year and a high population density (200 inhabitants/ km² on average). Furthermore, impacts on energy production (particularly hydroelectricity), distribution and supply facilities are likely to cause significant energy security concerns. Freshwater availability in most outermost regions is dependent upon storage of rainwater or upon seawater desalination facilities, which may respectively be at high risk due to changes in precipitation patterns and to their coastal location.

Thus, adaptation measures to increase the resilience of infrastructure have become vital for these regions. Current policy responses are focusing on the enhancement of technical and scientific knowledge, on the review of building and construction standards, on sustainable urban planning solutions and on the development of renewable energy sources that will increase energy self-sufficiency.

[17] The outermost regions are Guadeloupe, French Guiana, Martinique, Réunion, Saint-Martin, the Azores, Madeira, and the Canary Islands (and from January 2014 also Mayotte). They are covered by Article 349 of the Treaty on the Functioning of the European Union which recognizes their specific constraints and provides that the Council, on a proposal from the Commission and after consulting the European Parliament, shall adopt specific measures to lay down the conditions of application of the Treaties to those regions, including common policies.

2.3. Sector-specific impacts

2.3.1. Transport infrastructure

The infrastructure of all four transport modes are subject to climatic pressures and are subject to corresponding adaptation policies: rail (railways), road (roads and highways in general and specific cases of coastal and mountain roads), shipping (inland and ocean shipping, ports) and aviation (airports).

Rising temperatures and sea levels as well as an increasing frequency and intensity of extreme weather events (e.g. storms, heat waves, flooding) already have significant impact on the functioning of transport infrastructure in the EU.[18] However, climate change affects not only transport infrastructure, but also the distribution of transportation and traffic flows, e.g. as a result of changing tourism patterns. This can consequently alter infrastructure needs. 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.

The consequences of climate change are both negative and positive for transport infrastructure such as for rail, road, shipping and aviation, but will differ from region to region. In particular, the projected increase in the frequency and intensity of extreme weather events 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, transport disruptions and delays. For road transport infrastructure, weather stresses represent from 30% to 50% of current road maintenance costs in Europe (8 to 13 billion € p.a.). About 10% of these costs (~0.9 billion € p.a.) are associated with extreme weather events alone, in which extreme heavy rainfalls & floods events represent the first contribution.[19] However, also some beneficial impacts on transport can be expected, such as from reduced snowfall for most of the European regions in the longer-term.

A detailed assessment of relevant climate impacts on transport infrastructure is presented in annex 1.

Responding to climate impacts: railways between Copenhagen and Ringsted (DK) [20]

Increased precipitation and increased water flow in watercourses can affect the new railway line between Copenhagen and Ringsted. In connection with the project on expanding the track capacity between Copenhagen and Ringsted on Zealand, the Public Transport Authority, which has analysed the track capacity, has carried out a climate change impact assessment for the project. The goal of the impact assessment is to investigate a future rail track's robustness to climate change over a 100-year operating period. The assessment shows that especially increased precipitation and increased water flow in watercourses can impact on railway constructions, whilst other factors such as increasing temperatures, rising sea levels and rising groundwater will not have a

[18] For research on extreme weather events and their impact on the transport sector see_ EWENT project http://ewent.vtt.fi or WEATHER project www.weather-project.eu.

[19] Nemry F, Demirel H. Transport and Climate Change: a focus on road and rail transport infrastructures. EUR 25553 EN. Luxembourg (Luxembourg): Publications Office of the European Union; 2012. JRC72217)

[20] Available in the Danish Portal for Climate Change Adaptation: http://klimatilpasning.dk/en-US/Service/Cases/Sider/Adaptingrailwaystoclimatechange.aspx

significant impact. Of particular importance is an expected 20% increase in the intensity of rainfall in heavy downpours in the year 2100.

In areas where watercourse cross the track, under a bridge or tunnel, climate changes mean there is a risk that water cannot flow quickly enough and thereby build up and risk eroding the railway construction. Therefore a new track between Copenhagen and Ringsted will have a 30 per cent greater capacity for water flow than the norm that is used at present. The Public Transport Authority assesses that the recommendations for adaptation to climate change are robust in relation to the variations in the expected climate changes.

2.3.2. Energy infrastructure

Impacts of climate change, such as an increased frequency of extreme weather events or changing water and air temperatures have effects on energy transmission, distribution, generation and demand. Recent studies[21] suggest important impacts of climate change on the energy sector and underpin the need for adaptation, notably in the electricity sector.

The *transmission and distribution grids* are increasingly challenged by new seasonal and regional demand patterns as well as direct physical effects of extreme weather events (e.g. storms or floods). At the same time, they are also subject to new balancing requirements arising from the integration of significant volumes of electricity produced from renewable sources (typically sparsely distributed). Despite this dual challenge, a high degree of reliability needs to be ensured. Due to their comparatively lower physical robustness, older regional distribution networks are particularly vulnerable to extreme weather events (e.g. flashovers in rural areas).[22] The *generation* of electrical energy is affected by efficiency decreases due to climate change (e.g. decreasing availability of cooling water for electricity generators). However, in some parts of Europe, increased precipitation or more wind may also lead to new opportunities for hydropower or wind energy generation. Overall, floods are identified as a particular threat to electricity generators and related physical assets. Regional and seasonal *demand* and consumption patterns will change with an increasing ambient temperature. Projections suggest a reduction in space-heating in northern Europe and an increase in demand for cooling in southern Europe.[23] Additionally, extreme weather periods such as heat waves, cold spells, and droughts will lead to increasingly significant demand peaks, potentially causing demand-driven overstress of energy infrastructure. Scientific evidence suggests that regional and seasonal demand shifts are the most important, climate-induced change to the energy system.[24]

Table 1: impacts of changing climate parameters on different energy supplies. Source: European Commission (2011)

---

21 European Commission (2011), *Investment needs for future adaptation measures in EU nuclear power plants and other electricity generation technologies due to effects of climate change, final report*, conducted by ECORYS Nederland BV, contract TREN/09/NUCL/SI2.547222, Brussels. Asian Development Bank (2012), *Climate risk and adaptation in the electric power sector*, Manila.

22 The UK's 2012 climate risk assessment suggests that upgrading the existing distribution networks to cope with climate impacts will require between 1 and 100 million GBP per year by the 2080s. Department of Food and Rural Affairs (2012), *UK Climate Change risk assessment* (CCRA), London.

23 EEA (2010), "Adapting to climate change", *The European Environment – State and Outlook 2010*, Copenhagen.

24 JRC (2012) "PESETA II. The Impact of climate change on the European energy system", Report to the European Commission, DG Climate Action, Ispra.

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. A detailed assessment of relevant climate impacts on energy infrastructure is presented in annex 2.

2.3.3. Construction and buildings

Investments in buildings and other infrastructure are increasingly put at risk by changing climatic conditions and related extreme weather events. Due to the long lifespan of many buildings and other infrastructure and their great economic value, their preparedness and resilience to future impacts of climate change are critical.

