EMERGING PATTERNS OF RESILIENCE SYSTEMS IN URBAN DESIGN AND PLANNING

EMERGING PATTERNS OF RESILIENCE SYSTEMS IN URBAN DESIGN AND PLANNING

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Abstract

The current unfolding of the climate emergency urges cities to take action and lead the transition toward resilience and sustainability. While it is not clear exactly how and with which pace the emergency will develop, it is clear that the challenges of mitigating, adapting, and responding to shocks and stresses are increasingly gaining importance. In a densely urbanised area such as Europe, impacts mainly affect cities and towns' urban systems. Cities are at the forefront of the challenges arising from climate change emergencies both because they have a high concentration of exposed and vulnerable assets and populations and because they are the administrative units that control fundamental aspects of land governance. At the urban scale, planning and urban design practices are among the sharpest tools for reducing risk.

The notions and practices of Climate Change Adaptation (CCA), Disaster Risk Reduction (DRR) and Urban Resilience (UR) have been applied to urban systems to tackle these challenges jointly. Since urban environments are complex systems, intervention is not a simple task, especially with urgency. Complexity precludes the certainty of how interventions will fit in the system and how the system will react to them.

Based on these premises, the current research investigates the systemic effects of climate action in the domain of urban planning and design at the local level. This investigation is developed through different points of view to explore the fields in which these issues are evolving and apply locally, and it is based on a comparison between theory and practice approaches. To build the concept-to-practice framework, both conceptual contributions from the scientific community and operational contributions for implementation produced by the leading international organisations are considered. Then, the picture is enriched by analysing two European case studies to highlight the approaches that have been followed at the local level and have emerged from practice. The case studies also consider the spatial dimension of the city, where places are part of complex urban systems and have unique characteristics.

The research provides an operational framework that sheds light on the relationship between urban systems and climate change. The framework also highlights the intervention principles and planning methods used to shape climate action. In conclusion, different sources of knowledge are compared to develop a better understanding of how planning and urban design are used to intervene in urban systems to face the consequences of climate change.

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Introduction

Motivation

"Will anything shape urban life in the twenty-first century more than carbon—the efforts to abolish it, and the consequences of its pollution?" asks Daniel Aldana Cohen (2020).

Carbon is the basis of life as we know it, but not only in the biological sense. Our urban and economic systems have been, and still are, dependent on processes that emit carbon dioxide and other greenhouse gases. The amount of these gases that will still be emitted is the main factor that will decide the extent of future global warming and its consequences. The preferred horizon for this amount has been set at 1.5°C, and at the limit at 2°C, above pre-industrial levels by the Intergovernmental Panel for Climate Change (IPCC, 2018b).

"Climate change" means a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods of time. (United nations framework convention on climate change, 1992)

The emissions budget at our disposal is running out, and nations and cities are continually trying to reduce their carbon footprint to smooth percentages and bring them closer to reduction targets first, and climate-neutrality later. One example is the European Union's recent commitment to reduce emissions to 55% by 2030, on the way to neutrality by 2050.

Even if we could decarbonise our economic and urban systems within these timeframes fully, we would still face the consequences of climate change. These are already far-reaching and will affect us everywhere and unevenly. In addition to the devastating effects on terrestrial and marine ecosystems, the consequences of climate change also impact urban systems in the form of progressive pressures and acute destructive shocks.

Uncertainty about the future, the urgency to act and the complexity of how to do so has led many to define the moment in which we are as an emergency (Ripple, Wolf, Newsome, Barnard, & Moomaw, 2019; The Club of Rome, 2018).

Since the first in 2016, numerous cities worldwide have declared a state of climate and environmental emergency. By the end of 2020[1], there were more than 1800 cities from 33 different countries. 32 nations have also declared a state of national emergency, followed in November 2019, by the European Parliament's declaration of a global "climate and environmental emergency" (EP, 2019). In total, nearly one billion people live in territories that have declared a state of emergency at at least one, if not more than one, administration level.

This declaration of emergency is a piece of legislation passed by a governing body such as a city council, a regional board or even a national

1 Data presented in this paragraph is retrieved from an online database that collects worldwide declarations of climate emergency. Data available on https://climateemergencydeclaration.org, last access: December 2020.

government. Current declarations are mainly concerned with the need to contain global warming within acceptable limits defined by science and avoid massive biodiversity loss (EP, 2019).

The emergency is a concept closely linked to the occurrence of disasters, significant events that upset the system and its balance. Declaring a state of emergency means that a situation poses an immediate risk and requires urgent attention. Emergency has a limited duration in time, which varies according to the type of emergency in question and the persistence of the emergency conditions. When declined in the climate emergency case, this means that climate change poses an immediate risk and requires urgent attention in order to avoid the climate crisis, in which we go beyond the turning point of balance, the system's tolerance, triggering feedback loops. As an emergency, however, it also has some particular characteristics. Firstly, it has not escalated rapidly, unexpectedly or suddenly. The manifestation of the current conditions is a slow, gradual progression from slightly more acute and severe stages each day. It has not had a particular triggering event. Secondly, it is an emergency that requires urgency and great availability of means in the immediate term while having a very long horizon. The urgency is dictated by the recognised gravity of the situation and the need to "urgently take the concrete action needed in order to fight and contain this threat before it is too late", as stated in the first article of the emergency declaration of the European Parliament (EP, 2019). The horizon within which the emergency can be said to be over is not easily foreseeable either in terms of time or in terms of the desired future condition. Nor is it likely to be a sufficient condition for declaring the emergency ended if the current demands of zero emissions, phase-out of fossil fuels, sequestering carbon dioxide from the atmosphere and reforming all polluting sectors are achieved. That is because, even if we do achieve this, it will not prevent the emergence of countless local emergencies caused by acute shocks and disasters. Moreover, the occurrence of these impacts is not, nor can it be in the future, geographically linked to the regions responsible for the most significant amount of emissions. Climate change, and thus humankind in the industrial age, has triggered an emergency that transcends all geographical and administrative boundaries. There is the chance the state of emergency threatens to become the normal state (Beck, 1992) and therefore loses all exceptionality and urgency.

Having set the foundations of the urgency of the climate emergency, we must not forget what having to act in an emergency can entail. An emergency declaration is basically a request for external help, a declaration that ordinary means are no longer sufficient to deal with the current situation. However, the declaration is also a precise administrative instrument by which action is requested through extraordinary means, with exceptional funds and beyond the constraints of democracy, transparency and competition. The recent COVID-19 pandemic is an example of how centralised power can be exercised in emergencies, which can even result in the suspension of democratic and individual rights.

Moments such as these, following a shock or during an event, are delicate situations in which priorities are reassigned according to the risk-regulation reflex. The strong media exposure resulting from the materialisation of a risk leads to a demand from the public for security against the unfolding risk, often translated into stricter regulations that can raise the level of safety (Trappenburg & Schiffelers, 2012). These extraordinary regulatory processes following a disaster are moments when laws, the distribution of power and budgets change (Beck, 1992). They are windows of opportunity in which development patterns can be changed and chains of power broken (Birkland, 2006; Blakely, 2011), but they can also have negative effects. It may compromise other values like individual privacy, lead to overregulation and put unnecessary constraints on the market. Moreover, it can make new policies very expensive, or block innovation altogether (Trappenburg & Schiffelers, 2012).

Although it is not the purpose of this thesis to discuss how public opinion influences politics and how politics gives shape and direction to public opinion, from this perspective, it is clear that climate emergency declarations have a significance that goes beyond the merely symbolic one of a political declaration. They open a political season in which we can exploit these windows of opportunity and intervene in urban systems to address the challenges and risks arising from the climate crisis in an integrated manner.

Rationale, research questions and hypothesis

Climate change is driving a series of stresses and shocks to cities, which have different impacts on urban systems and their elements. Although cities are not new to these impacts, the intensity and frequency with which they occur lead to continuous emergencies with repercussions throughout the whole urban system.

Several disciplines are trying to counteract the effects of these impacts through different approaches, the most established of which have their roots in the fields of climate change adaptation (CCA), disaster risk management (DRR) and urban resilience (UR). However, given the complexity of the urban environment and the uncertainty resulting from ongoing climate change, how these disciplines are applied locally is a field in progress, where experimentation and attempts are adapted to a changing context.

Urban planning and design are two disciplines at the forefront of shaping responses to the climate emergency on a city scale. These disciplines are now faced with the challenge of managing, planning and designing in a dynamic context, where various uncertainties test the discipline's tools in their ability to modify the urban environment and manage different urban systems in an integrated way.

This thesis explores how cities address the issues arising from the current climate emergency in the complex urban environment. This perspective is analysed through the lenses of planning and urban design. The overarching question is:

→ How can Planning and Design contribute to adapting complex urban environments to shocks and stresses of the climate emergency?

This overarching question opens related research questions connected, as:

→ How are the approaches to risk management (CCA, DRR and UR) operationalizated in: 1) guiding documents for municipalities? 2) plans and actions implemented in cities?

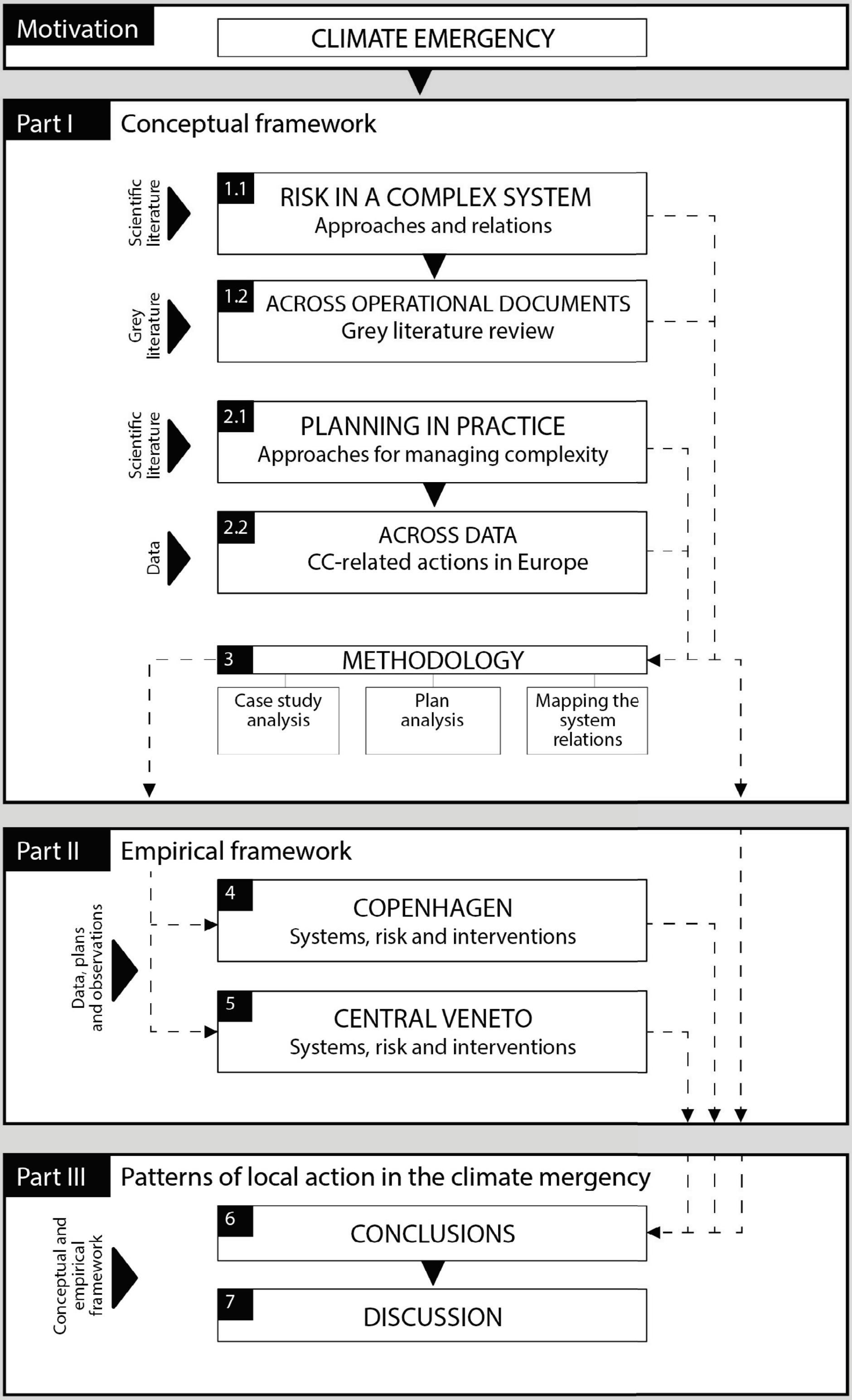
→ Which principles and planning modalities are currently applied to reduce climate risk and allow complexity to emerge in European cities?

Underlying these research questions is the assumption that the interaction of shocks and stresses of the climate emergency with cities forces us to consider the climate change challenge from the very perspective of the urban system as an interconnected open network of systems, rather than a single closed one. The hypothesis is that if risk spreads within urban systems by virtue of their interdependence, so there are principles and modes of planning that can contribute to adapting complex urban environments in a systemic way.

These research questions are not intended to find a single, definitive answer, but serve as a guide in constructing a research path that considers different sources and methods to approach the topics of the research questions.

The research aims at positioning between the academic perspective and the policymakers' and practitioners' one. Having an intermediate position, this research attempts to intercept the transfer of knowledge in the science-policy relation in both directions. On the one hand, by investigating the translation of conceptual knowledge into more operational practices, and on the other hand, how experiences and experiments can be generalised and brought back to theory.

The aim is to produce valuable indications both for the research community, which wants to understand the urban dynamics of intervention, and for practice, which wants to intervene in local contexts and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operationalise the knowledge available in this regard. This twofold objective is achieved by understanding the particular aspects of:

- → Finding the points of contact of the three approaches involved in risk management;
- → Understanding which interactions between urban environments and climate change are addressed in the various sources;
- → Identifying the principles that are applied to intervene in urban systems;
- → Understanding how planning approaches are used to intervene in the complex city.

Structure of this research

Beyond the current introductory section, the research structure is based on a division into three main parts. Part I contains the framework of conceptual, practical and methodological knowledge within which the research is articulated. Part II is composed of the empirical framework, in which case studies are examined through the knowledge elaborated in the first framework. Part III, the final one, the results of the first and second parts are examined. By comparing what emerges from the theory and the operational case studies, the main conclusions are discussed. Each of these parts is composed of several thematic chapters in different connections with each other, as shown in Figure 1.

Figure 1 - Structure of the research

The thesis has an internal organisation for the text divided into four hierarchical levels: parts, chapters, sub-chapters and paragraphs. The parts are numbered with roman characters (I, II and III) and divide the research into main frameworks. Chapters and sub-chapters follow a two-level Arabic numbering (chapter 1, sub-chapter 1.1) and detail specific issues, while paragraphs have no numbering and give substance to the higher levels.

The first part (I) is dedicated to building conceptual, practical and methodological knowledge. Within this, there are three chapters. Chapter 1 is dedicated to understanding risk in complex systems. Chapter 2 is dedicated to understanding how planning and design approaches handle risk at the city level. Finally, chapter 3 is dedicated to constructing an operational methodology that builds on the two previous chapters.

The first chapter (1) is focused on investigating the body of knowledge functional to frame the research field and understand how this is envisaged to be operationalised in practice. The chapter is divided into two sub-chapters according to the source of knowledge they address the question to. The first sub-chapter (1.1) takes the title of "Across the literature" precisely because it reviews some of the most relevant scientific texts. It focuses on building an overview of complex risks and their interaction with climate risk management approaches in urban settings. The second sub-chapter

(1.2) is dedicated to investigating the grey literature published on the subject by the main international actors in the field. These documents are the source through which it is intended to investigate how the conceptual knowledge of the first sub-chapter has been translated into operational documents. This sub-chapter is divided into paragraphs that present the methodology, results and conclusions that emerged from the review process.

The second chapter (2) is dedicated to investigating the tools available to the disciplines of planning and urban design to intervene in the complex urban environment and manage the risk arising from the consequences of climate change. The first sub-chapter (2.1) inquires the source of literature on how planning relates to complexity and how it is applied to shape climate actions. The second sub-chapter (2.2) is dedicated to investigating the CC-related actions currently taking place throughout the European cities. This sub-chapter analyses the available data that collect perceptions on CC risks and reporting of CC-related actions in European-wide databases.

The third chapter (3) is dedicated to summarising the main aspects that emerged from comparing the first two chapters and translating them into operational investigation methodologies to be applied to the case studies.

Part II is the empirical framework to investigate two case studies through the knowledge distilled in chapters 1 and 2 through the methodology built in chapter 3. It is composed of two chapters, the first dedicated to the urban area of Copenhagen (4) and the second to the urban area of Central Veneto (5). In these chapters, the in-depth study of individual cities allows close observations to be made at the urban scale, taking into account the context in which they occur, the instruments used, and the relationships and forms established. Both chapter 4 and 5 are articulated in three sub-chapters each, the same for both case studies to allow comparison.

Part III focuses on comparing the different results and insights that have emerged from the previous parts to reach a synthesis in which potential advice for local action in the climate emergency is highlighted. The comparison is between Part I's conceptual and operational framework and the empirical framework of Part II, as well as and the internal comparison between chapters and case studies analysed. Part III consists of two chapters: conclusion (6) and discussion (7). The conclusion chapter (6) compares the previously discussed chapters to highlight insights and valuable advice for operationalisation in the local context. The discussion chapter (7) is dedicated to re-reading the whole document focusing on research aspects, key facts, limitations of the approach, and future research areas.

Context of study and limitations

The research has the ambitious objective of describing and analysing ongoing and evolving phenomena. To choose a practical perspective and apply relevant tools and methods, it has been necessary to understand these evolving elements and set boundaries to the field of research.

The first evolving element is the object of study itself: as will be discussed later, contemporary cities are complex entities made up of systems interconnected to each other and in continuous evolution. Interactions with other systems are not limited to geographical, territorial or administrative boundaries but are dependent on infinite interconnected global systems. The recent COVID-19 pandemic is an example of the long chain of relations linking local effects with global causes. This dual relation between local and global is an element that recurs throughout the thesis, especially in the conceptual framework.

The second evolving element is the set of approaches that deal with risk, and these are climate change adaptation, disaster risk reduction and urban resilience. Although originating in different fields of knowledge, when translated to practice and applied in urban spaces, they have various overlapping points and competencies.

The third evolving element is how we regulate and plan the urban environment. The planning and urban design tools are at the forefront in responding to emerging challenges and are changing together with the urban context in its social, political and economic dimensions.

In order to somehow delimit this changing framework, I had to set boundaries and make choices:

→ I considered the urban environment an open system but limited the list of impacts considered to those directly related to climate change. There are CC-related significant events that impact remote places and then have repercussions in many other contexts. These events, such as economic and political crises, pandemics and major migrations, are not the main focus of this thesis.

→ While the following research considers the global dimension as well, it is mainly oriented towards the European urban context. Several reasons dictate this choice. First of all, the great variety of climate impacts. In order to treat the impacts of climate change in at least comparable terms, the research could not include all geographical and climatic contexts of the world. Despite its differences, the European continent has macro characteristics that unite it and allow specific impacts to be clearly identified. The second reason concerns the uniformity of the European context as a set of constitutional states, where there is a stable government system and a high level of democracy. And finally, the third reason is related to geographical proximity and the writer's personal experience, linked to the European urban contexts and systems.

PART I
A FRAMEWORK FOR CONCEPTS AND PRACTICE

This framework introduces the interpretation of the city as a complex entity, an open network of systems that exchange resources, energy and effects with the urban environment. These connected systems, where each one is interdependent to the other, also share the risks arising from the consequences of climate change. How climate change can interact with different urban systems is therefore dictated by the complex relationships between the systems themselves and how they can change in time and space. Therefore, the climate emergency is potentially affecting all systems, places and times. Addressing these challenges need to consider the diversity of potential states that an urban system can reach and how these perform under climatic stresses and shocks. How to intervene in such systems within the domain of planning and urban design fields is investigated both from the conceptual and operational point of view. Principles and intervention modalities are recognised in scientific literature, global policies, operational documents and current practice in European cities. An operational methodology is then built upon the results and insights in these chapters to be applied in Part II.

