Synthesis Report
URBAN CLIMATE RESILIENCE

URBAN-NEXUS

The research leading to these results has received funding from the European Union's Seventh Framework Programme [FP7/2007-2013] under grant agreement n° 282679.

This report forms project deliverable 2.1

Contents

1. About this report

1.1 Audience

This is the first in a series of synthesis reports produced by URBAN-NEXUS. These Reports are intended mainly for municipalities, policy-makers and businesses engaged in urban issues. They may also be of interest to organisations, institutions and networks involved in decision-making and developing partnerships to tackle problems encountered in urban sustainable development and management. This includes public sector agencies, utilities, the private sector, civil society organisations and community groups.

1.2 Purpose of the report

The synthesis reports will help inform debate and discussion as part of an ongoing "structured dialogue" across a network of urban researchers, professionals and actors on developing integrated approaches to the challenges and opportunities of sustainable urban development. The main forum for supporting a rich exchange and learning environment will be a series of "dialogue cafés" held in different European cities during the course of the project. These will encourage participants to identify and prioritise common issues and develop partnerships to help promote and deliver innovative, effective and integrated responses to improving urban sustainability.

Each Synthesis Report will address a different theme. The theme for this report is Urban Climate Resilience. It is intended to stimulate discussions at the first URBAN-NEXUS dialogue café that will be held 29th-30th May 2012 in Glasgow. The discussions will form a follow-up report due late summer, 2012, which will feed into subsequent thematic synthesis reports on health, land-use, urban governance, and data and monitoring. This will engender an evolving dialogue and foster integrated approaches to urban sustainability that become intrinsic to decision-making processes and partnership activity.

1.3 Report preparation

Climate change was identified as a priority research area as part of the work undertaken by the EU predecessor research project, URBAN-NET, in developing a strategic research framework for sustainable urban development. The URBAN-NET study was based on partners' collective knowledge and evidence pooled from across Europe as part of a comparative assessment of national and regional research programmes. The current report considers research, mainly European, undertaken in the four years since the URBAN-NET Framework was published. It also considers evidence from cities, towns and partnerships of practical interventions and strategies adopted to create resilience to climate change. This information was collected from the URBAN-NEXUS consortium, the strategic partners and a wider network of contacts. Examples of case studies and research are presented throughout the report to illustrate relevant sections. A complete list and summary details of all of the information provided is available as an annex to this report.

1.4 Concurrent reports and initiatives

The following European initiatives and projects concerning urban climate change adaptation emerged during the preparation of this report:

- the European Environment Agency's report on "*Urban adaptation to climate change in Europe*"[1];
- an EC-funded DG CLIMA project on "*Adaptation Strategies for European Cities*"[2]; and
- the EEA initiative, European Climate Adaptation Platform[3] (CLIMATE-ADAPT), which will eventually integrate urban content from the preceding project.

With the above in mind, this report focuses more specifically on European research rather than policy and implementation. Case study material collected beforehand is still included.

1.5 Use of terms

For ease of reading, the terms "urban" and "city" are used interchangeably throughout this document and no specific distinction is drawn between either term with regard to distinct morphologies or administrative boundaries.

1.6 Questions for the dialogue café

In preparation for the URBAN-NEXUS Dialogue Café on 'Urban Climate Resilience: Partnership Approaches', being held 29th and 30th May 2012 in Glasgow, we would like delegates to consider the following questions.

- With which of the key messages do you agree/disagree?
- Does the report cover the theme appropriately? What is missing and what should be covered in more depth?
- What do you find most encouraging or interesting in the report?
- What do you find most challenging in the report?

1.7 Acknowledgements

The authors would like to thank everyone who contributed case study material.

June Graham (Programme Coordinator) & Sacha Rawlence (Researcher)

Sniffer, May 2012 (on behalf of URBAN-NEXUS)

[1] Published 14th May 2012 http://www.eea.europa.eu/publications/urban-adaptation-to-climate-change
[2] *http://eucities-adapt.eu*.
[3] http://climate-adapt.eea.europa.eu/

2. Summary

We open with some key findings based on our overall personal impression of the evidence available from recent research and practice. Next, we provide an overview of urban resilience to climate change which outlines the critical role for cities in responding to climate change, both in reducing greenhouse gas emissions and in adapting to climate change impacts. We discuss the concepts of climate 'vulnerability' and 'resilience' in an urban context. This section on resilience also identifies areas and knowledge gaps that are discussed in later sections of the report.

The next section presents preliminary surveys of research and practice on the four key topics of

- Risk & Uncertainty;
- Governance;
- People; and
- Place.

For each topic we suggest areas for more detailed consideration in future URBAN-NEXUS activities on the themes concerning health, land-use, integrated urban management and data & monitoring.

Risk & Uncertainty
This first topic concerns the problems of assessing climate risks at a city level. Modelling climate change and predicting future trends at different spatial and temporal scales introduces a range of uncertainties, including feedback loops and potential tipping points in the natural environment and environmental processes and unknown impacts from socio-economic drivers which will influence future emission trajectories. These uncertainties are compounded by a range of data and monitoring issues associated with e.g. local data collection, verification, interpretation, accessibility etc. These issues will be considered in more detail as part of the URBAN-NEXUS activities and dialogue on "Data and Monitoring".

Governance
Understanding how uncertainty influences policy and decision-making and how communications can help effect positive behaviour change is an important element of our second topic on Governance. As a cross-cutting issue, climate change highlights the need for new approaches to governance in order to overcome the lack of coordination and integration, both vertically within traditional governmental hierarchies and also horizontally across the public, private and third sector. This also requires greater participation and genuine involvement by the different sectors, citizens, communities and individuals who are at risk and/or contribute to the risks.

Greater intergovernmental cooperation will also be required to address issues that need trans-boundary approaches, as the climate and impacted ecosystem services do not respect administrative boundaries. Current fragmentation of research, policy and practice between mitigation and adaptation also needs to be addressed. In order for governance to achieve the above changes and effect real progress.We conclude that the integration of social sciences and associated skills are vital in influencing key decision-making processes and behaviours. These governance issues will inform the future work of URBAN-NEXUS on integrated approaches to urban management.

People

Governance may be thought of as being fundamentally about **people** and how people live and carry on their social, cultural, personal and economic activities in a **place.** People and place are of course inextricably linked and are the final two topics to be considered. A changing climate will have direct effects on **people's** health and quality of life and will also bring indirect risks to broader social and economic activities, both as a result of impacts on the local urban fabric, infrastructure and services and also as climate impacts influence markets and ecosystem services further afield.

People's vulnerability and their ability to respond to climate change impacts are not determined solely by geographical location or physical attributes. They are significantly influenced by a range of social factors such as mobility, perceptions and agency to act. Economic factors also play a substantive role in determining the vulnerability and adaptive capacity of households and communities. The third section outlines some of the research gaps regarding the impacts on people and it will inform development of the URBAN-NEXUS "Health and Quality of Life" theme.

Place

How we develop and redevelop land, build and modify infrastructure, design, (re)configure the urban fabric plays host to how the changing climate is impacting and will impact urban lives. The impacts of climate change on **place,** discussed in the fourth and final section, include: flooding, as a result of rising sea-levels, river flooding (fluvial) or surface water flooding from the urban drainage network as a result of heavy rainfall (pluvial), landslides, drought, subsidence and the urban heat island effect. All of these have implications for the social, cultural and economic activities that take place in cities. The design and use of urban space and infrastructure is a fundamental driver in how resilient our cities are to climate change. Urban greenspace offers a relatively low-cost solution to managing a range of impacts such as flooding, drought, urban heat island effect etc., while bringing wider health and quality of life benefits and favouring economic investment. Greater understanding of the multiple benefits offered by greenspace and how to overcome barriers to greenspace provision will be given more consideration in the URBAN-NEXUS theme of "Competing for Land".

The report closes with some questions intended to stimulate discussions during the Dialogue Café on Urban Climate Resilience: Partnership Approaches, being held 29th and 30th May 2012 in Glasgow.

3. Key findings

KF1: There is a wealth of scientific and business research on climate change but a relative dearth of coordinated studies that adopt an integrated, i.e. multi-sector and multi-governance, urban perspective. This is despite cities and urban regions increasingly being seen as the ”prime movers” in terms of our ability to curb and conquer climate change. An integrated perspective is more common at a regional or national scale while urban relevant research is often sector specific, such as transport or building studies. Risk-assessments are often spatially defined on national, regional or environmental scales e.g. a river basin.

KF2: The majority of urban climate change research, policy and practice appears to be concerned with mitigation, energy efficiency, new developments, eco-towns etc. This is influenced by policy and economic drivers such as peak oil, fuel security and the global carbon market. As historic emissions have already locked in an element of unavoidable climate change, there is growing recognition of the need to adapt and improve resilience to climate change. It is recognised that adapting to climate change requires local knowledge and approaches. Nevertheless, more integrated research and knowledge exchange at a European and transnational level would help to improve understanding of, and hopefully catalyse, the economic, environmental, institutional and social changes needed to minimise adverse impacts and bring new opportunities and benefits to society from a changing climate.

KF3: There is a potentially confusing array of “urban sustainability models”, many of which omit any climate resilience considerations. Application and implementation may be hampered without translation for local users. However, an abundance of different urban climate vulnerability metrics and indicators risks causing greater confusion and a divergence of approaches that demand disparate data sets. This dependency on data collection, assimilation, verification and interpretation is resource intensive for already over-stretched municipalities, particularly smaller cities. There is scope for data exchange amongst researchers, professionals and practitioners but this requires ownership, access arrangements and data harmonisation across different systems and platforms. , which can be problematic. This can be a problematic, lengthy and costly process.

KF4: It is important to integrate the social sciences into cross-disciplinary research on urban climate resilience. Many of the activities associated with adapting to climate change and building urban resilience are dependent on decision-making processes, behaviour change, and good communications. This is particularly the case for the inherent risks and uncertainty surrounding climate change. Responding to climate change requires strategies that address the physical dynamics of systems and the social and institutional contexts. We also need psychological and communication approaches to understand and influence behaviour changes in the midst of great cultural diversity, beliefs and values and across all tiers of society and governance. More “people-centred” forms of engagement are essential. This means using cultural studies, social psychology, education tools, communication methods etc. to help raise greater awareness, promote positive behaviour changes, strengthen cooperation, enable multi-level governance and support public dialogue.

KF5: There appears to be more emphasis on research and technological measures for flood prevention, than on drought alleviation and associated risks from lower rainfall such as subsidence and wildfires. There are numerous technical solutions and options being developed for flooding. This may reflect a dominance of research agendas from more flood prone parts of Europe in the north and west. However, many cities, even in those regions not commonly considered to be at risk of drought, face water shortages. This could be a consequence of placing emphasis on what is perceived to be the most probable or pressing impact associated with a geographic region e.g. flooding in northern Europe and drought in southern Europe. Climate scenarios indicate that a multiplicity of impacts will be co-located, hence the need to take a strategic, integrated approach that considers all probable risks, their interactions and dependencies.

KF6: Just as the climate and climatic projections are changing, improving resilience must be understood as a continually evolving proces. It will be most successful if strategies are continually reviewed and revised to incorporate new knowledge about city vulnerabilities and potential impacts from interventions local and globally. Priorities need to be periodically reviewed and re-evaluated. A resilience strategy is a useful tool only to the extent that it is revisited over time and generates further action. The process of developing urban climate resilience — bridging sector gaps, raising awareness, creating new knowledge, improving coordination and, in particular, enabling organisational, institutional and individual development — is intrinsically more valuable than any stand-alone strategy.