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. Major threats to construction and buildings requiring short-term action include (1) extreme precipitation, which can be expected European wide, e.g. leading to water intrusion, damage to foundations and basements, destruction of buildings and infrastructure, overflowing sewers, land- and mud-slides, flooding, etc.; (2) extreme summer heat events, especially but not only in South Europe, e.g. leading to material fatigue and accelerated aging, decreased comfort and potentially severe health implications, high energy use for cooling, et cetera; (3) exposure of constructions to heavy snowfall; (4) rising sea levels that increase the risk of flooding. In addition, soil subsidence risks[25] are likely to increase, depending on the stability of building structures and their foundations.

Buildings and infrastructure can be vulnerable to climate change because of their design (low resistance to storms) or location (e.g. in flood-prone areas, landslides, avalanches). Flooding is (after earthquakes) one of the most costly kinds of disasters and this is mainly due to floods in built-up areas. Many European cities have been built along a river; and these rivers will respond to extreme rainfall or snowmelt events with extreme discharges, threatening the cities with floods. There is also a growing problem with overheating of the built environment being exposed to rising temperatures and extreme

25 Swiss Re. (2011), " The hidden risks of climate change: An increase in property damage from soil subsidence in Europe", Zürich.

heat, which is not only an issue for the construction material but also affects the occupant's comfort and health. In coastal areas, coastal protection (e.g. sea walls) may require increasing maintenance costs and higher frequency of readjustments.

A detailed assessment of relevant climate impacts on buildings is presented in annex 3.

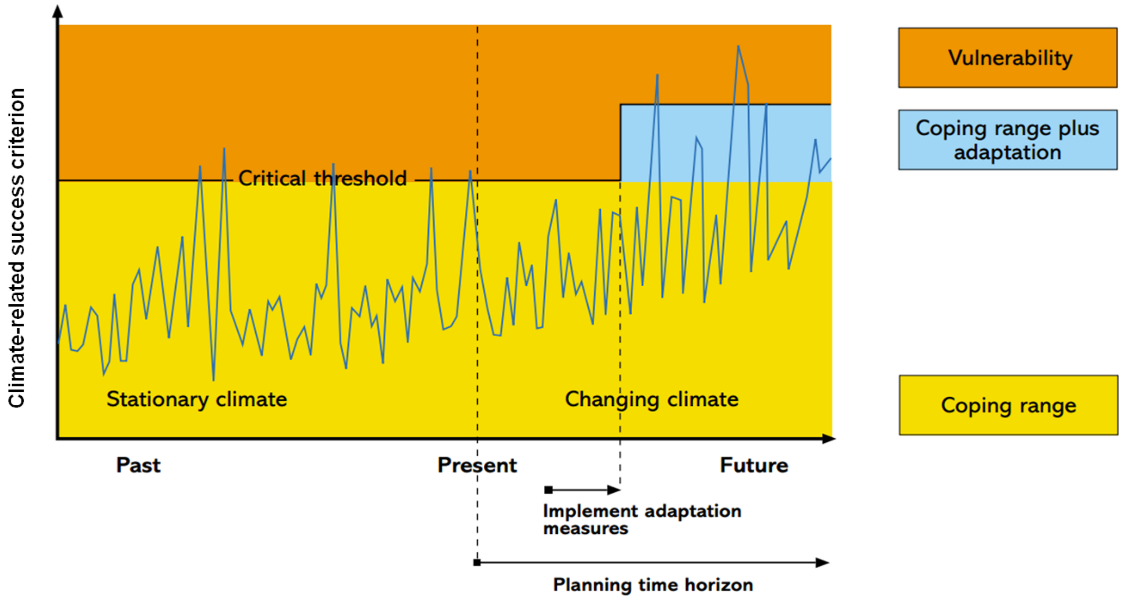
3. ADDRESSING COMMON CHALLENGES

While climate impacts and adaptation challenges differ from sector to sector, the on-going adaptation process also includes several common elements which will be highlighted in the following sector.

Adapting infrastructure to a changing climate needs to be considered in two ways. First, when **constructing new infrastructure**, climate resilience can be ensured by locating, designing and operating an asset with the current and future climate in mind. This is particularly important in the case of large infrastructure which usually has a lifespan of at least 20 years and investment decisions therefore influence future generations' well-being. Secondly, **existing infrastructure** can be made more climate-resilient by retro-fitting and/or ensuring that maintenance regimes incorporate resilience to the impacts of climate change over an asset's lifetime.

Design thresholds which are built into infrastructure project designs may be breached more frequently in a future changing climate. A changing climate may result in threshold failures once considered exceptional but acceptable, becoming unexceptional (i.e. normal) and unacceptable. Infrastructure may have to function within tighter margins between "normal" operation and critical thresholds. This may manifest itself in decreased efficiency of equipment and provide less margin for error before drastic management measures (such as reduced operation or throughput) need to be implemented.

Figure 1: The relationship between coping range, critical threshold, vulnerability, and a climate-related success criterion for a project. [Source: Willows and Connell (2003) modified].



Infrastructure is generally constructed in a manner that is resilient to the weather conditions of the past. Climate change makes it increasingly important to enhance and disseminate knowledge on the **present and future climatic conditions**.

Examples from the energy sector show that different types of infrastructure are built, maintained and operated following well proven construction codes, regulations and good practices in operating them. They take due account of siting characteristics, among which weather extremes (e.g. temperature, rainfall, water supply or wind) and other inputs (geology, earthquake, use of land etc…) are fixed based on historical records plus an engineering "safety" margin. New energy infrastructure projects integrate those factors in their feasibility analysis, both from an economic and a safety point of view. Variations in any of the above parameters due to climate change result in the need to perform scheduled revisions of the construction (when project is progressing) or operation specifications, in order to ensure that the operation and integrity of the infrastructure remain within the required safety margins at all time.

To achieve sector- and location specific climate resilience, there is thus a need for a thorough and coherent **assessment of local climate impacts** – based on historical records, but also including projections on future climatic conditions. Only detailed local assessments can provide greater confidence in understanding current and future climate variability and its impacts on installations. Subsequently, making climate change assessments and **system-wide vulnerability checks for interconnected installations**[26], developing long-term (investment) strategies and incorporating climate issues into planning and maintenance procedures can not only ensure the timely adaptation of installations but also avoid future negative externalities.

Land-use policies and spatial planning play a central role when developing new infrastructure. Overall, the climate resilience of infrastructure is not limited to its outfit but starts with sound spatial planning and the right choice for the site and necessary

[26] As an example see: RESNET - Resilient Electricity Networks for Great Britain (UK), http://www.arcc-cn.org.uk/project-summaries/resnet/

compensation measures.[27] The **appraisal of options** against the background of climate change and its impacts on a given site is crucial. As a result of local impact assessments, installations might be located differently, not necessarily causing any additional costs for the investor.

In order to enhance climate resilience for a given building or physical asset, also **green infrastructure**[28] or protective elements can make important contributions. In rural areas, multi-functional resilient ecosystems offer cost-effective options when integrated into land planning, e.g. using floodplain forests acting as a "safety valve" to store water and reduce the risk of flooding instead of 'grey' infrastructure. Such green infrastructure solutions are often cheaper in one-off and maintenance costs than purely technical protection solutions such as building dams and floodplain reservoirs. In cities and built-up areas, green roofs and walls through shading and evaporation, help to avoid the heat island effect, filter the air and can also contribute to the energy efficiency of buildings. Thus they also positively impact human health and contribute to emission reduction.