Chapter 1 - Risk in a complex system

1.1 Across the literature – Approaches to risk

Risks interconnected

In the report on global risks published annually by the World Economic Forum, the results of a multi-stakeholder survey on the main perceived short- and long-term risks are presented. Issues related to climate change and its consequences have increasingly dominated the global picture in terms of both the likelihood of their occurrence and the severity of impact if they were to occur (WEF, 2020). In the 2020 report, the top 5 positions in terms of likelihood and the top 3 positions in terms of impact are occupied by environmental risks (Figure 2). Risks arising from "extreme weather[2]" have occupied the first position in terms of probability since 2017, followed in varying order but always with high probability and severity of impact by "climate action failure[3]", "natural disasters[4]", "biodiversity loss[5]" and "human-made environmental disasters" (Figure 3).

Figure 2
The evolving Risks Landscape 2014-2020. Source: (WEF, 2020)

2 Extreme weather events(e.g. floods, storms): Major property, infrastructure, and/or environmental damage as well as loss of human life caused by extreme weather events.

3 Failure of climate-change mitigation and adaptation: The failure of governments and businesses to enforce or enact effective measures to mitigate climate change, protect populations and help businesses impacted by *climate change to adapt.*

4 Major natural disasters (e.g. earthquakes, tsunamis, volcanic eruptions, geomagnetic storms): Major property, infrastructure, and/or environmental damage as well as loss of human life caused by geophysical disasters such as earthquakes, volcanic activity, landslides, tsunamis or geomagnetic storms.

5 Major biodiversity loss and ecosystem collapse (terrestrial or marine): Irreversible consequences for the environment, resulting in severely depleted resources for humankind as well as industries.

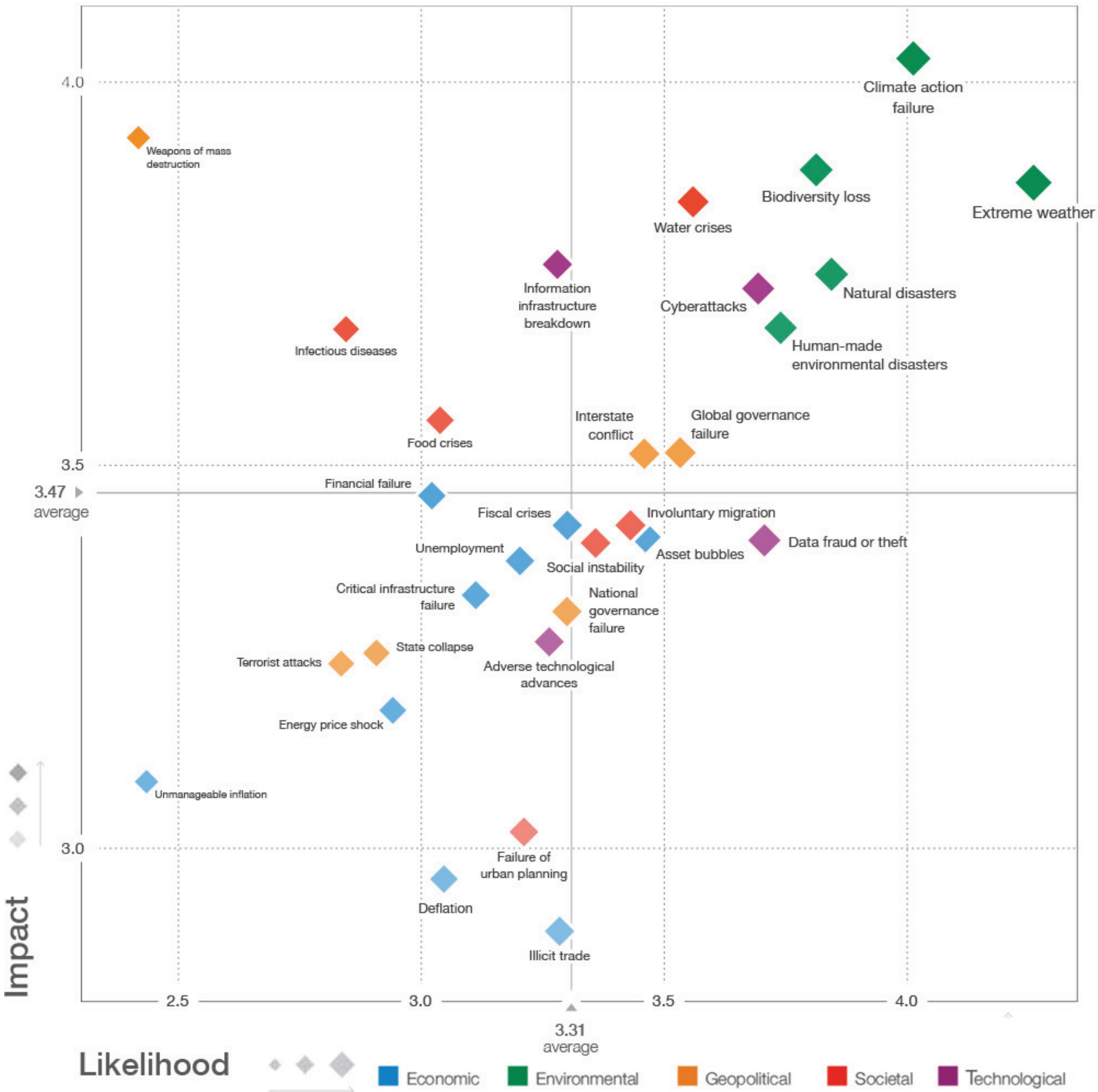


Figure 3
The Global Risks Landscape 2020.
Source: (WEF, 2020)

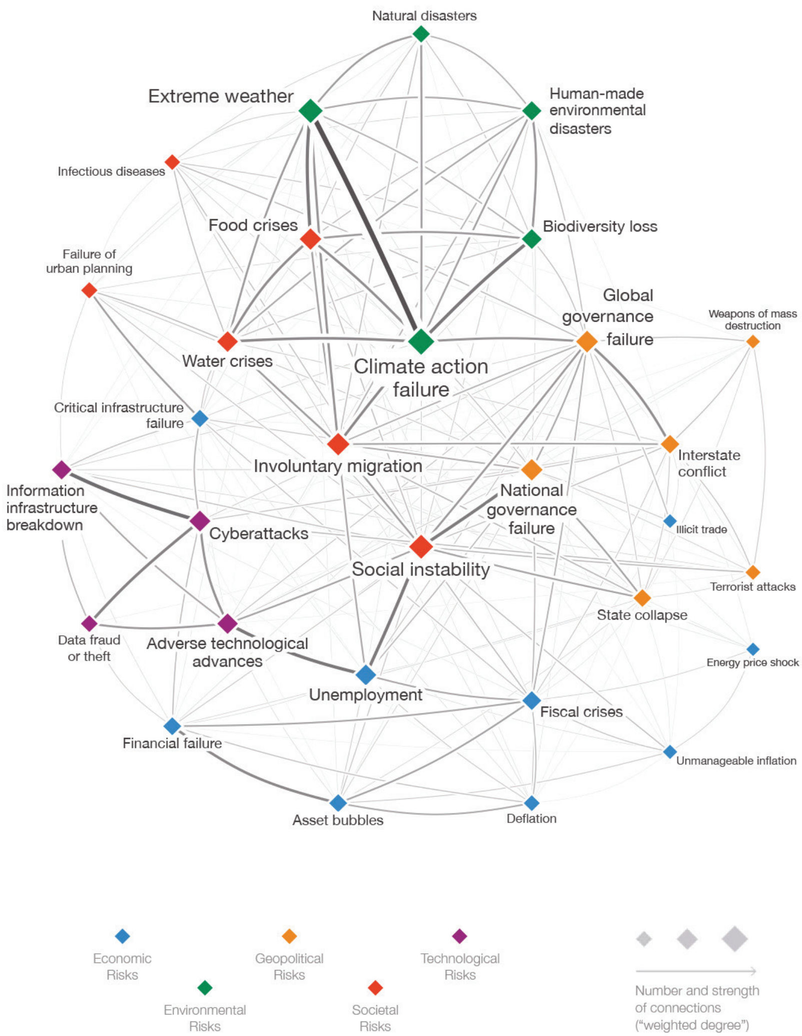


Figure 4
The Global Risks Interconnections Map 2020. The size of each risk is scaled according to the weight of that node in the system. The size of the links between risks is scaled according to the strength of the connection. Source: (WEF, 2020)

While dividing the risks into categories allows classification and an individual assessment, the picture that best conveys the complexity of the current risk is provided by the map of the interconnections between the global risks examined in the survey (Figure 4). From this, it is clear that risks are not isolated phenomena; they are deeply connected to each other in causal chains that influence each other and have repercussions throughout the entire system. Thus, while the introduction laid the groundwork for communicating the urgency of addressing the climate emergency, this picture also reveals the complexity of this emergency.

Key and emerging risks

In the latest Assessment Report (AR5) of the Intergovernmental Panel for Climate Change (IPCC) - the main scientific organisation that leads on climate change - risk is defined as "the potential for consequences where

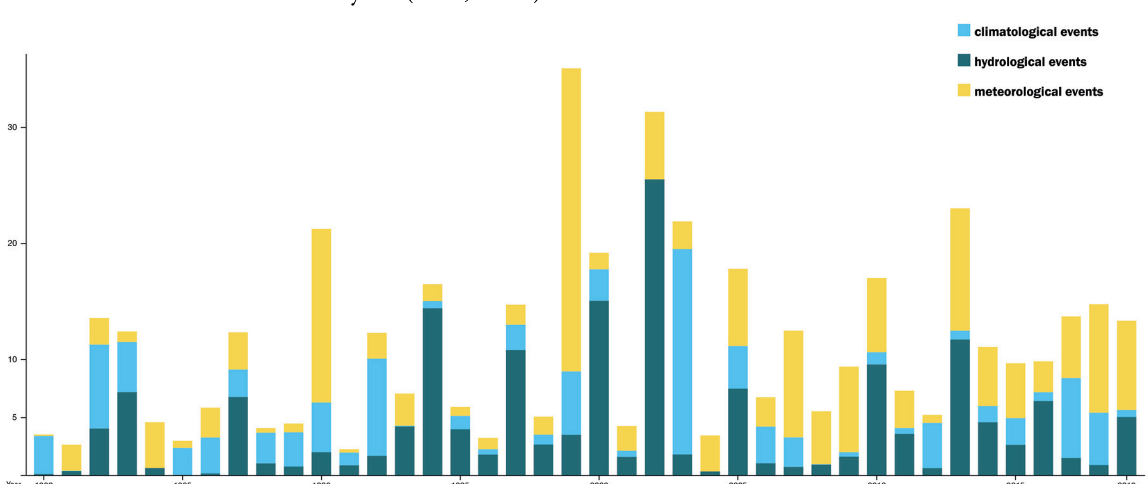
Figure 5
Economic damage caused by weather and climate-related extreme events in Europe, in EUR millions, adjusted for 2019 value (1980-2019). This graph focuses on events of three categories: meteorological events (storms), hydrological events (floods and mass movements) and climatological events (heatwaves, cold waves, droughts and forest fires). Source: European Environment Agency.

something of value is at stake and where the outcome is uncertain, recognising the diversity of values". As seen in Figure 3, risk is often referred as the probability, or likelihood, of occurrence of an event multiplied by the impacts if these events occur. While this definition embraces a broad concept of risk, the report also introduces distinctions useful in identifying different facets of risk. Key risks are recognised as those that potentially can have severe adverse consequences for humans and social-ecological systems.

These are named 'key' after the severity of the effects that the interaction of a climate hazard may have with a vulnerable and exposed system. In addition to these key risks, emerging risks are introduced in the AR5 (Oppenheimer et al., 2014). These arise from the interaction of events or trends over time with a complex system that causes indirect impacts, which may take place either near or far from the original climate impact's location. Through this view, it is possible to define the set of effects that arise from the interaction of a key impact with a complex system of interactions. This chain of effects, which are called indirect, cascading and systemic, may have unforeseen repercussions given the system's complexity.

Natural hazards are among the key identified risks that pose a serious threat to human life, both directly and indirectly. In recent years, climate change has made these events more extreme, profoundly worsening their consequences. Figure 5 shows, for example, how some CC-related events are also seriously damaging the economies of the European Economic Area (EEA).

According to the report published by the European Environment Agency, the economic losses caused by extreme events related to climate change from 1980 to 2019 account to a total of 446 billion euros for the EEA member states. On average, this equals to 11.1 billion euros per year, equal to nearly 3 percent of the gross domestic product of the countries analysed (EEA, 2021).



In a complex system

The interconnections between different risks arise from the very nature of the current complex system. In fact, it is challenging to trace unambiguous causes of these risks; risk is brought about by a combination of factors and elements that cause a conformation of the system that is predisposed to risk. This concept is made clear in a well-known example by Ulrich Beck (Beck, 1992) about water pollution from agriculture pesticides. The responsibility of this effect seems, at first glance, of the farmer. He is the one that spreads the pesticides in its fields and consequently in the water basins. However, analysing deeper the chain of actors and causes, the pesticide producer has its responsibilities since he commercialises a product that harms the environment. Furthermore, the international community, or the national or local one, is responsible for allowing both the production and the use of certain types of pesticides. And finally, the market pressures of enlarging and increasing the production of a single, standard agriculture product has their responsibility in enforcing intensive agriculture. And what about the global responsibility for climate change and the invasion of alien pests? Beck's logic is that the economic and social structure of the production of goods, necessary for life, is a complex system of relations. This complexity denies a specific identification of who or what is the cause of the effect. Every actor can act in the system, be part of it, and act through it without assuming its responsibilities.

Since the risk of the current system does not lend itself to a clear and unambiguous identification of the chain of cause and effect, it must first be analysed in its components in order to deal with it.

How is risk being addressed?

According to Hagman & Beer (1984), disasters and the associated risks of disaster occurrence result from 'unresolved development problems'. In addition to the probability of extreme weather events occurring, which is increasing in a climate change context, the unsustainable development paradigm based on unlimited growth, inequality and overconsumption is at the root of risk.

The most comprehensive approach to tackling the causes of risk is to address development issues, in which the social, economic and environmental aspects of development are managed sustainably in the pursuit of a higher quality of life for all people (UN, 1997). Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (UN, 1987) is thus the framework within which other more specialised approaches to dealing with risk have developed. In the following chapter, the three main ones are considered: climate change adaptation (CCA), disaster risk reduction (DRR) and urban resilience (UR). These approaches are first defined in their objectives, field of origin and characteristics. In doing so, their points of contact and differences with Sustainable Development (SD) and in between them are highlighted.

Borrowing a widely accepted definition by the IPCC, climate change adaptation is the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities (IPCC, 2014). CCA has its roots in scientific theory and has been developed as the progress of understanding the threat of climate change has increased (EEA, 2017). These threats from climate-human interactions are assessed based on climate risk assessments and climate models. Therefore, CCA focuses mainly on the future, with the aim of reducing risks arising from the consequences of current and future climate change. It is an evolving discipline and its approaches can face also new risks and rising uncertainties from climate change and climate variability. The domain of impacts that it mainly addresses are the climate, weather and hydrogeological ones. Together with these shocks, CCA approaches take into account impacts resulting from slow on-setting stresses as well (such as sea-level rise, biodiversity loss, etc.). It embraces as well a positive perspective on climate change, by including approaches that can exploit the benefits resulting from a changing climate. CCA practices generally originate from actors operating in the environmental sector, such as ministries, agencies or institutions related to environmental and climate issues.

Disaster risk reduction aims to prevent new and reducing existing disaster risk (exposure, hazard or vulnerability) and manage residual risk, all of which contribute to strengthening resilience and, therefore, achieving sustainable development (IPCC, 2018a; UNISDR, 2017). Its origins and culture are historically focused on humanitarian assistance following a disaster event; it has increasingly included approaches of civil protection as prevention, mitigation and preparedness, including changes to development processes (UNISDR, 2008). Approaches derived from DRR are based on the prevention and reduction of a wide range of hazards. Alongside risks also considered by CCA, namely climate, weather and hydrogeological risks, DRR includes geophysical, biological and human-related risks (Integrated Research on Disaster Risk, 2014). The firmly humanitarian aid and civil protection approach gives DRR an operational declination that focuses on managing existing risks in the present, learning from historical evidence.

Both CCA and DRR aim at reducing vulnerability and increasing the resilience of societies. More than a discipline in itself, resilience can be understood as a concept that has been employed and declined in various disciplines. As a technical term, the idea of resilience has its roots in

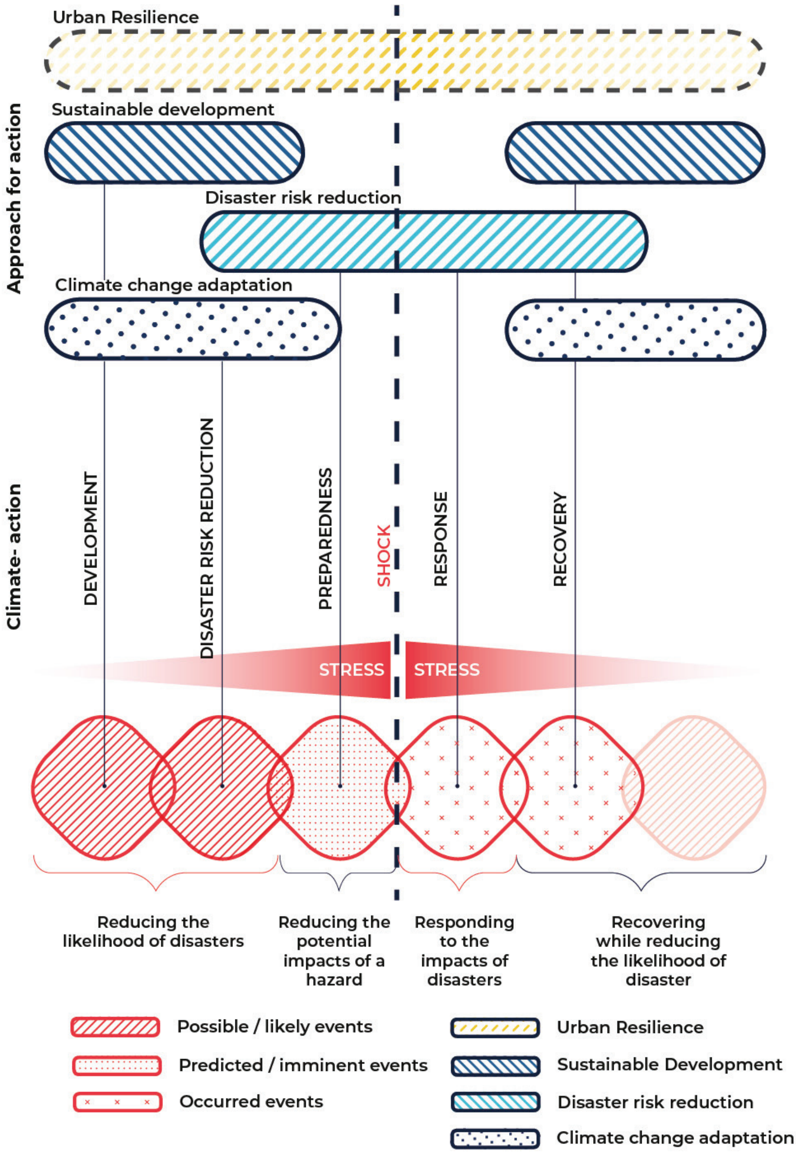


Figure 6
Framework based on the disaster reduction cycle that shows how different approaches for climate action overlap. Urban resilience is represented with less defined boundaries as it can relate to a wide range of typologies and climate action moments. Source: author elaboration based on and adapted from (IFRC, 2020; OECD, 2014).

the field of ecology (Holling, 1973), where it becomes one of the foundations for further studies, understanding that the natural state of a system is one of change rather than one in stability. It has then been developed and declined in different fields, to name the ones that relate more to urban environments: social-ecological systems (Carpenter, Walker, Anderies, & Abel, 2001), disaster resilience (Cutter, Burton, & Emrich, 2010), climate change adaptation (Nelson, Adger, & Brown, 2007), urban planning (Ahern, 2011; Meerow, Newell, & Stults, 2016). In its declination in the fields concerning cities and their response to risks from climate change, definitions have a focus on urban systems (Folke, 2006) and their ability to interact positively with both slow and fast onsetting climatic stress and shocks (IPCC, 2014; Meerow et al., 2016). Some definitions also take into account vulnerable populations and economic inequalities (ARUP, 2015a). With its many nuances, the concept of resilience generally emphasises the ability of the system and its elements to respond positively both before, during and after a climate shock or stress. A widely adopted definition of resilience for the domain of managing risk in urban systems is the following: "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management" (UNISDR, 2017).