KF7: Building resilience at the city scale requires more partnership working and collaborative approaches. No single organisation will create resilience alone. It requires a core team of local stakeholders from a diverse range of organisations, who are able to; agree on collective priorities, coordinate the work and keep abreast of new knowledge to inform and promote adaptation strategies. Implementing effective action requires ownership and direct engagement with a range of stakeholders. The most important characteristic is not technical expertise but the ability to coordinate across organisations in an open manner; work with diverse groups of people; recognise the validity of their insights, their knowledge, and their contribution and engagement in developing effective strategies.

4. An overview of urban climate vulnerability and resilience

4.1 The challenge of climate change for cities

Human population and our economic activity is increasingly concentrated in cities. Urban areas must be at the heart of addressing climate change, both to reduce greenhouse gas emissions to limit further change, and to improve resilience by adapting to unavoidable changes predicted as a result of past emissions. Across the globe, many cities are developing comprehensive programmes to reduce greenhouse gas emissions. Fewer cities, however, are making coordinated efforts to adapt and build resilience to climate change. This is despite evidence that urban areas across Europe are struggling to cope with current extreme weather events, which climate projections indicate will increasingly become the norm. Due to historic emissions of greenhouse gases, a certain amount of global climate change is inevitable over the coming decades, irrespective of emission reduction efforts. Adaptation needs to be considered as an equal and integral partner to mitigation. The current split between adaptation and mitigation efforts is discussed in section 5.2.2 on governance.

CLIMATE-FRIENDLY CITIES: A handbook on the tasks and possibilities of European cities in relation to climate change[4]

This handbook summarises methods and instruments available to European towns and cities from a city government perspective. The aim is to encourage cities to align recommendations on climate change to their specific conditions and circumstances. The target audience comprises decision-makers, politicians and professionals but it should also be of interest to the wider stakeholder community.

Key messages and recommendations are backed up by numerous practical examples and case studies. They are presented on a range of urban-relevant climate issues, such as: partnerships and multi-level governance; planning integrated strategies; spatial structure, urban-rural co-operation; disadvantaged social groups and social effects; architectural solutions, awareness and lifestyle. The handbook discusses a range of issues from governance to integrated strategic planning, and was initiated by the Hungarian EU Presidency.

The following ten key messages, from a study commissioned by the Committee of the Regions[5], highlight the vulnerability of cities and the need to emphasise the important role of adaptation in an integrated approach to urban climate resilience. These messages also highlight critical issues of governance and uncertainty which are discussed in sections 5.1 and 5.2.

[4] Ministry of Interior, Hungary – VÁTI Hungarian Nonprofit Ltd. for Regional development and Town Planning (2011), 'Climate-Friendly Cities – A Handbook on the Tasks and Possibilities of European Cities in Relation to Climate Change', Ministry of Interior, Hungary – VÁTI, Budapest.

[5] Ecologic Institute (Berlin/Vienna), AEA group, ICLEI (Local Governments for Sustainability), European Secretariat and the Regional Environmental Center for Central and Eastern Europe (REC), (no publication date, c. 2010). 'Adaptation to Climate Change: Policy instruments for adaptation to climate change in big European cities and metropolitan areas', Committee of the Regions, European Union.

1. Cities are dynamic and complex systems. Climate change will **interact with existing urban problems:**
    a. Some problems will get worse
    b. Some new problems will emerge
2. **Vulnerability** to climate change is more acute in cities than in rural areas.
3. Urban climate change adaptation strategies must be developed to **integrate** with - and build upon - existing sectoral and cross-sectoral agendas at the city level.
4. However, old solutions will not solve new problems; urban adaptation requires innovation, learning and **new governance structures**.
5. **Complexity and uncertainty present real barriers** to decision-makers on the ground, particularly given the complex interaction of vulnerabilities at the city level.
6. No single type of measure is able to eliminate vulnerability to climate change; a portfolio approach, for example combining **institutional, technological, infrastructure, educational and lifestyle responses**, is likely to be most effective.
7. A **wide variety of stakeholders** need to be involved in conception, design, implementation and evaluation of urban adaptation strategies at city level.
8. Cities need leadership, group-working, effective forms of knowledge transfer/ exchange and **integrated research** to begin the process of adaptation.
9. **Opportunities exist**; a renaissance in urban design and management could create sustainable and resilient cities.
10. An **iterative approach** is required in order to achieve progress in the short term as well as the required step changes in urban management.

4.2 The concept of vulnerability

Vulnerability is a central concept within numerous fields of research and policy, including natural hazards and disasters, poverty, development and food security. Understanding vulnerability to climate change is about trying to determine who will be harmed and what will be negatively affected.

"Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." IPCC, Fourth Assessment Report, 2007[6].

The above definition draws on three main criteria:

- **Exposure** - the degree to which a system is exposed to significant climatic variations such as sea level rise, temperature or precipitation;

[6] Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (Eds) (2007). 'Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change - Appendix I: Glossary', Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/publications_and_data/ar4/wg2/en/annexessglossary-p-z.html

- **Sensitivity** - the degree to which a system is affected, either adversely or beneficially, by changes in climate. For example, in a city that is exposed to sea level rise, built-up areas will be more sensitive than areas such as parkland that are used for recreation; and

- **Adaptive capacity** - the ability of the system to adjust to such changes, to 'moderate potential damages, to take advantage of opportunities, or to cope with the consequences' (IPCC, 2007).

Vulnerability, then, is the key concept when considering how urban societies, infrastructure and systems will be affected by climate change. It is complex and loosely defined, although the factors that determine it (exposure, sensitivity and adaptive capacity) have been identified. In order to make and inform policy, it is necessary to be able to **assess vulnerability** and to consider how it varies between different places and people.

4.3 Urban vulnerability to climate change

Urban areas are particularly vulnerable to the impacts of climate change. This is due to the density of infrastructure, population, services and economic activity. The type of impact varies in relation to geography and topography. For example, low-lying coastal cities are more at risk from a rise in sea-level; and cities in the south of Europe, on the whole, face a greater risk of drought than those in the north, with some notable exceptions such as London. The severity of impact is strongly influenced by urban physical characteristics such as city design, planning and the urban fabric and infrastructure. For example, the urban heat island (UHI) effect will vary with differences in building density, urban configuration and aspect and also the surface fabric and composition e.g. the type and extent of green and blue infrastructure. Difference in climate sensitivities also plays a part. While heat waves will be more extreme in the cities of southern Europe, less heat-tolerant populations in northern Europe will be sensitive to even moderate temperature changes. Most European cities have been developed, designed and built to cope with the historic climate record, not the future climate trends and extremes predicted by climate scientists. Moreover, cities' increasingly sophisticated and interdependent supply chains and transportation logistics - for water, energy, workforce, food and consumables - introduce intrinsic weaknesses, irrespective of any increased exposure to climate hazards. These characteristics further compound risks and create greater susceptibility to disruption.

There is no agreed method for quantifying urban vulnerability to climate change. "The most common way to overcome this constraint and to make the concept of vulnerability operational is to use indicators.... The general gaps relevant for developing climate change vulnerability indicators concern conceptual gaps, methodological questions, data concerns, and application gaps." [7]

[7] Schauser, I., Otto, S., Schneiderbauer, S., Harvey, A., Hodgson, N., Robrecht, H., Morchain, D., Schrander, J., Khovanskaia, M., Celikyilmaz-Aydemir, G., Prutsch, A. and McCallum, S. (2010). 'Urban regions: Vulnerabilities, Vulnerability Assessments by Indicators and Adaptation options for Climate Change Impacts – Scoping Study', ETC/ACC Technical Paper 2010/12.

Enhancing cities' capacity to manage their vulnerability to climate change in Sweden[8]

This FORMAS-funded project aims to enhance institutional capacity to assess society's vulnerability to climate change in cities and regions. The project will apply three methods: double exposure, climate vulnerability index and downscaled socioeconomic scenarios. It will also use a number of tools to project bio-geophysical impacts of climate change. The methods and tools, developed by international research, emphasise different aspects of vulnerability. The project also uses participatory methodologies to study how the vulnerability methods and impact tools are used within municipal and regional administration, i.e. in the decision processes that they are intended to support.

The project outputs include an integrated vulnerability assessment tool and criteria for robust decision making designed for planners within municipal and regional administrations.

The scoping study on urban vulnerability by the European Topic Centre on Air and Climate Change[8] set out to assess the feasibility of developing climate change related vulnerability indicators for urban areas, to support EU spatial development policy. Part of the study included a comprehensive review of the available literature and research, to identify knowledge gaps on vulnerability to different climatic threats. Their mapping of the extent of current knowledge and gaps is reproduced in Table 1. The main knowledge gaps in relation to exposure, sensitivity and adaptive capacity largely relate to data projections and scenario developments at urban relevant scales and are discussed further in section 5.1 on uncertainty and risk assessment.

ENSURE[9]

ENSURE is a European funded project which offers a new methodological framework for an integrated multi-scale vulnerability assessment based on a comprehensive, integrated and interdisciplinary understanding of risks and vulnerability.

Currently available indicators lack a socio-economic dimension, and other problems include (limited) availability of data, and incomplete published methodologies. The UK Adaptation Sub-Committee has taken a different approach. It reports "significant progress in developing a suite of outcome-focussed indicators that might have some success in providing a measure of the UK's real preparedness for climate impacts, rather than the checklist or process-oriented metrics that have been suggested previously"[10].

[8] Project contact is Anna Jonsson (annjo@tema.liu.se) at Linköping University.
[9] http://www.ensureproject.eu/ensureproject.html
[10] AEA (2011). 'Provision of research to identify indicators for the Adaptation Sub-Committee', Final Report, ED56687- Issue Number 3.

Table **1**: From ETC/ACC Technical Paper 2010/12, 2010[11]

Climatic impact /issue	Extent of knowledge available on …					Gaps
	Causes and effects on urban areas	Vulnerable systems, vulnerable groups and macro-regions	Components determining exposure	Components determining sensitivity	Components determining adaptive capacity	
Higher temperatures, heat wave and health problems	Intensively studied and well known effects	Identified (focus on vulnerable groups and health damage)	Clear causes, past and projected data available	Intensively studied and well known components, past data available	Suggestions exist, but little data available, no projections	difficult to project future changes in sensitivity and Adaptive Capacity
Decreased precipitation, water scarcity and drought	Studied but less in urban areas	Identified, but less in urban areas (focus on sectors and vulnerable systems, mainly in the Med., economic damages)	Clear causes, difficult reaction chain, past data available, but difficult to project	Intensively studied, very many and different components, past data available	Suggestions exist about adaptation measures, but little quantitative data available, no projections	Mainly studied for agriculture, tourism, biodiversity. Indirect effect on cities is little researched
Wildfires	Studied but less for urban areas	No focus on specific groups or systems, mainly Mediterranean, economic as well as health impacts	Clear circum-stances, difficult reaction chain, past data available but difficult to project	Components are identified (related to topography, fuel load) but none specific to urban areas	Suggestions available relate to mitigation of fires and protection before and during the fire	Urban areas are not in focus of the assessments although affected.
Heavy precipitation and fluvial floods	Intensively studied and well known effects	Identified (vulnerable groups and systems, health and economic damage)	Clear causes, difficult reaction chain, past data available but difficult to project	Intensively studied, very many and different components, past data available	Few suggestions exist, but little data available, no projections	Vulnerable groups difficult to determine, difficult projections
Intensive precipitation and urban drainage leading to floods	Studied and well known effects	Identified (drainage system, health and economic damage)	Clear causes, difficult reaction chain, past data available but difficult to project	Little studied, few important components, past data available	Suggestions exists regarding increased efficiency of urban drainage	Impacts depend on local circum-stances and are difficult to estimate and to predict
Sea level rise and storm surge-driven flooding	Intensively studied and well known effects	Identified (focus on coastal regions and economic damage)	Clear causes, past and projected data available	Intensively studied, many and regional variable components, past data available	Suggestions regarding general adaptive capacity and adaptation options	Vulnerable groups not determined in detail, socio-economic factors rarely investigated

[11] Schauser, I., Otto, S., Schneiderbauer, S., Harvey, A., Hodgson, N., Robrecht, H., Morchain, D., Schrander, J., Khovanskaia, M., Celikyilmaz-Aydemir, G., Prutsch, A. and McCallum, S. (2010). 'Urban regions: Vulnerabilities, Vulnerability Assessments by Indicators and Adaptation options for Climate Change Impacts – Scoping Study', ETC/ACC Technical Paper 2010/12.