While **engineering measures** (such as additional cooling circuits for power plants or design standards for distribution poles) can significantly increase the robustness and reliability of installations, also **non-engineering measures** should be considered. They may include more robust operational and maintenance procedures, better demand management and forecasting or early-warning systems.

Enhancing the resilience of buildings and other infrastructure to the adverse impacts of climate change should take place within an **integrated and synergistic approach** giving due consideration to other relevant issues (such as embodied and operating energy, insulation, air conditioning, on-site generation of renewable energy, water efficiency, materials efficiency, waste and toxics reduction and/or minimising urban sprawl). Where relevant, the development and revision of appropriate construction and maintenance **standards** for the construction of different types of infrastructure should be envisaged (see chapter 5.1.1).

Greening of roofs and facades in Austrian cities (AT)

Climate change will increase the urban heat island effect in the years to come. This meteorological phenomenon is linked to high density areas and characterized by high annual average air and surface temperatures, little cooling occurring at night, air pollution, an increased vegetation period and changing wind and rainfall patterns. Strategies to improve the urban climate include reducing the heat stored in cities, stimulating evaporation and storing rainwater for lengthy periods.

Greening of the roofs and facades of buildings helps ameliorating the urban climate,

[27] To support decision makers, planners and other keyplayers involved in infrastructure development as well as the interested public the Commission's services have recently published a working document containing Guidelines on Best Practice to Limit, Mitigate or Compensate Soil Sealing. This document provides information on the magnitude of soil sealing in the European Union, its impact on the environment – including the climatic aspects – and examples of best practice.
European Commission [SWD(2012) 101] - Guidelines on best practice to limit, mitigate or compensate soil sealing. Available at http://ec.europa.eu/environment/soil/sealing_guidelines.htm

[28] Green infrastructure investment is generally characterised by a high level of return over time and global reviews of restoration projects typically show cost-benefit ratios in the range of 3 to 75. See: Nellemann, C.E. Corocran (eds) 2010. Dead Planet, Living Planet – Biodiversity and ecosystem restoration for sustainable development. A rapid response Assessment. UNEP, GRID-Arendal. More information on http://ec.europa.eu/environment/nature/ecosystems/index_en.htm

while also being a means of adapting to climate change. Green roofs and green facades smooth temperatures or humidity changes, naturally cooling down temperatures during the summer and keeping warmth in winter. They also isolate from noise, provide clean and oxygenated air, store humidity and protect from extreme weather events. They are a natural habitat for fauna and flora, have a positive impact on the local microclimate and are actively contributing to the conservation of the environment and nature and to reducing operational costs in the long run.

To promote the greening of roofs and facades, many Austrian regional and local governments provide financial incentives and practical guidance on how to make Austria's cities greener – and buildings more climate resilient.

Additionally, guidelines for project managers in the field of infrastructure planning and operation can support adaptation processes. It may also be relevant to expand on the "**climate proofing"** and not only consider the resilience to the adverse impacts of climate change but also minimise the emission of greenhouse gases over the lifespan of the physical assets in question. The cost-benefit analysis usually applied to transport infrastructure projects needs to give due attention to the impacts of climate change including extreme weather events, climate proofing, and the range of relevant options.

Developing and managing infrastructure usually involves a wide range of **public and private actors**. Therein, public authorities at European, national, regional and local levels play a pivotal role not only in financing, but also in promoting climate resilient infrastructure by providing appropriate policy and regulatory frameworks, information and expertise. However, it is also action by others – investors, owner, operators, insurers and engineering/construction businesses[29] – which will determine the success and effectiveness climate risks management and other adaptation action. Considering for instance the current European energy market, the private sector, notably utility and electricity companies as well as transmission and distribution system operators, will play a central role in the adaptation process. Close cooperation between different levels of government and between the private and public sectors is therefore essential.

Electricity grid adaptation to climate change in Sweden and Norway

Scientific research suggests that national regulations and culture, company size and experience with weather incidents have far-reaching influence on adaptation to climate change in electricity distribution companies. A study[30] on four electricity grid companies in Norway and Sweden – two countries with similar climate conditions, but business environments – underlines this aspect. Of the four companies investigated in this study, investments by the two Norwegian companies were found to be strongly based on economic efficiency. This approach reflects the influence of the national regulatory framework that is efficiency-focused, in addition to an organisational culture where economic efficiency has a higher profile than other issues, such as the robustness of the system and the grid. In contrast, the two companies in Sweden focused on investments that have more of a balance between increasing the robustness of the grid and economic

[29] HM Government (2011), *Climate Resilient Infrastructure: Preparing for a Changing Climate*, London, p.33-40.

[30] Inderberg, T.H. and Løchen, L.A. (2012), "Adaptation to climate change among electricity distribution companies in Norway and Sweden: lessons from the field", *Local Environment: The International Journal of Justice and Sustainability*, 17 (6-7): 663-678.

efficiency, reflecting the national regulatory framework.

The Swedish companies have consequently been able to invest more in adaptation measures than the Norwegian companies. A major storm (Gudrun) in Sweden in 2005 that caused wide-spread damage has influenced the views on climate change by Swedish electricity companies. Such an extreme weather event exposed the vulnerability of the grid to future severe storms. One consequence has been for the larger Swedish company to speed up investment in underground cables to replace overhead transmission lines. Such investments are also seen as economically feasible in the long term. In Norway, the companies have experienced an increased frequency of heavy snow. Whilst the companies regard the replacement of overhead lines with underground cables as being too costly, the larger Norwegian company has adapted by increasing maintenance of the system, in addition to investing in insulated overland lines which are stronger and better able to withstand the weight of the snow. The study also highlights that the larger companies have more resources to plan for adaptive measures to cope with future climate change than the smaller companies. Local knowledge in small companies does not provide enough expertise for adapting to future vulnerabilities.

Awareness-raising and exchanges amongst these key stakeholders[31] will be vital to achieve a full penetration of the sector regarding its climate vulnerability and adaptive capacity. Overall, the stakeholders' adaptive capacity and knowledge will be decisive to achieve the right results.

In this respect, the development of **professional skills** and the exchange of experience, both for engineering and non-engineering adaption measures appear as vital. This area also represents a major economic opportunity, also to export know-how to outside the EU. In particular the engineering and construction sectors are challenged to develop further their ability to embrace probabilistic methods and flexible solutions, and to deal with complex risk scenarios. Adaptation, mitigation measures, and the needs of an evolving population and economy all make demands on engineering capacity.[32]

4. EU POLICY MAINSTREAMING

Within its competences and building on the 2009 white paper, the European Union is engaged in mainstreaming climate change adaptation in various EU policies and financial instruments including the European Transport Policy, the Connecting Europe Facility or EU cohesion policy. As outlined in the communication "…", these efforts will continue throughout the implementation period of the strategy. The following section provides an overview of the current EU policy approach and the uptake of climate change adaptation in EU legislation.