Global framework on Risk

We have seen how risk management can be approached from different starting points and with different methods and developments. Although having distinct origins and focuses, the approaches previously described share common objectives, overlapping in some aspects and complementary in others.

The convergence of these different fields of practice and knowledge has been built through the adoption of international frameworks and global policy agendas in which the United Nations has played a leading role since the 1970s (Figure 7).

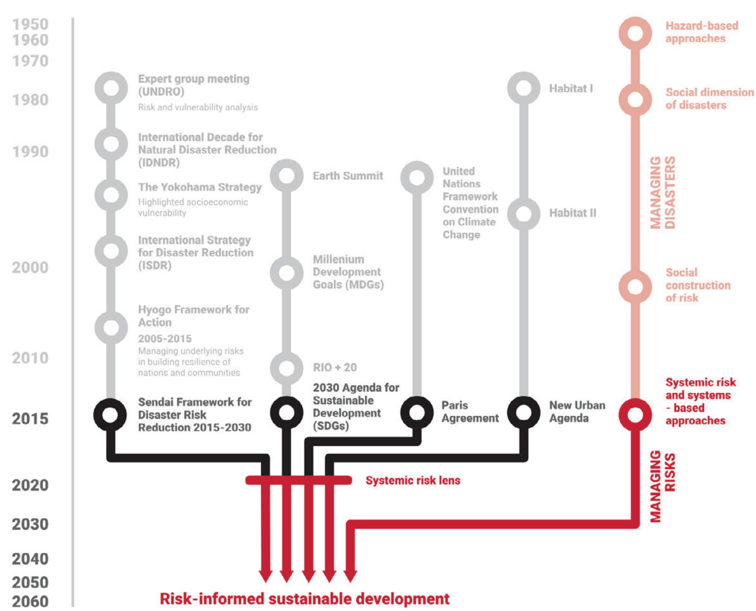


Figure 7
Convergence of global policy agendas on risk. Source: (UNDRR, 2019)

In this perspective, 2015 was a landmark year in which a series of UN agreements were adopted within the UN agency framework: Sendai Framework for Disaster Risk Reduction, Sustainable Development Goals (SDGs), COP21's Paris Climate Conference, and Habitat III (Figure 8). These frameworks build up visions, a set of goals and targets to achieve a future where significant progress is made on the disaster, sustainable development, climate and urbanisation challenges of today. These frameworks reflect and shape the social, economic and environmental challenges of the 2015-2030 timeframe, and they build on the successes and challenges of previous international frameworks. The following paragraphs highlight the shared vision behind these frameworks, and then a summary of the path that shaped each of these documents is provided.

While focusing on different disciplines and approaches, these agreements have provided coherence and compatibility between different policy areas. Through different perspectives, these agreements have shaped a more comprehensive resilience agenda, through the declination of this approach in the fields of sustainable development, humanitarian aid, urbanisation, climate action and disaster reduction (Murray, Maini, Clarke, & Eltinay, 2017). Taken individually, each of these agreements does not address the full spectrum of possible shocks, stresses and disturbances within the system (Peters, Langston, Tanner, & Bahadur, 2016a). However, through the different documents, a set of approaches emerges that can address risks systematically and address key interactions across policy domains (Nilsson, Griggs, Visbeck, & Ringler, 2016).

In the effort to understand how resilience is viewed from different lenses in these frameworks and the points in common, Peters et al. (2016b) carried out a content review focusing on how the resilience concept features within them.

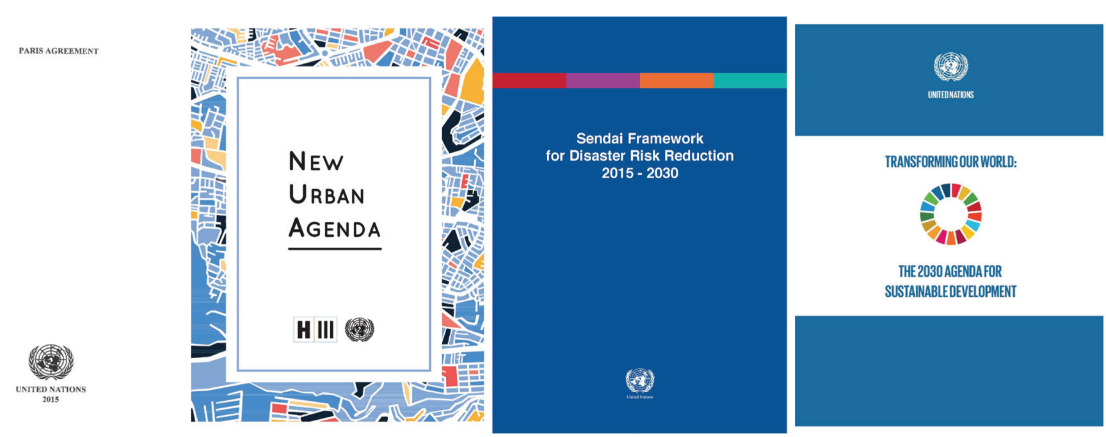


Figure 8
Landmark agendas: Paris Agreement, New Urban Agenda, Sendai framework for Disaster Risk Reduction, The 2030 agenda for Sustainable Development for Disaster Risk Reduction, The 2030 agenda for Sustainable Development.

Their work shows that the concept of resilience to risk is shared by all frameworks and is present in many of the objectives of the individual documents, albeit with different nuances. All four frameworks see resilience as a means to cope with the variety of shocks and stresses and as a valuable tool to intervene in a large number of systems, such as healthy and productive oceans and coastal ecosystems, migration, agriculture, infrastructure, technology, and cities and human settlements. While the objective is shared, the ways to address risk differ from framework to framework. The Paris agreement focuses on the adaptive capacity of systems, in other words, their ability to change and adapt to change. The SDGs also refer to this capacity (Target 13.1 strengthening resilience and adaptive capacity to climate-related hazards and natural disasters) and include anticipatory capacity, in other words foreseeing shocks and stresses. This is referred to, for example, as improving human and institutional capacity on early warning (Target 13.3) or anticipatory adaptation planning (target 13.2 and 13.b). The Sendai framework links resilience to both this anticipatory capacity and the absorptive capacity, which can withstand shock and stresses, for example, by strengthening preparedness and disaster risk governance. Throughout its broad scope, the New Urban Agenda focuses mainly on the adaptive capacity, although there are several sections in which it incorporates the indications Sendai and aims to build anticipatory capacity as well (Table 1).

Table 1
Resilience capacities in the four international frameworks. Anticipatory capacity (foresee shock and stress), absorptive capacity (withstand shock and stresses), adaptive capacity (changing, adapting to shock and stresses). Based on (Peters et al., 2016b; Sarmiento, 2018)

	Climate agenda	Sustainable Development agenda	Disaster risk reduction agenda	Urban agenda
Anticipatory capacity		x	x	x
Absorptive capacity			x	
Adaptive capacity	x	x		x

Disaster Risk Reduction

In the 1970s and 1980s, increasing attention to the severity and scale of certain natural disasters raised the need to prevent the most disastrous effects of these events. Anticipating these effects to prevent them posed the need to develop methods for risk and vulnerability analysis. This process was followed by the 1979 Expert Group Meeting organised by the United Nations Disaster Relief Coordinator and the development of the International Framework of Action for the International Decade for Natural Disaster Reduction (IDNDR) sanctioned for the 1990s. The objective of this decade was to reduce the effects (loss of life, poverty, social and economic disruption) of so-called natural disasters, mainly in developing countries, through internationally coordinated actions.

This joint effort had one of its most significant moments in the approval during the 1994 World Conference on Natural Disaster Reduction (WCDR) of the Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation (UN, 1994). Together with its principles and Action Plan, the strategy marks a turning point by emphasising the role of human actions in reducing socio-economic vulnerabilities to natural hazards.

The strategy has undergone continuous review processes intending to change the approach from disaster protection to risk management, integrating it with sustainable development activities. The Yokohama Strategy review process peaks with the 2005 WCDR, during which it is used as the foundation for the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters (HFA) (UN/ISDR, 2005). Within this framework, Member States are responsible for preventing and reducing the risk of disasters within their territories in conjunction with national and local stakeholders, recognising the importance of coordination between and within sectors. It also affirms the need to tackle risks through a multi-hazard approach that also addresses underlying risk factors.

As this decade of work within the HFA failed to counter the growth in physical losses and economic impacts (UNDRR, 2019), the following WDCR laid the groundwork for a new approach. Within the third WDCR in 2015, the Sendai Framework (UNISDR, 2015) was adopted, which shifted the focus from an approach of protecting economic and social systems from expected impacts to one geared towards transforming development and growth patterns in a way that could manage a broad spectrum of risks in an integrated manner. Understanding risk management from this perspective means pursuing sustainable models for economic growth, social and environmental systems not to exacerbate the underlying causes of risks and increase the resilience of systems to external shocks. Its overall goal is to strengthen system resilience to achieve the outcome of reducing the negative impacts of disasters. This focus on resilience results from the shift from a disaster management approach to a risk management approach and is included in several targets and indicators. The overall goal is oriented to "*prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience*" (UNISDR, 2015).

Climate Change negotiations

In the field of counteracting climate change, the first United Nations conference on the human environment held in Stockholm in 1972 saw the recognition of the impact of human activities on the ecological balance of the planet. At this conference, environmental protection was established as a common goal to be pursued globally by reducing harmful behaviour to the ecosystem.

Over the years, various initiatives have followed, including founding essential bodies such as the UNFCCC and IPCC , together with international agreements to set concrete objectives aimed at protecting the planet. Among the most important of these, the Kyoto Protocol of 1997 was the first global agreement to enshrine the need to reduce greenhouse gas emissions into the atmosphere. This need was strongly reaffirmed and given legally binding force in 2015 in the Paris Agreement on Climate Change (UN, 2015). The central objective of the Paris Agreement is to strengthen the global response to the hazard of climate change. On the mitigation effort, a goal was set to contain emissions of climate-changing gases to keep the global temperature increase below +1.5°C. In addition to pursuing deep and rapid emission reductions, the climate negotiations also addressed the need to pursue adaptation to improve the ability to cope with current and future impacts of climate change. The breadth of the field in which adaptation can intervene is defined in Article 7 of the Paris Agreement, which defines its objective as "*of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal*" (UN, 2015 Article 7).

Sustainable development

Sustainable development has its roots in the conferences and agencies that led the climate change negotiations, and in the 27 principles adopted at the 1992 Earth Summit in Rio de Janeiro, the idea of a global partnership to conserve, protect and restore the integrity of the Earth's ecosystem. The Rio Declaration, the Agenda 21 and the Statement of Forest Principles all have their roots in this Summit. The Rio de Janeiro conference highlighted how different social, economic and environmental factors are interdependent and evolve together, and how success in one sector requires action in other sectors to be sustained over time. In 2000, the Millennium Summit established the eight Millennium Development Goals (MDGs) that included commitments by all countries to reduce poverty and hunger and tackle ill-health, gender inequality, lack of education, and lack of access to clean water and environmental degradation. Following various review processes on the MDGs, the United Nations Summit on Sustainable Development then adopted the Agenda 2030 and its 17 Sustainable Development Goals (SDGs) in 2015. In addition to the global goals for poverty reduction, sustainable development and peace contained in the MDGs, the SDGs also introduce resilience in two goals and eight targets related to poverty, built infrastructure and human settlements, agricultural production and vulnerability to climate extremes and disasters. Here, resilience is regarded as a quality to be 'strengthened', 'built' and 'developed', a tool to reduce the exposure of people and systems to shocks and stresses and a foundation for economic growth and prosperity (Peters et al., 2016b).

Table 2
UN-led agreements concluded in 2015–2016 that promote climate and disaster resilience and their convergence on DRR and CCA. Source: (EEA, 2017)

Sustainable urban development

As the international community started witnessing fast growth in the urban population and migration to cities, governments began to recognise the need for sustainable human settlements. However, cities have since continued to expand in scatter pattern, often due to weak urban planning, poor urban management, land regulation crises, and real estate speculation factors.

With an initial focus on recognising shelter and services as fundamental human rights and making governments accountable to ensure that this is possible, the Habitat I conference led to the Vancouver Declaration in 1976 and the foundation of the United Nations Human Settlements Program or UN-Habitat. As it was clear that the urbanisation trend was expected to grow further and cities were facing significant social challenges, a new agenda and an updated declaration were then developed in 1996 at the Habitat II conference held in Istanbul, focusing on providing "adequate housing for all" and "viable human settlements in a changing world".

The New Urban Agenda was adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito in 2016. It builds on previous agendas and aims at a new urban development model to allow cities to fulfil their role as drivers of sustainable development and promote equity, welfare, shared prosperity, and sustainable natural resources management. It also marks an important innovation by explicitly including the concepts of resilience and DRR in its vision and principles, promoting risk-based approaches that target all hazards and include the whole of society. As the last of the post-2015 agenda-setting frameworks in terms of time, the NUA has included several approaches with the other frameworks, particularly with the Sendai Framework, which aims to increase the resilience of cities by integrating DRR strategies into urban development plans.

UN-led agreements	Contribution for convergence on DRR and CCA
Sendai Framework for Disaster Risk Reduction (SFDRR)	• Formulates priorities for actions and targets for DRR, coordinated with climate adaptation efforts where relevant; • Acknowledges climate change as a driver of disaster risk; • Addresses disaster preparedness for effective response and to 'build back better'.
2030 Agenda for Sustainable Development	• Provides an overarching framework connecting the DRR and CCA targets and commitments with poverty reduction, economic growth, social inclusion and environmental protection; • Explicitly addresses the challenge to combat climate change (SDG13), and directly and indirectly addresses DRR and adaptation in several other SDGs.
Paris Agreement on Climate Change	• Limits human-induced global temperature rise to 2 °C (1.5 °C) compared with pre- industrial levels; • Addresses climate adaptation as a part of climate change policies (Article 7), and confirms Loss and Damage initiative as cornerstone of global policy architecture (Article 8).
Habitat III - New Urban Agenda	• Focuses on urban environment as the major hotspots of vulnerabilities; • Formulates New Urban Agenda as a vehicle for better integration of various policies contributing to sustainable development.

Intervening in a complex system

The previous chapter outlined the many facets of CC-related risk, the range of approaches that have been developed to reduce it and the convergence of global agendas (Table 2). The interaction of this risk with the urban environment requires introducing the available planning tools to achieve this goal in complex systems. In this section, the view of cities as open and complex systems is introduced. In this perspective, the limitations of a planning approach based on prediction and control are highlighted: the imperfect understanding of cause-and-effect dynamics, the uncertainty of the outcomes of an intervention and the vision of future static equilibrium to strive for.

The understanding of the city as a machine, with a clear hierarchy of coordinated parts that assure its functioning, dominated the thought and practice of urbanism and planning for the second half of the 20th century (Batty & Marshall, 2017). This conceptualisation sees the city as a system isolated and distinct from its surroundings and whose functioning is oriented towards a static equilibrium. This equilibrium is pursued through regulatory systems that are centralised and aim to govern the system in a top-down manner.

However, this conceptualisation showed limits in dealing with cities that have innumerable interactions within the system and between a system and its environment. Cities are part and are made of a set of systems, eventually global, much larger than the city's administrative boundaries. This shift in perspective is illustrated by a famous line that states that we used to look at complicated (but understandable) systems, and now we look at complex (and non-understandable/predictable) systems (Cilliers, 1998).

A stream of thought has developed that seeks to describe the city as a set of systems interconnected; this goes by the name of complexity sciences (Batty, 2013). It has had numerous contributions in recent decades and has established itself as an interdisciplinary research field involving urban phenomena scholars, including urban geographers, planners, urban designers and others (Portugali, 2012b).

Through the set of complexity approaches, these scholars consider that the elements of the urban systems assume their importance based on the relationships between them, and these are continually evolving. Consequently, there is no static equilibrium between the elements, and their evolution is linked to the dynamics of continuous interactions of different systems rather than one centralised order.

Cities may appear to be in equilibrium because of the lag between the speed at which the physical built environment changes and how human behaviour changes, but complexity science considers cities to be in a state of perpetual disequilibrium. Rather than a perfect understanding of the city's state at any given time, the focus shifts to those processes that continuously move the system into a new equilibrium that, if it happens fast enough, implies a continuous state of disequilibrium. Growth and change represent continuous readjustments to the state away from equilibrium (Batty, 2005).

Considering the city from this perspective also has implications for the relationships that climate change has with urban systems and how planning interacts with these relationships. The aim of "maintaining, or returning to, a state of equilibrium" that underlies some resilient planning approaches carries with it the contradiction of assuming that there is a state of equilibrium to aim for. Batty & Marshall (2017), based on Geddes' idea of considering the city "organic, growing or evolving", highlight the existing paradox of planning that seeks to intervene in dynamic systems through static interventions:

> "…modern urban planning seeks to intervene in systems that have enormous complexity, growing and evolving rather than being designed in any top-down fashion. This has fundamental implications for examining the resilience of cities not as engineered optimised systems but as organic evolving systems which follow the laws of resilient natural systems." (Salat, 2017)

In this perspective, urban complex systems are considered more like biological systems than mechanical ones, and there is an unfillable gap of what can be predicted and planned. This gap is driven by uncertainty embedded in the forecasting, modelling, understanding, and decision-making processes and their effects on the system (Moroni, 2015). Attempting to govern this complexity with planning tools brings with it challenges highlighted by Marshall (2012). He describes the three kinds of uncertainties embedded in the complexity vision of cities as open systems, and this brings:

- The unknowability of the system as it is
- The unknowability of the effects of interventions
- The unknowability of the optimal future state.

The first unknowability is about understanding the system as it is in the present. This includes questions as: where can the system's boundaries be traced, of which parts it is precisely made of and what are all the relations between them. There is always a degree of uncertainty when trying to take a static picture of the system. For finite objects, such as a machine or a building, it is generally possible to know all the parts that compose them and their role in the whole. For complex systems, such as cities and ecosystems, this knowledge level is more challenging to achieve. Firstly, because they are systems that are not finite and have blurred boundaries, which always have relationships, influences and exchanges with wider systems (e.g. regions, for cities, and wider ecosystems for local ecosystems). This does not mean that to know the local, one must necessarily have perfect knowledge of the global. However, in general terms, one must always consider different scales and the unpredictable relationships that may or may not take place between them. Moreover, the relationships within complex systems may change over time, and the parts they are composed of may change role and function. The evolution of these relationships does not follow a linear course, which means that they are not predictable, and the way they change may not be reversible.