Climatic impact /issue	Extent of knowledge available on ...					
	Causes and effects on urban areas	Vulnerable systems, vulnerable groups and macro-regions	Components determining exposure	Components determining sensitivity	Components determining adaptive capacity	Gaps
Saltwater intrusion into aquifers	Studied but less in urban areas	Identified, but less in urban areas (focus on systems and coastal region, economic damages)	Clear causes, very difficult reaction chain but projections difficult	Studied, components are identified, but difficult to project	Few adaption options related to water uses and management exist,	Limited data available on geographic distribution of the impact
Mass movements and erosion	Studied but not specific for urban areas	No focus on specific vulnerable systems or groups, mainly mountains, and on economic damages	Complex causes, very difficult reaction chain, past data available but very difficult to project	Suggestions exist related to geo-physical structures, weak link to urban areas	Only generic suggestions about adaptation measures exist, weak link to urban areas	Urban areas are not in focus of the assessments (effects might be indirect)
Wind storms	Studied mainly in North and Western Europe	Identified, focus on vulnerable systems and economic damages	Clear causes, difficult reaction chain, past data available, not possible to project	Some components are identified related to built structures	Very few suggestions exist	Occurrence, strength and effects of storm is difficult to project
Vector – borne and other diseases	Studied but not specific for urban areas	Suggestions exist, focus on vulnerable groups and health damage	Difficult reaction chain, past data available but difficult to project	Intensively studied, very many components, past data available	Suggestions exist but little data available, no projections	Urban areas are not in focus of the assessments (effects might be indirect)

4.4 Resilience

The concept of 'resilience' is closely related to that of 'vulnerability'. The IPCC (2007)[12] defines resilience as 'the ability of a social or ecological system to **absorb disturbances** while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the **capacity to adapt to stress and change'**. Resilience may be considered as being the converse of vulnerability. It could be argued that the ultimate aim of adaptation policy is to progress from vulnerability (the potential for loss or harm) to resilience (the potential to recover or rebound).

[12] M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (Eds) (2007). 'Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change - Appendix I: Glossary', Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. http://www.ipcc.ch/publications_and_data/ar4/wg2/en/annexessglossary-p-z.html

emBRACE - Building resilience amongst communities in Europe[13]

This project addresses urban resilience, also touching on governance and data/ indicators.

The emBRACE project aims to improve the pan-European framing of the resilience concept. The project uses interdisciplinary, socially inclusive and collaborative methods. It will develop a conceptual and methodological approach to clarify how the resilience capacity of a society confronted with natural hazards and disasters can be characterised, defined and measured. Based on a systematic evaluation of a broad literature base, the project will first develop an initial conceptual framework. Existing datasets will be interrogated to identify variables that provide indications of resilience, and which are consistent with the framework. The framework and data will then be 'tested' and ground truthed by means of several carefully-chosen European case studies (in the Czech Republic, England, Germany, Italy, Poland, , Switzerland, and Turkey) which will be differentiated by hazard, governance setting, socio-demographic-economic context, and scale. Recommendations on indicators to measure resilience will be based on practical experience and grounded theories.

Many studies that have tried to measure adaptive capacity have used broad-brush economic or demographic proxies, such as gross domestic product (GDP), levels of education and access to resources. Adaptive capacity is often seen in terms of economic development on the basis that greater economic resources enable people to adapt more easily. In contrast, Grothmann and Patt (2005)[14] make a distinction between 'objective' adaptive capacity (e.g. time, money, knowledge, entitlements, relevant support) and 'perceived' adaptive capacity which recognises that motivation and perceived abilities are important determinants of decision-making and subsequent action. So, they maintain, "while a region or area may score highly on an objective measure of adaptive capacity, socio-cognitive variables are an important factor that may influence the actual degree of vulnerability".

4.5 Critical evidence gaps for decision-makers

Scientific capabilities, for projecting future climate change and the resulting impacts, are growing rapidly. Economic studies, such as the Stern Review[15], have helped elucidate the potentially enormous costs to society of not taking action to address climate change. There are still large uncertainties when it comes to 'downscaling' these projections and estimates to levels that are useful to local decision-makers. This inherent uncertainty in climate change trends and impacts feeds through to vulnerability assessments and decision-making tools. Policy-makers and stakeholders need decision-making processes that can accommodate not only scientific gaps but also gaps in our understanding of socio-cultural attitudes and behavioural responses. Section 5.1.4

[13] http://embrace-eu.org/ This data was supplied in a template submitted by Sylvia Kruse, Research associate, Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), sylvia.kruse@wsl.ch

[14] Grothmann, T. and Patt, A. (2005). 'Adaptive capacity and human cognition: the process of individual adaptation to climate change', *Global Environmental Change*, 15, pp. 199–213.

[15] Stern, N. (2006). 'Stern Review on the Economics of Climate Change', HM Treasury, London. http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/6520.htm

considers the impact of uncertainty on decision-making. This is further complicated by the back-drop of changing demographics and economic uncertainty.
Understanding and managing climate change risks at the urban scale requires:

- common understanding and interpretation of likely future climate change scenarios and risks;
- strong leadership to develop promising and shared visions of how cities can create sustainable development pathways; and
- open, multi-level governance to manage decision-making which delivers equitable, effective and flexible solutions that offer long-term resilience in the face of short-term political agendas. See section 5.2 on governance.

More information to inform long-term policy decisions is needed on[16] :

- the costs and benefits associated with different adaptation options;
- the trade-offs between location-specific social, environmental and economic factors; and
- optimal timing of different options for effective adaptation investment and risk management.

Stadtklimalotse (Urban climate pilot)[17]

The challenges for local policymakers have been addressed in Germany by the Stadtklimalotse project.

This is an online decision support tool for urban climate change adaptation. It is aimed at planners and policy makers from small and medium sized towns and cities, who need quick and easy access to information. It is mainly focused on German and German speaking audiences. However, most of the measures are applicable for any city or town. International best practice examples are included. The database of urban climate change adaptation measures contains 138 measures in ten fields of action (energy, health, tourism, water, infrastructure, transportation, green spaces, air quality, agriculture, forestry), 330 links to legislative texts and 61 examples for planning and implementation of measures; further background information on climate change research; and an integrated tool for a quick urban vulnerability assessment. These are used to guide the reader through the process of adaptation, raise key questions in a structured manner, and suggest methods and examples. It does not attempt to make direct recommendations for action.

This has been applied in Stuttgart as an integrated regional approach to adaptation, encompassing the city and surrounding towns – see section 5.2.4 on lessons learned from experience of governance.

[16] Ramieri, E., Hartley, A., Barbanti, A., Duarte Santos, F., Gomes, A., Hilden, M., Laihonen, P., Marinova, N., and Santini, M. (2011). 'Methods for assessing coastal vulnerability to climate change', European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation, ETC CCA Technical Paper 1/2011.
[17] www.stadtklimalotse.net/english/ information provided by Mark Fleischhauer, Senior Research Fellow at TU Dortmund University, Institute of Spatial Planning (IRPUD), mark.fleischhauer@tu-dortmund.de

5. Evidence from research and practice

This chapter discusses the main findings from an assessment of recent European research and practical examples of initiatives, strategies and projects on building urban climate resilience. It is presented on the basis of four subthemes: risk and uncertainty; governance; people; and place.

5.1 Risk and uncertainty

5.1.1 Introduction

Our understanding of climate change is hampered by many unknowns, ignorance and bias. The complexity and seemingly chaotic nature of the climate system challenges the construction of reliable projections about the magnitude and pace of change. This means that the risk assessment of climate impacts and vulnerability is subject to considerable uncertainties. Scientific uncertainties associated with modelling projected impacts, data collection, verification etc., married with uncertainties surrounding socio-economic influences on greenhouse gas emissions and on the vulnerabilities of people and place, hamper decision-making (Yohe and Oppenheimer, 2011)[18]. Improved understanding, characterisation and communication of uncertainty are critical to the development of robust policy options and stimulating positive changes in peoples' attitudes and behaviour.

The climate of Europe is strongly influenced by the North Atlantic Ocean circulation.

Thermohaline circulation (THC) of the Atlantic Ocean helps to moderate Europe's climate, bringing warm water from the equator to the continent's shores. The THC is often referred to as the 'ocean conveyor belt' since large volumes of water are transferred between different regions. It is also known as the Meridional Overturning Circulation (MOC).

There is concern that climate change may impact the THC, possibly even shutting it down. The consequences for Europe could be dire. Reliable quantification of the variability and stability of the THC and its atmospheric implications is therefore a major challenge in climate research, not only for the purpose of assessing the likelihood of rapid climate changes, but also to assist planning in both the public and private sectors .

THOR[19], "Thermohaline Overturning – at Risk?" has established an operational system that will monitor and forecast the development of the North Atlantic THC on decadal time scales. It will assess its stability and the risk of a breakdown in a changing climate.

[18] Yohe, G. and Oppenheimer, M. (2011). 'Evaluation, characterization, and communication of uncertainty by the intergovernmental panel on climate change—an introductory essay', *Climatic Change,* 108: 629–639.
[19] THOR is a European Commission FP7 funded collaboration project http://www.eu-thor.eu/

5.1.2 Data availability

A common concern for decision-makers is the lack of spatially and temporally disaggregated data. This is needed to model climate projections, assess climate risks and implement effective strategies and policies at the city level. However, data availability is highly variable and sometimes costly to obtain. Research is underway on methods for downscaling regional climate change model outputs to spatial and temporal scales that are useful for urban planning, despite data gaps[20] [21].

Data needs: an urban socio-ecological atlas

The Urban Atlas Portal[22] is a collaboration between twelve cities around the world: Bangalore, Canberra, Cape Town, Chicago, Helsinki, Istanbul, New Delhi, New Orleans, New York City, Phoenix, Shanghai and Stockholm. The aim is to develop new tools for understanding the social-ecological capacities to provide access to and sustain ecosystem services. The Urban Atlas maps the spatial extent of selected ecosystem services and biodiversity, and to what extent different socio-economic groups have access to these services.

This is the first time users are able to compare cities of different size and wealth to see how varying social contexts, customs and norms, can affect urban ecosystems and vice-versa[23]. It should offer a starting-point in addressing the reported lack of data that is comparable between cities.

