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There are a number of different future-city visions being developed around the world at the moment: one of them is Smart Cities: ICT and big data availability may contribute to better understand and plan the city, improving efficiency, equity and quality of life. But these visions of utopia need an urgent reality check: this is one of the future challenges that Smart Cities have to face.

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# SMART CITIES CHALLENGES

## SMART ENVIRONMENT FOR SUSTAINABLE RESOURCE MANAGEMENT

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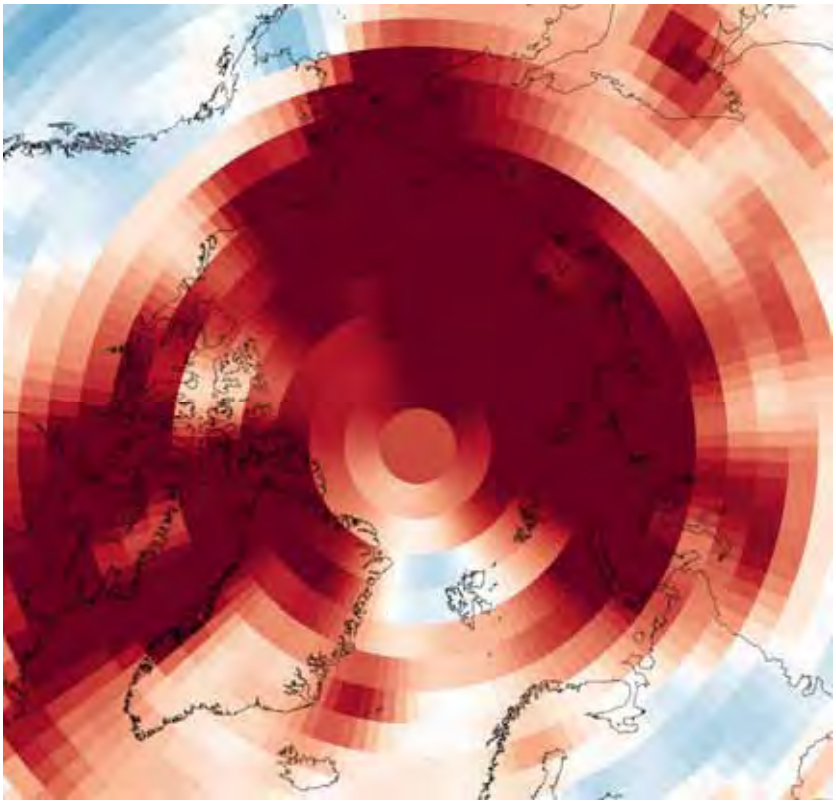

# CLIMATE CHANGE ADAPTATION

## CHALLENGES AND OPPORTUNITIES FOR SMART URBAN GROWTH

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ABSTRACT

Climate change is one of the main environmental issues challenging cities in the 21th century. At present, more than half of the world population lives in cities and the latter are responsible for 60% to 80% of global energy consumption and greenhouse gas (GHG) emissions, which are the main causes of the change in climate conditions. In the meantime, they are seriously threatened by the heterogeneous climate-related phenomena, very often exacerbated by the features of the cities themselves.
In the last decade, international and European efforts have been mainly focused on mitigation rather than on adaptation strategies. Europe is one of the world leaders in global mitigation policies, while the issue of adaptation has gained growing importance in the last years. As underlined by the EU Strategy on adaptation to climate change, even though climate change mitigation still remains a priority for the global community, large room has to be devoted to adaptation measures, in order to effectively face the unavoidable impacts and related economic, environmental and social costs of climate change (EC, 2013). Thus, measures for adaptation to climate change are receiving an increasing financial support and a growing number of European countries are implementing national and urban adaptation strategies to deal with the actual and potential climate change impacts.
According to the above considerations, this paper explores strengths and weaknesses of current adaptation strategies in European cities. First the main suggestions of the European Community to improve urban adaptation to climate change are examined; then, some recent Adaptation Plans are analyzed, in order to highlight challenges and opportunities arising from the adaptation processes at urban level and to explore the potential of Adaptation Plans to promote a smart growth in the European cities.

KEYWORDS:
Climate Change, Urban Adaptation, Smart Growth

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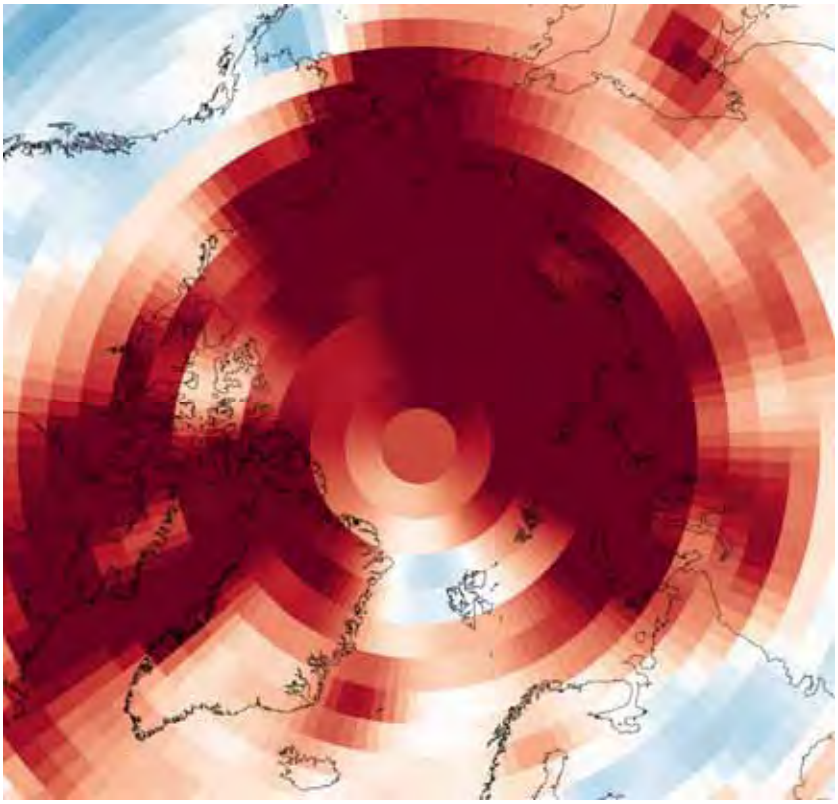

# 气候变化适应

## 智能城市增长的挑战和机遇

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摘要

气化变化是城市在二十一世纪所面临的主要环境问题之一。欧洲城市容纳了该地区人口的四分之三，并占用了总体能源消耗和温室气体（GHG）排放的60%至80%，这是造成气化条件变化的主要原因。与此同时，欧洲城市受到各类与气候相关的现象的严重威胁，而这些与气候相关的现象常常因这些城市的自身功能而更加恶化。

在过去十年中，国际和欧洲一直将工作重点放在缓解战略而非适应战略上。欧洲是倡导全球缓解政策的先导之一，而与此同时适应性问题的重要性在过去几年中也有所提升。尽管气化变化缓解战略仍然在全球范围内保持优先地位，但随着针对气候变化适应的欧盟战略得到强化，为有效应对气候变化所带来的不可避免的影响和相关的经济、环境及社会成本，必须为适应措施的应用提供更大空间（EC，2013）。因此，有关气候变化的适应措施正在得到越来越多财政上的支持，并且越来越多的欧洲国家正逐步实施国家和城市适应战略，来应对当前和潜在的气候变化影响。

依上述考虑因素，本文探讨了目前在欧洲城市中实施的适应战略的优势和劣势。首先要审查关于提高城市对气候变化适应能力的主要欧共体建议；然后分析一些最新的适应方案，其目的是突显出在城市层面的适应过程中所生产的挑战和机遇，并探讨适应方案对于在欧洲城市中促成智能增长的潜在能力。

关键词
气候变化；城市适应；智能增长

# 1 CITIES DEALING WITH CLIMATE CHANGE IMPACTS

Climate change and the growth of urban population are widely recognized as the major drivers of change in the 21st century.

Climate change, which represents one of the most challenging issues of our time, refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007). According to IPCC, it is largely due to greenhouse gas (GHG) emissions. Carbon dioxide ($CO_2$) is the most important anthropogenic GHG and recent data confirm that consumption of fossil fuels accounts for the majority of global anthropogenic GHG emissions (IPCC, 2011).

At present, more than half of the world population lives in cities and it will further increase by 2050. In Europe, the 73% of the population was living in urban areas in 2011 and the level of urbanization is expected to be at 82% by 2050 (UN, 2012) (fig. 1).

Hence, as the cities are responsible for 60% to 80% of global energy consumption and GHG emissions, it is clear that the two phenomena are largely interconnected and that the ways in which climate change and urban population trends will develop and interact "will be of great consequence to the well-being of human populations as the century proceeds" (Klein, Schipper, Dessai, 2003). According to the last report of the IPCC (2013), indeed, the "continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions".

Thus, cities play a key role in face of climate change and climate related phenomena. On the one hand, urban lifestyle and economy are largely responsible for global energy consumption and contribute for about the 70% to the GHG emissions (Birkmann et al. 2010; EU, 2011). On the other hand, cities are seriously threatened by the impacts of climate change, requiring serious and effective strategies addressed to reduce their exposure and vulnerability to climate-related phenomena and, consequently, to prevent the potential damage to urban population.