The second unknowability is connected to the first and concerns the dynamics of how the system will change. The wider the timeframe, the more difficult it is to predict how the system will change and why. This is why it is hard to predict what will be the effects of a specific intervention in the system, and therefore decide how to intervene since the system is not closed, fully understood and known in all its dynamics. To return to the example of the machine cited above, we can have a certain degree of certainty as to what effect there will be on the machine's state should we decide to intervene or not. The action-consequence relationship occurs within a domain that we know, in which the parts have a defined and static function. As far as complex systems are concerned, this relationship occurs in an open system where - even if we have a perfect representation of the present moment - there is no certainty in the effects of an intervention because the system is dynamic and evolving on its own. For example, although we have all the statistics available on the species that make up a specific ecosystem, it is not possible to be sure how the ecosystem will react to introducing a new species or a change in the environment. The same applies to urban systems; the effects of introducing new commercial spaces can be diverse and conflicting and follow unpredictable paths.

The last unknowability is related to how the system should look in the future. There is no optimal future state, no static endpoint to reach. While for a machine, the optimal future state is the one in which it functions, and any other state deviating from this is somehow a less preferable state, the same is not valid for complex systems. An ecosystem is a collection of parts and species that are constantly competing with each other for resources. From a natural point of view, there is no balance of species that is preferable to another. The presence of a tropical species in the North Sea is part of the evolution of that ecosystem in response to environmental stimuli; it is not preferable or not in itself compared to the previous or next moment. Similarly, there are constant changes in the evolution of cities that have no static and unique destination. Parts can change function, be incorporated or excluded from systems, and have desirable effects today that may be harmful tomorrow.

These three aspects of planning in complex cities are also recognised by Portugali (2008, 2012). Portugali supports his arguments by applying the concept of paradox to highlight three noteworthy aspects that concern planning in the complex urban context. He describes them as three closely interconnected and interrelated aspects that are inalienable from planning. Firstly, he states that it is not possible to isolate cause-effect relationships from other variables in a complex system. This aspect has many elements in common with Marshall's reasoning described above and, in particular, with the unknowability of understanding how the system functions at a given time. The second aspect that Portugali highlights is that within the system, change occurs following more the logic of a mutation than that of mechanical intervention. Thus, he states that it is difficult to predict the effects of an intervention, not so much because of the lack of data but because of the nature of change itself. This aspect is in close connection with Marshall's second unknowability related to intervention in the system. Finally, Portugali raises doubts about predicting or projecting the current system into the future, which has some resonance with Marshall's third unknowability.

All these uncertainties end up building the paradox of urban planning in complex systems: which is the role for planning in an open system we cannot fully understand, in which we cannot fully foresee the outcomes of our intervention, and that we cannot predict which future optimal state it should tend to?

These questions are particularly relevant to the climate change agenda, which must consider complex, dynamic and highly uncertain socio-ecological systems. The role of planning is no longer just about predicting and controlling the future, whereas to focus on understanding relationships and dependencies to be prepared for unpredictable futures. The aim is not to reduce complexity but to take advantage of the interrelations and dependencies to strengthen the systems' adaptation and resilience.

The following sub-chapter (1.2) of this thesis explores these questions by researching how they are addressed in prominent international organisations' operational documents across the planning fields concerning risk.

1.2 Across operational documents – Review of how complexity is addressed in risk-related grey literature

In the previous section, the boundaries of the concepts related to climate risk and what approaches have evolved in the urban context to reduce, cope, and prevent them were defined. The sources chosen for the previous section are the scientific literature and international agreements, from which it was possible to determine the framework within which these approaches are established.

Within this section, many grey documents are also taken into account to understand how these concepts and approaches are made operational at the urban scale, beyond global agreements and frameworks.

Outline of the review

This review considers scientific and technical reports, toolkits and guidelines as documents included in the broader category of Grey Literature (GL), defined – in the International Conferences on GL held in Luxembourg (1997) and in New York (2004) – as "Information produced on all levels of government, academics, business and industry in electronic and print formats not controlled by commercial publishing, i.e. where publishing is not the primary activity of the producing body" (Castro & Salinetti, 2006).

In the fields of urban resilience, climate change adaptation and disaster risk reduction, there is a large and dynamic body of scientific literature from various disciplines and with many points of contact. A selection of this has been included in the first two chapters, seeking to select relevant authors and prioritise convergence points between disciplines.

The review's main objective is to leverage knowledge and approaches learnt from grey literature to trace the emerging relation between CC-related impacts and urban elements.

Especially concerning their planning and urban design applications, these knowledge fields are confronted with a continually evolving object. There is a substantial body of grey literature produced by different international actors dealing with translating scientific knowledge into operational guidance to foster its application to urban contexts. Therefore, this review focuses on reports, toolkits and guidance produced by different international actors, government and regulatory reports, and guidance from non-government, non-profit or policy institutions, and influential private actors in the field. This choice lies in the fact that these documents are produced to guide, help and support local actors in applying conceptual knowledge to their context. For this reason, there is a greater likelihood that actors that are giving practical and operational form to resilience, adaptation and disaster risk reduction at the local level have come more into contact with this type of literature, rather than only the scientific one. Grey literature published by these actors is a particular case in which an attempt is made to apply scientific theory to the local scale, maintaining a general dimension that can be applied to different contexts. Therefore, analysing these tools gives a vision of how - from the perspective of these institutions and actors - UR, CCA and DRR can be developed at local scales.

In these documents, this review aims to recognise how different approaches address some specific issues concerning climate action's operationalisation in urban systems. The focus is on the relations between the effects of climate change and urban elements. The results of this review are divided into three paragraphs that trace three distinct focuses of these relations.

The first set of relations aims to reconstruct the set of relationships that emerge from the impacts of climate change in the urban environment on the sectors and elements of the urban system. In doing so, it seeks to explore the first unknowability of planning in a complex environment as described by Marshall and to understand how it is addressed when confronted with practice. In fact, Marshall states that a complete knowledge of the urban system and all the relationships that insist on it are precluded by its complex nature (Marshall, 2012a). It also comprehends the issues of where the system's boundaries can be traced, which parts it is precisely made of, and the relations between them. Therefore, this review wants to investigate how the documents analysed have approached knowledge of the current urban state and what framework of relationships between climate change and the urban environment has been taken into account. To investigate this relationship, the first research questions is formulated as it follows:

→ Which potential effects/consequences have climate-related hazardous events on the urban system, and which systems/sectors are affected/exposed?
→ Which are the elements part of the systems? Which relations exist between them are cited?

The second results paragraph investigates the set of relationships between CC-impacts and urban environments from a future perspective. From this set of relationships, it emerges how the city is imagined in the near future in relation to CC-impacts. This system's future state serves as a reference point for the document to approach and strive through intervention in the system (the third results paragraph). To collect this description of the future vision in the documents, the question guiding this second set of results is:

→ What is the description of the desired future city regarding the relation between CC-impacts and urban systems?

This part refers to the third challenge of planning within the complex city, the unknowability of the system's future state.

The third set of relations investigated is about which intervention in the existing system (first set of relations) is described to reach the desired future state (second set of relations). Therefore, the actions, interventions, and measures suggested adapting, responding, and being resilient to climate change impacts. These relations are connected to the second uncertainty of Marshall (2012) and concern the dynamics of how the system will change and the effects of intervention in the system. Thus, this third set of relations answers the question:

→ Which principles are considered to reach the desired future state?

and, more broadly:

→ How to intervene in the system to reduce risk?

Methods and materials

An extensive search strategy was used to ensure the inclusion of a wide variety of grey literature available on developing the approaches of Climate Change Adaptation, Disaster Risk Reduction and Urban Resilience at different scales ranging from regional to city-wide, and different agencies and authors, ranging from private engineering firms to United Nations offices. In order to search this body of literature, a variety of methods have been applied. The first step was to explore the SCOPUS database to determine which of these GL documents were most cited in the scientific literature. The database was queried with search terms such as "approach", "guidance", "guideline", "methodology", and "toolkit" to include different possible terms that the variety of developers may have used to refer to the object of this review. These were searched in conjunction with terms referring to climate change and its interactions with the urban environment. These included "disaster risk reduction", "(climate change) adaptation", "resilience", and "climate plan" and referred to the urban environment as "urban", "city", and "local". In these strings, the "*" matches lexically related terms (e.g., plurals, verb conjugations). The research was then refined to include only documents in English, Spanish, and Italian languages.

Selection of the documents

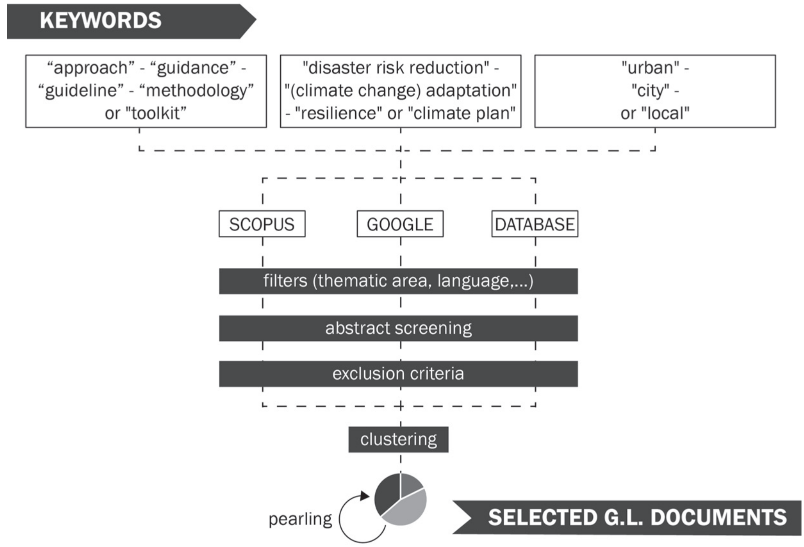


Figure 9
Structure of the selection process

Other filters have been applied to include only documents that matched the subject areas of “Environmental Science” and “Engineering” in order to exclude non-related categories. After a further screening based on the reading of the abstracts, the results were read in search of references to grey literature documents offering tools and recommendations on how local and regional bodies can operationalise knowledge to face climate emergencies.

Besides, various combinations of the search terms were used to search for grey literature in Google (first 5 pages), in key agencies websites and sectorial online databases as (http://resiliencetools.net/) and (https://www.resilienceshift.org/tools/). The final selection of the assessment tools that are suitable for inclusion in the study was based on the following criteria:

- They should have a clear focus on CCA, DRR or Resilience;
- They should have a clear relation to Urban Planning or Urban Design;
- They should cover more than one sector (e.g. tool that only covers transport are excluded);
- Tools and Guidelines related should be freely accessible.

During the reading of the grey literature documents, cross-references to other documents were found and included in the list by literature pearling method, in which it has been examined the reference list and to find other documents that may have been missed by the database searched.

Exclusion criteria:

- If the same agency/author has published two or more documents in which one includes the other, the older ones have been excluded. If, on the other hand, the documents are complementary, they have been brought together and assessed as a whole;

→ If documents only refer to a wider scale than regional o local scale, they have been excluded (e.g. guiding documents for National Adaptation plans);
→ If documents only refer to sectorial aspects and do not include relations with other urban systems, they have been excluded (e.g. guidance only for the energy sector).

The structure of the process has been represented in Figure 9.

A widely-recognised limitation of grey literature, which distinguishes it from scientific literature, is that it is not subject to a rigorous review process of content, methodologies and data (Farace & Schöpfel, 2010). This has been taken into account in selecting which publications to include in this review, preferring publications that come from reliable sources such as, for example, international agencies that have a history of activity in the field and publications with a significant reference bibliography in the field.

Table 3
Overview of the documents included

Name	Acronym	Developer	Typology of developer	Year	Reference
RESIN (multi-tool)	**IVAVIA**	RESIN H2020	Research Network	2018	(Hincks, et al. 2018; Lis et al., 2018; RESIN, 2018)
Future Cities Adaption Compass	**Adaptation compass**	FUTURE CITIES INTERREG	Research Network	2014	(Future Cities, 2013, 2014)
Planning for adaptation to climate change. Guidelines for municipalities	**ACT**	ACT - Adapting to Climate change in Time	Research Network	2013	(Giordano, Capriolo, & Mascolo, 2013)
Guide to Climate Change Adaptation in Cities	**CCA World Bank**	The World Bank	Supranational organization	2011	(The World Bank, 2011)
City Resilience Index	**CRI**	ARUP	Private Firm	2015	(ARUP, 2015)
City Water Resilience (LR + Fram+ Appr+ methodology)	**CWR**	ARUP	Private Firm	2019	(ARUP, 2017, 2019a, 2019b)
Adaptation Wizard v.4.0	**Wizard (UKCIP)**	UK Climate Impacts Programm	Research Network	2013	(T. and C. P. A. UK, 2014)
Climate Change Risk Assessment Guidance (Climate Action Planning Framework + interdepencies)	**C40**	C40 Cities	Network of cities	2018	(C40 Cities, 2017, 2018)
Developing Local Climate Change Plans	**UN-H**	UN-HABITAT	Supranational organization	2012	(UN-HABITAT, 2012)
Disaster Resilience Scorecard for Cities	**DRSC**	UNDRR	Supranational organization	2017	(UNIDRR, 2015)
Quick Risk Estimation tool	**QRE**	UNDRR	Supranational organization	2017	(UNIDRR, 2015)
CityStrength -Resilient Cities program	**CityStrength**	The World Bank	Supranational organization	2018	(Lynch, 2018)
Resilience Systems Analysis	**RSA**	OECD	Supranational organization	2014	(OECD, 2014)

An overview of the selected documents

From this search process within various databases and subsequent exclusion and merging processes, 13 clusters of significant GL documents were selected. These are listed in Table 3, sorted according to publication date. This table shows the developers of these documents and the type of institution to which they belong among the following: Research Network; Private Firm; Supranational organisation; Network of cities.

Table 4 presents the clusters of selected GL documents, henceforth referred to as documents, and a first general classification of their content. This classification concerns two aspects: the approach or central theme and the scale to which they refer. The former identifies the primary approach in which the document is rooted and possibly other approaches considered within the document among the following: Climate change adaptation (CCA), Urban Resilience (UR), and Disaster risk reduction (DRR). The second aspect that is considered within the documents is the scale to which they refer. For some of them, there may be more than one, such as Resilient Systems Analysis (RSA), which foresees that it can be applied at the national, regional and city scale. The sign "n/a" means that a unique answer is not available as the document leaves open the possibility of being applied at different scales, depending on the user.

Table 4
Overview of the documents' themes and scales

Acronym	Themes			Scale
	Principal	Other	Other	
IVAVIA	CCA	UR	DRR	City
Adaptation compass	CCA	DRR		City
ACT	CCA	DRR		Municipality
CCA World Bank	CCA	DRR	UR	City
CRI	UR			City
CWR	UR			Basin
Wizard (UKCIP)	CCA			Organisation
C40	CCA	UR		City
UN-H	CCA	UR	DRR	City
DRSC	DRR	UR		National and Local authorities
QRE	DRR			n/a
CityStrength	UR			city
RSA	UR			City, regional, national

Results and relations 1 - Understanding the system

This first set of results and relations focuses on the aspects concerning the current state of the city. These are examined through the hazards taken into consideration, the type of baseline chosen and the interdependencies considered between the systems.

Hazards

One of the prerequisites for including the documents in the current review was that they had to do with the effects of climate change. Therefore, all documents include a list of hazards arising from climate change. The distinctions and definitions found in the Integrated Research on Disaster Risk (2014) documents were used for classification. The categories are defined as follows:

- → Hydrogeological: a hazard caused by the occurrence, movement, and distribution of surface and subsurface freshwater and saltwater.
- → Meteorological: a hazard caused by short-lived, micro- to-meso scale extreme weather and atmospheric conditions that last from minutes to days.

Acronym	Themes			Hydrogeological			Meteorological	
	Principal	Other	Other	Riverine flood	Pluvial flood	Landslide	Heatwave/ Coldwave	Storm
IVAVIA	CCA	UR	DRR	Y	Y	Y	Y	Y
Adaptation compass	CCA	DRR		Y	Y	N	Y	Y
ACT	CCA	DRR		Y	Y	N	Y	Y
CCA World Bank	CCA	DRR	UR	Y	Y	Y	Y	Y
CRI	UR			Y	Y	Y	Y	Y
CWR	UR			Y	Y	Y	Y	Y
Wizard (UKCIP)	CCA			Y	Y	Y	Y	Y
C40	CCA	UR		Y	Y	Y	Y	Y
UN-H	CCA	UR	DRR	Y	Y	Y	Y	Y
DRSC	DRR	UR		Y	Y	Y	Y	Y
QRE	DRR			Y	Y	Y	Y	Y
CityStrength	UR			Y	Y	Y	Y	Y
RSA	UR			n/a	n/a	n/a	n/a	n/a

- Climatological: a hazard caused by long-lived, meso- to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability.
- Geophysical: a hazard originating from solid earth.
- Human-related: or human-induced. A hazard originated from human systems, whether they are social, economic, political, health or environmental (e.g. pandemics, war).

All of the documents included the most well-known climate hazards, such as hydrogeological and meteorological hazards. Documents arising from the UR and DRR thematic fields are more likely to consider impacts from Geophysical hazards, while these are not considered in CCA-oriented documents. However, only a few documents consider human-related hazards, which also include social, economic, political, health, and environmental aspects (Table 5). Documents that consider these hazards are based on, or at least include, the Urban Resilience approach. The "n/a" means that these hazards can or cannot be considered based on how the document is applied.

Table 5
Table showing the climate-change-induced hazards considered in the documents

	Climatological		Geophysical		Human-related				
	Drought	Wildfires	Volcanic activity	Earthquake	Social	Economic	Political	Health	Environmental
	Y	Y	N	N	N	N	N	N	N
	Y	N	N	N	N	N	N	N	N
	Y	Y	N	N	N	N	N	N	N
	Y	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Y
	Y	Y	Y	Y	Y	Y	n/a	Y	n/a
	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Y	Y	N	N	N	N	N	N	N
	Y	Y	N	N	N	N	N	Y	N
	Y	N	N	N	Y	N	N	Y	Y
	Y	Y	Y	Y	Y	Y		Y	Y
	Y	Y	Y	Y	N	N	N	Y	Y
	Y	Y	Y	Y	Y	Y	Y	Y	Y
	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Baseline

In the context of Marshall's first unknowability of planning in the complex city, what method and perspective one document choose to describe urban systems in their current state can give different baselines. This description is called baseline: a 'snapshot' of conditions before an intervention from which progress can be assessed (Pringle, 2011). This baseline shapes from which perspective the documents choose to understand the urban systems.

In climate change adaptation areas, the emphasis has been placed on vulnerability assessment baselines up to IPCC Report 5 (IPCC, 2014). This report has tried to harmonise approaches with Disaster Risk Management practices by shifting it towards a risk assessment baseline, including the value of vulnerable systems and elements through the exposure factor. While the pre-IPCC AR5 documents also considered the degree of exposure (i.e. the degree to which a station comes into contact with a hazard), the IPCC AR5 changes this to focus more on what is exposed (Jeremy G. Carter et al., 2015; Connelly, Carter, Handley, & Hincks, 2018). Resilience practices are also aligned with this approach, but the emphasis is shifted to systems' positive characteristics rather than risk. It aims at assessing the systems that support all-round well-being, no matter what risks it faces (OECD, 2014). Therefore, assessing the resilience baseline is oriented towards the existing capacities based on the future resilience status to be achieved. The resilience baseline adds elements that address the complexity and inter-linkages of various risks.

In the context of this review, the following distinctions were used:

- → Vulnerability baseline: focus on the vulnerability of elements and systems.
- → Risk baseline: also considers the exposure of valuable systems, focusing on the consequences of possible impacts.
- → Resilience baseline: focus on characteristics that allow the system to cope with impacts.