The transport sector fulfils crucial economic and social functions and is highly depending on the environmental situation. Investment in **transport infrastructure** is increasingly

[31] While all European nuclear facilities had assessed the effects of climate change within their mandatory periodic safety reviews by 2011, around 30% of fossil-fuelled power generators had made similar climate change assessments. In other areas, notably renewable electricity as well as transmission/distribution, only up to 5% of all facilities had undergone a climate check.
European Commission (2011), *Investment needs for future adaptation measures in EU nuclear power plants and other electricity generation technologies due to effects of climate change, final report*, conducted by ECORYS Nederland BV, Brussels, on page 76.

[32] Royal Academy of Engineering (2011), *Infrastructure, Engineering and Climate Change Adaptation – ensuring services in an uncertain future*, London.

put at risk by changing climatic conditions and related extreme weather events. Due to the long life span of the majority of transport infrastructure and their great economic value, their preparedness and resilience to future impacts of climate change are critical.

The proposal for the new TEN-T Guidelines[33] includes climate resilience, in particular under article 41: during infrastructure planning due consideration shall be given to risk assessments and adaptation measures adequately improving the resilience to climate change. Additionally, where appropriate, due consideration should be given to the resilience of infrastructure to natural or man-made disasters.

TEN-T projects, co-financed under the Connecting Europe Facility, are expected to contribute to promoting the transition to a climate- and disaster-resilient infrastructure. All transport modes are eligible for funding. Co-financing rates may be increased by up to 10 percentage points for actions enhancing climate resilience.[34]

Next to adaptation to climate change, the trans-European transport (TEN-T) network should provide the basis for the large-scale deployment of new technologies and innovation, which, for example, can help enhance the overall efficiency of the European transport sector and curb its carbon footprint. This will contribute towards the Europe 2020 strategy and the Transport White Paper's target of a 60% cut in greenhouse gas emissions by 2050 (based on 1990 levels) and at the same time contribute to the objective of increasing fuel security for the Union.

With its policies and within its competences, the European Union actively contributes to adapting **energy infrastructure** to climate change. The energy sector is of vital importance for Europe's economic performance. Climate change has consequences for the sector's stability, sustainability and resilience. Both mitigation and adaptation are policy responses which need to be taken on board. Energy infrastructures, from overhead lines and pipelines to power stations, play a critical role for supplying European citizens and businesses with energy. Significant investment, both from the private and the public sector, will be needed in the next decades to adapt some of the sector's physical assets to a changing climate.

The 2008 Commission Green Paper on a secure, sustainable and competitive energy network stated that "the implications of climate change for Europe's energy networks, for example the positioning of plants, power lines and pipelines, need to be taken into account."[35]

The new guidelines for trans-European energy infrastructure (TEN-E Guidelines)[36] therefore also include "climate resilience" as a parameter for the energy system-wide cost-benefit-analysis for projects of common interest in electricity transmission and storage and in gas (Annex 5). The objective of preventing and increasing the Union's energy infrastructure to natural or man-made disasters, adverse effects of climate change and threats to its security are also highlighted in recital 8.

---

[33] Proposal for a regulation of the European Parliament and of the Council on Union, *Guidelines for the development of the trans-European transport network*, COM(2011) 650 final/2 of 19/12/2011, Brussels.

[34] Proposal for a Regulation of the European Parliament and of the Council, *Establishing the Connecting Europe Facility*, COM (2011) 0665 final of 19/10/2011, Brussels.

[35] Green Paper *A European Strategy for Sustainable, Competitive and Secure Energy*, COM (2006) 105 final of 8/3/2006, Brussels; and Green Paper *Towards a secure, sustainable and competitive energy network*, COM (2008) 782 final of 13/11/2008, Brussels.

[36] Proposal for a Regulation of the European Parliament and of the Council, *Establishing Guidelines for trans-European energy infrastructure*. COM(2011) 658 final of 19/10/2011, Brussels.

Future EU investment under the TEN-E policy, in particular through the Connecting Europe Facility (2014-2020)[37], is expected to contribute to enhancing the system's resilience and to tackling part of the investment needs for the adaptation of electricity grids.

Overall, electricity systems have to become more interconnected and flexible, and new infrastructure development and reinforcement will be necessary. In particular, the deployment of smart grid technologies[38] will play a part in managing the variability of demand and supply. The 2012 Ten Year Network Development Plan[39] of the European Network of Transmission System Operators identifies an overall investment need in trans-European transmission infrastructure of about 100 billion EUR, addressing both mitigation and adaptation objectives. [40] While adapting energy infrastructure to cope with changing temperatures and to withstand extreme weather events is crucial to guarantee the energy systems (current and future) reliability, mitigation measures (e.g. energy efficiency in buildings) can make important contributions to deal with energy demand peaks and/or system overstress.

Buildings, from private households to hospitals or industrial installations, are the most common type of infrastructure which is also relevant to other infrastructure sectors (e.g. railway stations, airport buildings). Given the important role of the private sector, adaptive action will – in most cases – be taken by private owners. National, regional and local bodies play a role in both adapting their physical assets to climate change and in considering climate adaptation in legal planning frameworks and permission granting procedures. The European level can however play also an important role in stipulating the uptake of climate considerations in planning and construction: firstly, by ensuring the uptake of climate resilience in EU infrastructure investment policies, and secondly, by promoting new construction standards.

5. INSTRUMENTS

5.1. EU instruments for improved climate resilience

Improving the climate resilience of existing and future infrastructure from the impact of climate change is predominantly a Member State responsibility. Both, the private and the public sector play an essential role. The EU nevertheless has an important role in providing several instruments which can help improving a project's adaptive response and resilience. This may apply during design and planning but also in the course of retrofitting.

Most infrastructure sectors are strongly regulated, which means that policies governing these sectors play an important role and might need to be revised in the light of current and future climate changes. One of the most important type of instrument used to regulate infrastructure sectors are standards at EU level, which often include references

[37] Proposal for a Regulation of the European Parliament and of the Council, *Establishing the Connecting Europe Facility*, COM (2011) 0665 final of 19/10/2011, Brussels.

[38] Communication from the Commission to the European Parliament and the Council, *Renewable Energy: Progressing towards the 2020 target*, COM (201) 0031final of 31/01/2011, Brussels.

[39] European Network of Transmission System Operators for Electricity (2012), *10-Year Network Development Plan 2012*, Brussels.

[40] A recent study estimates the investment needs for adaptation between €637 and €654 million per year for EU-26 without Malta; Institute for European Environmental Policy (2012), *"Optimal use of the EU grant and financial instruments in the next multi-annual financial framework to address the climate objective"*, Interim Report, London.

to (directly or indirectly) weather/climate related pressures. Furthermore, revised guidelines for the Environmental Impact Assessment and the Strategic Environment Assessment as well as the Floods directive contribute to climate resilient investment. Additionally, guidelines for climate-proofing infrastructure projects can support this process.

5.1.1. Technical Standards

When revising existing or building new structures, technical standards are used in every phase during the lifetime cycle of an infrastructure. Standards can apply during the planning phase (e.g. risk assessments, environmental standards), the design phase (e.g. Eurocodes), the construction phase (European and national product standards, implementation standards) and the maintenance phase (e.g. environmental standards, safety standards). Thus standards have an important impact on the resilience of products, processes and construction. In this process, both European/international standards as well national or sector-specific requirements play a central role.