Up to now, major efforts have been addressed to promote mitigation strategies, aimed at reducing GHG emissions, while less attention has been devoted to adaptation strategies, aimed at improving cities' capability to deal with the impacts of climate change. In Europe, one of the world leaders in global mitigation policies, ambitious energy and climate change objectives have been established in 2007 by the EU 20-20-20 Strategy. In 2011, the 2050 Energy Roadmap set new long-term targets, addressed to achieve the 80-95% reduction of GHG emissions by 2050 (compared to 1990) (Egenhofer, Alessi, 2013).

The issue of adaptation is gaining importance only recently: the EU Strategy on adaptation to climate change, adopted in 2013, clearly underlines that "although climate change mitigation must remain a priority for the global community (…), we (…) have no choice but to take adaptation measures to deal with the unavoidable climate impacts and their economic, environmental and social costs" (EC, 2013). Thus, the measures for adaptation to climate change are receiving an increasing financial support and a growing number of European countries are implementing national and urban adaptation strategies to deal with actual and potential climate change impacts (Birkmann, 2011). The focus on adaptation stems from the growing and shared awareness that, despite the efforts to reduce GHG emissions, climate change is going to occur (Solomon et al., 2007) and its impacts will be particularly severe in urban areas (ICLEI, 2011), due to the concentration of people and assets.

In Europe, the changes in climate conditions are already affecting numerous countries and are going to spread on all European countries. Nevertheless, according to the results of the ESPON 2013 Programme, climate stimuli are heterogeneous in nature and typology and not uniformly distributed in the European regions.

Hence, in order to understand the impacts of climate change on European cities, both the heterogeneous distribution of climatic stimuli in the European regions and the role of urban features in modifying regional climate conditions have to be taken into account.

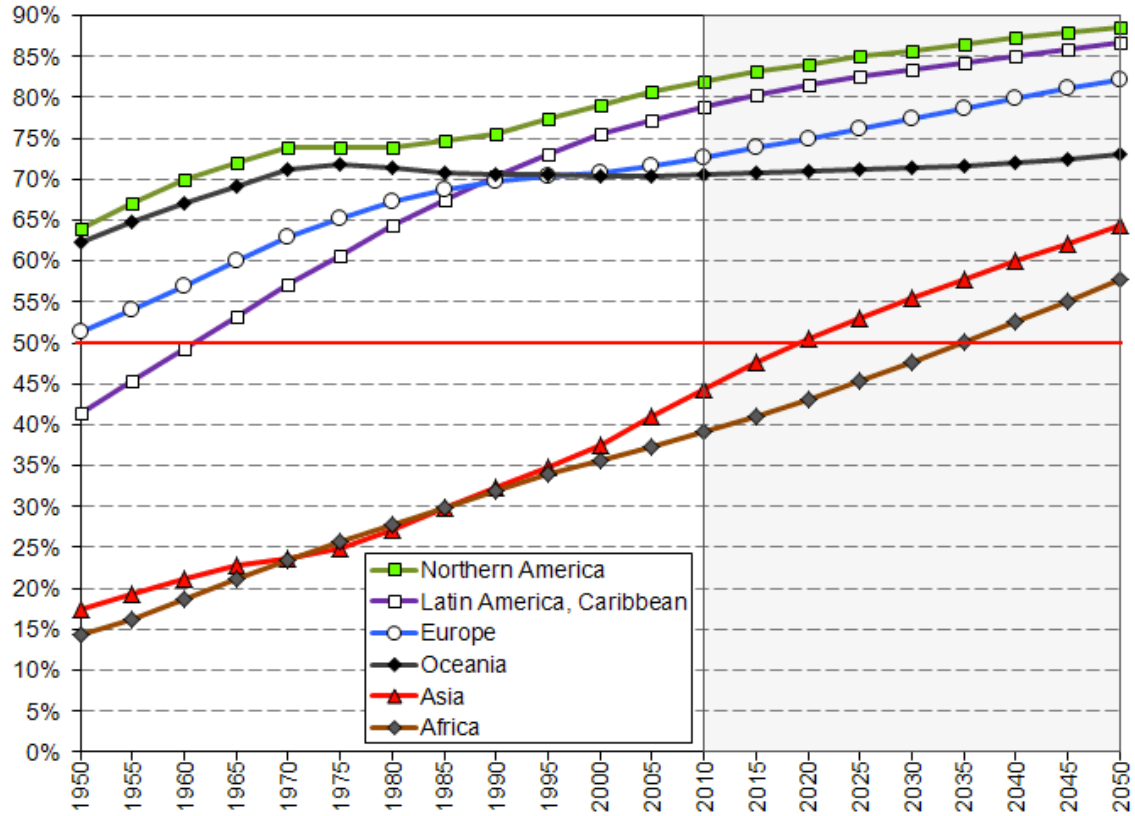


Fig. 2 Urban Population by major geographical areas (% on total population)

Numerous scholars have pointed out the key role of local factors in modifying climate change impacts on urban areas (McCarthy et al., 2010; Nguyen Xuan, 2011), even though up to now the features of urbanized areas have received little attention in climate model projections (IPCC, 2007).

Nevertheless, it is largely recognized that cities may experience different impacts in respect to surrounding regions, due to heterogeneous factors: for example, a high degree of surface sealing may impair rainwater drainage, reinforcing the urban heat island effect (Magee et al., 1999; Müller, 2012; Lehmann et al. 2012); the prevalence of built-up areas on natural spaces creates a peculiar microclimate in cities, which may affect air temperature, wind direction and precipitation patterns. Moreover, the growing concentration and the ageing of urban population may exacerbate exposure and vulnerability of cities to climate-related phenomena. Finally, since cities are strongly dependent on their hinterland, namely for food and water supply, they are also significantly vulnerable to climate change impacts occurring in the surrounding areas (Hunt and Watkiss, 2011; McEvoy et al., 2010).

Thus, due to the variability of climate phenomena in the European regions and to the peculiar features of cities, impacts may be very heterogeneous, ranging from floods to droughts, from cold snaps to heat waves, with serious consequences for human health, livelihood and urban assets. Cities in low-elevation coastal zones have also to deal with the combined threat of sea-level rise and storm surges.

Although detailed quantitative analyses of climate-related hazards on a city scale are still at an early stage, in the last decade, numerous scholars and institutional documents have focused on the potential impacts of climate change on cities. Thus, referring to the existing studies for a detailed description of the main impacts of climate change on European cities (McEvoy, 2007; Wilby, 2007; Hunt and Watkiss, 2009; EEA, 2012), it is worth mentioning here only the most common ones.

*Heat waves*

Climate-change projections suggest that the length, the frequency and the intensity of summer heat waves will increase in the next future, affecting different European Regions, with significant effects on human health, mainly on vulnerable population (elderly, people affected by chronic respiratory diseases, etc.) (Schär et al., 2004; Meehl and Tebaldi, 2004; D'Ippoliti et al., 2010). The phenomenon can be worsened by the

features of cities themselves: the lack of blue and green areas, the population density, the additional heat production due to the concentration of human activities may aggravate the phenomenon in the cities located both in the South and in the North of Europe.

*Sea-level rise*

Sea-level rise is one of the most certain elements of climate change and probably the most studied impact of climate change on coastal cities (Hunt and Watkiss, 2009). Many European cities are close to coastal areas and will be highly vulnerable to rising sea levels and associated increases in extreme events such as storm surges. A rise of 20 centimeters (possible by the year 2030) could threaten the coastal settlements, wetlands, and lowlands. The entire Dutch coast, Hamburg, Copenhagen, and Venice could be affected. Raising dams could be very expensive for individual countries and regions. Moreover, sewage treatment in coastal cities is geared to a certain range of water levels and the rising sea levels may contribute to make this infrastructure obsolete.

*Flooding*

Many scholars agree that climate change will affect precipitation pattern worldwide, with serious impacts on cities. Nevertheless, there is still a great deal of uncertainty in findings about climate-change impacts on future extreme precipitation and considerable differences among estimates of precipitation in different climate models and for different emission scenarios. Floods have caused the greatest economic losses in Europe in the last years (EEA, 2012). Flooding phenomena result from the interaction of rainfall, surface run-off, evaporation, wind, sea level, and local topography: hence, due to the changes in climate conditions, they can be significantly increased in cities. Most European cities are already committed to address flood risk issues, even though the types of flooding they have to face are heterogeneous, from flash floods to urban drainage floods or to coastal floods, occurring during storm surges when there are temporary increases in sea levels above the normal tidal range (EEA, 2008).

*Water scarcity and droughts*

Water availability is crucial for urban development: “fresh water is used for drinking,by industry (production processes and cooling), energy production, recreation, transport and nature. Sufficient water of good quality is therefore indispensable to ensure human health and to fuel the economy” (EEA, 2012).

Water is a crucial issue for Europe. In 2007, the European Commission adopted a Communication on Water Scarcity & Drought (WS&D) (EC, 2007), which identified seven policy areas that had to be addressed in order to move Europe towards a water-efficient economy. In 2012, “A Blueprint to Safeguard Europe's Water Resources”, addressed “to tackle the obstacles which hamper action to safeguard Europe's water resources and based on an extensive evaluation of the existing policy” (EC, 2012) has been issued.