In addition to concerns about the common challenge of missing or unreliable data and the consequent uncertainty of models, the OECD and Development Global Science Forum[24] highlight other issues including:

- the trend to build more and more complex models which can be difficult or slow to build, expensive, and not necessarily more effective than simpler models;
- the challenges of (and need for) integrating a variety of separate research disciplines (physical, social, applied sciences) and different modes/traditions of data definition in model-making;
- the challenges of scale and the need to formulate a clearly defined spatial focus (urban regions, peri-urban and suburban domains, urban cores, precincts and sites);
- the challenges of creating comparability in the face of the variety of current responses and activity;

[20] Mehrotra, S., Natenzon, C. E., Omojola, A., Folorunsho, R., Gilbride, J., and Rosenzweig, C. (2009). 'World Bank Commissioned Research: Fifth Urban Research Symposium - Cities and Climate Change: Responding to an Urgent Agenda'. Marseille, France.
[21] SUDPLAN http://cordis.europa.eu/projects/93723_en.html
[22] http://www.urbanatlasportal.org/UAP/
[23] http://seedmagazine.com/content/article/urban_resilience/P4/
[24] Delegation of Australia to the OECD (2009). 'Developing effective models of urban environments to address the challenges of sustainability and climate change', Project Proposal – Update draft September 2009.

- the dynamic nature of urban systems, and the need for models that confront this including life-cycle analysis.

The EEA stresses the need for more data on the cost of climate change impacts and adaptation, and better methodologies for understanding the complexity of the economic consequences of climate change[25].

5.1.3 Uncertainty

The EEA categorises three types of uncertainty[26]:

1. incomplete knowledge e.g. of climate systems;
2. insufficient observed trends leading to low confidence in the results of models, which can be due to an absence of data or insufficient (spatial or temporal) resolution; and
3. uncertainty in future socio-economic developments e.g. demographic, technological and socio-economic developments.

Some of the causal links and factors which introduce uncertainty into climate predictions are illustrated in table 1, from Pidgeon and Fischer (2011)[27]. The middle column shows the causal chain leading from the anthropogenic sources of climate change to their impacts. The four charts show estimates for different effects in that chain, linked (by arrows) to causal factors that introduce uncertainty into theses estimates. In the top-left chart, different assumptions about future human activities lead to different estimates of total emissions. The other three charts show uncertainties in cumulative emissions depending on uncertainty about climate feedback (top right), climate sensitivity depending on uncertainty about radiative forcing (bottom right), and change in global cereal production depending on uncertainty in temperature rise and carbon fertilisation (bottom left). Interactions between elements in the chain also create further significant uncertainties.

5.1.4 Uncertainty and decision-making

The UK Government's progress report on climate change adaptation[28] states that climate risks are not yet embedded into strategic decisions: "Investment planning does not factor in the full range of climate uncertainties... Embedding climate change more fully into decision-making could reduce the legacy of future adaptation costs." The report describes "uncertainty" as including both future climate projections and socio-economic scenarios, and calls for the full range of economic, social and

[25] EEA (2008). 'Impacts of Europe's changing climate — 2008 indicator-based assessment, Chapter 8 – Data gaps, uncertainties and future needs', Report 4/2008, pp193-207. http://www.eea.europa.eu/publications/eea_report_2008_4

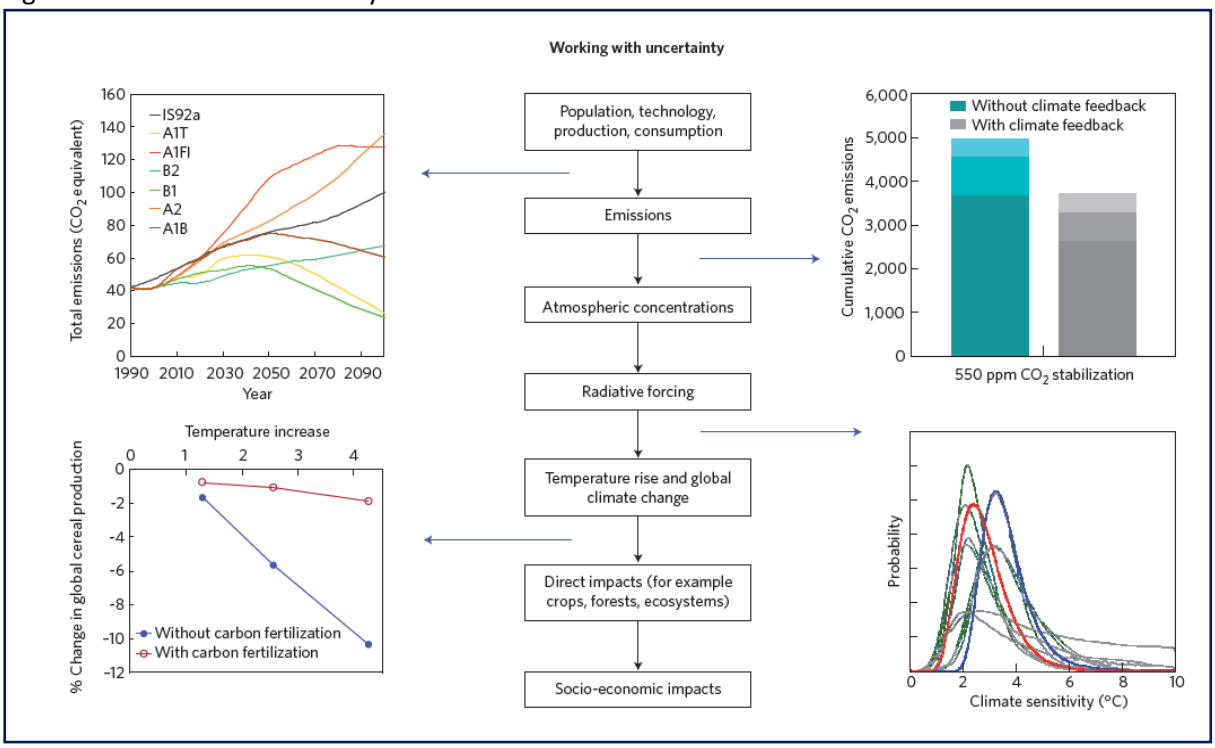
[26] EEA (2008). 'Impacts of Europe's changing climate — 2008 indicator-based assessment, Chapter 8 – Data gaps, uncertainties and future needs', Report 4/2008, pp193-207. http://www.eea.europa.eu/publications/eea_report_2008_4

[27] Pidgeon, N, and Fischoff, B. (2011). 'The role of social and decision sciences in communicating uncertain climate risks', *Nature Climate Change*, Vol 1, April 2011, http://www.nature.com/nclimate/journal/v1/n1/full/nclimate1080.html

[28] Adaptation sub-committee (2011). 'Adapting to climate change in the UK – measuring progress'.

environmental risks to be considered. Similar findings are reported for Scotland but with even greater problems arising from a lack of data availability and problems of data disaggregation[29].

Figure 1: Sources of uncertainty in climate assessments [30]



The latest UK Climate Projection model (UKCP09) takes a probabilistic approach[31] to addressing the uncertainty issues, by decision-making based on three sources of uncertainty:

- natural climate variability;
- uncertainty in the climate models; and
- uncertainty in future emissions.

Although this approach has proved more challenging, it has forced deeper understanding and awareness of climate variability and impacts amongst decision-makers[32].

Planners and decision-makers have to accommodate projected changes across many realms; demography, economics, technologies, etc. Each of these has a notoriously high degree of uncertainty (inherently higher than climate change modelling) and any dependent decisions are subject to assumptions and limitations. In the case of climate change adaptation, these assumptions and limitations will be dependent on the knowledge, or the lack thereof, on the rate of climate change, impact variability and the availability and effectiveness of global emission reduction measures.

[29] http://www.theccc.org.uk/reports/adaptation/asc-scotland

[30] Pidgeon, N, and Fischoff, B. (2011). 'The role of social and decision sciences in communicating uncertain climate risks', *Nature Climate Change*, Vol 1, April 2011. http://www.nature.com/nclimate/journal/v1/n1/full/nclimate1080.html

[31] http://ukclimateprojections.defra.gov.uk/content/view/1981/500/

[32] Pers. Comm. Joe Hagg, Senior Scientist – Climate Change, SEPA/Adaptation Scotland, February 2012.

PREPARED

PREPARED [33]aims to promote the systematic evaluation of uncertainties in urban water systems. Assessing uncertainties is necessary to improve the quality of measurements; to improve modelling, by accounting for uncertainties in model structures, inputs, parameters and outputs; and to help decision-making.

5.1.5 Communicating uncertainty

The EEA believes that uncertainty must be acknowledged and discussed: "Ignoring uncertainty increases the risk of inappropriate action to tackle the challenge of climate change and its impacts on the environment, the economy and human well-being"[34].

A special issue of the journal *Climatic Change* features ideas for communicating scientific uncertainty[35]. The contributing authors assert that the oversimplification of uncertainty in the IPCC Assessment Reports can be misinterpreted leading to overconfidence in climate projections and risk assessments[36]. They argue that the IPCC should make low-probability, high-consequence outcomes more vivid and be clearer about areas where there is vigorous dispute among scientists[37]. Concerted efforts are needed to explore and characterise uncertainty and eliminate bias from the consensus building process. The difference between statistical uncertainty and scenario uncertainty also needs to be made clearer[35].

Communicating clearly and transparently on what is and is not understood about climate change by the scientific community is an important value shared by the contributing authors. Failure to communicate clearly can have dire consequences for the nature of reporting on climate research:

> *"However careful and painstaking the process by which the IPCC and other climate assessments are carried out, their policy-relevance will be greatly constrained if the critical work they do is defined in the eyes of policymakers and the public by politically savvy detractors who mischaracterise scientific uncertainties and exploit the media's fascination with reporting alleged controversy."* Ekwurzel et.al, 2011.[38]

[33] http://www.prepared-fp7.eu/prepared-home2
[34] EEA (2008). 'Impacts of Europe's changing climate — 2008 indicator-based assessment, Chapter 8 – Data gaps, uncertainties and future needs', Report 4/2008, pp193-207. http://www.eea.europa.eu/publications/eea_report_2008_4
[35] (2011) 'Special Issue: Guidance for Characterizing and Communicating Uncertainty and Confidence in the Intergovernmental Panel on Climate Change'. *Climatic Change* 108.
[36] Curry, J. (2011). 'Reasoning about climate uncertainty', *Climatic Change* 108:723–732.
[37] Socolow, R. H. (2011). 'High-consequence outcomes and internal disagreements: tell us more, please', *Climatic Change* 108:775–790.
[38] Ekwurzel, B., Frumhoff, P. C. and McCarthy, J. J. (2011). 'Climate uncertainties and their discontents: increasing the impact of assessments on public understanding of climate risks and choices', *Climatic Change* 108:791–802.

5.2 Governance

5.2.1 Introduction

ICLEI (the International Council for Local Environmental Initiatives) refers to climate change as being "… an exam in good governance and management, requiring strong political leadership and commitment. Extreme weather events regularly highlight deficient adaptive capacity within urban systems and management – damage to technical infrastructure and buildings, disruption of municipal and health services, poor social cohesion and emergency management – which can be considered as failures of previous political decisions and administrative actions" [39]. The urban governance of climate protection involves changes to the relations between levels of the state, and new network spheres of authority. This challenges traditional distinctions between local, national and global environmental politics. Improved governance is likely to differ from former approaches.

5.2.2 Participation

Local government authorities cannot effectively address the massive challenges posed by climate change without the widespread grassroots involvement of a variety of actors in civil society, such as citizens' groups, students and neighbourhood associations. These non-governmental stakeholders can play key roles in both contributing to the development of sound government policies, and in ensuring that such policies are effectively implemented. Of equal importance is the need for well trained, knowledgeable and engaged professional urban businesses (including engineering, urban planning, architects, construction and services or utilities companies) to assist and advise local authorities and to provide efficient services and invest in effective infrastructure.