At European level, **Eurocodes** can be a suitable instrument for addressing climate resilience in different infrastructure sectors. Eurocodes are a set of European Standards (EN) for the structural design of buildings and civil engineering works, produced by the European Committee for Standardisation (CEN) to be used in the European Union. They provide for compliance with the requirements for mechanical strength, stability and safety as basis for design and engineering contract specifications. The Eurocodes embody national experience and research output together with the expertise of CEN Technical Committee 250 (CEN/TC250) and of International Technical and Scientific Organisations and represent a world-class standard for structural design. The Commission has asked CEN to prepare a proposal for how to incorporate climate change and extreme weather events in the Eurocodes.

Based on ISO Guide 64, CEN has developed and adopted **CEN Guide 4** "Guide for the inclusion of environmental aspects in product standards", which aims to provide a helpful tool for people involved in standardization who are not necessarily environmental experts to take the potential environmental aspects related to their standards into account. Following discussions with the Commission, CEN is currently considering how to amend Guide 4 to take into account climate change in the development and revision of standards.

Furthermore, the Commission is currently in dialogue with the three European standardisation organisations (CEN, CENELEC and ETSI) to prepare a **programming and standardisation mandate**. Its main objective is to contribute to building and maintaining a more climate resilient infrastructure in three selected sectors (transport, energy and buildings/construction). The scope of the mandate is both to identify and prioritise all standards relevant for climate change adaptation and to revise "priority standards" accordingly. Additionally, if deemed necessary during this exercise, new relevant standards could be developed. The mandate also includes the development of tools (i.e. guidance or other type of documents) that will ensure that adaptation to climate change is taken into account in a systematic way when new European standards are developed. The Commission intends to receive first results by 2015.

5.1.2. Environmental Impact Assessment and Strategic Environment Assessment

The Environmental Impact Assessment (EIA) and the Strategic Environmental Assessment (SEA) can be appropriate instruments to mainstream adaptation, helping to improve the climate resilience of infrastructure.

The **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 EIA Directive requires that environmental impact assessments shall identify, describe and assess the direct and indirect effects of a project on the human beings, fauna and flora, soil, water, air, climate, the landscape, material assets and cultural heritage and the interactions between these factors (Article 3). The Directive is currently under revision[41], proposing new, clearer amendments towards addressing new challenges, i.e. biodiversity, climate change, disaster risks and availability of natural resources throughout the whole EIA process... In addition, 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.

The **Strategic Environment Assessment** (SEA) can also serve as an effective tool for climate change adaptation, especially by introducing climate change considerations into development and planning processes. 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."[42]

The 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 (P/Ps) that fall into the scope of the SEA Directive[43]. 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.

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 P/Ps through SEA is not yet fully developed. This is partly linked to the fact that the notion of climate change adaptation in planning processes is relatively recent. Moreover, the primary focus of SEAs so far has been to evaluate the impact of a P/P on the environment rather than the

---

41 Proposal for a Directive of the European Parliament and of the Council amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment COM(2012)628.

42 IPCC (2007), "Summary for Policymakers", *Climate Change 2007: Impacts, Adaptation and Vulnerability*,[Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds.], Cambridge University Press, Cambridge, UK, p.20.

43 Directive 2001/42/EC of 27/06/2001of the European Parliament and of the Council of 27 June 2001 on assessment of the effects of certain plans and programmes on the environment.

impact of environmental change on a P/P. However, additional guidance for integrating climate change and biodiversity in SEA is under way, also providing a clearer picture of how to target climate change adaptation in the context of the Strategic Environmental Assessment (SEA) Directive.

The early assessment of climate resilience of proposed projects could also be advised in the context of the intended **streamlining of environmental assessment procedures** under the new TEN-E Guidelines, with a view to achieving faster, better and more sustainable permitting of energy infrastructure projects of common interest.

5.1.3. Framework for the assessment and management of flood risks

Floods can have major negative impacts on infrastructure with damages to human health, the environment, cultural heritage and economic activity. Infrastructure therefore needs to be designed to withstand potential flooding, also taking into account the potential impact of climate change on the frequency and intensity of floods. In the design of flood defense infrastructure, changing flood intensities and patterns need to be considered.

The European Union's **Floods Directive** (2007/60/EC) is an existing legal instrument which establishes a framework for the assessing and managing flood risks. It aims at reducing adverse consequences for floods and calls for adequate information tools. The Directive requires the establishment of flood hazard maps, flood risk maps and flood risk management plans.

From the end of 2013, flood hazard and risk maps shall be made publically available for the following scenarios:

a) floods with low probability, or extreme event scenarios,

b) floods with a medium probability (likely return period ≥ 100 years),

c) floods with a high probability.

These flood risk maps shall display the flood extent, the water depths and the water flow. They are helping to identify which already existing infrastructure is under risk or which infrastructure might be at risk if it would be built within an area of potential significant flood risk. The maps can serve as a valuable tool for identifying current and future flood risks and thus support investment decisions and spatial planning.

The Directive also asks Member States to develop cross-sectorial flood risk management plans which include measures on prevention, protection and preparedness. They are based on existing land-use policies, planning processes, engineering and non-engineering options and involve both public and private actors. Regular updates of maps and plans (every six years) will enable authorities to base their scenarios on the latest findings of climate change research.

5.1.4. Climate "proofing" of infrastructure

An assessment of an infrastructure 's risk-exposure and vulnerability to climate change impacts is vital to guarantee its long-term sustainability. Accordingly, for some EU policy areas, climate resilience has already been taken up as a parameter in obligatory cost-benefit analyses during the the project development phase.[44] Evidence[45] also

[44] For example, the proposal for 'guidelines for trans-European energy infrastructure' COM(2011) 658 includes, in annex V, the 'system resilience, including disaster and climate resilience, and system

suggests however, that there is a certain lack of awareness of project promoters for climate issues and insufficient knowlegde on how to conduct the climate resilience checks for projects, especially private sector-driven projects.

To support project managers to make their physical assets more climate resilient, the Commission will publish, as part of the EU Adaptation Strategy package, "**Guidelines for project managers: Making vulnerable investment climate resilient**"[46]. They include a methodology and step-by-step guidance to systematically assess the climate resilience of infrastructure projects and improve their sustainability and liability in changing climate conditions. The guidelines are intended to complement existing project appraisal and development procedures but not to replace them.

Such climate proofing can be expected to increase costs for infrastructure projects. A World Bank study[47] found that the net cost of adapting infrastructure to climate change is no more than 1-2% of the total cost of providing that infrastructure. However, at the same time, climate resilience may decrease costs over a longer period as it helps preventing damages to and interruptions of infrastructures. Overall, the cost of adaptation appears small in relation to other factors that may influence the future costs of infrastructure.

The Commission strongly encourages the use of the guidelines, both in EU-funded projects and more widely. They sit within the evolving policy context on adaptation in the Commission, which is seeing climate resilience being incorporated into a number of policy areas and financing instruments of relevance to asset and infrastructure.