At present, water scarcity and droughts represent a threat not only to the drier areas in Europe, although dry conditions reduce water availability for drinking and sanitary purposes, but also for central and eastern European regions. Moreover, water resources might further decrease in Europe due to the “increasing imbalance between water demand and water availability” and climate change may reduce the availability and reliability of the water supply and exacerbate the adverse impacts, “with the occurrence of more frequent and severe droughts in many parts of Europe” (EEA, 2012).

Thus, climate-related hazards, combined with the high vulnerability of cities to extreme meteorological events, will induce an increase in the frequency and in the consequences of the existing risk levels and, consequently, in the damage costs, as largely demonstrated by the heat waves that affected numerous cities in Central and Western Europe (2003) and in Eastern Europe (2010) or by the urban drainage flood in Copenhagen (2011).

The pivotal role of cities in addressing climate change has been largely recognized in the last decade (Betsill, Bulkeley, 2007; Bulkeley et al. 2011). Nevertheless, while numerous European cities have joined the Covenant of Majors, giving rise to a mitigation strategy, few of them have started an adaptation process addressed to establish local strategies - closely related to the existing disaster risk reduction and to land use

planning strategies - for enhancing urban resilience in face of "the unavoidable climate impacts and their economic, environmental and social costs" (EC, 2013).

Based on these premises, this paper explores the potential of Adaptation Plans to promote a smart growth in the European cities, translating the challenge of climate change into a chance for a better urban development (Birkmann et al, 2010). The term "smart" is referred, on the one hand, to the principles established by the Smart Growth Network[1] and addressed to the development of sustainable communities and places that are attractive, convenient, safe, and healthy (ICMA, EPA, 2006; Inam, 2011). On the other hand, it refers to the current debate on "smart cities", meant as cities where investment in human and social capital and in communications infrastructure actively promote the overall urban performances and, above all, the quality of life of citizens and the management of natural resources (Caragliu, Del Bo, Nijkamp, 2009; Papa, Gargiulo, Galderisi, 2013).

Hence, being sustainable development one of the most urgent challenges that smart cities have to deal with (Schaffers et al. 2011), by optimizing energy and water usage and by offering safer cities, climate adaption plans, through an effective use of ICTs, could largely contribute to make European cities safer and, above all, to effectively integrate environmental issues (from energy saving to risk prevention and mitigation) into sustainable land use planning processes, capable of enhancing the quality of life and prosperity for current and future generations as well as to protect and improve the quality of urban environment.

## 2 EUROPEAN STRATEGIES IN FACE OF CLIMATE CHANGE: FROM MITIGATION TO ADAPTATION

Europe has been defined as one of the world leaders in the global mitigation policies, whereas only recently the focus of European policies has been shifted towards adaptation issues. As remarked by the EU Strategy on adaptation to climate change, although three quarters of the population of Europe live in urban areas, European cities "are often ill-equipped for adaptation" (EC, 2013).

Mitigation and adaptation strategies, although complementary, differ both in their objectives and in their temporal and spatial scales of references. Mitigation strategies, which aim at reducing GHG emissions, generally result from international agreements, although implemented at national or local levels, and refer to a long-term perspective. Adaptation strategies, which aim at adjusting natural or human systems in response to actual or expected climatic stimuli or their effects (UNISDR, 2009), are strongly characterized as site-specific measures. Moreover, as they generally refer to the scale of the impacted system, they are defined and implemented at local level - although sometimes based on wider common platforms at national or upper level - and provide local benefits (Bulkeley et al. 2009; Walsh, 2010; EEA, 2012).

Focusing on mitigation issues, it is worth mentioning that the two milestones of the European path for reducing GHG emissions can be identified in the "20-20-20" Strategy and in the "Roadmap for moving to a competitive low carbon economy in 2050" (Galderisi, Ferrara, 2012; Gargiulo, Pinto Zucaro, 2012). The first one, adopted in 2007 by the European Council, established ambitious energy and climate change objectives, consisting of three key objectives to be achieved by 2020:

- a 20% reduction in EU GHG emissions from 1990 levels;
- an increase in the share of renewable energy up to 20%
- an improvement of 20% in energy efficiency.

Currently, the EU is on track to meet the first target, good results have been recorded in respect to the second one, but the third one is still far from being achieved.

1 The Smart Growth Network is a partnership of government, business and civic organizations that support smart growth. It has been created in the late Nineties and, based on the experience of communities that have used smart growth approaches to create and maintain livable neighborhoods, has developed a set of ten basic principles (http://www.epa.gov/smartgrowth/about_sg.htm).

The Roadmap 2050, issued in February 2011, has established new targets, related to a long-term scenario and addressed to reduce GHG emissions by 80-95% by 2050 compared to 1990.

Moreover, the EU has started numerous initiatives addressed to improve knowledge and awareness in respect to adaptation issues. The numerous reports published since 2007 by the European Environment Agency (EEA) on adaptation to climate change, the White Paper "Adapting to climate change: Towards a European framework for action", issued in 2009, the web-based European Climate Adaptation Platform (Climate-ADAPT), launched by the EU and the EEA in 2012 and the related EU Cities Adapt Project - addressed to support European cities in developing and implementing a climate change adaptation strategy by exchanging knowledge and good practices, and by developing tools and guidelines - the EU projects on climate adaptation (e.g. BaltCICA, 2009-2012; RAMSES, 2012-2017) show the growing attention to climate adaptation and, mainly, the growing awareness of the need to enhance cities' resilience in face of climate related risks. Furthermore, on the 16th of April 2013, the EU Strategy on adaptation to climate change, addressed to enhance preparedness and capacity to respond to the impacts of climate change at different levels, from the European one up to the local level, was issued (EC, 2013).

The strategy promotes coordination and information-sharing among the Member States, also through a further development of the European climate adaptation platform (Climate-ADAPT); encourages the State Members to adopt adaptation strategies, providing funds for improving national adaptation capacities; supports adaptation in cities by launching a voluntary commitment based on the Covenant of Mayors initiative; guarantees that adaptation issues are considered in different sectors of EU policies. The Strategy represents a key step towards the adoption and the implementation of effective adaptation strategies at different levels, since in Europe, "adaptation is in most cases still at an early stage, with relatively few concrete measures on the ground. Some Member States have developed sector-specific plans, such as plans to cope with heat waves and droughts, but only a third carried out a comprehensive vulnerability assessment to underpin policy" (EC, 2013).

At present, referring to the national level, it is worth noting that more than half of the European Member States have adopted an adaptation strategy, in many cases followed by action plans.

Shifting to the city level, which represents the focus of this study, although cities are considered as pivotal both to mitigation and adaptation issues, the European cities that have drawn up an adaptation plan are still few and mainly located in North-Central Europe (UK, Finland and Germany). A recent study highlights that, on a sample of 200 large and medium sized cities located in 11 European countries, the "35 % of European cities studied have no dedicated mitigation plan and 72 % have no adaptation plan. No city has an adaptation plan without a mitigation plan. One quarter of the cities has both an adaptation and a mitigation plan and set quantitative GHG reduction targets, but those vary extensively in scope and ambition" (Reckien et al., 2013).

The obstacles to an effective climate change adaptation at city level are numerous and heterogeneous (Adger et al., 2009; Bulkeley et al. 2009; Corfee-Morlot et al. 2011). First of all, it is worth underlining that adaptation has to be conceived not as a one-time effort but as a process articulated in different interrelated phases (fig. 4) (Hennessy et al., 2007; The World Bank Group, 2011, UN, 2013): a knowledge phase, addressed to assessing climate impacts and risks at urban scale; a preparation phase, addressed to define strategies and measures for adaptation; a response and revision phase, addressed to implement, monitor and update the defined measures. In the knowledge phase, the main difficulties are related both to the downscaling of climate change models to urban scale and to the assessment of urban vulnerability to climate-related phenomena. Scientific information about the future climate conditions is generally characterized by high uncertainty.