The OECD conference on competitive cities expanded on the need for a change of approach to governance. It reported that "as city governments move to implement climate change policies, existing relationships with certain economic sectors and other partners will need to be redefined. Governments will need to make decisions on every aspect of policy – from deciding whether to institute top-down or bottom-up controls to the exact nature of the policy tools... City governments face special considerations with regard to their exact jurisdictional authority, available capacity for implementation and enforcement, and co-ordination with the private sector and other affected parties[40]."

The need for participation by non-governmental stakeholders is being explored by a research programme underway at the UK's Tyndall Centre. The programme focuses on the role of "non-state actors in multilateral climate diplomacy as well as non-state climate governance in the transnational arena". It also "seeks to better understand the interface between the intergovernmental negotiating process and transnational networks of business, civic, indigenous and local government actors". This aims to advance understanding of "non-state actors' significance for governance, transparency, legitimacy, effectiveness and the symbolic value of international cooperation"[41].

[39] http://www.iclei-europe.org/fileadmin/templates/iclei-europe/files/content/ICLEI_IS/Topics_pages/WS_4_Background_Document_Adaptation_November_2010.pdf

[40] OECD (2008) 'Competitive Cities and Climate Change', OECD Conference Proceedings, Milan, Italy, 9-10 October 2008. http://www.oecd.org/dataoecd/12/38/42554913.pdf

[41] http://www.tyndall.ac.uk/research/governance/nsa

5.2.3 Coordination and integration

The lack of coordination and integration across urban governance structures, both vertically and horizontally, is a key issue for the implementation of local climate policies and action plans. It can hinder institutionalisation within the local administration and integration with other sector plans (such as energy, transport and land use). Responsibility for local climate change policy often lies within environmental departments. This can raise co-ordination and integration problems if the environmental department or agency does not have the authority to implement comprehensive policies. A lack of internal co-ordination within metropolitan governments may therefore pose serious problems for adaptation policies[42]. This is compounded where more than one authority has a role in decision-making and implementation, e.g. where action is needed at a regional or transnational scale such as in river management and water resource planning for large catchments such as the Danube.

To overcome the problems of **fragmentation**, the OECD[43] recommends more cooperation and collaboration. At present local governments make and implement a wide range of policy decisions, making use of economies of scale to reduce excessive fragmentation and inefficiencies. Conversely, as municipal governments are often confined by physical boundaries that may not best reflect the needs of the metropolitan region, multi-agency and other co-operative governance frameworks become necessary. Effective climate change responses at the local level will therefore require greater **intergovernmental collaboration** also.

Another integration issue is the observed **split between policies that address mitigation and adaptation**. The IPCC's Fourth Assessment Report on climate change impacts, adaptation and vulnerability calls for improved understanding of the synergies between adaptive capacity and climate change mitigation. It asks how policies intended to enhance one could reinforce the other[44]. This question is asked in the light of the seemingly disproportionate volume of research and initiatives concerned with low carbon and energy reduction in comparison with studies on adaptation. This may be due to the greater scope for cost-savings offered by carbon efficiency measures and economic incentives driven by monetisation of carbon under the EU emissions trading scheme. The lack of an integrated approach to mitigation and adaptation runs the risk of incentivising approaches, policies and behaviours for one driver that exacerbates or constrains the other. For example, revisions to building standards, intended to reduce carbon emissions from the building stock, that do not take account of changing climate conditions may cause longer-term problems for the health and comfort of the occupants under future climate conditions.

[42] Kern, K. and Alber, G. (2008) 'Governing Climate Change In Cities: Modes Of Urban Climate Governance In Multi-Level Systems', Chapter 8 of OECD Conference Proceedings, Milan, Italy, 9-10 October 2008, http://www.oecd.org/dataoecd/12/38/42554913.pdf

[43] OECD (2008) 'Competitive Cities and Climate Change', OECD Conference Proceedings, Milan, Italy, 9-10 October 2008. http://www.oecd.org/dataoecd/12/38/42554913.pdf

[44] Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson C.E. (Eds) (2007). 'Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change - Technical Summary to Climate Change 2007: impacts, adaptation and vulnerability', Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. P78.

Spatial adaptation strategies to climate change: model region Stuttgart[45]

The region of Stuttgart has had an integrated strategy for climate mitigation and adaptation supported by concrete measures for many years. The aim is for the regional climate strategy to serve as an integrating concept for the region, engaging multiple departments and administrative levels.

The main activities include:

- Supporting clustering initiatives and demonstration projects
- Establishing a centre of competence for (regenerative) fuel cells
- Advising communities on measures for climate protection
- Organising events, fairs and international projects
- Promoting electric transportation and new mobility technologies.

There are also numerous actions concerning town and traffic planning. This project is supported by the Stadtklimalotse decision-support tool (see section 4.5).

A further area of **fragmentation lies between policy and research**. A comparison of national adaptation strategies conducted in 2009[46] identified an urgent need for new climate adaptation research that connects innovative science with local, regional and sectoral policy needs. Factors driving the development of adaptation policy vary across European countries, but a common issue is **institutional barriers.** Institutional barriers are likely to be bigger impediments to adaptation than the technical feasibility of specific adaptation measures. A new, multi-level governance framework addressing urban development policies will be critical for meeting the challenge of climate change. City and regional leaders will need to work with others to design strategies for addressing local climate change risks. Central governments can complement efforts by assisting cities to better respond to climate change and by providing scientific assessments that justify intervention. Likewise, local governments are needed as partners to implement nation-wide climate change response policies, while at the same time designing their own policy responses that are tailored to local contexts.

The OECD[47] describes alternative modes of climate governance, including self-governing, governing through enabling, governing by provision and governing by regulation. They also discuss the relevance of these governance modes for both mitigation and adaptation policies. If we fail to make use of the opportunities to incorporate urban adaptation strategies into broader social, cultural and economic decision-making processes across all spheres of governance, there will be adverse consequences for urban populations and economies

[45] This information was supplied by Babette Scurrell at Bauhaus Dessau. The project contact is Prof. Dr.-Ing. Stefan Siedentop at the University of Stuttgart, Stefan.siedentop@ireus.uni-stuttgart.de . http://www.region-stuttgart.org/vrs/main.jsp?navid=68 ; http://www.region-stuttgart.org/vrs/main.jsp?navid=438

[46] http://www.peer.eu/publications/europe_adapts_to_climate_change/

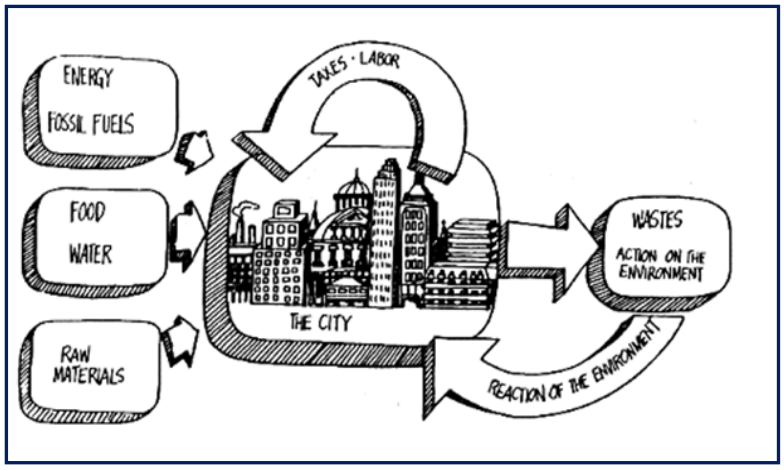
[47] OECD (2008) 'Competitive Cities and Climate Change', OECD Conference Proceedings, Milan, Italy, 9-10 October 2008. http://www.oecd.org/dataoecd/12/38/42554913.pdf

Resilis, a project for cities' organisational resilience, France[48]

Resilis brings together policy and research domains by taking a systems approach to multi-level governance. It is a collaborative research project about the management of human and technical urban systems for cities' organisational resilience. The project aims to develop innovative organisational and methodological solutions to improve urban resilience, using three types of measures:

- A better multi-scale and multi-actor governance,
- Building up the populations' self-reliance, and
- An optimized management of technical networks.

The main objective is to design methods and tools dedicated to local authorities, network managers and populations, in order to adapt and design social and technical urban systems able to cope with and absorb disturbances.



An illustration of the urban system, by J. De Rosnay[49].
City inputs and outputs, with associated impacts on the environment, generating feedback loops which affect the city. Work and taxes are part of an internal feedback loop.

We clearly need new and improved means of communication and interpretation that take account of cultural, emotional, and values-based behaviours; and approaches that foster open and democratic deliberation and decision-making. Emerging technologies, particularly in the field of communications and information, bring both challenges and opportunities for accountable and inclusive governance. Greater integration of social sciences and humanities into climate change research agendas could offer invaluable insight and innovative approaches to support decision-making under new governance structures and also support positive behaviour change.

If we take an integrated approach to increasing our resilience to the impacts of climate change, real social, economic and environmental benefits could be realised. Elements that could comprise such an integrated approach to building urban climate resilience might include: poverty alleviation; improved public health and valued human capital; healthy functioning ecosystems and

[48] http://www.resilis.fr/en Template supplied by Vincent Cousin, Industrial Advisor, Advancity, vincent.cousin@advancity.eu
[49] http://www.resilis.fr/en/index/menu/menuid/64; English version taken from http://pespmc1.vub.ac.be/macroscope/Chap1.html.

environmental assets; and the adaptive design, planning and management of the built environment, including land-use planning and (re-)development, infrastructure and the urban fabric and function, much of which is discussed further in the following sections on **People** and **Place.**

5.2.4 Lessons learned from practice

An interdisciplinary research review of literature and practice concludes that effective urban development programs, which incorporate climate change responses, must take a multidimensional approach to risk assessment[50]. Cities, the review argues, need to undertake risk assessment in order to decide for themselves what is the right mix between mitigation and adaptation, to avoid the commonly-occurring mismatches between needs and responses in regard to who should mitigate, how much to adapt, and why. This need for clarity in decision-making is reflected in a survey of people impacted by climate change in Canada (by floods) and Australia (by drought): people associate very different causes, impacts and actors to climate change and adaptation – i.e. whose job it is and what hinders action[51].

The Clean Air Partnership studied six early adapters to climate change: London, New York, Boston, Halifax, Vancouver and Seattle[52]. It identified several factors that supported successful adaptation strategies, of which the following have a direct bearing on governance:

- "Knowledgeable and committed political or executive champions", and the "Creation of a specific inter-agency or inter-departmental organisation to lead the adaptation process to ensure the collaboration of relevant stakeholders" as witnessed in the cases of London and Seattle;
- "the collaboration of a local community of strong researchers prepared to work with local governments on climate impacts and adaptation". These include academic, government and private sector researchers and was witnessed in all six case studies; and
- dedicated staff and budgets as witnessed in the case of London and New York.

A report from Infrastructure Canada on the development of disaster resilient communities identifies a number of barriers to adaptation[53]. These include governance-related issues of gaining (and holding) the attention of local policy makers, and coordinating local government department policies and practices.

[50] Mehrotra, S., Natenzon, C. E., Omojola, A., Folorunsho, R., Gilbride, J., and Rosenzweig, C. (2009). 'World Bank Commissioned Research: Fifth Urban Research Symposium - Cities and Climate Change: Responding to an Urgent Agenda'. Marseille, France.