Table 6
Table showing how GL documents approach the description of the system's current state: which typology of baseline they include and which exposure they consider

Although some documents did not fully consider the concept of exposure in their baseline, in many of them, some indications describe which elements of the system CC-impacts affect. These interactions have been grouped into three categories according to which elements they consider: some documents describe only the system/sector that may be affected by a particular impact, other documents also specify physical elements of the city that are at risk, and finally, a smaller proportion of the documents also consider interdependencies between elements, sectors and systems that may take place during a CC-related impact.

The results of these categorisations are presented in Table 6. A comparison of topics, baseline types, and exposure does not reveal a sharp distinction between approaches. Generally speaking, CCA-based documents have a baseline focused on vulnerabilities, with some risk baseline elements included in more recent documents. With a few exceptions, they do not include resilience elements by not considering, for example, interconnected risks or the system's ability to cope with them. Regarding effects and exposed elements, they generally indicate which systems are exposed, having only sometimes detailed information about effects on physical elements and risk relationships between elements and systems. Instead, documents grounded in DRR and UR have a baseline that is more solidly based on risk and, in some cases, resilience. Most of these documents include the exposure component down to the detail of physical elements and interdependencies between them and systems.

Fields marked "n.d." concern aspects of the document cited but not developed, and it is up to the user to include them or not in implementation.

Acronym	Themes			Type of baseline			Exposure		
	Principal	Other	Other	Vulnerability	Risk	Resilience	On systems	On physical elements	Inter-depedencies
IVAVIA	CCA	UR	DRR	Y	Y	Y	Y	Y	Y
Adaptation compass	CCA	DRR		Y	Y	N	Y	Y	Y
(ACT)	CCA	DRR		Y	N	N	Y	N	N
CCA World Bank	CCA	DRR	UR	Y	N	N	Y	Y	Y
CRI	UR			Y	Y	Y	n.d.	n.d.	n.d.
CWR	UR			N	N	Y	Y	N	Y
Wizard (UKCIP)	CCA			Y	N	N	Y	Y	N
C40	CCA	UR		Y	Y	N	Y	Y	Y
UN-H	CCA	UR	DRR	Y	N	N	Y	Y	n.d.
DRSC	DRR	UR		Y	Y	Y	Y	Y	Y
QRE	DRR			Y	Y	N	Y	N	N
CityStrength	UR			Y	Y	Y	Y	Y	Y
RSA	UR			Y	Y	Y	Y	n.d.	Y

While the interactions between urban systems and specific CC-impacts can change according to local contexts, some of the analysed documents provided a general view of frequent relations that emerge between them. Others built chains of relations that link hazards, impacts and exposed urban systems. Finally, some of these documents have also traced the consequences of CC-impacts to determine the effects they cause directly and indirectly. From the analysis of these relationships, it is possible to reconstruct the complexity of the current city and how it is interpreted within the documents considered.

A Map of Interdependencies

In this regard, Figure 10 represents a summary of all the interactions cited in the grey literature analysed and aims to provide a picture of the set of complex relations considered within the data source between the system's elements and the climate change impacts. Understanding these relations is the first necessary step to respond to climate change, regardless of the purpose of the process, be it resilience, adaptation or disaster risk reduction. However, this set of interdependencies is far from being complete, and it will eventually evolve and include new interactions as they take place, are traced and recognised.

Some of the documents considered did acknowledge interdependencies between the sectors and the elements of the urban system and climate change effects. However, there is limited availability of methods and approaches to assess or understand the growing complexity of interdependencies between systems. This is also valid for the potential of shocks and stresses to cascade and compound in terms of impact within and between systems (ARUP, 2017).

Results and relations 2 – The vision of the future

This second set of results and relations investigates the relationships between CC-impacts and urban environments from a future perspective. From this set of relationships, it emerges how the city is imagined in the near future in relation to CC-impacts. This system's future state serves as a reference point for intervention in the system, which will be discussed in the next paragraph. The question guiding this second part is: "What is the description of the desired future city regarding the relation between CC-impacts and urban systems?". In order to gather these aspects in the considered documents, the described reference vision was searched. Where this was not explicitly available, it was often implicitly deduced from the definition of resilience, adaptation or risk that is adopted in the documents. Table 7 summarises the results of this second part: the future vision encompassed in each document is presented alongside each document's theme to allow

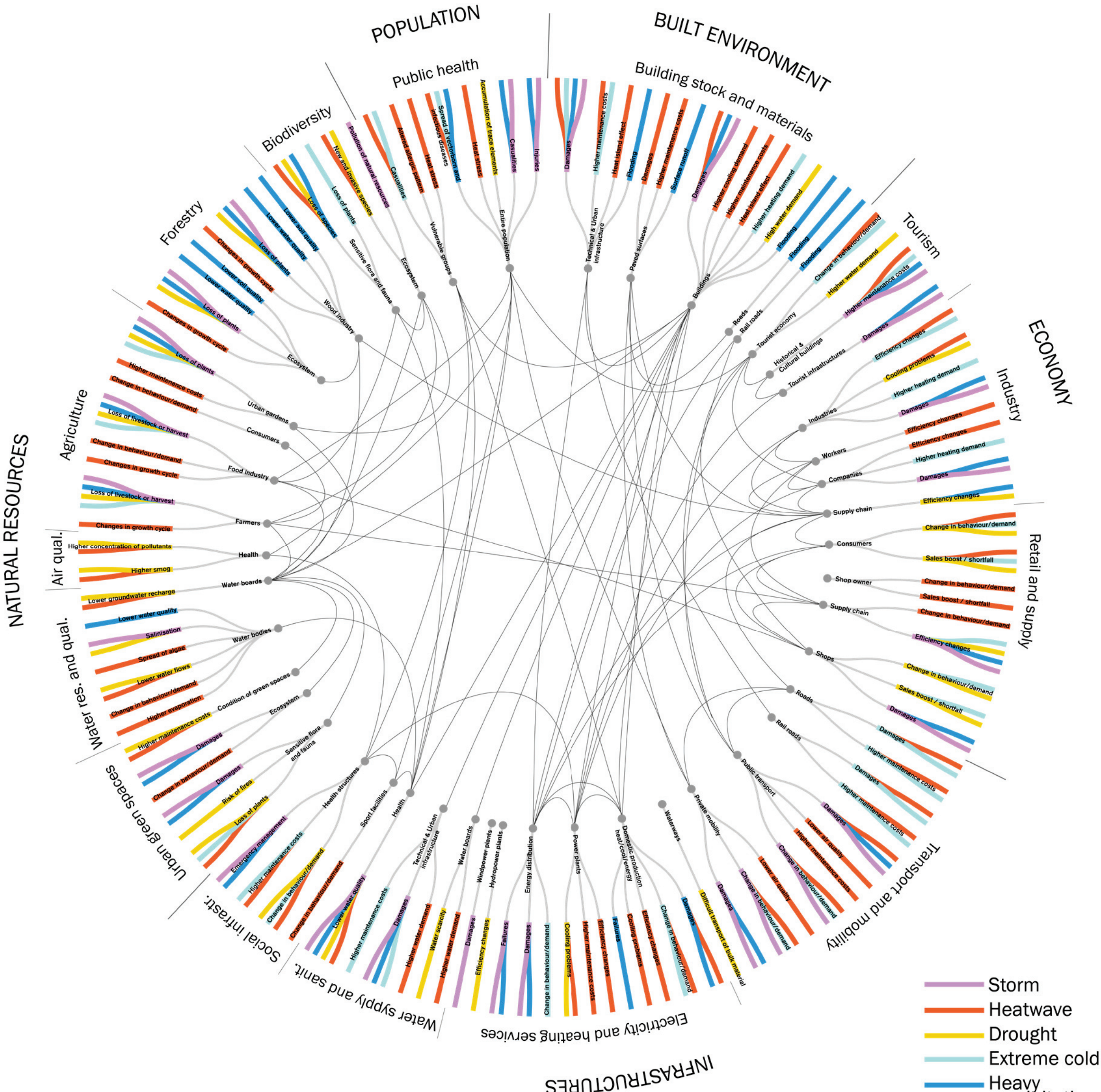


Figure 10
Map of interdependencies. Author's interpretation of the interdependencies (lines in the middle) cited in the grey literature documents between the impacts of CC and urban systems and elements. Starting from the external level, there are Sectors and Sub-sectors. Then, each colour represents an impact between: drought, heatwave, extreme cold, heavy precipitation, and storm. These impacts cause an effect, specified above the coloured line, on system elements marked by a grey dot. These elements are connected between them based on the relations and cascading effects cited in the documents.

comparison between the originating approach (CCA, UR and DRR) and the contents of the vision.

Table 7
The future vision encompassed in each of the analysed documents

Documents based on the climate change adaptation approach generally have a vision of the future city as decarbonised, in which the impacts of human activities on the environment are minimised. The CCA approach is, therefore, often associated with a focus on mitigation together with adaptation. The future state in which the city can have a positive relationship with climate change is often described as being achieved through physical interventions in the city. The city has a form and structure that can adapt to CC-impacts and contain risk, rather than the intangible and organisational capacities that other approaches rely on.

Documents DRR-based envisage a future city in which vulnerabilities are identified, understood, and addressed to reduce the impact of climate events on the various urban systems, especially on the most vulnerable lives. As it emerges in the DRSC, this approach recognises an active role of the city in understanding, preventing, and intervening in risk reduction, focusing on organisational capacities rather than the physical dimension of the city.

In the documents that arise from the field of urban resilience, the vision of the desired ideal city serves to create the framework within which to assess the current city and define how to intervene. The assessment of the city's current state is based on principles and qualities attributed to the resilient city already from its very definition. The envisioned resilient city is often defined through two levels. For example, in Arup's CRI, the general ones are called Goals or Principles, and the detailed ones are called Sub-goals or indicators. The formers describe the cross-cutting and typical characteristics of many sectors and urban aspects, which are then linked in the latter ones to indicators that evaluate some specific aspects attributed to the first level.

Another example is the CWR, which maintains an approach highlighting the urban system's gaps to achieve a more resilient state than the current one. The way they set the baseline assessment is already oriented to the desired resilience stage. Naming a few Goals, as an example: "Adaptive and integrated planning", "Effective regulation and accountability", "Effective disaster risk response and recovery" or "Healthy urban spaces". They are themselves the perspective from which we look at the current state, the policy titles to be followed up, and the final state to be achieved.

Having defined which indicators belong to the ideal city, some frameworks go so far as to develop an index as Arup's CRI. The indicators' data are statistically transformed into standardised units, which can then be weighted and summed up into an index score, allowing cities to have an

Document Acronym	Themes Principal	Other	Other	Future Vision	Source
IVAVIA	CCA	UR	DRR	Vision for cities where human activity contribution to climate change is mitigated, climate impacts risk is reduced, and the system's resilience to future climate hazards and socio-economic drivers.	Lis et al., 2018 p.4-5
Adaptation compass	CCA	DRR		Vision for cities prepared to cope with the effects of climate change. Urban structures are adapted in a way that the impacts of a changing climate will not endanger the urban living environment, interrupt the functioning of cities and preclude sustainable development.	Future Cities, 2014 p.5
ACT	CCA	DRR		Vision for cities adapting to climate change and strengthening their capacity to assess vulnerability to climate change impacts and identifying corresponding plans and investments to increase their resilience.	Giordano, Capriolo, & Mascolo, 2013 p.11
CCA World Bank	CCA	DRR	UR	The future desired vision is a city that manages risks and long-term resilience to be prepared for existing and future climate impacts, limiting their magnitude and severity. A city that is able to respond quickly and effectively, in an equitable and efficient way.	The World Bank, 2011 p.11
CRI	UR			Envisions a city that well functions - providing good health, a safe environment, social harmony and prosperity - in the face of multiple hazards, rather than preventing or mitigating the loss of assets due to specific events.	ARUP Framework, 2015 p.5
CWR	UR			The envisioned future is a water-resilient city that can survive and thrive in the face of shocks and stresses related to water and its effects on the water system. With the capacity to provide access to resources, protect from hazards and connect through water-based mobility.	ARUP CWRA, 2019 p.6
Wizard (UKCIP)	CCA			It envisions robust urban environments in the face of inevitable climate change, and exploit opportunities as well, making cities more attractive and with a better quality of life.	T. and C. P. A. UK, 2014 p.13
C40	CCA	UR		A future state for the city where systems are reshaped so that they are decarbonised and resilient to climate hazards.	C40 cities, 2018
UN-H	CCA	UR	DRR	The future city envisaged has reduced greenhouse gas emissions, protects the vulnerable to the direct and indirect impacts of climate change stress and shocks and has built resilience in the economic, social, psychological, physical and environmental factors that humans need to survive and thrive.	UN-HABITAT, 2012 p.19
DRSC	DRR	UR		The envisioned future city can understand risks it may face, mitigate those risks, and respond to disasters so that loss of life or damage to livelihoods, property, infrastructure, economic activities, and the environment is minimised.	UNIDRR, 2015 p.3
QRE	DRR			See DRSC	UNIDRR, 2015 p.3
CityStren-gth	UR			The envisioned future city is resilient and can change, adapt, absorb and learn to a variety of shocks and stresses while still providing essential services to its residents.	Lynch, 2018 p.9
RSA	UR			The envisioned future city is prepared for, mitigating or preventing negative impacts, and can adjust, modify or change to moderate potential damage, take advantage of opportunities, or create a new system to avoid the shock in the future.	OECD, 2014 p.9

overall value that measures their current state. The intervention process will then aim to improve this index and the various indicators that the index is composed of. Consequently, based on this index it will be possible to assess progress in this process. UNDRR's QRE is based on a similar approach, where an ideal state is kept as a future vision to aim for.

Results and relations 3 – Intervening in the system

To complete the logical framework with which the grey literature documents have been analysed, it remains to be understood how to intervene in the system, addressing the systemic effects of climate change impacts (Results and relations 1) to achieve the desired future state (Results and relations 2).

This third set of relations concerns the intervention approaches to counteract the effects of climate change, and therefore which principles are suggested to adapt, respond and be resilient to climate change impacts. These relations are connected to the uncertainty of Marshall (2012) concerning the dynamics of how the system will change, of what will be the effects of a specific intervention in the system. Thus, this third set of relation answers the questions:

→ Which principles guide intervention in the current state to reach the desired future system state?

and, more broadly,

→ How to intervene in the system to reduce risk?

Based on (Braithwaite, 2002), in this framework, the distinction used between rules and principles is that the former implies a specific prescription, while the latter has a more generic or unspecific prescription. Principles instead tend to be vaguer, have a broader range of applications, and find a more defined shape and boundary once applied in a specific context. The documents analysed tend to give general indications for intervention rather than precise rules or practices so that they can be relevant and applied in very different contexts - be they regulatory, geographical or instrumental. For this reason, indications of how to intervene in the system are presented in the form of principles to be followed or qualities that the various systems should have.

About 30 of these principles, qualities and ways of intervention have been recognised within the documents. Some of these may have overlapping or competing fields of application, but together they constitute the set of principles that the documents considered use for risk reduction. The results are reported in alphabetical order in Table 8 with a title, the definition and the indication from which of the analysed documents the definition comes from.

Table 8
Different principles from the GL review presented in alphabetical order. Definition are transcribed synthetically and based on the cited document.

Principles	Definition	Source
Adaptive Management	Flexibility and adaptive management are core principles, building in support and space to adapt to changing risks, opportunities and evidence.	IFRC
Compensatory DRM	Compensatory disaster risk management activities strengthen the social and economic resilience of individuals and societies in the face of residual risk that cannot be effectively reduced. They include preparedness, response and recovery activities, but also a mix of different financing instruments, such as national contingency funds, contingent credit, insurance and reinsurance, and social safety nets.	DRSC
Connectivity	The degree of connection or separation between people, places, and things. The nature and strength of the interactions between system components.	OECD
Corrective DRM	Corrective disaster risk management activities address and seek to remove or reduce disaster risks which are already present and which need to be managed and reduced now. Examples are the retrofitting of critical infrastructure or the relocation of exposed populations or assets.	DRSC
Diversity and Redundancy (see: Redundant)	Having many different forms, types or ideas and excess capacity and back-up systems which enable the maintenance of core functionality in the event of disturbances.	OECD
Flexible	Flexibility implies that systems can change, evolve and adapt in response to changing circumstances. This may favour decentralised and modular approaches to infrastructure or ecosystem management. Flexibility can be achieved through the introduction of new knowledge and technologies, as needed. It also means considering and incorporating indigenous or traditional knowledge and practices in new ways.	ARUP (frame); UKCIP
Green infrastructure	Contribute to the increase of ecosystems resilience and can halt biodiversity loss, degradation of ecosystem and restore water cycles. At the same time, green infrastructure use the functions and services provided by the ecosystems to achieve a more cost effective and sometimes more feasible adaptation solution than grey infrastructure.	ACT; Ivavia, Adapt compass
Grey infrastructure	Correspond to physical interventions or construction measures using engineering services to make buildings and infrastructure essential for the social and economic well-being of society more capable of withstanding extreme events.	ACT; Ivavia, Adapt compass
Inclusion (see: Inclusive)	Representation of diverse stakeholders in in decision-making processes.	OECD
Inclusive (see: Inclusion)	Inclusion emphasises the need for broad consultation and engagement of communities, including the most vulnerable groups. Addressing the shocks or stresses faced by one sector, location, or community in isolation of others is an anathema to the notion of resilience. An inclusive approach contributes to a sense of shared ownership or a joint vision to build city resilience.	ARUP (frame)
Integrated	Integration and alignment between city systems promotes consistency in decision-making and ensures that all investments are mutually supportive to a common outcome. Integration is evident within and between resilient systems, and across different scales of their operation. Exchange of information between systems enables them to function collectively and respond rapidly through shorter feedback loops throughout the city.	ARUP (frame)
Learning and Innovation	The acquisition of knowledge or skills leading to a change in collective awareness, resulting in new norms, ideologies and institutions.	OECD
Preparedness	The knowledge and capacities to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions.	OECD

The IPCC (2014) framework recognises that possible interventions in the system to reduce risk are either directed to increase adaptive capacity or/and reduce vulnerability and exposure. Although differences within the analysed documents exist, it is still possible to draw up in general terms which principles the various disciplines focus on. Regarding the resilience approach, intervention in the system is mainly considered an increase in Adaptive Capacity. This is also shared by the Disaster Risk Reduction approach, where a reduction in exposure and vulnerability accompanies an increase in adaptive capacity. On the other hand, adaptation approaches focus on vulnerability reduction and include an increase in adaptive capacity. (Figure 11)

Having set this first picture to frame how the approaches aim to intervene in the system, there is then another distinction on the typology of principles that are presented by the various documents. In this regard, Pringle (2011) elaborates a distinction concerning the ways of intervening in the system. This distinction was elaborated concerning adaptation principles, but for the purpose of this review is also applicable in the domain of resilience and disaster risk reduction. He distinguishes two main categories of possible intervention: Building Adaptive Capacity (BAC) and Delivering Adaptation Actions (DAA).

He defines the former (BAC) as those planned interventions that aim at "developing the institutional capacity to respond effectively to climate change (by) creating the necessary regulatory, institutional and managerial conditions for adaptation actions to be undertaken". This include, but is not limited to, interventions as: raising awareness; changing standards, legislation and best practice guidance; developing policies, plans and strategies; changing internal organisational systems; working in partnerships.

While delivering actions (DAA) are defined as those planning interventions that involve "taking practical actions to either reduce vulnerability to climate risks or exploit positive opportunities and may range from simple, low-tech solutions to large-scale infrastructure projects". This includes, but is not limited to, interventions as reducing local exposure to climate risks, changing practices to take advantage of climate conditions, managing or reducing local sensitivity.

Based on this distinction, the various principles identified were categorised. The results show that 19 of these principles belong to the category of Building Adaptive Capacity interventions, 10 of these principles belong to the category of Developing Adaptive Actions. Finally, 5 of these principles may belong to both categories depending on how they are treated in the documents.