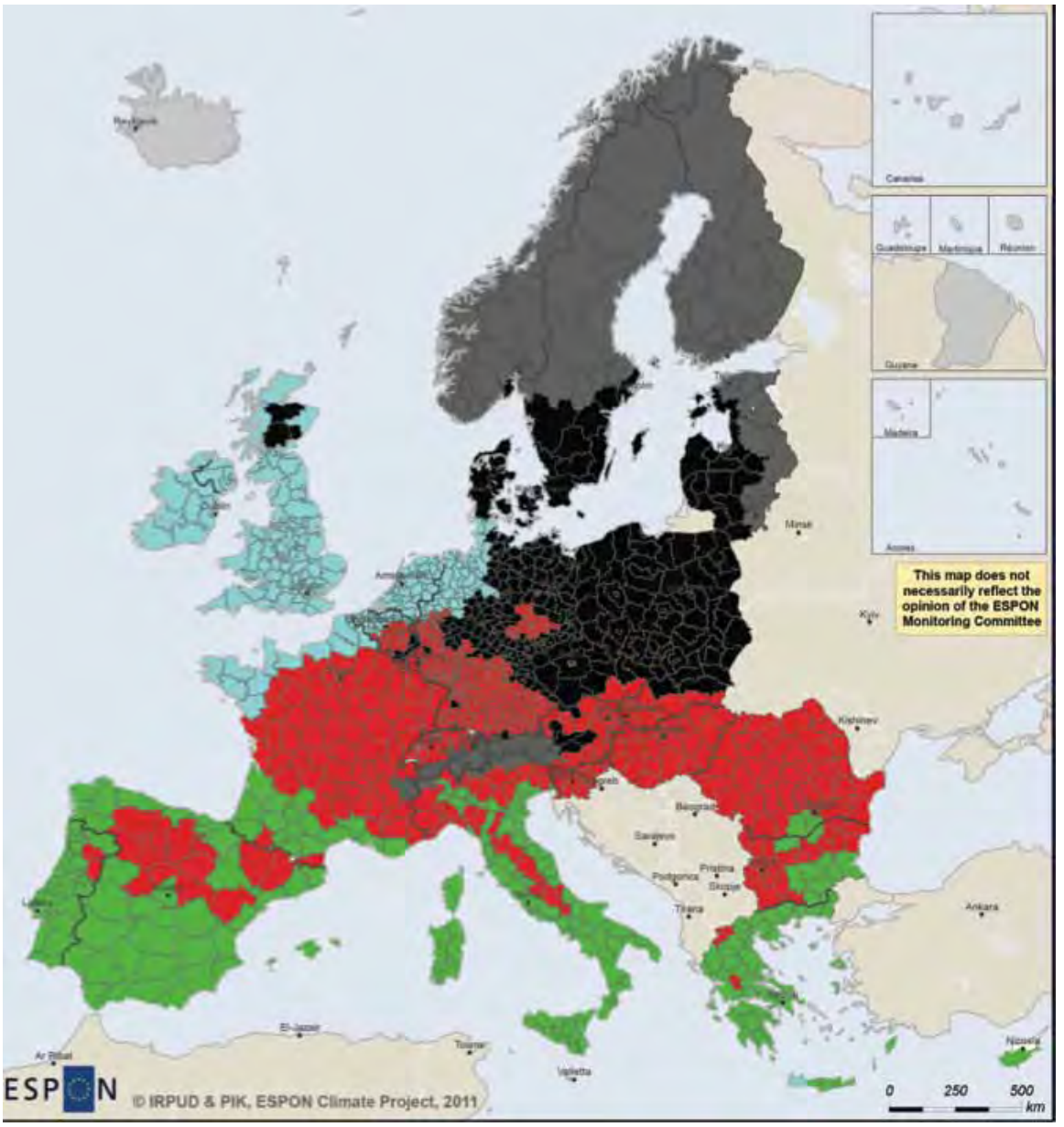


Fig. 3 European Climate Change Regions

The uncertainties that characterize large/regional scales climate models are generally exacerbated when these models are downscaled at city scale, which is the crucial step for identifying the city-specific impacts and, consequently, to identify vulnerabilities. Furthermore, on a city level, the climate impact assessment should take into account both the gradual/long term climate-related impacts (increases in the mean temperature or sea level rise) and the sudden shocks due to the changes in the intensity and frequency of extreme events (Wilbanks et al., 2007; Corfee-Morlot et al, 2011; Hunt and Watkiss, 2011).

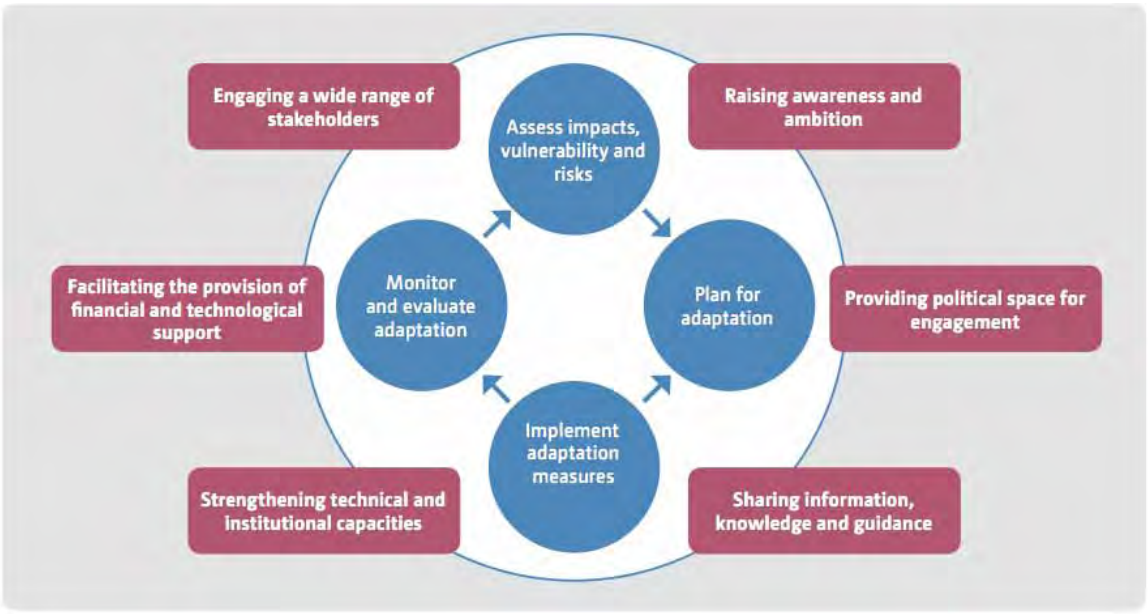




Fig. 4 (a, b, c) Examples of Adaptation Processes

Further difficulties in the knowledge phase arise from the assessment of urban vulnerabilities to the heterogeneous impacts of climate change. The assessment of the multi-dimensional concept of vulnerability shows difficulties and uncertainties largely debated in the field of natural hazards and related, for example, to the need for taking into account the different facets of vulnerability (physical on built and natural environment, systemic, economic, etc.) as well as the adaptive capacities of an urban context (Birkmann, 2006; Galderisi et al., 2008; UNISDR, 2009; Menoni et al. 2011). The different temporal perspectives of climate change impacts, combined with the uncertainties that affect long-term urban development trajectories, make even more difficult the assessment of urban vulnerability to the climate-related phenomena.

The uncertainties that characterize the knowledge phase have also repercussions on the preparation phase, addressed to single out effective adaptation strategies. The availability of a reliable risk assessment is crucial, in fact, to identify priorities as well as the availability of in-depth and disaggregate information on the heterogeneous risk factors (hazards, exposure, vulnerabilities) is essential to outline appropriate adaptation strategies. Moreover, the heterogeneity of adaptation measures represent a significant difficulty in the preparation phase. Even though they can be grouped under some general categories – 'grey' measures, relying on technology and civil engineering projects; 'green' or nature-based measures and 'soft' measures addressed to alter human behavior (EEA, 2013) – urban adaptation measures have to be site-specific and tailored on the urban context. Thus, these measures have to be defined according to the peculiarities of local impacts and to the vulnerabilities arising from the physical, functional and socio-economic features of the considered city.

Moreover, climate change may affect different sectors (from land use to transportation, from water supply to energy). Hence, the need for coordination across different sectors and for broad partnerships including local communities, nonprofit organizations, academic institutions and the private sector has been largely emphasized as a potential barrier to an effective adaptation. Numerous scholars have pointed out, in fact, the importance and at the same time the difficulty in coordinating policies and measures across both local agencies and levels of government, as well as among institutions, private stakeholders and communities, (Bulkeley et al, 2009; Corfee-Morlot et al., 2011).

Finally, the need for integrating adaptation strategies, disaster risk reduction (DRR) policies and land use and transportation planning choices at local level has been also emphasized. According to Corfee-Morlot et al. (2009), adaptation strategies could be important for reducing "vulnerability to current and future hazards such as floods, water shortage or heat waves, even though "cities should also consider incremental or gradual changes in climate that affect government operations or community life in less immediate and visible ways than conventional disasters" (The World Bank Group, 2011). Moreover, Hallegatte et al. (2011) emphasize that "land use decisions and zoning may exacerbate or limit the vulnerability of urban dwellers and of infrastructures to the growing threat of climate change".

Obviously, an effective integration of adaptation policies into existing tools for risk reduction as well as for urban and transportation planning is a key challenge for cities, given the difficulties that they currently face in guaranteeing an integration of DRR policies into land use planning tools (Galderisi, Menoni, 2007).

Nevertheless, such integration could be a great opportunity for cities and communities, generally dealing with significant resource constraints, to access financial resources and to reduce potential conflicts between climate change issues and other local priorities. According to the Guidelines for Climate Change Adaptation in Cities provided by the World Bank, "cities that are able to integrate adaptation well with a broad spectrum of existing planning processes and goals - including priorities in disaster risk reduction, sustainable development, and poverty reduction - will be best positioned to thrive in this new era of climate change" (The World Bank Group, 2011).

The complexity and long-term horizon of climate change phenomena, of the evolution of cities as well as of the adaptation processes assign a key role to the revision phase, important for ensuring the effectiveness of the whole process.