[51] Lynam, T. (2012). Stockholm Seminar on the 'Social understandings of climate change and social adaptation to climate change'. http://www.stockholmresilience.org/seminarandevents/stockholmseminars/previousseminars/2012/ss2012/makingsenseofclimatechangeandadaptation.5.7b7173c2134634aef76800024775.html

[52] Clean Air Partnership (2007). 'Cities Preparing for Climate Change: A Study of Six Urban Regions' http://www.cleanairpartnership.org/pdf/cities_climate_change.pdf

[53] Henestra, D., Kovacs, P., McBean, G. and Sweeting, R. (2004). 'Background Paper on Disaster Resilient Cities', Toronto: Institute for Catastrophic Loss Reduction. http://www.dmrg.org/resources/Henstra.et.al-Background%20paper%20on%20disaster%20resilient%20cities.pdf

5.3 People

5.3.1 Introduction

People's vulnerability to climate change impacts is affected by individual, social and economic circumstances[54, 55]. A conceptual model of vulnerability to climate change was outlined in 1999 as the first step in appraising and understanding the social and economic processes which facilitate and constrain adaptation[56]. The model put social and economic well-being at the centre of analyses, reversing the scientific tendency to base assessments on the resilience of natural resources or ecosystems. It argued that whilst the socio-economic and biophysical processes that determine vulnerability are manifest at the local, national, regional and global level, the degree of vulnerability itself is associated with individuals and specific social groups. Over a decade later, we are only just beginning to see broader social and economic issues being given consideration in research into the causes and consequences of climate change for people.

5.3.2 Health risks

Climate change poses a range of health risks, outlined in Figure 2, some of which will compound pre-existing health problems. **Increasing temperatures** associated with climate change can have direct impacts on human health, particularly respiratory problems[57]. The WHO expects that rising air temperatures will exacerbate **urban air pollution** which already causes 1.2 million deaths per year[58]. Air pollution in urban areas is a major environmental health concern for Europe. Although there is much uncertainty about the relationships between health, weather and climate, even small changes in seasonality could affect a large number of people with respiratory complications and have a significant aggregate impact on health services. Climate change may affect exposure to both indoor and outdoor irritants and pollutants. Indoor irritants include mould/fungi, damp in modern building materials, cockroaches and dust mites. Outdoor exposure to irritants such as pollen that induces hay-fever may change in duration or onset. Local and national differences in pollen sensitivity make the forecasting of future health impacts difficult.

[54] Romero Lankao, P. and Tribbia, J. (2009). 'Assessing patterns of vulnerability, adaptive capacity and resilience across urban centers', National Center for Atmospheric Research, Mexico. Also published at http://www.pacificdisaster.net/pdnadmin/data/original/UCAR_2009_Romero.pdf

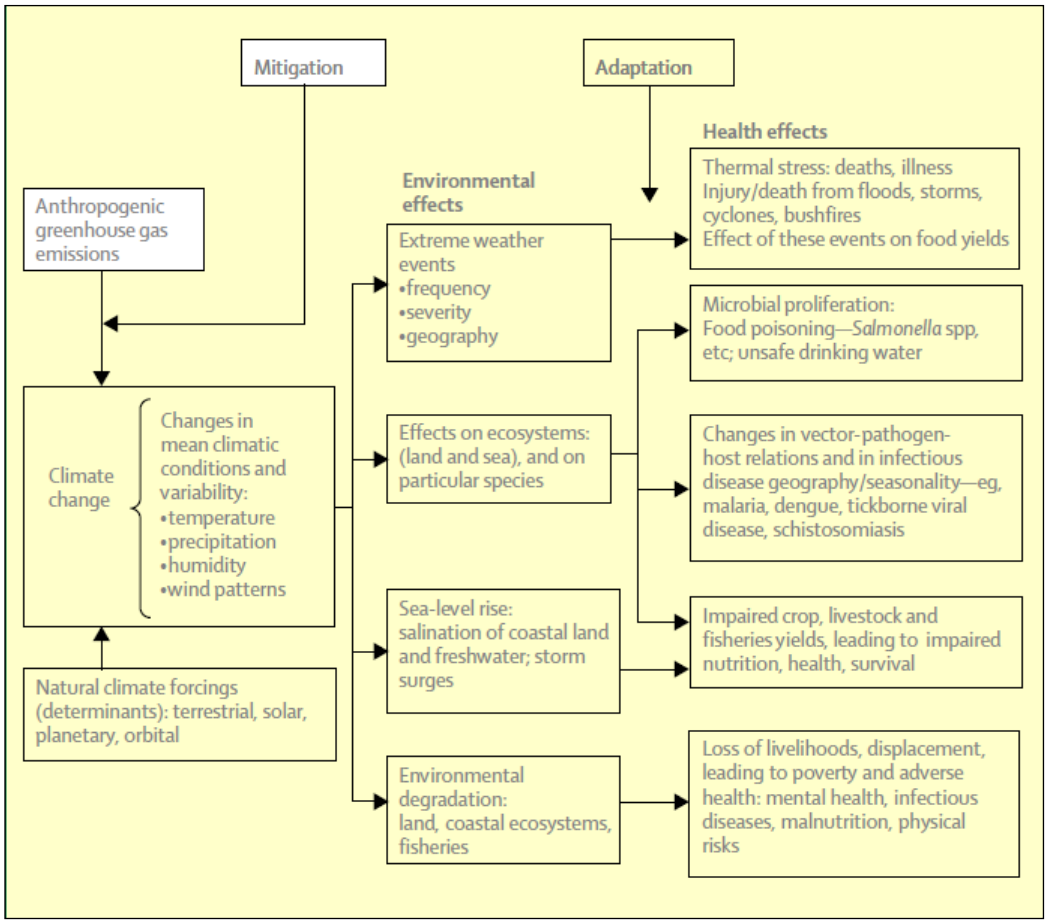
[55] Bartlett, S., Dodman, D., Hardoy, J., Satterthwaite, D. and Tacoli, C. (c. 2009) 'Social aspects of climate change in urban areas in low- and middle-income, Contribution to the World Bank Fifth Urban Research Symposium on Cities and Climate Change: Responding to an Urgent Agenda http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1256566800920/6505269-1268260567624/Satterthwaite.pdf

[56] Adger, W. N. and Kelly, P. M. (1999). 'Social Vulnerability to Climate Change and the Architecture of Entitlements', *Mitigation and Adaptation Strategies for Global Change*, Volume 4, Numbers 3-4, 253-266.

[57] European Environment Agency (2008) "Impacts of Europe's changing climate — 2008 indicator-based assessment"

[58] World Health Organisation (2009). 'Protecting health from climate change – connecting science, policy and people'.

Figure 2: Schematic summary of main path ways[59]



Research by the Joseph Rowntree Foundation[60] suggests that people's vulnerability to extreme **heat** is a complex outcome of contextual factors and social processes:

- exposure to high temperatures at home, at work or in local communities because of the design and fabric of their housing or urban environment, or type of employment;
- sensitivity to heat stress, influenced by their respiratory, physical or mental health, age or relative acclimatisation to heat;
- capacity to adapt to circumstances in order to anticipate, escape or treat heat stress – e.g. ability to pay for air-conditioning, physical access to local cool outdoor spaces, or type of housing tenure (council tenants, some private tenants and care home residents may not have options to adapt their accommodation);
- self-perception of vulnerability, willingness to act to avoid heat stress, and awareness of heat stress and how to prevent it;
- social networks and their 'visibility' or connection with the outside world (e.g. with social services);

[59] McMichael, A. J., Woodruff, R. E. and Hales, S. (2006). 'Climate change and human health: present and future risks', *The Lancet*, Vol. 367, Issue 9513, pp 859-869

[60] http://www.jrf.org.uk/publications/vulnerability-heatwaves-and-drought-adaptation-climate-change

- transience, lack of local knowledge or inflexibility, which may reduce people's chances of receiving support during heatwaves.

The increased risk of river and coastal flooding has significant health consequences, causing deaths, injuries, outbreaks of infectious disease, and psychosocial problems. Floods may disrupt water treatment and sewage disposal systems, with a consequent increased risk of water-borne diseases.

The EEA expects an increase in water- and food-borne diseases as temperatures rise[56]. For example, increasing temperatures are associated with rises in cases of salmonella poisoning from food and from bathing-water quality; water-borne diseases arise from changes in rainfall patterns; floods carry germs; and droughts lead to stressed supplies and possible sanitation issues.

Health effects of flooding in the UK[61]

In June and July 2007, the wettest weather since British records began swept across the country, flooding dozens of cities. The reported health effects included drowning; acute stress, depression and other mental health problems; asthma attacks resulting from exposure to mould in flood-damaged buildings; and diarrhoea. This all happened despite the well-developed infrastructure and emergency services, demonstrating that their current configuration – in the UK and potentially in other countries – does not offer sufficient protection in the face of extreme weather.

The EEA anticipates an increasing range (in terms of both latitude and altitude) of disease-carrying insects[62]. Consequently, changes are needed to current monitoring and public health measures. The present methods for modelling projections are felt to be inadequate: "Few studies incorporate adequate assumptions about adaptive capacity [among others]". According to the European Centre for Disease Prevention and Control, climate change will influence the distribution and transmission of communicable diseases in a number of ways[63]. These include impacts on the actual disease pathogens themselves or changes in the distribution of vectors, such as ticks and mosquitoes, which may carry the diseases. Other factors are changes in people's behaviour that increase their exposure to risks, such as spending more time outdoors in areas where insects live.

5.3.3 Social aspects of vulnerability

Limitations of data, tools and methodologies are barriers to local decision-makers identifying socially vulnerable people and targeting appropriate responses. For example, in assessing social vulnerability to flood risk, "it is important to know the characteristics of the population at risk, not just the number of properties in an affected area... Demographic change and climate change will significantly increase the number of people at risk"[64].

[61] Rosenzweig C., Solecki, W. D., Hammer, S. A. And Mehrotra, S. (Eds) (2011). 'Climate change and cities: first assessment report of the Urban Climate Change Research Network (ARC3)', Cambridge University Press, Cambridge and New York. P191.
[62] EEA (2008). 'Impacts of Europe's changing climate — 2008 indicator-based assessment', Report 4/2008. http://www.eea.europa.eu/publications/eea_report_2008_4
[63] ECDC TECHNICAL DOCUMENT (2010), 'Climate change and communicable diseases in the EU Member States', Handbook for national vulnerability, impact and adaptation assessments
[64] Joseph Rowntree Foundation (2011). 'Pluvial (rain-related) flooding in urban areas: the invisible hazard'.

Municipality of Budapest, package of measures for summer heat[65]

The Municipality of Budapest and district Local Governments have formed a partnership with the Metropolitan Public Place Cleaning Company, Metropolitan Gardening Company, public administration offices, libraries, doctors' surgeries, shopping malls and hypermarkets. In order to reduce city temperatures, street surfaces are watered once or twice each day. Public health information about heat and hydration is disseminated via public sector organisations' websites. Practical steps to reduce impacts on health include the distribution of drinking water, the provision of taps and sprinklers in the parks, and allowing residents to visit air-conditioned public buildings to cool down during the day.

When these measures were implemented in the summer of 2011, there was a significant decrease in the number of ambulance call-outs on extremely hot days.

Those with a greater understanding of how to identify vulnerable people, including the research community, non-governmental organisations, social services, spatial planners, public health and climate change/sustainability teams, may not be sufficiently engaged in informing local responses to climate change risks. The Joseph Rowntree Foundation suggests that an explicit consideration of social justice issues, coupled with clearly defined roles for key agencies and more effective working by the many stakeholders involved across sectors and organisations, is likely to improve outcomes for vulnerable people[66]. The key message is that adaptation initiatives must build resilience among those most vulnerable to climate change in order to contribute to the goals of achieving social justice and sustainable development. Table 2 illustrates the health impacts of a number of climatic threats on groups with specific vulnerabilities.