Table 8 (follows from previous page) Different principles from the GL review presented in alphabetical order. Definition are transcribed synthetically and based on the cited document.

Principles (follows)	Definition	Source
Prospective DRM	Prospective disaster risk management activities address and seek to avoid the development of new or increased disaster risks. They focus on addressing disaster risks that may develop in future if disaster risk reduction policies are not put in place; examples are better land-use planning or disaster-resistant water supply systems.	DRSC
Redundant (see: Diversity and Redundancy)	Redundancy refers to spare capacity purposely created within systems so that they can accommodate disruption, extreme pressures or surges in demand. It includes diversity: the presence of multiple ways to achieve a given need or fulfil a particular function. Examples include distributed infrastructure networks and resource reserves. Redundancies should be intentional, cost-effective and prioritised at a city-wide scale, and should not be an externality of inefficient design.	ARUP (frame)
Reflective	Reflective systems are accepting of the inherent and ever-increasing uncertainty and change in today's world. They have mechanisms to continuously evolve, and will modify standards or norms based on emerging evidence, rather than seeking permanent solutions based on the status quo. As a result, people and institutions examine and systematically learn from their past experiences, and leverage this learning to inform future decision-making.	ARUP (frame)
Relocation	Relocation of exposed population or assets to remove or reduce already present risks.	DRSC
Resorceful	Resourcefulness implies that people and institutions are able to rapidly find different ways to achieve their goals or meet their needs during a shock or when under stress. This may include investing in capacity to anticipate future conditions, set priorities, and respond, for example, by mobilising and coordinating wider human, financial and physical resources. Resourcefulness is instrumental to a city's ability to restore functionality of critical systems, potentially under severely constrained conditions.	ARUP (frame)
Responsiveness	Reacting quickly and positively in the event and aftermath of a crisis.	OECD
Robust	Robust systems include well-conceived, constructed and managed physical assets, so that they can withstand the impacts of hazard events without significant damage or loss of function. Robust design anticipates potential failures in systems, making provision to ensure failure is predictable, safe, and not disproportionate to the cause. Over-reliance on a single asset, cascading failure and design thresholds that might lead to catastrophic collapse if exceeded are actively avoided.	ARUP (frame)
Self-organisation	The capacity to form formal or informal networks, institutions, organisations or other social collectives independently from the state or other central authority.	OECD
Social cohesion	Shared values and communities of interpretation, reducing disparities in wealth and income, and generally enabling people to have a sense that they are engaged in a common enterprise.	OECD
Soft non-structural approaches	Correspond to design and application of policies and procedures and employing, inter alia, land-use controls, information dissemination and economic incentives to reduce vulnerability, encourage adaptive behaviour or avoid maladaptation. They require careful management of the underlying human systems. Some of these measures can facilitate the implementation of grey or green measures (e.g. funding, integration of climate change into regulations).	ACT; Ivavia, Adapt compass
Thresholds	Acceptable levels of well-being, clearly defined access to rights and sustainable limits to common resources.	OECD

In Table 9 these results are compared with the documents' three categories: CCA, Resilience and DRR. Whether or not a principle belongs to these categories was determined by reading the context in which these principles are treated within the documents considered. As this procedure is based on interpretation, it is not excluded that some of these principles find application in more categories than those marked.

However, it is possible to reconstruct a general picture, from which it emerges that the documents that have resilience as their primary approach have principles within them that have Building Adaptive Capacity (BAC) as their main objective, having 17 principles belonging to this category as opposed to 5 in the Developing Adaptive Actions (DAA) category. The documents rooted in the climate change adaptation approach (CCA), on the other hand, included principles from both categories in equal measure, with 6 principles in each. Finally, documents rooted in Disaster Risk Reduction (DRR) approaches have a more significant number of BAC principles (7), than DAC (4).

The category of principles belonging to the Resilience approaches is also the most numerous, as many documents base their intervention approach on the description of the qualities that a resilient system should have. In contrast to other principles related to established approaches, it is more challenging to merge these principles together. The merging process is more straightforward, for example, for more defined principles, such as green infrastructure.

Figure 11
Visualization of the different principles emerged from the GL review on "How to intervene in the system to reduce risk".

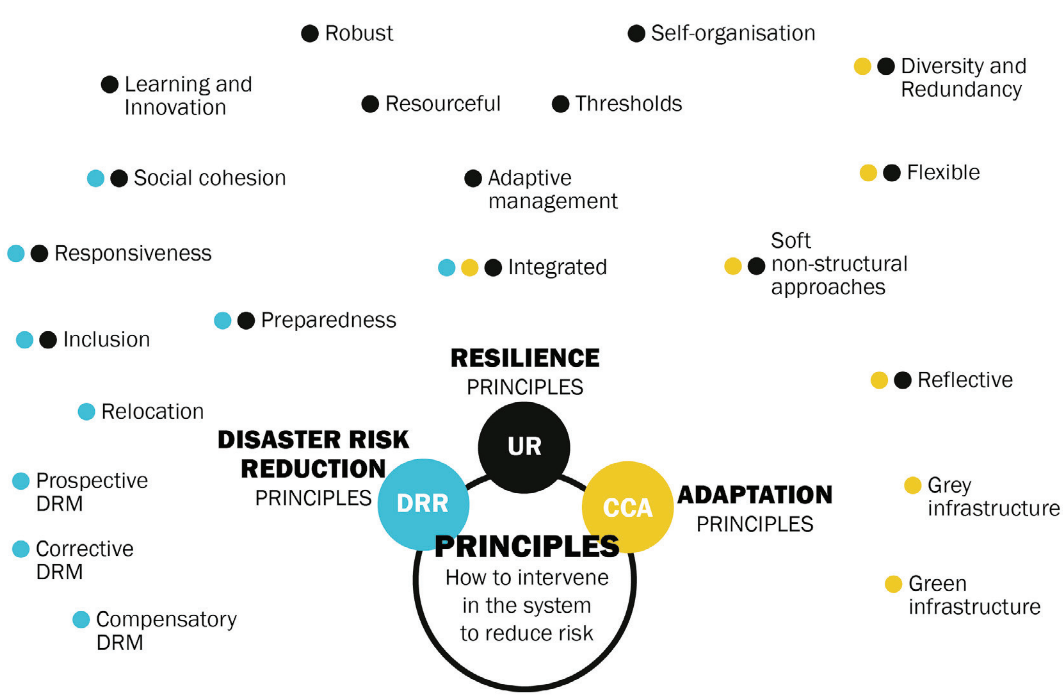


Table 9
Different principles emerged from the GL review on “How to intervene in the system to reduce risk”, their typology (BAC or DAA) and their presence or not in CCA, UR and DRR documents.s.

BAC or DAA	Principles	CCA	Resilience	DRR
BAC	**Adaptive Management**		X	
BAC	**Compensatory DRM**			X
BAC	**Connectivity**	X	X	
DAA	**Corrective DRM**			X
BAC and DAA	**Diversity and Redundancy**	X	X	
BAC and DAA	**Flexible**	X	X	
DAA	**Green infrastructure**	X		
DAA	**Grey infrastructure**	X		
BAC	**Inclusion**		X	X
BAC	**Inclusive**		X	X
BAC and DAA	**Integrated**	X	X	X
BAC	**Learning and Innovation**		X	
BAC	**Preparedness**		X	X
BAC and DAA	**Prospective DRM**			X
BAC	**Redundant**	X	X	
BAC	**Reflective**	X	X	
DAA	**Relocation**			X
BAC	**Resorceful**		X	
BAC	**Responsiveness**		X	X
DAA	**Robust**		X	
BAC	**Self-organisation**		X	
BAC	**Social cohesion**		X	X
BAC and DAA	**Soft non-structural approaches**	X	X	
BAC	**Thresholds**		X	

Conclusion

Employing the above-described methods, this sample of documents was selected to represent the different approaches and methods that are disseminated by the main international actors in the fields described above. This sample was selected, reduced and merged to approximately 13 documents or document clusters. These documents guide, support, and define practices applied at the urban level to manage climate change impacts. This sample of documents was investigated through three questions investigating how to intervene in a complex system to reduce climate risk.

The first question concerns how the current system is described and investigated, i.e. how the city is understood in the face of climate impacts. The data collected from the various documents emerge that all of them include an investigation of the most well-known climate hazards, such as hydrogeological or meteorological hazards. However, only a few documents consider human-related hazards, which include social, economic, political, health, and environmental aspects. Overall, some of the documents did acknowledge the existence of interdependencies between the urban system's elements and sectors in facing the effects of climate change. However, it emerges that there is limited availability of methods and approaches to assess or understand the growing complexity of interdependencies between systems. This is also valid for the potential for shocks and stresses to cascade and compound in terms of impact within and between systems.

The second part investigated the desired set of relationships between the city and the CC-impacts in a future state. This vision function is what the document aims at, and on which it builds the way to intervene in the current system. Comparing various documents on these aspects showed that the CCA-based ones focus on the city's physical relationship and the CC impacts. The future city is envisioned as "shaped in the way that" or "has the structures that" it can adapt, rather than the intangible and organisational capacities that DRR and UR approaches envision.

The third part investigated how to intervene in the system to address the systemic effects of climate change (R&R1) to achieve the system's desired future state (R&R2). This is connected to the uncertainty of Marshall (2012) concerning the dynamics of how the system will change. Within the documents, this has been recognised and collected in the form of principles, understood as directions for intervention that can be adapted to different contexts while retaining their meaning. The results show a significant variety of principles collected and merged where they were very similar and kept distinct where they had different nuances. Most of the principles are common to one or more documents, even those with different approaches (CCA, UR, DRR). The field of UR is particularly rich in principles of intervention, and this can be traced back to the way they describe the current system (R&R1) and how they envision the future state (R&R2). UR-based documents focus on the qualities that a resilient system should have. Consequently, the intervention principles that build the system's capacity (BAC) are predominant in these documents. Although less represented in the proportion of principles reported in this review, delivering actions (DAA) are present in all documents. Some of these, such as green or grey infrastructure, represent various intervention modes grouped under one principle.

Overall, a picture emerges of the relationship between cities and climate change in which:

→ CCA-based documents look at the city primarily in terms of its vulnerability and are physically oriented both in terms of the vision of the ideal city and in the modes of intervention.
→ UR-based documents look at the city through the qualities with which it interacts with climate change. The vision of the ideal city has a guiding role for both the current analysis and the modes of intervention.
→ DRR-based documents look at the city in terms of risk and how the city responds. Intervention in the system follows capacity-building principles, oriented towards the ideal city's vision as aware of and prepared for any risk.

Finally, the system maps provide an overview of the relationships of effects and interventions mentioned while approaching the complex city. The first map gathers and combines the interdependencies between the elements of the urban systems and the CC-related impacts. This output is helpful for two reasons. First, to overcome the mono-sectoral approach that addresses the risks of an impact on the urban system one at a time. Secondly, to understand the chain of effects that a CC-related impact has on all urban systems in a connected way, to understand the interdependencies between the various urban elements. On the other hand, the second map gives the overall picture of the principles to intervene in the system. This picture helps understand the commonalities between different approaches to develop intervention strategies that integrate various disciplines and have more options for risk reduction.

Chapter 2 - Planning and design approaches for handling risk at the city level

2.1 Across literature and plans

How planning relates to complexity

The previous section highlighted the challenges of planning cities as complex systems and how they cannot be designed in every part as can be done for finite elements such as buildings and objects. When it comes to complex environments such as regions, cities or neighbourhoods, the way spatial intervention can take place refers to three approaches to planning (Marshall, 2012a): **planning by design, planning by coding and planning by development control**. While one approach does not exclude the other and they are frequently used in combination, they are quite different in nature and processes.

Planning by design

The first approach, **planning by design**, is linked to a masterplan, blueprint or other kinds of representation of a future state to be reached through the plan. This conforms to the disciplines related to design, where design is the representation of a product, a building or a city once the plan has been implemented in all its phases and processes. It is based on a process that ends once the plan is ready, and Marshall defines this kind of plan as "*a preconceived conception of the finished state of a specific whole entity*". The planning process based on this approach starts from the moment of analysis, where the system's current state is described and fixed in time. From the point of view of complexity, the system is here thought of as closed, concluded and defined in space and time. Therefore, the resulting plan is a series of modifications of the current state and an imagination of how the system can be represented in the future, once the plan is implemented. This type of planning is linked to the concept of predict&control, which presupposes a specific knowledge of the current state, the consequences of the interventions, and the future state to be achieved. The same conditions that Marshall's complex vision calls into question (see the previous paragraph on (Marshall, 2012a)). Despite these limitations, planning by design is an approach that can enable complexity. It can be applied at different scales, dealing with buildings or neighbourhoods without resulting in rigid comprehensive plans that define all aspects of a city.

An example of planning by design is the masterplan drawn up for the transformation and regeneration of the Farini terminal in Milan by OMA and other studios (Figure 12). Through the design of the masterplan, the designers propose a definitive configuration of the space, where the order

Figure 12
The "Agenti climatici" masterplan for Scalo Farini in Milan, Italy. Source OMA

and relationship between the elements are defined. The location of bridges, buildings, roads and greenery, their size and function are defined through the masterplan and is presented in its future finished form.

Planning by coding

Planning also occurs through **codes**: generic specification of allowable and necessary components or (un)desired relationships between the city's elements. Codes regulate or coordinate different aspects and designs, and recommending or forbidding the relations between them (Marshall, 2012b, 2012a). They have been extensively used to control building types, heights and materials (Carmona, Marshall, & Stevens, 2006), but they can also support any vision for the urban space (Murrain & Bolgar, 2004). Codes can give precise indications or regulate more abstract relations, allowing certain flexibility in implementation while still fixing boundaries on specific aspects. Although also addressing design issues, they may have objectives beyond aesthetics, such as mediating private and public interests. Marshall (2012b) define their domain as "*a diversity of practices, traditions and formats, extending from urban scale locational regulations to the prescription of architectural design details, and from abstract legalistic ordinances to illustrated examples in building manuals.*" These are referred by Alfasi & Portugali (2007) as "*planning rules*" that concern the relations between the various elements that compose a city. These planning rules are not intended as rigid plans but rather as "*a set of regulatory planning principles or rules that refer to qualitative local and global relations in the city*" (Portugali, 2012a). As an example, he takes the location of an industry in a residential context. A strict land-use approach would prohibit its location, while a planning-rules approach might allow its location if it respects specific characteristics that do not conflict with the residential fabric. For example, it might prohibit the location of a noisy or polluting industry while allowing an environmentally non-polluting high-tech factory in a residential area based on a non-conflictual relation.

Another example of coding to manage the relationships between different systems and needs is the rather recent introduction of the sustainable stormwater regulation approach within the UK planning framework. The relationship between sealing due to construction and stormwater management is an issue that is at the centre of numerous impacts and regulated according to distinct approaches (Pasi, Negretto, & Musco, 2019). In the UK, the Flood and Water Management Act of 2010 formalised a general review of the strategy to manage the relationship between construction and rainfall-runoff. This Act laid the foundations for implementing Sustainable Urban Drainage Systems (SuDS) and their coordination with planning permission procedures at an early stage. England and Wales have begun to draw up technical guidelines (Non-statutory Standards for Sustainable Drainage) to impose minimum criteria and standards on developers for the design, construction, operation and maintenance of these systems. Although strongly recommended, the implementation of SuDS is not a mandatory requirement: SuDS are prescribed for all projects involving more than one building unit, unless it can be shown to be too costly or technically impractical due to unfavourable conditions. Through coding the technical performances, the required functions and the design measures are prescribed according to a hierarchy of consequential principles (priority levels) (Table 10). Projects are required to comply with the level 1 principles and implement them within the building project. If this principle is not applicable due to obvious contextual or project conditions, the developer can move to the next priority level that contains less demanding recommendations. Through this consequential system of principles and recommendations, the standards ensure that the most beneficial techniques and functions are at least considered for each land transformation project and applied where possible. The standards still allow the setting of desired parameters, but leave a certain degree of freedom on how to achieve them.

Table 10
Priority levels of the statutory standards for sustainable drainage in Wales (Welsh Government, 2018).

S1 – Surface water runoff destination
Priority level 1: Surface water runoff is collected for use;
Priority level 2: Surface water runoff is infiltrated to ground;
Priority level 3: Surface water runoff is discharged to a surface water body;
Priority level 4: Surface water runoff is discharged to a surface water sewer or another drainage system;
Priority level 5: Surface water runoff is discharged to a combined sewer.

S2 – Surface water runoff hydraulic control
Priority level 1: Surface water should be managed to prevent, so far as possible, any discharge from the site for the majority of rainfall events of less than 5mm.
Priority level 2: The surface water runoff rate for the 1 in 1 year return period event should be controlled to mitigate the negative impacts of the development on the morphology and associated ecology of the receiving surface water bodies.
Priority level 3: The surface water runoff (rate and volume) for the 1 in 100 year return period event should be controlled to mitigate negative impacts of the development on flood risk in the receiving water body.
Priority level 4: The surface water runoff for events up to the 1 in 100 year return period should be managed to protect people and property on and adjacent to the site from flooding from the drainage system.
Priority level 5: The risks (both on site and off site) associated with the surface water runoff for events greater than the 1 in 100 year return period should be considered. Where the consequences are excessive in terms of social disruption, damage or risk to life, mitigating proposals should be developed to reduce these impacts.
Priority level 6: Drainage design proposals should be examined for the likelihood and consequences of any potential failure scenarios (e.g. structural failure or blockage), and the associated flood risks managed where possible.

S3 – Surface water quality management
Surface water runoff should be treated to prevent negative impacts on the receiving water quality and/or protect downstream drainage systems, including sewers.

S4 – Amenity
The design of the surface water management system should maximise amenity benefits.

S5 – Biodiversity
The design of the surface water management system should maximise biodiversity benefits.

S5 – Design of drainage for construction, operation and maintenance
Priority level 1: All elements of the surface water drainage system should be designed so that they can be constructed easily, safely, cost-effectively, timely and with the aim of minimising the use of scarce resources and energy
Priority level 2: All elements of the surface water drainage system should be designed so that maintenance and operation can be undertaken easily, safely, cost-effectively, timely and with the aim of minimising the use of scarce resources and energy.
Priority level 3: The surface water drainage system should be designed to ensure structural integrity of all elements under anticipated loading conditions over the design life of the development site, taking into account the requirement for reasonable levels of maintenance.

In the landmark example of Seaside, Florida, urban codes have been used together with a masterplan to regulate urban components' possible relations and conformations. While the masterplan depicts a final vision for the place, where everything is in its place (Figure 13) and just as contemporary masterplanning may contemplate implementation through phases, parts and little flexibility, but mainly these have to be implemented fully to work at its best. Coding, expressed in Figure 14, is a system of relations that can be applied wherever needed and at different times. It also leaves space and flexibility for local adjustment or specific designs. These codes specify standards for plot size, area and location of yards, porches, outbuildings, parking and building height. Codes broadly anticipate general types of development, and proposals are deemed acceptable in detail if they comply with the specifics of the codes (Kropf, 2012).