The implementation of the adaptation measures have to be constantly monitored, evaluated and revised, according both to the updating of the available knowledge on climate change and climate-related phenomena and to the effectiveness of policies, programs and measures. Nevertheless, "monitoring and evaluation is proving to be particularly difficult, as indicators and monitoring methodologies have hardly been developed" (EC, 2013). Hence, the revision phase has an inherent complexity and is currently considered one of the weakest areas of adaptation process, due to the difficulties of monitoring heterogeneous measures (grey, green or soft ones), affecting different sectors, acting on different scales and over different time spans. Moreover, the common lack of financial, human and technical resources, of baseline data and historical trends as well as the insufficient sharing of information across different sectors have to be considered.

## 3 ADAPTION PLANS: TOOLS FOR SMART GROWTH?

This paragraph will be focused on three Adaptation Plans: the London Mayor's Climate Change Adaption Strategy "Managing Risks and Increasing Resilience, (2011); the Copenhagen Climate Adaptation Plan (2011); the Rotterdam Climate Adaption Strategy (2013).

The selected cities are defined as climate leader cities, being very active both on mitigation and adaptation issues: they belong to the C40-network of the world's cities engaged in mitigation actions (Reckien et al., 2013) and can count on adaptation strategies established on a national level.

Since the selected Plans have been approved very recently, we do not intend here to provide an assessment of their effectiveness. Based on the available on-line documents, we will try to point out and compare their main features and, so doing, we will seek to understand their potential for overcoming obstacles and barriers previously discussed and, above all, to answer the main research question posed by this paper: may adaptation plans contribute to the promotion of a smart growth in the European cities?
To this aim, in respect to each case-study, the capacity to integrate smart solutions in the different phases of the adaptation process as well as to improve the quality of life of the citizens, to preserve and enhance the quality of natural environment, to promote participatory processes - increasing the awareness of communities and decision-makers about the climate-related phenomena and consequent risks - to integrate adaptation policies into DRR and land use planning processes will be explored.

*London*

The Greater London, with a population of 8,173,941 (Census data, 2011), is the biggest city in the UK and the largest one in Europe. According to the UK legislation, in 2007, the responsibility for climate change mitigation, adaptation, and energy strategies have been transferred from central government to the Greater London Authority (GLA), which includes the Mayor and the Assembly.
The GLA has the duty to assess the consequences of climate change and to define adequate strategies. It has also extensive planning powers and is responsible for producing London-wide strategies for spatial planning and environment (the latter includes adaptation, mitigation and energy policies). Thus, according to the current legislation, the GLA has the opportunity to coordinate the actions of different partners and to guarantee that proposed actions are effectively implemented (Davoudi et al., 2011). Recently, the GLA has played a key role at both international and local level: it "has acted as a driving force at the international level, through putting its weight behind the C40 Climate Leadership Group and its association with the Clinton Climate Initiative"; moreover, at local level, it "has taken steps to address the various climate challenges" (Davoudi et al., 2011).
The milestones of the London strategy for addressing climate change issues can be identified in The Mayor's climate change mitigation and energy strategy, "Delivering London's Energy Future", and in The Mayor's Climate Change Adaption Strategy, "Managing Risks and Increasing Resilience", both of them issued in the October 2011. The former details the Mayor's strategic approach to reduce London's CO2 emissions by 60% of the 1990 levels by 2025 and to secure a low carbon energy supply for London. The latter, on which we will focus here, is addressed to evaluate the consequences of climate change on the city of London, to prepare the city for dealing with the impacts of climate change and extreme weather and, in the meanwhile, to protect and enhance the quality of life of citizens.
The London Strategy emphasizes that adaptation has to be shaped as a dynamic and flexible process, capable of dealing with the many uncertainties related to the future of climate and of city development. In fact, "measures that address the impacts of our climate today may not provide an acceptable level of protection in the future, or enable us to make the most of the opportunities that arise, and so new measures will be needed. There is, therefore, no steady-state of being adapted" (London Mayor's Climate Change Adaption Strategy, 2011). Moreover, the Strategy emphasizes that climate change adaptation
not require new policies or new planning tools but the capacity of understanding "how climate change may affect the world around us and then routinely integrating that understanding into our decision-making processes to make better choices" (The Mayor's Climate Change Adaption Strategy, 2011).
The London Strategy grounds on the UK Climate Projections 2009 (UKCP09), which updates the UK Climate Impacts Programme 2002 (UKCIP02), and provides probabilistic projections for a number of atmospheric variables (such as temperature, rainfall and humidity) according to different emission scenarios, temporal and geographic scales. It focuses on three main climate-related risks: flooding, drought and overheating. In respect to each risk, a wide range of actions and measures has been provided.

All the measures are organized into a framework stemming from the Emergency Planning: the Prevent-Prepare-Respond-Recover (P2R2) framework. The prevention measures aim at preventing the events through structural measures as well as through spatial planning.

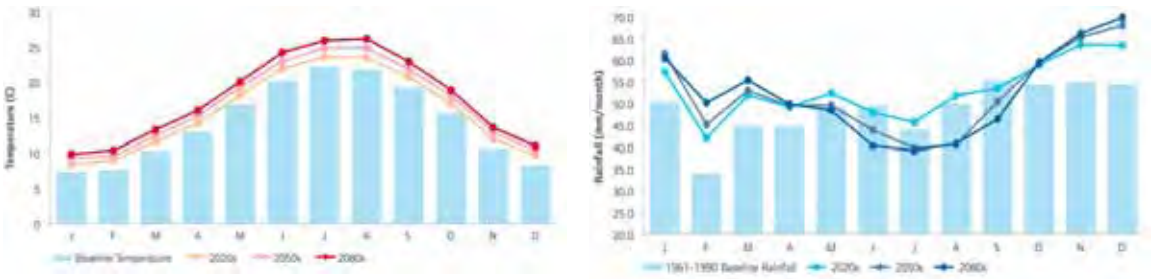

Figure 5 Average monthly maximum temperatures (°c) in London over the century, under a medium emissions scenario, compared to baseline period (left); Average monthly rainfall (mm of rainfall per month) in London over the century, under a medium emissions scenario, compared to baseline period (right)

The preparation measures are addressed to improve the preparedness of institutions, communities and individuals in face of the different risk factors through Risk Management Plans, Early Warning Systems, insurances mechanisms, etc.

The response measures aim at reducing the consequences of events through an effective emergency planning, while the recovery phase refers to post-event interventions and is addressed to guarantee a "rapid, cost-effective and sustainable return to normality" (Davoudi et al., 2011).

Grounding on the these premises, the Adaptation Strategy focuses on each risk, in order to assess current and future impacts, taking into account the probability of the hazardous events, their consequences, the exposed people and assets and their vulnerability.

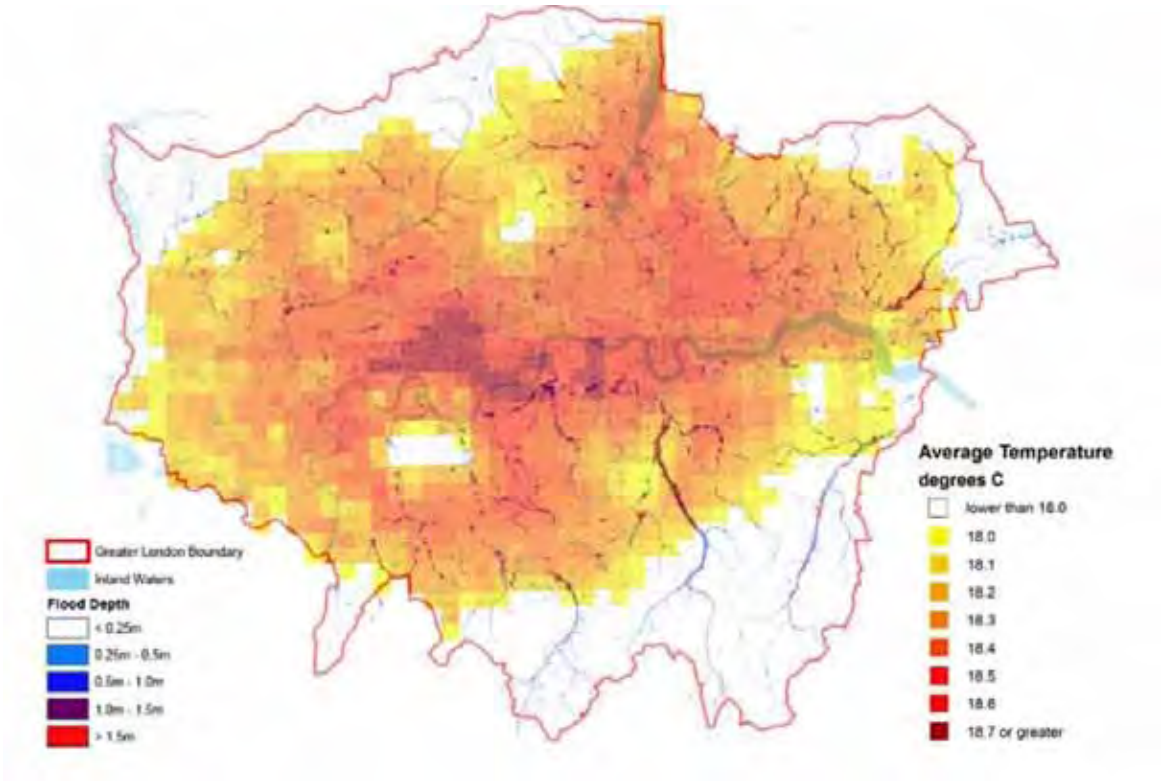


Fig. 6 The Combined Flood and Overheating Risk in London

For each risk, the Plan outlines the general vision and, according to it, the main policies and actions to be put in place. Then, the Plan focuses on the impacts of the different climate-related hazards on four key aspects - health, environment, economy and infrastructures - providing specific actions for each aspect.
Finally, in the last section, a roadmap to build up a resilient London in face of the different threats has been outlined: the Plan provides in fact a detailed list of the objectives to be achieved in the time span 2010-2013, specifying the related actions and the subjects in charge of their implementation.