Given the important role of EU-funded infrastructure projects in Europe's infrastructure investment, a coherent climate proofing of EU-funded infrastucture projects[48] (e.g. in the cost-benefit analysis or environmental impact assessment) could not only help in ensuring greater sustainability of action but also in promoting climate change adaptation as a EU policy priority. 'Leading by good example' could also trigger important spill-overs to project development approaches for other public and private infrastructure projects.

Examples of European financial institutions addressing climate risk and adaptation in project appraisal and development[49]

---

security, notably for European critical infrastructure as defined in Directive 2008/114/EC' as an aspect to be considered for cost-benefit analyses for electricity transmission and storage.

45 Agrawala, S., et al., (2011), "Private Sector Engagement in Adaptation to Climate Change: Approaches to Managing Climate Risks", *OECD Environment Working Papers*, No. 39, OECD Publishing.

46 European Commission (2012), *Guidelines for Project Managers: Making vulnerable investments climate resilient*, conducted by Acclimatise and COWI A/S, contract no. 071303/2011/610951/SER/CLIMA.C3.

47 The World Bank (2009), *The Costs of Adapting to Climate Change for Infrastructure*, Washington.

48 The 2009 White Paper *Adapting to climate change: towards a European framework for action*: "Infrastructure projects which receive EU funding should take climate-proofing into account based on methodologies to be developed. These methodologies would then be incorporated into the TEN-T, TEN-E guidelines and EU Cohesion Policy."

49 Summary results of a review of eight financial institutions and their screening criteria and appraisal tools for climate related finance. The study for DG CLIMA, *Cooperation with EU financial institutions: climate related standards in assessing investments and infrastructure projects* is in

European Investment Bank (EIB) have recently developed a number of sector strategies which include addressing climate change adaptation. The EIB will only finance projects that fulfil the requirements described in their Environmental and Social Statement and Handbook. This includes projects applying cost effective, appropriate adaptation measures where there is a risk of significant adverse impacts from climate change and increased frequency of extreme weather events. The EIB also actively promote adaptation projects such as water resource management.

European Bank for Reconstruction and Development (EBRD) undertook a project to develop a methodology for understanding the risks posed by climate change and impacts on the bank's operations. This is helping climate resilience to be included in investment projects where appropriate. The project developed guidance and practical tools to integrate climate risk assessment and adaptation into EBRD's project cycle. EBRD is also participating in the Pilot Programme for Climate Resilience (PPCR), which is pioneering pro-adaptation technical assistance and investment projects.

KfW Entwicklungsbank's projects undergo a systematic two step climate change assessment to ensure potential impacts are managed and opportunities are capitalised. The first step is an initial assessment to assess risks of anticipated climate change and opportunities for additional mitigation measures. If significant climate change risks or mitigation potentials are identified, a more detailed second stage is undertaken. A modification of the project design, the implementation of risk mitigation measures or an additional project phase could result from this in-depth analysis.

5.2. Financing climate resilient infrastructure

Financing the adaptation of existing and the climate-resilient construction of new infrastructure is a major challenge. This investment need cannot be met by traditional sources of **public financing** alone. Indeed, public capital investment in infrastructure has on average declined in OECD countries over the last decades.[50] This is linked to a potentially new role of the public sector for infrastructure investment. Infrastructure was viewed as a public good, and most countries' infrastructures have been built and maintained with public money. With increasing constraints on public finances, the maintenance of existing systems and the construction of new facilities are delayed in many parts of Europe.

This significant infrastructure investment gap will need to be bridged by both the public and the **private sector**, including institutional investors. **Public-private partnership structures** (PPP) are emerging as popular models for funding infrastructure investment. Aside from the simple need for new financing sources, PPPs can deliver extra-benefits, such as skills brought by the private sector or faster implementation of projects.

Failure to make significant progress towards bridging the infrastructure gap could prove costly in terms of slower economic growth and loss of international competitiveness. Economic infrastructure drives competitiveness and supports economic growth by

---

progress at the time of writing these Guidelines, and is being undertaken by the consortium AEAT, ODI and Adelphi.

50 The OECD average ratio of capital spent in fixed investment (mainly infrastructure) to GDP fell from above 4% in 1980 to approx 3% in 2005. See OECD (2011)

increasing private and public sector productivity, reducing business costs, diversifying means of production and creating jobs.[51]

The following section will focus on three aspects which should deserve particular attention in the on-going debate on climate adaptation financing:

1. the EU's contribution to financing climate-resilient infrastructure investment;
2. private-sector infrastructure investment; and
3. the role of institutional investors, such as pension funds and insurance companies.

5.2.1. EU financing

The European Union is a major investor in public infrastructure projects. European, investment-based development policies such as EU cohesion policy, TEN-T and TEN-E, help overcoming gaps in infrastructure needs, especially in Convergence regions in order to generate the preconditions for growth and jobs.

The EU primarily addresses this issue through **EU cohesion policy** and in particular in less developed Member States and regions which have a low endowment of basic infrastructure. The policy aims at creating growth and jobs through delivering Europe 2020 and thereby strengthening social, economic and territorial cohesion in the EU. For EU cohesion policy, the funds at its disposal amount to some € 344 billion in the current 2007–2013 period. The largest share is allocated to the Convergence Objective (€ 212 billion) covering significant shares in infrastructure investment in the 100 least prosperous NUTS 2 regions. Planned investment in transport infrastructure alone amounts to some EUR 81.7 billion. In addition, the cohesion fund (€ 70 billion) supports investment in transport and environmental infrastructure in the 15 Member States with the lowest levels of national income. Combining different EU sources, it is estimated that some EUR 400 billion have been invested in the TEN-T network projects since 1986 – almost a third coming from EU sources, much of it from the Cohesion Fund. [52] The TEN-T budget for 2007-2013 amounts to EUR 8 billion.

EU grants for infrastructure projects are often combined with loans from the **European Investment Bank**. The Bank's targeted lending programmes are structured on the basis of its public policy objectives of economic and social cohesion, growth and employment, environmental sustainability and climate action. In 2012, individual loans for a total of € 23.4 billion (equivalent to 52.3% of total lending inside the EU) were made for infrastructure (i.a. energy, transport, water supply). The Bank recognises that adaptation to climate change is necessary and aims to actively promote climate resilience and adaptation in the projects it finances. In 2011 the EIB's lending volume for dedicated adaptation projects inside the European Union was € 873.56 million.

Overall, the share of financing provided by the European Union for climate-resilient infrastructure illustrates a high – and growing – demand for climate investment.

---

[51] Kennedy, C. and J. Corfee-Morlot (2012), *Mobilising investment in low carbon, climate resilient infrastructure*, OECD Environment Working Papers, No. 46, Paris.

[52] European Commission (2010), *Investing in Europe's future: Fifth report on economic, social and territorial cohesion*, Brussels.

The European Union will step up its efforts in financing climate-resilient infrastructures in the **2014-2020 budgetary period**. It is foreseen[53] that a minimum of 20% of the overall 2014-2020 EU budget will go in climate-related investments. This is expected to have significant impact on infrastructure in Europe's less developed regions (formerly "converenge regions"), where most EU funding will be allocated. However, the newly introduced Connecting Europe Facility will also be available in more developed regions. The proposed funding plan is intended to speed up long-term investments in roads, railways, energy grids, pipelines and high-speed broadband networks. Using a significant, dedicated EU budget, the facility unites different networking infrastructure policies under one umbrella and is expected to create additional synergies between different sectors.