[65] Template supplied by Miklos Marton, Project Manager at the Regional Environmental Center for Central and Eastern Europe, MMarton@rec.org.

[66] Joseph Rowntree Foundation (2011). 'Vulnerability to heatwaves and drought: adaptation to climate change', http://www.jrf.org.uk/publications/vulnerability-heatwaves-and-drought-adaptation-climate-change

Table 2 Climate impacts on specific vulnerable groups[67]

		Climatic threat / issue						
		Higher temperatures Heat wave	Sea level rise and storm surge-driven flooding	Heavy precipitation and fluvial floods	Heavy precipitation and urban drainage floods	Wind storms	Vector- and water-borne diseases, atopic diseases	Land slides
Group	Elderly	High vulnerability due to physical fragility (cardio-vascular diseases & respiratory conditions, diabetes);increased by social isolation	Greater risk of drowning; may lack physical or financial resources for effective response during & after event	High post-disaster vulnerability: more often in need of emergency shelter (lack of social and financial resources)	No reliable results	Tend to be reluctant to evacuate or leave dwelling despite warning; may lack physical and/or financial resources for effective response	More susceptible to waterborne infections	Likely to have post traumatic stress in the aftermath of landslides (Sarno, Italy)
	Sick	Particularly high risk for those with renal & cardiovascular conditions, diabetes	Post-flood morbidity (and mortality) is significantly higher for flood victims who suffer from pre-existing health problems		No reliable results	No reliable results	Immuno-compromised people are affected disproportionately by waterborne infections	No reliable results
	Disabled	No reliable results	(Elderly) persons with disabilities more at risk due to lack of physical resource for effective response (e.g. move to higher level)		No reliable results	No reliable results	No reliable results	No reliable results
	Young	Higher risk due to physical fragility (children 0-4)	No reliable results	No reliable results	No reliable results	No reliable results	Probably more likely to be affected by waterborne diseases	No reliable results
	Low income groups	Higher vulnerability due to poorer health status; more likely to live in neighbourhoods with greater exposure to heat stress	More likely to live in vulnerable locations (also applies to some affluent people who prefer coastal estates); less mobility for evacuation	High post-disaster vulnerability: less likely to hold insurance; less educated: more often dissatisfied with damage compensation		More likely to live in poorly built houses, insufficient financial reserves for purchasing supplies before/ services after an event; less mobility for evacuation	Probably more likely to be disproportionately affected due to limited access to sound health services (e.g. regular vaccination)	Low & middle income countries: more likely to settle in hazardous physical environment, e.g. marginal land, hillsides
	Ethnic minorities	More likely to live in neighbourhoods with greater exposure to heat stress	Less likely to live in flood-prone coastal areas (reduces vulnerability)	More likely to live in flood-prone /low-lying urban areas	No reliable results	More likely to rely on information from peers, which can lead to ineffective disaster preparedness	No reliable results	High post-disaster vulnerability: difficulties in obtaining adequate and affordable

[67] See Schauser et.al; (2010) footnote 7

Individuals' vulnerability to heat appears to have a very strong social dimension. Many of the contributing factors coalesce within disadvantaged communities. While temperature can be mapped and modelled within urban environments, the extent to which people are vulnerable to heat stress is difficult to assess without detailed local knowledge. There may also be links between people's vulnerability to drought and their vulnerability to high temperatures. An understanding of vulnerability to both of these hazards draws attention to the ways in which people on low incomes, in particular locations, with particular medical conditions or mobility restrictions, may be the least protected and therefore the hardest hit.

Targeted responses to hot weather in Toronto[68]

Toronto's Heat Alert and Response System is considered to be a prime example of climate change adaptation. A Heat Alert is called, and broadcast on local media, when hot weather is forecast that has a greater than 65% chance of contributing to excess deaths.

The Hot Weather Response Plan coordinates the efforts of several municipal and community agencies to provide heat-related services to vulnerable populations. These include children, the elderly, those with pre-existing illnesses, and the homeless. Response measures include opening cooling centres and extending the hours of swimming pools. Local targeting is achieved by an integration of health data with social and geographic data using GIS. This can combine, for example, physical factors that are likely to increase exposure to heat (such as surface temperature) and factors that may affect people's resilience to heat (including age).

Although not concerned specifically with urban social issues arising from climate impacts, many of the research and policy gaps identified in a Sniffer report relate to urban populations[69]. These include impacts concerning potentially higher crime rates, employment and education. Other issues needing further exploration and action include the impact of global climate change on migration (climate refugees) and more focus on promoting community-led adaptation, including action by the private sector and voluntary organisations.

5.4 Place

5.4.1 Introduction

The impacts of climate change on place are largely dependent on three main factors: geography, topography and land-use. We cannot change geography or topography but we can change how we use land. The configuration of our towns and cities; how we plan, design and (re)develop urban infrastructure; the materials and urban fabric that we use are all factors that influence urban climate resilience and future energy needs of cities.

[68] Rosenzweig C., Solecki, W. D., Hammer, S. A. And Mehrotra, S. (Eds) (2011). 'Climate change and cities: first assessment report of the Urban Climate Change Research Network (ARC3)', Cambridge University Press, Cambridge and New York, P205.

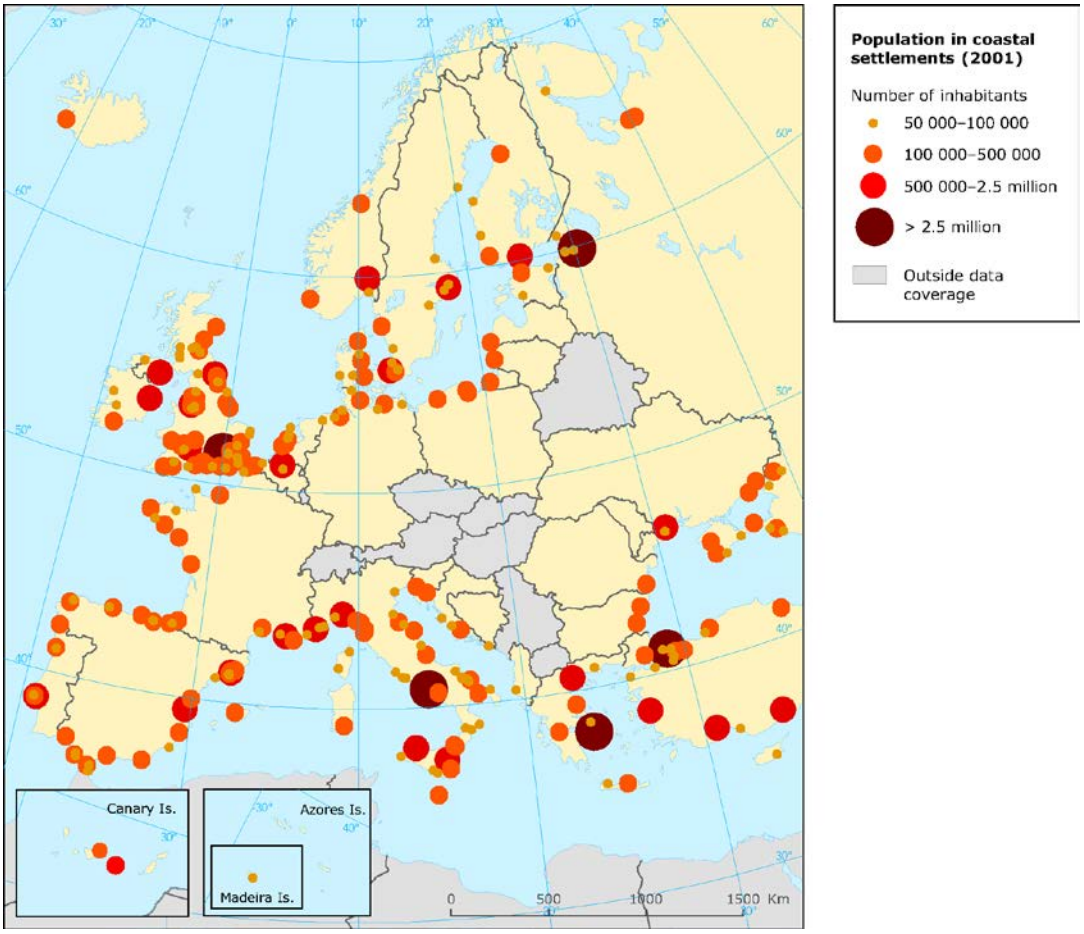
[69] http://tinyurl.com/7rgo4vt

The UK Committee on Climate Change warns that land-use planning decisions can be a double-edged sword: "Land use planning decisions can directly help to increase resilience to climate risks, but can also lock future generations into a development pathway that increases vulnerability or one that will be very costly to maintain or reverse" [70]. The Committee notes that, although national and local policies appear to be having an effect, there is no data on the amount of development that is still happening in areas of flood risk or behind eroding coastlines.

5.4.2 Flooding

Approximately half of the European population lives 50 km or less from the coast[71], with 19% (86 million) living within a 10 km coastal strip[72] – see Figure 3 below. It is likely that such numbers will increase in the future, especially in the more densely populated urban regions, putting more people and assets at risk from rising sea level.

Figure 3: Population concentrations[71]



[70] ASC (2011). 'How well is Scotland preparing for climate change?' First report to the Scottish Government by the Adaptation Sub-Committee of the UK Committee on Climate Change, Chapter 5, 'Analysis of progress in the priority areas'.
[71] ESTAT (2009). 'Statistics in Focus', 47/2009.
[72] EEA (2006). 'The changing faces of Europe's coastal areas', EEA Report No 6/2006, European Environment Agency, Copenhagen. http://www.eea.europa.eu/publications/eea_report_2006_6

Flood risk will also increase for settlements in low-lying areas (more common in deprived areas of cities), homes with a ground floor, and the absence of SUDS (Sustainable Urban Drainage Systems) which are easier to fit in new-build and urban development rather than for existing settlements[73].

Flood resilient technologies that can be used to protect buildings include barriers, protection walls and flood products. Much of the existing technology is typically temporary in nature and requires human intervention such as a householder or local authority team. The development of smart products that work within flood resilience systems and can be modelled and implemented as part of national regulations and policy is the basis of the SMARTesT project[74]. More than two thirds of European cities have to deal with flood risk management issues on a regular basis. Early Warning Systems (EWS) can play a crucial role in mitigating flood risk by detecting conditions and predicting the onset of a catastrophe before it occurs, and by providing real time information during an event. The UrbanFlood project[75] is investigating the use of sensors within flood embankments to support an online early warning system, with real time emergency management and routine asset management. The EWS framework will link sensors via the internet to predictive models and emergency warning systems, to assess their condition and the likelihood of failure.

Urban regeneration and sustainable urban drainage[76]

The neighbourhood of Augustenborg (Malmö, Sweden) has experienced periods of socio-economic decline in recent decades, and frequently suffered from floods caused by overflowing drainage systems. Augustenborg underwent a significant regeneration between 1998 and 2002, in part to improve flood risk management. Significant physical changes in infrastructure took place as a result, focusing on the creation of sustainable urban drainage systems, including ditches, retention ponds, green roofs and green spaces. The project has resulted in a successful outcome as the rainwater runoff rates have decreased by half, and the increase in green space has improved the image of the area.

Complementing the development of early warning systems, FloodProBE[77] is focusing on cost-effective flood protection and damage mitigation measures for urban areas. FloodProBE will develop, test and disseminate technologies, methods, concepts and tools for risk assessment and mitigation, focussing particularly on the adaptation of new and existing buildings (retrofitting) and on infrastructure networks.