*Copenhagen*

It is the capital city and the most populated city in Denmark, with a population of 559.440 in 2013 and more than one million inhabitants in the urban area. In the last years, the city of Copenhagen has devoted large attention to climate issues.
Copenhagen aims to be the first carbon neutral capital city in the world, with a reduction of city's $CO_2$ consumption from current level of around 2.5 million tonnes to 1.2 million tonnes in less than two decades.
To achieve such an ambitious goal, the city has adopted the CPH Climate Plan 2025, focused on energy consumption, energy production, mobility, and city administration: "wind farms, citywide efficient heating systems, energy efficiency, and the development of public transportation networks and bike routes are some of the initiatives in the works to bring Copenhagen closer to its carbon-neutral goal" (CPH Climate Plan 2025). Moreover, in 2009, the city started the adaptation process, with the draft of the City of Copenhagen Climate Plan. In 2011, in order to continue to be a safe and attractive city to live and spend time in, despite the expected changes in the future climate, Copenhagen has adopted its Climate Adaptation Plan. The local climate projections are based on the IPCC's reports as well as on the reports from the Danish Meteorological Institute (DMI) in connection with the climate strategy for the Capital Region, on the publications of the Water Pollution Committee of the Society of Danish Engineers and on the high-water statistics of the Danish Coastal Authority.
Nevertheless, uncertainties due both to climate projections as well as to urban development trajectories are largely emphasized. The Plan highlights that the "IPCC's projections for the development of climate are relatively certain for the next 30 to 40 years" and that "no one knows precisely how the world will develop technologically, in population terms, politically etc., or precisely how this will affect the climate, and whether this will be overlain by natural disasters etc." (Copenhagen Climate Adaptation Plan, 2011).
Therefore, the Plan provides a flexible strategy capable of meeting uncertainties, by incorporating new knowledge and technology as and when they emerge.


Fig. 7 The Copenhagen Climate Adaptation Process

Adaptation strategy identifies as primary challenges the impacts of heavier precipitations, sea-level rise and storm surges, while as secondary challenges focuses on the impacts of higher temperatures and consequent urban heat islands and on the indirect impacts affecting human health, biodiversity, air quality.

In respect to the primary challenges, the Plan includes a detailed risk analysis, outlining different risk scenarios according to the magnitude of the hazardous events, to different time spans and taking into account the potential effects of protecting measures.

Risk analysis provides a comparison among the potential damage, in monetary terms, of the different scenarios, according to the land use of the affected areas. Nevertheless, an in depth analysis of exposure and vulnerability to the different hazard factors is missing.

According to the different risk scenarios, the Plan outlines three different adaptation levels:

- level 1, aiming at reducing the likelihood of the event up to its complete prevention, includes structural measures as well as building regulations (e.g. dikes, building higher above sea level, etc.);
- level 2, aiming at reducing the impacts of the event, includes for example warning systems for rain, adaptation of public spaces in order to store rainwater etc.;
- level 3, aiming at reducing the consequences of the event, includes for example measures addressed to improve emergency preparedness.

Moreover, adaptation measures are structured in respect to different geographical scales, from the regional one up to the district, street and building levels.

Although the Plan is primarily concerned with the safeguard of the city and its inhabitants against climate change impacts, it is firstly intended as an opportunity to promote urban development so that Copenhagen may continue to be one of the world's best cities to live in (Copenhagen Climate Adaptation Plan, 2011).

Fig. 8 The Hazard Scenarios: Floods In A 100-Year Rain Event In 2110

Thus, the Plan outlines a wide range of measures and projects, all of them clearly framed into the proposed vision for future development: the "Greener Copenhagen". Such a vision contributes to strengthen a tradition started in the late 1940s, with the "Copenhagen Finger Plan", which has shaped urban development on a regional scale, by limiting built-up areas to linear corridors starting from the central core and separated by green areas.

| | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| Measure<br>Geography | Reduce probability | Reduce scale | Reduce vulnerability |
| Region | Establishment of dikes | Establishment of warning system for high waters | Protection of vulnerable infrastructure, metro, S-trains, tunnels |
| Municipality | Establishment of dikes | Planning, warning | Planning, preparedness |
| District | Raised building elevation, dikes | Preparedness, sandbags etc. | Moving of vulnerable functions and installations |
| Street | Raised building elevation, dikes | Preparedness, sandbags etc. | Moving of vulnerable functions and installations |
| Building | Raised building elevation | Backwater valves, sealed basements, preparedness, sandbags etc. | Moving of vulnerable functions and installations |

Fig. 9 The Articulation by Levels and Geographical Scales of the Adaptation Measures

According to such a vision, the Adaptation Plan suggests measures addressed to:

- preserve and look after existing green spaces;
- provide the city with more green and blue spaces;
- create continuous green networks in the city.

Finally, it is worth noting that the Adaptation Plan pays large attention to integrate the climate adaptation measures into existing planning tools at local level as well as into existing tools for disaster risk reduction and emergency preparedness; it provides a detailed overview of costs and the time scheduling of all the foreseen measures and projects, although in respect to a short time span (2011-2015).

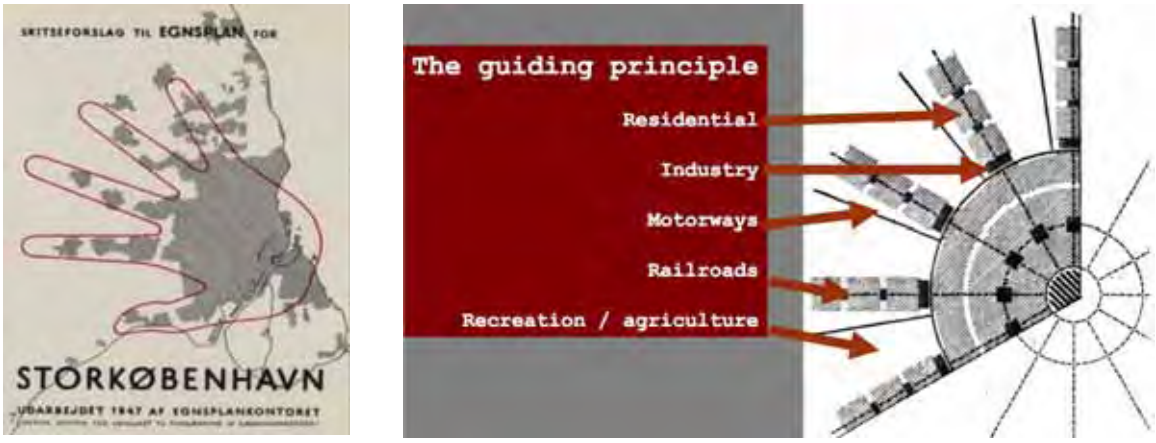


Fig. 10 The Copenhagen Finger Plan: Principles

*Rotterdam*

The city, with a population of approximately 600.000 inhabitants, is the second-largest city in the Netherlands and the biggest port city in Europe.

As Copenhagen, Rotterdam has outlined a comprehensive strategy to address climate change aimed, on the one hand, at reducing by 50% $CO_2$ emissions in 2025 in respect to the levels in 1990; on the other hand, to adapt to climate change effects, in order to guarantee a fully climate change resilient city by 2025. Rotterdam has always lived with the threat of water: “the dams, dikes and land reclamation have brought the dangers

and the risk of flooding under control (…). This has made Rotterdam, although still vulnerable, one of the safest delta-cities in the world" (Rotterdam Climate Adaption Strategy, 2013).

Nevertheless, in face of a changing climate and of a city that is still growing and continuously developing, the likelihood of casualties, losses and economic damage in case of flooding, might significantly increase.

Hence, the main goal of the Adaptation Strategy is to build up a climate-proof Rotterdam by 2025. To achieve such a goal, the city's strategy is addressed to develop smart solutions, capable of integrating technical innovation and urban development, technology and nature, large-scale and small-scale solutions. The Rotterdam strategy points out the need for increasing robustness of the complex system of storm surges barriers and dikes, canal and lakes, sewers and pumping stations, even though it clearly emphasizes that structural measures, although essential, are not sufficient for dealing with a changing climate. Hence, the need for solutions capable of involving all the aspects of urban development and, above all, of enhancing urban resilience is outlined.

The Adaptation Strategy grounds on the climate scenarios developed by the Royal Meteorological Institute of the Netherlands in 2006 and on the considerable knowledge developed within the Delta Programme, a national program issued in 2013 and addressed to protect the Netherlands from flooding and to secure a sufficient supply of freshwater for generations ahead.