EU climate investment in action: the Port of Rotterdam (NL)

In 2012, the European Investment Bank has granted a € 900 million loan for a 20% expansion of the Port of Rotterdam. The funds are part of the 'Maasvlakte 2' project and will finance part of the € 3 bn in land reclamation. The port authority will enlarge the port area by 2000 hectares, bring the coastline 3.5 km further in the sea and build a deep-sea container and specialist facilities. Europe's largest port will see important improvements that will benefit inside and outside the European Union by accommodating increasing traffic and economic links.

The EIB provides a long-term loan over 30 years for an important project that will improve road and rail tracks, waterways, including 5 km of quayside and 12 km of seawalls, all of which have been designed to adapt to future climate change impacts, such as storms and sea-level rise. Furthermore, environmental aspects are cured, such as including a cycle path, a beach, a railway line, a sea bed protection area reservoir and enlarging the dune area.

5.2.2. Private-sector investment and business opportunities

A changing climate represents both a threat to economic activity and physical assets and an opportunity for new businesses and investment. Considering these risks and opportunities, the private sector's adaptive practices are two-fold:

First, companies aim at **value protection** to ensure the resilience of physical assets and planning responses to maintain business as usual. Companies are increasingly expected to demonstrate their long-term resilience, helping shareholders to understand the risk that climate change presents to their portfolios. Physical risks to fixed assets and infrastructure, impacts on supply chains, and shifting patterns in demand for goods and services could potentially also become material factors in the corporate credit risk assessment of banks.[54] When ensuring a company's business resilience, the protection of infrastructure plays a central role, both in terms of company buildings and of other assets ensuring supply chains (e.g. transportation fleets). Therein, regional events can have

[53] Amended proposal for a Council Regulation laying down the multiannual financial framework for the years 2014-2020, COM (2012) 388 final of 6/7/2012, Brussels.

[54] HSBC Case study on *New insurance products and climate risk*, Available at: http://unfccc.int/files/adaptation/nairobi_work_programme/private_sector_initiative/application/pdf/hsbc.pdf

global impacts (e.g. the floods in Thailand in 2011 caused significant physical damage and major disruption to supply chains across the globe).

Secondly, climate change adaptation offers **possibilities for value creation**. Adaptive practices are targeted at devising solutions that contribute to the ability to pursue new revenue-generating opportunities and help suppliers, stakeholders, and customers adapt to a changing climate.[55] Innovation in infrastructure solutions to meet new needs stemming from climate change effects can be considered as an important driver of future business and growth in the SME sector – provided that the right mix of skills and expertise is developed to respond to such demand.

Overall, the necessary investment in private infrastructure is expected to trigger additional investment and to create jobs. Finding new solution to better adapt infrastructure to climate risks and unlocking this potential for value creation can additionally foster **economic growth** in Europe. Adaptive business practices which are strategic, not reactive, can make an important contribution to Europe 2020. [56]

Climate risk awareness of businesses: Carbon Disclosure Project

The Carbon Disclosure Project's "Global 500 Climate Change" report (2012)[57] which provides information on adaptation in the world's 500 largest companies shows that increasing incidents of extreme weather events have significant impact on commercial infrastructures. Disrupted business operations and supply chains, caused by droughts in the Russia or floods in the USA, can have global business impacts. In 2012, 81% of reporting companies identified physical risk from climate change, with 37% perceiving these risks as a real and present danger, up from 10% in 2010. 2012 has also seen a 10% increase year-on-year in companies integrating climate change into their business strategies (2012: 78%, 2011: 68%). Overall, climate change hasn't dropped off the board's agenda during the economic downturn. In 2012, 96% of the world's largest companies reported that they have board or senior executive oversight of climate change.

5.2.3. The role of insurance

Insurance plays a central role in handling climate risks related to infrastructure and physical assets. The 2013 Commission "Green Paper on the prevention and insurance of disasters" discusses this aspect further and consults the wider public on possible future legislative action.

---

55 Finley, T. and Schuchard, R. (2011), *Adapting to Climate Change: A Guide for the Energy and Utility Industry,* BSR. http://www.bsr.org/reports/BSR_Climate_Adaptation_Issue_Brief_Energy_Utilities.pdf

56 According to the Flash Eurobarometer 342 on "SMEs, Resource efficiency and Green markets" only a minority of EU SMEs (26%) is providing green services and products to adapt, mitigate or restore environmental quality. At the same time, SMEs are discouraged to adopt a more pro-active stance on climate change adaptation and mitigation because of specific obstacles, such as limited knowledge, information and technical support as well as lack of time and resources to make the necessary invesments.

57 CDP – Carbon Disclosure Project (2012): Climate Resilient Stock Exchanges – Beyond the Disclosure Tipping Point. Carbon Disclosure Project, London. Available at https://www.cdproject.net/CDPResults/CDP-Global-500-Climate-Change-Report-2012.pdf

Insurance can be considered from three perspectives: as a market, as an instrument for adaptation, and as an industry and investor. All three perspectives are important when considering climate change and infrastructure.

Climate change could severely affect the **functioning of insurance markets for infrastructure**. The impacts are likely to be in the same areas where the catastrophe insurance markets already experience difficulties. These may intensify as a result of climate change. Three main areas are identified that might be affected by potential impacts: the risk transfer conditions (price/coverage), the availability[58] and the demand. It might be expected that climate change will increase the demand for insurance, due to higher risk. Also, if not addressed, climate change could lead to insurance becoming less affordable or unaffordable, particularly for lower income population. The forthcoming Commission Green Paper on the prevention and insurance of disasters will discuss these aspects more in detail.

Insurance can also be a valuable **tool for adaptation**. It can support adaptive practices in three main ways: by helping to manage climate change risks; by providing incentives for climate risk prevention; and by disseminating information on climate change risks and risk prevention measures. Insurance should be part of strategic risk management which needs to be observed for existing assets and activities, as well as new ones. In order to give incentives for risk prevention, insurance prices should be risk based and adequately adjusted according to risk prevention efforts taken by customers. Finally, 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.[59]

Together with other institutional investors (such as pension funds or mutual funds), the insurance sector can also play a **role in future infrastructure investment**. With over US$65 trillion in assets held at the end of 2009 in OECD countries alone, institutional investors could be key sources of capital, financing long-term, productive activities that support sustainable growth, such as green energy and infrastructure projects.[60]

Availability of insurance for physical assets

As a result of increasing climate 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[61] 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

58 ‘Availability’ means is the hazard covered at all, as opposed to ‘coverage’ i.e. how extensive is the insurance in terms of items and values.

59 Andrew Dlugolecki (2012): "*Insurance and climate change: A report for DG Climate Action (CLIMA) under the project 'Support to the development of the EU strategy for adaptation to climate change*'".

60 OECD (2011), “Pension Funds Investment in Infrastructure: A Survey”, *International Futures Programme, Project on Strategic Transport Infrastructure to 2030*.