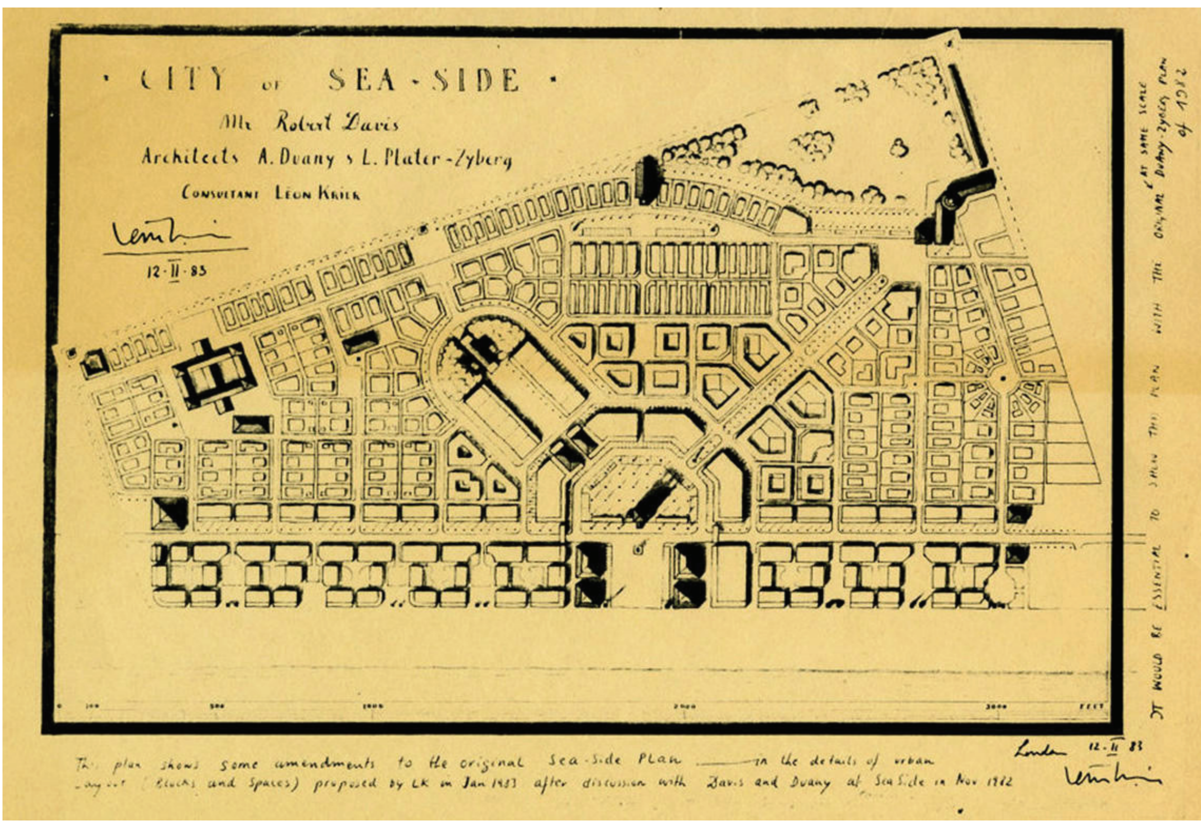


Figure 13
Masterplan for the Town of Seaside. Source: Duany Plater-Zyberk & Company (DPZ) 1983

Planning by development control

The third approach, **planning by development control**, allows planning to control complexity by deciding what development can take place by approving or rejecting specific design or layout proposals. Usually, public authorities apply this type of planning on private projects, where the public body checks that the proposal complies with public interest aspects. This

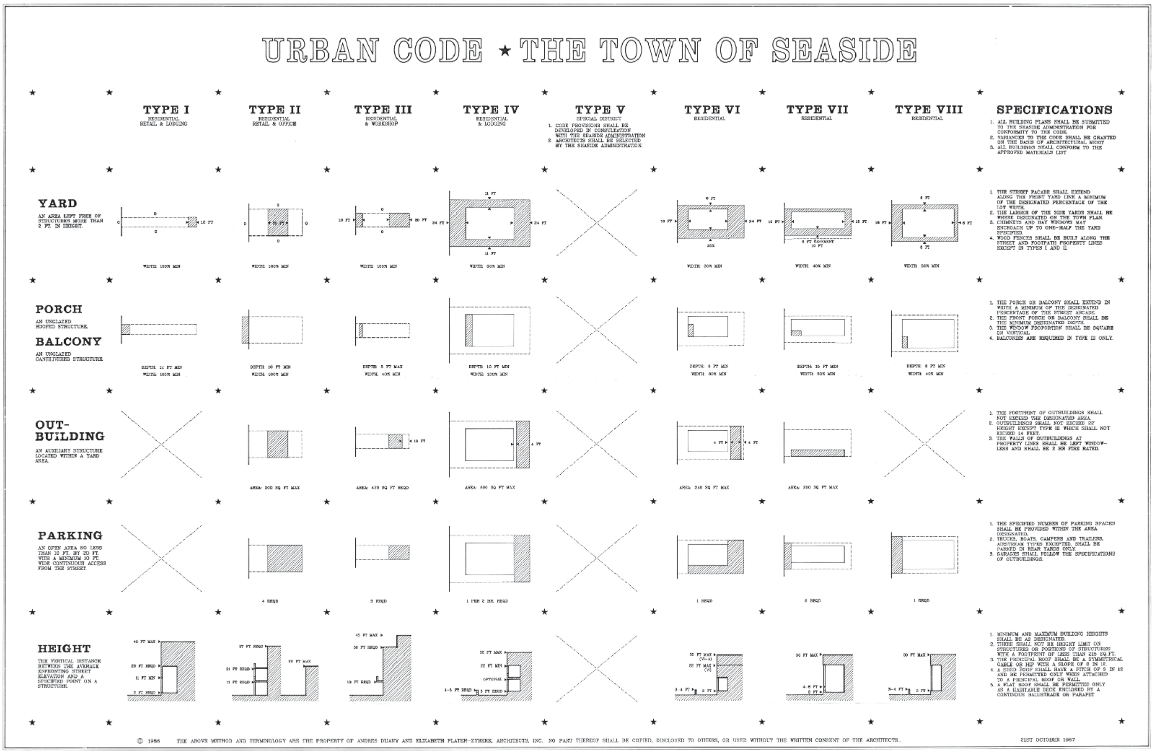


Figure 14
Urban code for the Town of Seaside. Source: Duany Plater-Zyberk & Company (DPZ) 1983

can be seen as an artificial selection to secure the public interest and override the market selection, which may be only oriented to individual interests (Marshall, 2012a).

Their function to evaluate, approve or reject the plans prepared by the many urban agents is also proposed by (Portugali, 2012a) in the form of "planning-judges", professionals specialised in planning and law. In the process of evaluating proposals, not only the defined laws and rules are taken into consideration, but also the principles and relationships that can be established. Portugali also sees this process as particularly effective in considering the proposal's relationships with less represented stakeholders in the decision-making process, such as local communities or the environment as a common good.

An example of this occurs in the Environmental Impact Assessments that became mandatory in the Member State of the European Union through what is known as the EIA Directive (Directive 85/337/EEC[6], as amended by Directives 97/11/EC[7] and 2003/35/EC[8]). The EIA process has been implemented by the different states with some differences, but has in common the objective of determining and evaluating the effects that a proposed action would have on the environment before deciding whether or not to proceed with it (Hollick, 1999). The means of achieving this objective are laid down in Article 2 of the Directive, which states that, before

6 OJ L 175, 5.7. 85, p. 40.
7 OJ L 73, 14.3. 97, p. 5.
8 OJ L 156, 25.6.03, p.17.

development consent is given, specific public and private projects likely to have significant environmental effects by virtue of their nature, size or location are made subject to a requirement for development consent and an EIA. EIA applies "downstream" to specific public and private projects, while the Strategic Environmental Assessment (SEA) applies "upstream" to specific public plans and programmes (COM, 2009). This means that the EIA is an example of planning by development control which takes place after a project has been submitted and assesses its relationship to collective interests, in this case concerning the environment. Based on the contents of the environmental impact study and the comments received, the competent authority assesses whether to give consent to the project or one of its variants, and which prescriptions are necessary for the mitigation of unfavourable impacts on the environment.

From the limitations of planning that emerged in the previous section, these three approaches provide planning with the possibility of managing complexity through precise indications but within a flexible and adaptive framework.

Table 11 extracted from Marshall (2012a) summarises these planning types according to their initiative, purpose or field of application, and mode. Planning by design is generative and addresses site-specific proposals, in which it responds to specific needs and can originate from public and private initiatives. Coding is also a generative public approach, but with a general scope of application to ensure basic standards and effective relationships between urban elements. Finally, development control acts selectively on the proposals that emerge from the generative design and/or coding approach and takes place in the public domain. Thus, development control ensures that proposals for a given site align with the public interest and establish the desired relationships.

Table 11
The planning system seen as a combination of three types of planning. Source from (Marshall, 2012a)

	Role	Scope	Mode
Planning by design	Private or public	Site-specific	Generative
Planning by coding	Public	Generic	Generative
Planning by development control	Public	Site-specific	Selective

Defining urban design

The three types of planning, either simultaneously or partially, find application in various forms in multiple contexts and at different scales. In particular, they also find application in the field of urban design, a discipline that deals with the physical form of the city.

The practice of urban design has emerged in close relationship with the disciplines of architecture and planning. These disciplines share several characteristics, and it is difficult to draw a clear boundary line that distinguishes where one begins and ends the other. Design, physicality, and relevance to urban space are the main features recognised in urban design and architecture. On the other hand, urban design shares larger scales and reasoning through principles and rules with planning.

There is no unanimous consensus on the qualities and characteristics of the discipline, but an operational definition emerges from Cozzolino et alia's research:

> "Urban design is a creative and purposeful activity with collective and public concerns that deals with the production and adaptation of the built environment at scales larger than a single plot or building. Its main scope is to impress a certain degree of order in the shaping of new physical developments and in the creation and management of the public realm. It operates in two main ways: first, by visualising the physical outcome of particular projects through drawings or, second, by providing rules to deal with the physical forms of future transformations. This practice requires the capacity to analyse the current state of affairs, sketch out possible workable scenarios and implement them in reality." (Cozzolino, Polívka, Fox-Kämper, Reimer, & Kummel, 2020)

Their definition emerges from comparing relatively recent definitions of urban design provided by 12 contemporary scholars, including Biddulph, Carmona, Childs, Cuthbert, Dovey, Lang, Madanipour, Marshall, Moughtin, Neuman, Sternberg and Talen.

From this definition, it is possible to recognise some aspects of urban design in common with planning. These are related to 1) both public and private purpose; 2) the generative nature of urban design; 3) both design and coding approaches; and 4) both site-specific and general scope.

1. The object of urban design is what is larger than the single building or the single plot. This means that its domain is not confined to the private interest or area, but it is also involved in public space and collective interests, confronting complex urban systems.
2. It is generative, whether related to the production of the built environment or its adaptation. It aims to generate solutions, scenarios, and relations to give a particular order to the built environment.

3. It includes two of the three approaches to planning, those of a generative nature: design and coding. Through the design approach, it defines possible physical conformations of the intervention, representing the preconceived conception of the finished state of a specific site. However, urban design can also be achieved indirectly by introducing rules, principles, and codes that prohibit, limit or recommend specific future relationships between urban elements.
4. Through these two possible modes of intervention, urban design certainly has a site-specific application by defining form through design and other aspects through coding. However, it can also have a general value through codes that are not site-specific.

Table 12
Key international city network and initiatives concerned with local adaptation. Source: (EEA, 2020)

CC-related plans currently taking place in European cities

This section aims to explore the types of planning that are taking place in European cities regarding the effects of climate change. For the purpose of this section, documents that operationalise the three disciplines listed in the first part are included: these concern mitigation in conjunction with adaptation to climate change and documents that explicitly address resilience and disaster risk management.

Cities are recognised as one of the most complex and, at the same time, most rewarding contexts in which to take action to combat climate change. In this endeavour, European cities can count on a significant governance and support structure at the national and international level. The global agendas described in the previous chapter tend to have an indirect role on adaptation at the local level mediated and translated into regulations and guidelines through the instruments available to the European Union and the states. The core of the European Union's climate action is the "Strategy on adaptation to climate change" of 2013, recently updated in 2021 in the new EU Strategy on Adaptation to Climate Change titled "Forging a climate-resilient Europe" (European Commission, 2021). This strategy, together with the EU Floods Directive of 2007, EU Urban agenda of 2016, European Green deal of 2019 and other landmark documents, have incorporated, translated and shaped the global objectives in the European urban context. The 2021Adaptation Strategy itself links directly to the Paris Agreements, the 2030 Agenda and the Sendai Framework and incorporates all three objectives of the CCA, UR, and DRR approaches: to increase adaptive capacity, strengthen resilience and reduce vulnerability to climate change. In shaping these goals, the European Commission recognises that action needs to be taken at all levels, but focuses particular attention

Key international city networks and initiatives concerned with local adaptation

The Covenant of Mayors for Climate and Energy — Europe (European Commission) took its current shape in 2016, when the Covenant of Mayors, which started in Europe in 2008, joined forces with the Compact of Mayors to become the Global Covenant of Mayors for Climate and Energy, including the European chapter. The signatories commit to submitting a sustainable energy and climate action plan (SECAP) within 2 years after the local council decides to join the initiative, outlining the key planned actions. Since October 2015, local authorities have committed to reduce their GHG emissions by at least 40 %, increase their resilience to the impacts of climate change and secure access to sustainable and affordable energy by 2030. The support offered to signatories involves technical guidance, feedback on the SECAP and access to knowledge. Regular experience-sharing workshops and webinars are organised in various languages. The Covenant of Mayors office develops good practice case studies on adaptation in signatory cities and shares through the online library the resources developed by partner organisations and EU-funded projects. It also manages jointly with the EEA the Urban Adaptation Support Tool. There are 2 669 signatories in EEA member and collaborating countries as of April 2020, including 442 that have submitted a SECAP. https://www.covenantofmayors.eu

The Making Cities Resilient Campaign (United Nations Office for Disaster Risk Reduction, UNDRR) (2010-2020), aimed to work with cities, towns and local governments to increase their overall resilience to disasters by implementing risk reduction strategies. A 10-point checklist of essentials for making cities resilient served as a guide for a city's commitment to improving its resilience and was the organising principle for reporting and monitoring during the campaign. The participating local governments were expected to be proactive not only within their jurisdiction but also through sharing knowledge with others (UNISDR, 2019). As of June 2019, 645 local authorities in Europe participated. In February 2020, the new initiative 'Making Cities Resilient 2030' was proposed for launch in late 2020 (UNDRR, 2020). https://www.unisdr.org/ campaign/resilientcities

The Global Resilient Cities Network (GRCN) carries on the foundational work of 100 Resilient Cities (Rockefeller Foundation), which was set up in 2013. In partnership with its global community of cities and chief resilience officers, The GRCN continues to deliver urban resilience through knowledge sharing, collaboration and collective action, seeking to inspire, foster and build resilience around the world. The GRCN's mission is to connect cities and build partnerships to design, invest and scale urban resilience solutions worldwide to help urban communities thrive in the face of acute shocks and chronic stresses. Sixteen European cities participate in the initiative. https://www.resilientcitiesnetwork.org

C40 Cities convenes networks that provide a range of services to support cities' climate change efforts. Three networks are active under the adaptation implementation initiative. The Connecting Delta Cities Network aims to share knowledge and experience among a dozen delta cities from around the world, including Copenhagen, London, Rotterdam and Venice. The Cool Cities

Network, led by Athens and working in partnership with the Global Cool Cities Alliance, supports city efforts to reduce the impact of the urban heat island effect. The Urban Flooding Network aims to assist cities in addressing the impacts of floods and includes nine European cities. C40 provides adaptation master classes with workshops or training, tools and good practice repositories. https://www.c40.org

The Council of European Municipalities and Regions brings together the national associations of 130 000 local and regional governments from 41 European countries. Members meet regularly to advocate and exchange best practices on all topics. One expert group specifically focuses on climate and energy, and participates in the Climate Adaptation Partnership of the urban agenda (see Box 4.1). https://www.ccre.org

Climate Alliance is a European city network with around 1 700 members in 26 European countries. It has coordinated a working group on climate change adaptation since 2015. About 40 member cities participate in the annual meetings, sharing practical experiences, advice and knowledge. The network's secretariat regularly relays information about relevant guidance, publications and events to its members (personal communication from Lea Kleinenkuhnen, Climate Alliance, 2020). https://www.climatealliance.org

Eurocities is a European network of about 180 large member and partner cities, which provides a forum to its members to exchange information on, among other topics, nature-based solutions, cloudburst risks and water management, and discuss financial instruments for climate action. Eurocities also organises climate roundtables, where member cities can exchange experience of challenges and solutions, and gathers good examples of adaptation plans and strategies developed by member cities to inspire peers (personal communication from Heather Brooks, Eurocities, 2019). http://www.eurocities. eu

ICLEI — Local Governments for Sustainability is a global city network with around 160 members in Europe. It produces regular news about the latest developments on climate adaptation and urban resilience, and organises the annual European Urban Resilience Forum (ICLEI, 2019). https://www.iclei.org
Urban

on the urban and local dimension and the central role of climate-resilient planning at this scale.

Another factor supporting and guiding planning at the local level are international networks of cities working on local adaptation. These networks help the city develop a straightforward approach to climate change by providing guidance, developing local capacities, and giving best practices. These networks are either European or international in scope and provide various services and benefits to the participating cities. The main ones are described in Table 12. Together with national regulations, and National Adaptation Strategies (NASs) and National Adaptation Plans (NAPs), these networks are the main enablers and triggers of local climate planning.

Membership of these networks is voluntary, and individual cities can decide according to their needs which network to join. Other determining factors are the influence of other cities, political will and context, resulting in a great geographical variability that can be seen in Figure 15. Overall, the widespread participation of local authorities in various initiatives indicates excellent potential for progressing adaptation planning and action in Europe (EEA 2020).

Local planning can address climate change in different ways. Cities can choose to develop a stand-alone Local Climate Plan (LCP). Such plans are focused on climate change, and they are more flexible as they are not bound by planning cycles. By allowing intervention in several sectors simultaneously, they can provide an opportunity for a more comprehensive action while improving coordination and avoiding maladaptation. They can also give more visibility to climate change issues, attracts external funding and provide a clear framework for monitoring and evaluation (UN-HABITAT, 2012). Cities, alternatively or as a complementary approach, can choose to mainstream climate change objectives into existing development, land-use and other plans. This approach ensures the integration into existing planning cycles, budgets and planning hierarchy, defining clear responsibilities for the implementation (The World Bank, 2011).

Reckien et al. (2019) provide an excellent observation point for understanding the framework of climate planning taking place in European cities today. In their classification, the concepts of mitigation and adaptation are treated both as dedicated planning and as part of sectoral or cross-sectorial plans such as resilience and emergency plans. Furthermore, they distinguish between dedicated and mainstreamed LCPs (Table 13). Dedicated LCPs include comprehensive and stand-alone plans, such as plans that explicitly address climate change and its mitigation and/or adaptation. Within this category (A), they distinguish plans according to the triggering factor that led to the development of such a plan: A.1 plans have their origins in the will of the urban authority, A.2 plans are those that originate from a request of national legislation, and finally plans that originate from an international network belong to category A.3.

Mainstreamed LCPs are instead distinguished between horizontal (B) and vertical (C) mainstreaming. The formers (B) are resilience, emergency or sustainability plans that address climate change issues. They are called horizontal because they are cross-sectoral, including interactions between different policy fields and have general objectives that include climate change and other focuses. The latter (C) are stand-alone plans that address climate change by focusing on a sector (e.g. energy plans or water management plans) or a particular climate change impact (e.g. heatwave plans or flooding plans).