Based on this knowledge, the Plan identifies the main climate-related phenomena affecting the city:

- higher sea and river levels;
- more intensive rainfall;
- longer period of droughts;
- heat waves.

For each phenomenon and in respect to different temporal spans, the Plan provides risk maps, singling out vulnerable areas and elements. Moreover, the main interactions among the different phenomena are taken into account. In face of the different risks, the Plan provides an articulated adaptation strategy, a framework to promote, favor and stimulate initiatives of different actors. The provided strategy combines, indeed, top-down and bottom up initiatives, as well as large-scale and small-scale solutions, ordinary actions of management and maintenance and new developments projects, general guidelines and detailed projects.

The adaptive measures are based on the risk features and the peculiarities of each urban area (outer and inner dike areas; compact city; port area, etc.) and range from the flood-proof buildings and public spaces to the floating communities, from the green roofs and facades to the green-blue corridors.

Moreover, in respect to each considered risk, the Plan provides a sample project, generally an on-going one, which represents a sort of "guide-project" for tackling the phenomenon at stake.

The Rotterdam Climate Adaptation Strategy devotes large attention to the development of smart solutions capable of increasing city's smartness. The integration of ICTs into an innovative and adaptive flood control system as well as tools for promoting community's involvement have been developed and tested.

"Smart gaming, a war room like 'demonstrator', decision support systems, application of sensor technology in dikes and many other tools will be developed and integrated into one system to make Rotterdam a smarter and safer city in the future" (Dircke, Molenaar, 2010). Among the smart solutions it is worth mentioning the "Interactive Climate Atlas", which is accessible to different stakeholders, provides general information about climate scenarios, vulnerable areas and buildings and allows the comparison among the consequences of various climate scenarios; the "Climate Adaptation Tool Box", a key tool for project managers, urban and building designers, which provides an overview of potential adaptation measures for different spatial scale-levels and objectives.

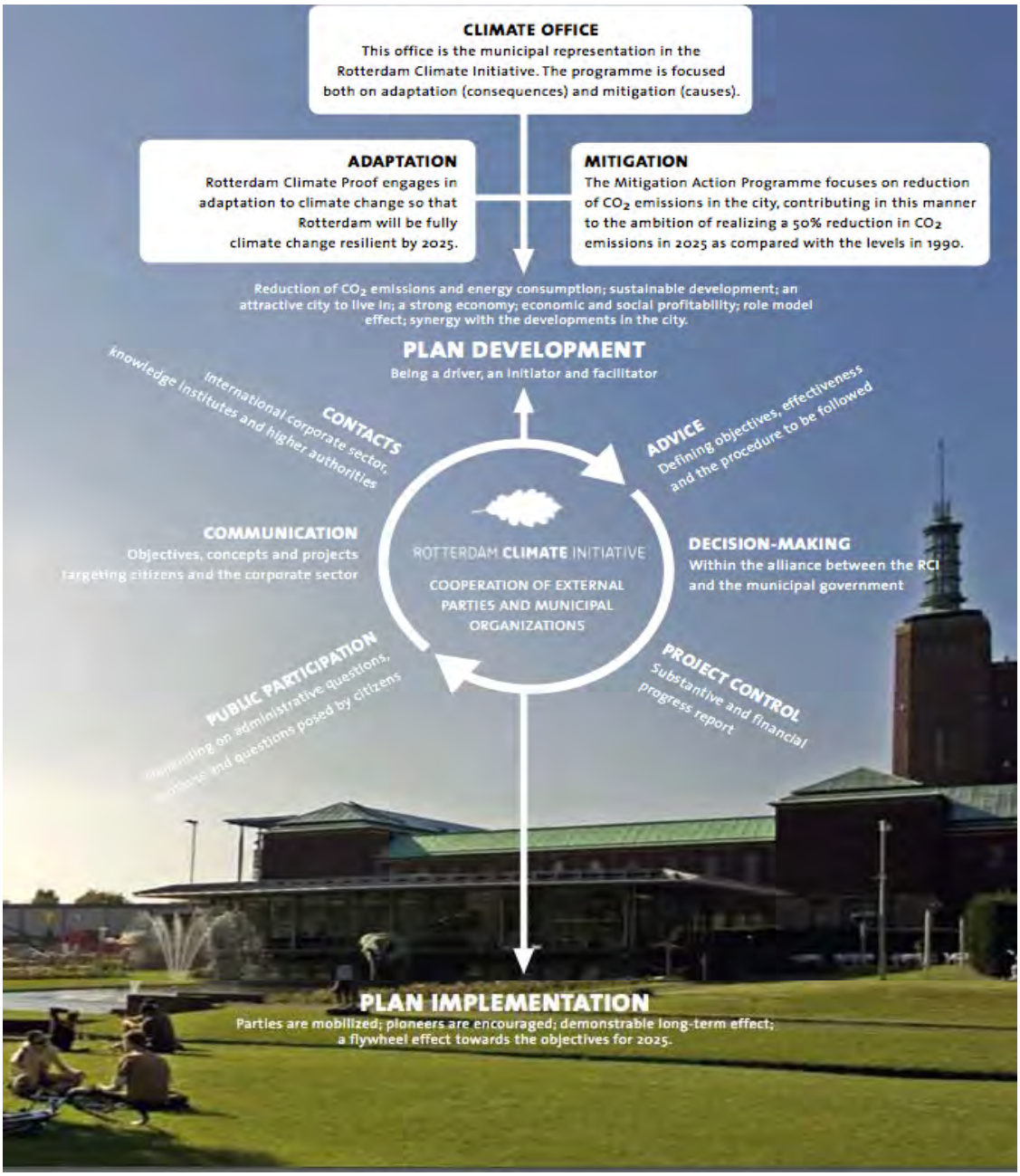


Fig. 11 The Rotterdam Climate Strategy

Fig. 12 Urban Heat Island: Risk Map

Moreover, based on the opportunities offered by the digital environment, the potential of new communication tools - such as the apps for smart phones or the social media - has been explored. In the same line, the "Climate Game" - which allows users to play an active role in the adaptation process, learning more about the various involved interests and stakeholders and about the consequences of different choices - has been developed. All these tools are addressed to inform people, improving the awareness of the community about the climate-related phenomena and consequent risks, but also to favor and sustain bottom-up initiatives and to build up consensus on adaptation measures. Moreover, they largely contribute to disseminate knowledge, which represents a key issue for enhancing urban resilience in face of climate change (Davoudi, 2013; Galderisi, 2014).

Summing up, based on the case studies here briefly described, adaption plans seem to have a great potential for starting innovative processes, addressed to make European cities safer and, above all, to integrate environmental issues (from energy saving to risk prevention and mitigation) into sustainable land use planning processes, also through an extensive use of ICTs.

The proposed examples are addressed not only to prevent or reduce the impacts of the numerous climate-related hazards but, above all, to preserve and enhance the quality of life and prosperity for current and future generations as well as to protect and improve the quality of urban environment. Moreover, they seem to have the potential for overcoming most of the obstacles that currently curb adaption processes. Nevertheless, even though the selected Adaptation Plans represent a cutting edge in the European context, they present strengths and weaknesses that will be briefly discussed in the following.

First of all, the proposed case studies result from multilevel and integrated climate policies, developed according to a clear structure of competences and duties both at national and at local level. In the UK the responsibility for climate change mitigation, adaptation, and energy strategies have been transferred from central government to the Greater London Authority, which has extensive planning powers and is responsible for producing London-wide strategies for spatial planning and environment. Denmark is characterized by a close cooperation among national and local government. In 2008, the Danish Ministry of Climate, Energy and Building published the general strategy for climate change adaptation, which promotes and supports the coordination among Local Authorities and favors informed decisions at lower levels.

The Netherlands has a long tradition of cooperation among different government bodies, stakeholder organizations and citizens. National government, provinces, municipalities and regional water boards work together, indeed, with inputs from the social organizations and the business community, in order to realize climate resilient urban areas. Moreover, in the 2012, the "Delta Act", a nationwide programme addressed to coordinate adaptation strategies at the local level, entered into force. On the local scale, the three case studies have developed an integrated climate policy, since Mitigation and Adaptation Plans have been issued together or within a few years. Such a circumstance is important in order to guarantee synergies and to reduce the conflicts, which often arise between mitigation and adaptation policies. For example, compact settlements may reduce energy demand and transport emissions; on the opposite, the increase in built mass would intensify the urban heat island effect, posing serious problems to urban drainage. Furthermore, the increasing urban heat island effect would lead to an increased use of air-conditioning and, consequently, to an increase in emissions (Walsh et al., 2010).

As for the knowledge phase, the case studies present relevant strengths in respect to the assessment of the climate-related hazards. Despite the difficulties related to the downscaling of large-scale climate models, the selected plans provide in-depth analyses of the climate-related phenomena on an urban scale, based on large-scale scenarios and in-depth studies at local scale.


**Fig. 13 The Rotterdam Climate Game**

On the opposite, they show some weaknesses in the vulnerability assessment, since they do not provide any definition of vulnerability and do not refer to the long and rich tradition of studies and researches on vulnerability carried out in the field of natural hazards. In this field, although methodologies for analyzing and assessing vulnerability are still heterogeneous, the concept has been widely recognized as a multi-dimensional one, comprising different aspects (physical, systemic, social, economic, environmental, institutional, etc.), constantly interacting in time and space (Birkmann, 2006; Galderisi et al., 2013; UNISDR, 2009; Menoni et al., 2011).