[73] Joseph Rowntree Foundation (2011). 'Pluvial (rain-related) flooding in urban areas: the invisible hazard'.
[74] SMARTEST FP7 http://www.floodresilience.eu/en
[75] UrbanFlood http://urbanflood.eu
[76] http://www.grabs-eu.org/membersArea/files/Executive_summary.pdf
[77] http://www.floodprobe.eu/

5.4.3 Drought and associated risks

The Joseph Rowntree Foundation has summarised multiple ways in which hot and dry weather can cause disruption to the economy, society and the environment[78]. They include:

- Water shortages (domestic, agriculture, industry, fire and rescue) when combined with low precipitation and high water use;
- Increase in the number and severity of wildfires (grassland and forest);
- Failure of transport networks due to buckling rails and overheating of train and tram power sources;
- Failure of power supplies due to overheating of electricity sub-stations and lack of cooling water;
- Impaired water quality, caused by evaporation leading to concentration of water pollution and low flows in water courses;
- Increased hospital admissions and pressure on care services;
- Psychological impacts, increased violence and social unrest.

Drying out of the subsoil during periods of drought can lead to subsidence, causing structural damage to properties and infrastructure. According to the insurance industry, property damage from soil movement is equivalent to that incurred from flooding and it eclipses the costs incurred by most other natural hazards in some European regions. The risk of soil subsidence is not only increasing but it is also spreading to new geographic areas in Europe[79]. Extreme drought can lead to acute shortages and recurrent rationing of water, causing political and social competition over water resources. Extreme drought can also have a huge impact on local economies, leading to the closure of businesses, schools and leisure facilities. Measures intended to alleviate water shortages, such as water metering and charging, may create more social and health problems due to problems of water affordability.

Seasonal changes in water availability will also influence groundwater dynamics, and the water balance of groundwater systems. This occurs especially in mountain regions, where small variations in temperature can have a critical influence on rainfall, snowfall and snowmelt[80].

A catalogue of European adaptive initiatives for the water sector has been compiled by PREPARED[81], to support the implementation and development of solutions for addressing climate change impacts on the urban water sector. An online version will follow to help cities, utilities and other stakeholders plan new investments and build connections and alliances with other planners and engineers. Suggested technologies to assist adaptation in the water sector are detailed by UNEP[82].

[78] Joseph Rowntree Foundation (2011) 'Vulnerability to heatwaves and drought: adaptation to climate change', http://www.jrf.org.uk/publications/vulnerability-heatwaves-and-drought-adaptation-climate-change

[79] Swiis Re (2011) 'The hidden risks of climate change: an increase in property damage from soil subsidence.'

[80] GENESIS FP7 http://www.genesis-fp7.eu/

[81] PREPARED FP7 http://www.prepared-fp7.eu/

[82] UNEP (2011). 'TNA Guidebook Series: Technologies for Climate Change Adaptation – The Water Sector'. http://tech-action.org/Guidebooks/TNA_Guidebook_AdaptationWater.pdf

5.4.4 Urban fabric and infrastructure

Buildings and infrastructure are vulnerable to climate change impacts, from flooding, storms and subsidence to the urban heat island (UHI) effect, all of which can cause acute damage and also accelerate long-term degradation of the urban fabric. Without more frequent routine maintenance and management, the health and safety risk from damaged buildings and infrastructure will increase. A study of the Norwegian coastal city of Bergen[83] anticipates accelerated atmospheric corrosion of building facades based on an annual average temperature increase of 2^0C and increase in precipitation of twenty per cent, leading to higher maintenance costs. It recommends adaptation measures including the reduction of air pollutants, monitoring of degradation, adjustment of building standards and guidelines, and use of more suitable materials and building techniques.

Adaptation measures to reduce the UHI include those that can be applied to individual buildings, such as green roofs and walls, and those that are addressed by planning at a neighbourhood or city scale. An URBAN-NET pilot study on the UHI effect confirmed the potential for using geometry to mitigate daytime thermal stress. TOPEUM[84] reports on observations and first experimental results from a field measurement campaign at the neighbourhood/urban scale. The ultimate goal of the project is to investigate the influence of urban design and architectural parameters in the resulting urban climate and consequent energy usage. “Whilst the general cause of overheating of cities is known, it is not well understood how much influence different urbanisation characteristics and building materials have on the intensity of urban overheating.”

Reducing the UHI effect in Tokyo[85]

Tokyo’s Metropolitan Government has addressed the UHI in its environmental masterplanning since 2002. Measures undertaken include urban planning to improve the flow of wind through the city, installing pavements that block heat and absorb moisture, roadside tree plantings, and increasing the greening of the roofs and walls of buildings.

There have been numerous studies assessing the effectiveness of different applications of urban greenery (street trees, green walls), and various cities encourage their uptake through planning policy.

[83] Grøntoft, T. (2011) ‘Climate change impact on building surfaces and facades’, *International Journal of Climate Change Strategies and Management*, Special issue on ‘Municipalities addressing climate change: a case study of Norway’ Vol. 3 No. 4, 2011, pp. 374-385.
[84] Neophytou, M., Forkaides, P., Panagiotou, I., Ioannou, I., Petrou, M., Sandberg, M., Wigo, H., Linden, E., Batchvarova, E., Videnov, P., Dimitroff, B. And Ovanov, A. (2011). ‘Towards optimization of urban planning and architectural parameters for energy use minimization in Mediterranean cities’, Proceedings of the World Renewable Energy Congress, 8-13 May 2011, Linkoping, Sweden.
[85] Rosenzweig C., Solecki, W. D., Hammer, S. A. And Mehrotra, S. (Eds) (2011). ‘Climate change and cities: first assessment report of the Urban Climate Change Research Network (ARC3)’, Cambridge University Press, Cambridge and New York. P240.

5.4.5 Greenspace for increased resilience

Suggested roles for greenspace in climate adaptation include: surface water management; stormwater absorption (street planters can absorb 75% of stormwater); wetlands in floodplains to reduce river flooding impacts, coastal greenspace to shelter against floods and erosion, and mitigation of the UHI effect[84]. To counteract the UHI in Freiburg, planning regulations require new buildings to be aligned with the prevailing winds and parking areas on the windward side of buildings to be 'green' rather than paved. This increases ambient moisture levels, helps to 'flush out' air pollution and provides natural cooling. Urban greenspace offers general quality of life improvements by providing shading and leisure and recreation space. It also brings multiple benefits for urban biodiversity such as providing green corridors and supporting ecosystem services. A comprehensive list of greenspace interventions and their multiple, beneficial impacts is given on pp10-12 of the greenspace scotland report[84].

Barriers to greenspace provision include:

- Limited knowledge regarding why and how to adapt; by planners, decision makers and the public;
- Cynicism;
- Policy gaps - Chicago, Portland and Toronto all have policies requiring or encouraging green roofs, whilst other cities may not;
- Limited resources – more focus is needed on the costs of alternative actions and of doing nothing;
- Conflicts over land-use, especially for valuable urban land[84].

The North American urban agriculture experience[86]

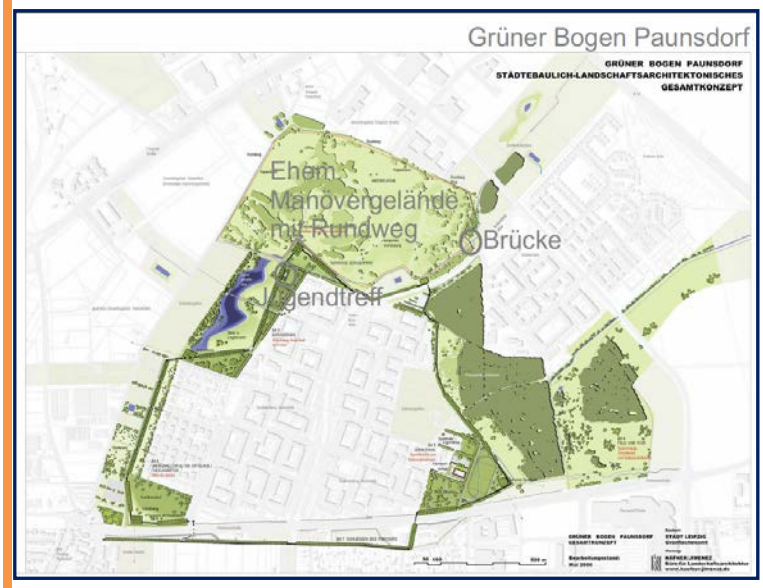
This project demonstrates the multiple benefits of greenspace. It describes local growing to combat the difficulty of accessing healthy, local and reasonably-priced food, to combat the UHI effect, and to serve as stormwater abatement. An example is given of an Urban Agriculture Plan for Oakland (California), which includes an inventory of vacant land, and a tax credit for such land put into agricultural use.

The GRaBS (Green and Blue Space Adaptation for Urban Areas and Eco-towns) project aims to fill a gap in planning: "Green infrastructure including gardens, parks, productive landscapes, green corridors, green roofs and walls and blue infrastructure such as water bodies, rivers, streams, floodplains and sustainable drainage systems, play a vital role in creating climate resilient development – a role, which is currently not sufficiently recognised and utilised and lacks integration in mainstream planning[87]". The GRaBS website includes a database of 15 case studies and describes "the processes that have supported the implementation of adaptation responses in a range of urban

[86] http://blogs.worldbank.org/sustainablecities/the-north-american-urban-agriculture-experience?cid=ISG_E_WBWeeklyUpdate_NL
[87] http://www.grabs-eu.org/

areas across the world. The case studies therefore identify and highlight key factors in different areas (e.g. governance, stakeholder relationships, science and research) that influenced the success of adaptation responses in different locations" [88]. There is a summary paragraph for each case study, some of which are included in the Annex to this report. Governance and data issues are identified as prominent barriers to adaptation.

GreenKeys: knowledge exchange across 12 European cities[89]



GreenKeys promotes urban greenspaces to improve the quality of life and increase the sustainability of cities. It is a partnership between 12 municipalities with eight research partners.

Pilot projects in each city involve local stakeholders to identify ways of increasing accessibility, social/ recreational value and ecological benefit. Examples of best practice from these pilots will be exchanged throughout the network. The plan shown here is for Leipzig.

Encouraging investment in green and blue infrastructure will become increasingly difficult in a worsening financial climate. Critical literature reviewsof greenspace and quality of life have highlighted a lack of research evidence quantifying the economic and social value of greenspace[90]. In an attempt to address this greenspace scotland has investigated the potential for applying the Social Return on Investment (SROI) approach to demonstrate and quantify the multiple benefits and impacts of greenspace and the activities which they attract. Their pilot study, 'Social Return on Investment of urban nature sites'[91] applies SROI to four urban nature sites to assess their value, and suggests refinements to the method for future studies. The SROI method may strengthen arguments in support of greenspace provision for urban climate adaptation and other co-benefits.

[88] http://www.grabs-eu.org/membersArea/files/Executive_summary.pdf
[89] http://www.greenkeys-project.net/en/home.html
[90] For example, http://www.greenspacescotland.org.uk/default.asp?page=465
[91] greenspace scotland and SNH (2011) 'Developing the role of greenspace in climate change mitigation and adaptation', http://www.greenspacescotland.org.uk/greenspace-and-climate-change.aspx

6. About URBAN-NEXUS

URBAN-NEXUS enables knowledge transfer and stimulates dialogue to form long-lasting partnerships amongst researchers, practitioners, policy makers, civil society and SMEs. It promotes integrated approaches to sustainable urban development.

URBAN-NEXUS

URBAN-NEXUS is a Coordination and Support Action funded by European Framework Programme 7 from 1st September 2011 until 31st August 2014.

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UWE – University of the West of England, UK

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