61 Swiss Re (2007) *Flood: an Insurable Risk.* Swiss Re, Zurich.

62 ABI (2008) *Revised Statement of Principles on the Provision of Flood Insurance*. July 2008. Association of British Insurers, London.

adverse selection, and the risk is bundled with other hazards is a 75 year frequency, i.e. 1.3% probability.[62]

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.[63]

[63] ABI (2011) *Under-pricing of the flood element of home insurance for domestic customers at significant risk*. Research Brief. Association of British Insurers, London.

6. ANNEX

6.1. Annex 1: Climate risk and impacts on transport infrastructure

	TYPE	CLIMATIC PRESSURES	RISKS	TIME FRAME of expected impact	REGIONS mainly affected
RAIL infrastructure	Rail	Summer heat	• Rail buckling; • material fatigue; increased • instability of embankments; • overheating of equipment (e.g. engine ventilation, acclimatisation); • 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.	No information	No information
		In general:	• Reduced safety; • increased cost for reparation and maintenance; • disruption of "just in time" delivery of goods and passengers		
ROAD infrastructure	Roads (including 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	No information	No information
		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		
	Coastal roads	Sea level rise	• Damage infrastructure due to flooding; • coastal erosion; • road closure	Medium negative (2080)	European wide
		Extreme storm events		No information	No information

	TYPE	CLIMATIC PRESSURES	RISKS	TIME FRAME of expected impact	REGIONS mainly affected
		Heavy precipitation events		Medium negative (2025) to high negative (2080)	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
AVIATION infrastructure	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, outbuildings and access roads	Medium negative (2080)	European wide
		In general:	• Interruption and disruption to services supplied and to ground access; • periodic airport closures; • higher maintenance costs		
SHIPPING infrastructure	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)	No information	No information
		In general:	• Disruption of "just in time" delivery of goods; • stop of inland shipping; • welfare losses		
	Maritime transport	Sea level rise	• Navigability could be affected by changes in sedimentation rates and location of shoals; more frequent closure	Medium negative (2080)	European wide
		Change in sea conditions	• More severe storms and extreme waves might affect ships	No information	No information
		Less days	• Reduce problems with ice		

	TYPE	CLIMATIC PRESSURES	RISKS	TIME FRAME of expected impact	REGIONS mainly affected
		below freezing	accumulation on vessels, decks, riggings and docks; • Occurrence of dangerous ice fog	Medium positive (2080)	European wide
		Reduced sea ice	• Improved access; • longer shipping seasons; • new shipping routes	Summer sea ice could completely disappear in the Arctic Ocean somewhere between 2013-2040	No information
	Ports	Extreme storm events	• Devastation of infrastructure; • Interruptions and bottlenecks in the flow of products through ports	No information	No information
		Sea level rise		Medium negative (2080)	European wide
		Floods/ landslide		Medium negative (2025) to high negative (2080)	European wide
		In general:	• Disruption of "just in time" delivery of goods; • welfare losses; • increased cost for reparation and maintenance		
URBAN TRANSPORT	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 runoff	Medium negative (2025;2080) to high negative (2080)	2025: Southern, Western 2080: Eastern, Southern, Northern, Western, Central
		Sea level rise and storm surage 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

6.2. Annex 2: Climate risks and impacts on energy infrastructure

	TYPE	CLIMATIC PRESSURES	RISKS	TIME FRAME of expected impact	REGIONS mainly affected
TRANSMISSION AND DISTRIBUTION infrastructure	Primarily electrical transmission and distribution networks	Extreme high temperatures	• Decreased network capacity	Medium negative (2025) to extreme negative (2080)	EUwide
		Snow, icing, storms	• Increased chances on damages to energy networks/blackout	Medium negative to low positive (2050)	NWEU
		Heavy precipitation	• Mass movements (landslides, mud and debris flows) causing damages	Time frame, magnitudes and frequencies uncertain	Especially mountainous regions
	Primarily Transmission networks (oil and gas)	Melting permafrost	• Ties of gas pipelines in permafrozen ground cause technical problems (this is touching only arctic supply pipelines and not the EastWest 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	EUwide
	Primarily Storage and Distribution	Storms in connection with high tides and SLR	• Threats to refineries and coastal pipelines • due to SLR/high tide/storms		

	TYPE	CLIMATIC PRESSURES	RISKS	TIME FRAME of expected impact	REGIONS mainly affected
ENERGY SUPPLY AND DEMAND	Hydropower, largescale (downstream 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 (pluvialregime fed) stations	Medium negative (2025; 2080) to high negative (2080)	EUwide
	Hydropower, small scale (upstream/alpine)	Increased glacial runoff 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 longterm (2080) negative	EUwide
		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 Northern Europe: negative (highly uncertain)
		Solar irradiation	• Inverse proportional to cloudiness		
	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)	EUwide
		Floods	• Risk of flood damages due to location of most thermal facilities at water bodies (rivers)		
		Extreme low water flows	• Reduced cooling water availability		

6.3. Annex 3: Climate impacts on buildings/construction sector

CONSTRUCTION Infrastructure	CLIMATIC PRESSURES	RISKS AND IMPACTS				TIME FRAME of expected impact	REGIONS mainly affected
		RISK	**Potential ENVIRON-MENTAL impacts**	**Potential ECONOMIC impacts**	**Potential SOCIAL impacts**		
	Changing precipitation patterns	Fluvial /urban drainage flooding	Pollution (waste dumps, gas stations)	Through physical damage to buildings Maintaining infrastructure	Water safety of inhabitants Maintaining infrastructure	2020 Medium /low	Cities on rivers and cities with inadequate drainage systems
		High snow load		Through physical damage to buildings, Maintainining infrastructure	Safety problem Maintaining infrastructure	2020	Mountain areas, northern Europe
		Building and infrastructure subsidence and landslides	NA	Through physical damage to buildings Maintaining infrastructure	Safety Maintaining infrastructure	2050 Medium /low	Mountain areas
		Water scarcity, drought and implications for water resources	Limitations for green roofs	Internal water use limited. Subsidence of clayrich soils and peat soils causing foundation damage	NA	2020 Medium /medium	Southern Europe
	Temperature increases	Heat/ cold related deaths	NA	Decreased labour productivity, higher costs for cooling, Increased costs for emergency /medical services /supplies	Health impacts	2050 Medium /medium	Improving in NE, deteriorating in SE
		Diseases (vector and waterborne diseases)	NA			2050 Medium /low	Europewide
		Air quality and health	NA			2020 Medium /low	Europewide, notably south
	Sea level rise	Sea level rise and storm surge flooding Salt water intrusion	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	2080 Medium /low	Coastal cities
	Extreme events (storms)	Direct wind storm damage	NA	Physical damage to buildings Maintaining infrastructure	Inconveniences by service disruption of electricity and water	2080 Low /low	Europewide, coastal areas
		Disruption of power, communication, other services	NA			2050 Low /low	Europewide, coastal areas

		CLIMATIC PRESSURES	RISKS AND IMPACTS RISK	Potential ENVIRON-MENTAL impacts	Potential ECONOMIC impacts	Potential SOCIAL impacts	TIME FRAME of expected impact	REGIONS mainly affected
	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	
	Reduction of electricity demand by consumer (through selfsupply 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	
		Droughts	High energy demand by pumping for irrigation				Low negative	Southern and Eastern Europe