Unfortunately, based on the available on-line documents, the examined Plans provide aggregate risk evaluations, generally expressed in monetary terms, paying scarce attention to the different aspects of urban vulnerability and including little or no vulnerability maps (generally only maps of the exposed elements to the different hazard factors are available). This represents a weak point in current adaptation plans. Even though risk assessment is important to identify priority areas and sectors, in fact, vulnerability analysis is crucial to outline appropriate adaptation policies. Moreover, although some of the case studies explicitly refer to resilience, the latter is not defined and no indicators for measuring resilience are provided.

As for the preparation/response phase, all the selected Plans show a great awareness of the uncertainties that, characterizing the knowledge phase, reflect on the preparation phase. Indeed all of them refer to a short-term time horizon and emphasize that adaptation does not represent a steady state. The selected Plans outline dynamic and flexible adaptation processes in face of the uncertainties related to changing climate projections, to urban development trajectories as well as to future technical development and capable of continuously incorporating new knowledge and revising, accordingly, their goals, objectives and actions. Although with reference to a short time span, most of them provide a detailed economic and temporal program of adaptation measures, articulated in respect to different geographical scales or to different urban areas, singling out subjects and tools for their implementation.

In respect to the obstacles that generally characterize the preparation phase - related to the heterogeneity of policies, to the need for integrating adaptation policies into existing planning tools and, consequently, for coordinating different stakeholders - it is worth noting that all the sample Plans emphasize that climate change adaptation does not require new policies or new planning tools. On the opposite, all of them clearly state that adaptation requires a clear understanding of how climate change may affect the context at stake and the integration of such understanding into all decision-making processes affecting urban development. Furthermore, they emphasize the need for linking adaptation strategies to other policies and projects, as well as to existing management and maintenance programs and, namely, for mainstreaming adaptation policies into existing disaster risk management and land-use planning process. As mentioned above, such integration requires an intensive cooperation among different stakeholders. Therefore, it is crucial to have shared aims for a climate-proof urban development and the capability of coordinating all the involved stakeholders.

As for the revision phase, it has to be noticed that whereas the Mitigation Plans, grounding on international or European thresholds, may constrain their strategies to precise targets - which facilitates the control on the effectiveness of the implemented strategies and actions – the Adaptation Plans generally include site-specific measures, referred to the peculiarities of the impacted systems. Hence, both the comparison among different Plans and the monitoring of the adaptation process are generally more difficult.

Furthermore, even though the analyzed Plans provide a detailed economic and temporal planning of the proposed actions, none of them provide indicators capable of monitoring the effectiveness of the foreseen actions. Finally, a weak area of the analyzed adaptation plans can be related to the usage of smart tools for improving the awareness of climate-related impacts among different stakeholders.

Only the Rotterdam Plan provides smart solutions (e.g. sensor technologies, decision support systems, interactive knowledge tools, etc.) for collecting and disseminating knowledge as well as for building up consensus on adaptation measures and sustaining bottom-up initiatives.

## 4 CONCLUSION

In face of the impacts of the climate-related phenomena (floods, heat waves, etc.) that numerous European countries are already suffering and following the initiatives started by the EU for improving knowledge and awareness of adaptation issues, numerous European cities have recently started an adaptation process, despite the significant obstacles due to the uncertainties in the future climate scenarios.

This contribution, after a brief description of the main impacts of climate change on urban areas and of the main hints provided by the European Community to improve urban adaptation to climate change, has been focused on three Adaptation Plans:

- the London Mayor's Climate Change Adaption Strategy "Managing Risks and Increasing Resilience, (2011);
- the Copenhagen Climate Adaptation Plan (2011);
- the Rotterdam Climate Adaption Strategy (2013).

The three selected Plans represent a cutting edge in the European context where, although cities are widely recognized as pivotal both to mitigation and adaptation issues, up to now most of them do not have an adaption plan (Reckien et al., 2013).

The selected case studies have allowed a better understanding of the challenges and opportunities arising from the adaptation processes. On the one hand, in fact, they shed light on the numerous difficulties related to the different phases of the process.

On the other hand, they clearly underline that adaptation planning might be a great opportunity for promoting a sustainable and smart growth, enhancing urban resilience in face of "the unavoidable climate impacts and their economic, environmental and social costs" (EC, 2013).

| Key-Aspects | | Adaptation Plans | | |
|---|---|---|---|---|
| | | London (2011) | Copenhagen (2011) | Rotterdam (2013) |
| integrated Climate Policy | *Availiability of a National Climate Strategy* | ✓ | ✓ | ✓ |
| | *Availiability and integration with a Mitigation Plan* | ✓ | ✓ | ✓ |
| Knowledge phase | *Hazard assessment: availability of climate studies at local scale* | ✓ | ✓ | ✓ |
| | *Definition of vulnerability as multidimensional concept* | | | |
| | *Availability of vulnerability maps (in the on-line documents)* | Mainly Exposure maps | | ✓ |
| | *Risk assessment* | Risk as a combination of probability and cost of damage | Cost of damage in respect to different hazard scenarios | Risk maps combining hazard and vulnerability |
| | *Multi - Risk Assessment* | | A qualitative assessment combining different threats is available | |
| | *Typology of available scenarios* | Hazard | Hazard | Risk |
| Preparation/Response Phase | *Fexible strategy capable of meeting uncertainties* | ✓ | ✓ | ✓ |
| | *Short term horizon for adaptation policies* | ✓ | ✓ | ✓ |
| | *Detailed economic and temporal planning of the adaptation measures* | ✓ | ✓ | |
| | *Measures articulated for geographical scale/urban areas* | | ✓ | ✓ |
| | *Capacity of integrating large scale and small scale solutions* | ✓ | ✓ | v |
| | *Availability of Guide-Projects* | | ✓ | ✓ |
| | *Integration with tools for Risk Prevention/Mitigation and Emergency Planning* | ✓ | ✓ | ✓ |
| | *Integration with tools for Land Use Planning* | ✓ | ✓ | ✓ |
| Revision Phase | *Avaiability of indicators for monitoring the adaptation process* | | | |
| Smart tools | *Smart tools for disseminate knowledge among different stakeholders* | | | ✓ |
| | *Smart tools for increasing people awareness* | | | ✓ |

Fig. 14 The key aspects of the London, Copenhagen and Rotterdam Adaptation Plans (*in green the main weaknesses*)

In respect to the opportunities, it is worth noting that climate change phenomena and their increasing impacts on urban areas are forcing planners to look behind, paying a renewed attention to the principles of environmental planning.

The concept of adaptation to the threats as well as to the opportunities arising form the natural environment has always represented, in fact, a crucial issue for environmental planners (Whiston Spirn, 1973; Michel, 2000; Steiner, 2006). Such issue can be currently revisited and improved according to the large debate developed in the last decades on sustainability and resilience.

In respect to the challenges, it is worth stressing that the selected experiences do not seem to fully benefit either by the significant results already achieved in the field of risk analysis or by the significant opportunities arising from the current debate on smart cities. As for the first point, despite the numerous projects funded by the European Community and addressed to promote the building up of a shared knowledge and common methodologies among the scholars working in the field of natural hazards and the scholars involved in studies and research on climate change, a difficulty in transferring concepts, methods and results from one field to the other still persists. This is even more troubling in the light of the close relationships between climate related impacts and the increasing occurrence of natural hazards (e.g. floods) and of the consequent need, largely emphasized in current experiences, for better integrating adaptation

strategies and DRR policies and for including both of them into the wider framework of urban planning processes. As for the second point, according to some scholars a city can be defined smart when investments in human/social capital and IT infrastructure fuel sustainable growth and enhance a quality of life, through participatory governance (Nam and Pardo, 2009; Papa, Galderisi, Gargiulo, 2013). Unfortunately, the application of ICTs in the adaptation processes, although they could play a key role in each phase of the process, seems to be still at an early stage. Only the Rotterdam Climate Adaption Strategy, in fact, explicitly focuses on the opportunities arising from the ICTs in disseminating knowledge, improving the awareness of the climate change consequences among different stakeholders, favoring the information exchange and sustaining bottom-up initiatives.

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## IMAGE SOURCES

Fig. 1: http://commons.wikimedia.org/wiki/File:ArcticYearlongTempAnom_HR.jpg

Fig. 2: UN, Department of Economic and Social Affairs, Population Division (2012)

Fig. 3: Greiving et al., 2011

Fig. 4: 4a) United Nations (2013); 4b) http://weadapt.org/knowledge-base/adaptation-decision-making/adaptation-planning-process; 4c) Hennessy, Fitzharrisì et al. (2007)

Fig. 5, 6: London Mayor's Climate Change Adaption Strategy (2011)

Fig. 7, 8, 9: Copenhagen Climate Adaptation Plan (2011)

Fig. 10: Vejre, Skov-Petersen, Henschel (2007)

Fig. 11, 12: Rotterdam Climate Adaption Strategy, 2013

Fig. 13: Source: http://vimeo.com/68119632

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