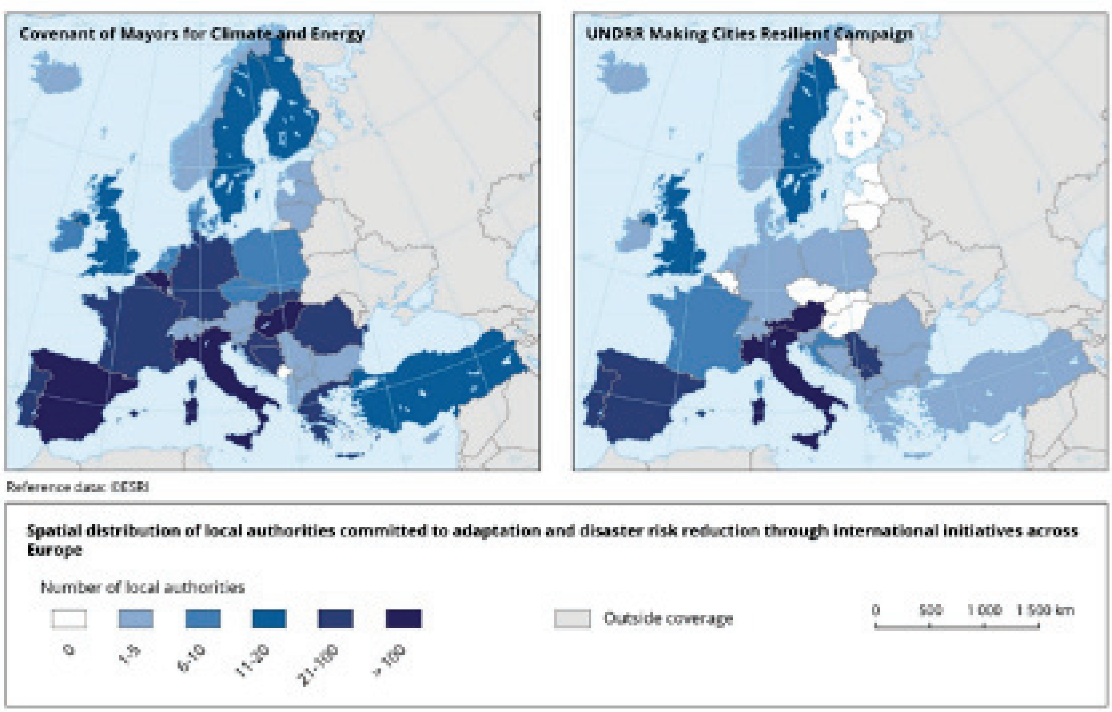


Figure 15
Spatial distribution of local authorities committed to adaptation and disaster risk reduction through international initiatives. Source (EEA, 2020)

Their sample is based on cities surveyed in Eurostat's Urban Audit database, currently known as "Statistics on European cities". The authors survey 885 core cities of the EU-28 trying to represent all NUT3 regions, at least 20% of the population of each state and cities of all sizes.

Figure 16 shows the survey results by Reckien et al. (2019) about the focus on adaptation, excluding the results concerning mitigation only. Priority in this representation is given to adaptation to highlight whether the surveyed cities had an official plan aiming at this goal. As mentioned earlier, category B also includes cross-sectoral plans, such as resilience or sustainability plans, where tackling climate change is part of a larger objective. In order to better interpret the results of Reckien's survey summarised in the image, one must also take into account the protocol that was followed in analysing the plans that each city has. This protocol states that if a city has a dedicated adaptation plan, and therefore of category A, this takes precedence over the plans of the other types and therefore, for the purposes of representation, only type A is shown. It follows that it may be that a city that has a type A plan also has type C sector plans, but Reckien and the other authors have chosen not to include them.

The results of the survey show that:

→ There is a disparity between northern and southern Europe in the number of cities with a plan addressing adaptation. The origin of this disparity is linked to many factors. One of these is the difference in national legislation. Some states, such as France (for cities with more than 50,000 inhabitants), the United Kingdom and Denmark, have national legislation that obliges cities to have a dedicated LCP, which for the purpose of this survey were classified in category A2. The presence of national legislation has a significant impact, in the case of Denmark all four cities in the sample have a dedicated plan.

→ Southern European cities are largely members of international mitigation networks. The results of the twin survey show that around 75% of Italian cities and 50% of Spanish and Portuguese cities have a mitigation plan linked to an international network. Networks such as the Covenant of Mayors have been very popular for their mitigation component, and now that they have launched new targets that also include adaptation, it is very likely that cities in Southern Europe will adopt LCPs linked to A3 adaptation.

Table 13
Typology of Local Climate Plans (LCPs) with a clear focus on climate change and those developed for the entire urban region. Source: (D. Reckien et al., 2014)

Type	Comprehensive and stand-alone (A)	Mainstreamed and inclusive (B)	Partial GHG sources and impacts, stand-alone (C)
Autonomous (1)	A1 – Local Climate Plan of the urban authority/administration that comprehensively addresses climate change. (e.g. Local Climate Adaptation Plan)	B – Climate change aspects included in another municipal plan. (e.g. Resilience Plan, Sustainability Plan; Development Plan; Core strategy)	C – Local Climate Plan, addressing partial aspects of climate change in stand-alone documents, relating to particular sectors (e.g. energy), or particular impacts (e.g. heatwaves, flooding)
National Regulation (2)	A2 - Local Climate Plans produced in response to requirements of national legislation, and published as stand-alone document		
International induced (3)	A3 – Local Climate Plan developed under the auspices of international urban climate networks.		

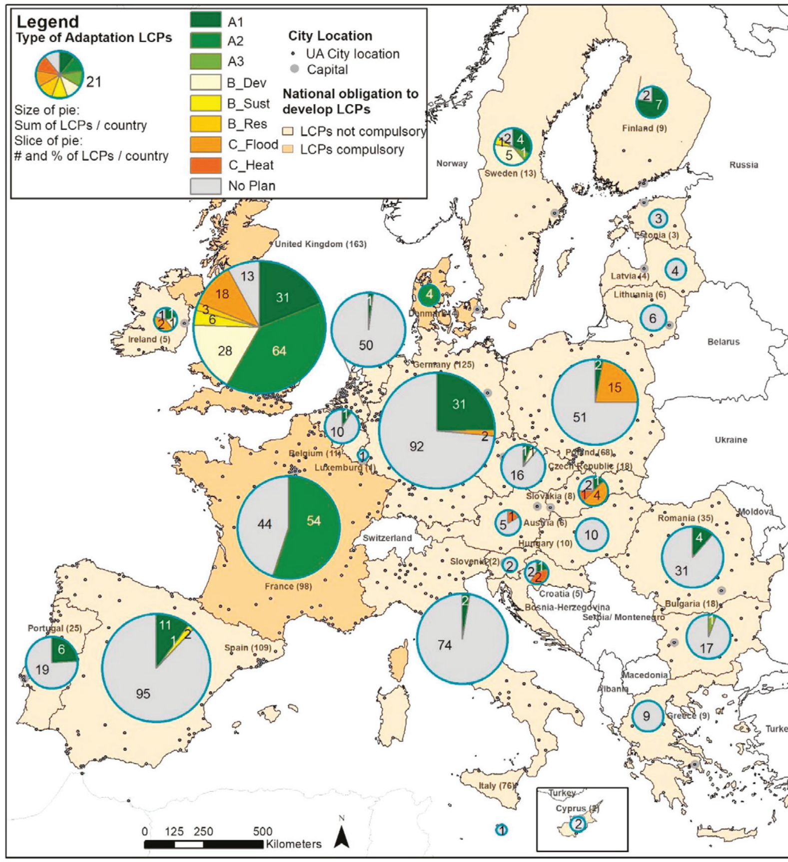


Figure 16
Map of types of Local Climate Adaptation Plans (Adaptation-LCPs) across 885 cities of the Urban Audit Core collection of cities in the EU-28 countries. Dark, medium and light green represent type A LCPs, which here represent dedicated LCPs. Yellow to dark orange represents type B and C LCPs and a form of mainstreaming of the climate issue. Grey patches depict cities without LCPs The figure in brackets behind the name of the country corresponds to the total number of UA cities in the country. Source: (D. Reckien et al., 2019).

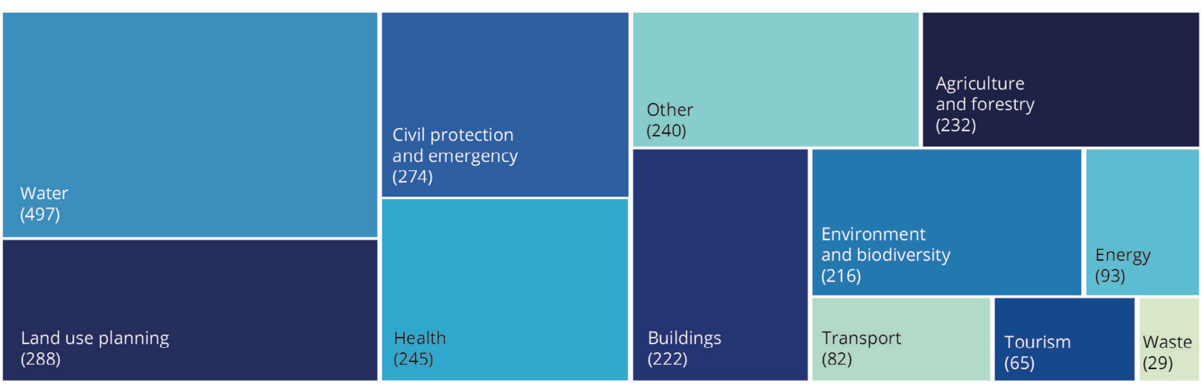
→ There are some cases where there is no stand-alone adaptation plan, but adaptation issues have been addressed within other plans or for some impacts. In terms of plans, the most frequent are plans that address development, resilience and sustainability. Plans that address climate change impacts individually focus on flooding and heatwaves.

CC-related actions currently taking place in European cities

The Covenant of Mayors (COM) database records all planned actions by signatories cities within their LCPs. An analysis of this database's actions shows that they most frequently address the water management, land use planning, civil protection and emergency, and health sectors. However, many sectors are affected by actions in the COM, and some actions interact with more than one sector, demonstrating that the variety of sectors affected by the effects of climate change and the response actions are becoming systemic (Figure 17). The results on sectors most affected by adaptation actions are also confirmed by other studies based on different databases (Aguiar et al., 2018; Castán Broto & Bulkeley, 2013).

The database of the Carbon Disclosure Project on adaptation in cities contains reporting from 163 cities. The cities reporting to CDP are predominantly large and located in southern or northern Europe (65 and 52 cities, respectively), with fewer cities from western Europe (32) and the lowest number from central and eastern Europe. This data was collected by CDP and ICLEI - Local Governments for Sustainability. The database contains a large number of actions, classified by type and sector. In the European Environment Agency report (2020) the types of actions contained in this database and the number of actions for that type are listed. The authors of the report also divide these actions into social, institutional or structural/physical according to the IPCC (2014) classification of adaptation options (Figure 18). This analysis shows that most of the measures reported belong to the first two categories and are "soft", i.e. they are linked to the creation of knowledge, plans, monitoring or awareness. This predominance may be linked to the fact that these measures often occur in the early stages of the adaptation process because they are preparatory to later stages. Physical or structural intervention actions, such as grey and green infrastructure, are present but in smaller numbers. This may be related to the fact that they concern implementation phases that are more advanced in time and more expensive than soft measures.

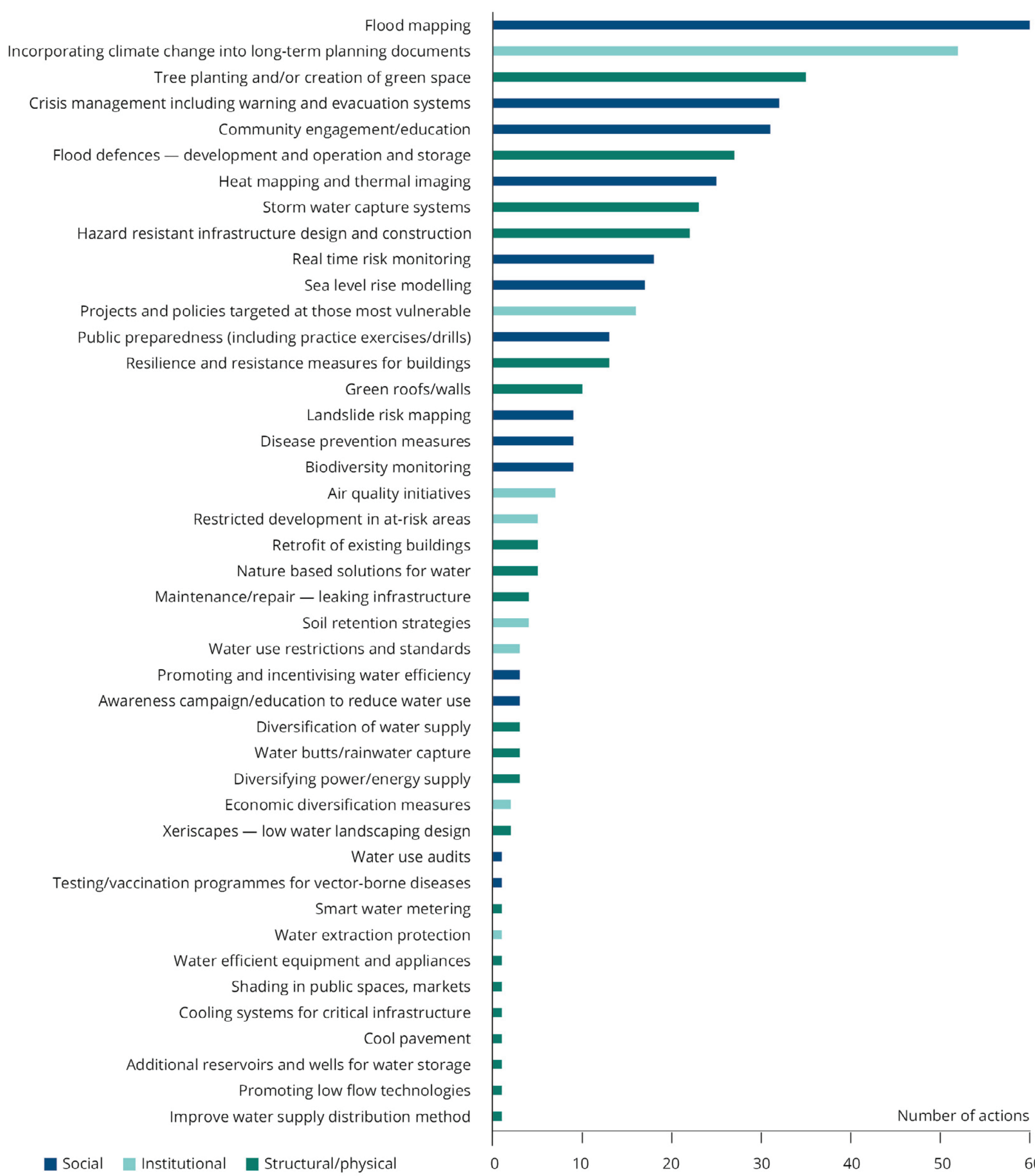
Figure 17
Adaptation actions planned by the Covenant of Mayors signatories, by sector. Source: (EEA, 2020)



There are also a large number of actions that are planned and carried out that do not have an explicit reference to climate change but that deal with related issues and have positive effects on the interaction between cities and climate change. Local plans and programming are rich in these measures that contribute to risk reduction, system resilience, hydraulic safety or directly to adaptation without being labelled as such. This body of measures does not enter into surveys based on explicit keywords, as in the case of these reviews (Aguiar et al., 2018; Pelorosso, 2020; D. Reckien et al., 2019; Diana Reckien et al., 2018), or into databases built on the basis of actions reported by partner cities, as in the case of CDP or COM databases.

Figure 18
Types of adaptation actions planned by cities in Europe. Source: (CDP & ICLEI, 2020; EEA, 2020)

These actions are unlikely to become part of the collection of best practices that serve as a reference for other contexts undertaking adaptation planning. They may have ancient origins, as in the case of all those adjustments that the city of Venice has developed over the centuries in order to live with the sea, or they may refer to regulatory, cultural and climatic contexts specific to only a few places. At the moment, there is no comprehensive review of these minor adaptation actions (Bertin, Negretto, Patassini, & Musco, 2019), and the investigation of these takes place for minor territorial, cultural and normative portions. In the following chapters, this issue will be further investigated within the selected case studies.



2.2 Across the data - CC-related actions currently taking place in European cities

Outline of the review

Within this chapter, an analysis is presented that seeks to capture the relationships that CC has at the local level, taking the cities' perspective and building on their reporting. This approach complements the previously analysed guidance documents drawn up by major international actors, by reversing their perspective. On the one hand, guidance documents refer to a generic city and describe the relationships and impacts it may have with CC from a general perspective. When using these guidance documents, it is then up to the individual cities to apply the generic indications in their specific context. On the other hand, this section starts from the opposite point of view, i.e., summarising the knowledge that each individual city has of the interactions of CC with its context, and from this, it draws a more general picture. In order to allow the comparison of the two perspectives, an attempt has been made to keep the terminology as consistent as possible between the two worlds, focusing on the same questions that guided the review in Chapter 1.2. These aim to understand what direct and indirect relationships are established between urban systems and CC impacts. The first part is related to understanding what consequences CC impacts have on urban systems, which sectors are involved, and its severity. The second part is oriented towards understanding through which actions these impacts are addressed, which sectors are most affected, and their effects on urban systems..

Methods and materials

The Carbon Disclosure Project and ICLEI collect the databases that are used for analysis in this section. These databases collect data produced by local government reporting and are, therefore, an excellent starting point for understanding the perspective of each local government's practice and experience of its context. Cities voluntarily submit their reports in a standard format that, through targeted questions, multiple answers, and open-ended responses, aims to collect their knowledge and make it comparable. Two databases are used.

The first database focuses on hazards and their effects, the most recent version available being from 2017. The items considered for this analysis include the fields of: Region; Country; City; Climate Hazard; Hazard magnitude; Impact description; Most impacted sectors. An example of the database can be found in Table 14. The complete databases can be found in ANNEX I. The terms used in this analysis for shares, hazards, sectors and

9 https://guidance.cdp.net/en/guidance?cid=21&ctype=theme&idtype=ThemeID&incchild=1&microsite=0&otype=Questionnaire&tags=TAG-637%2CTAG-570%2CTAG-13013%2CTAG-13002

co-benefits are based on those used for data collection and can be found on the CDP website[9].

The second database focuses on the actions cities have taken to tackle climate hazards, with the most recent version collecting data from 2020. The entries considered for this analysis include the fields of: Region; Country; City; Climate Hazard; Adaptation action; Status of action; Sectors/areas adaptation action applies to; Co-benefit area; Population. An example of the database can be found in Table 15 with the various multiple responses available.

The analyses are mainly based on highlighting the most frequently reported relationships between one category and another. In the first database, the relationships investigated are those between hazard, severity and most affected sectors. In the second database, the relationships investigated are those between hazard, action, sectors of implementation and co-benefits.

Since the databases collect the answers given by the staff of the local governments involved, they do not always have scientific accuracy. They may sometimes collect perceptions, while in other cases they are based on more rigorous assessments developed by cities. The agencies that collected the data also provided comprehensive guidance on definitions and meanings, thus attempting to standardise the framework within which local government responses are provided. In some cases, the answers provided were incomplete or had typing errors. In order to enable effective and unambiguous cataloguing, some entries were corrected within the limits of not distorting the content. Entries that were partial or duplicates were eliminated in order to have a complete sample in all fields and without repetition. Records that had no information within the fields considered in the subsequent analysis were defined as partial. Duplicate records were defined as those that had the same information within the City and Hazard field for the first database, and City and Action for the second database. Cities did not have a minimum or a maximum number of records to be reported, so some cities are more represented than others.

Table 14
Sample of the first database on hazards

CDP Region	Country	City	Organization	Climate hazard	Magnitude	Impact description	Most impacted sectors		
Europe	Italy	Milano	Comune di Milano	Extreme hot temperature > Extreme hot days	Serious	Heat waves cause a larger incidence...	Public health	Energy	Environment

CDP Region	Country	City	Organization	Climate hazard	Adaptation action	Action title	Status of action	Sectors/areas adaptation action applies to
Europe	Italy	Milano	Comune di Milano	Extreme hot temperature > Extreme hot days	Green roofs/ walls	Let's green the city: spreading green roofs and walls	Pre-implementation	Agriculture and Forestry; Energy; Spatial Planning

Table 15
Sample of the second database on actions

As compiling was voluntary, some countries may be more represented than others. All records outside those with Region = "Europe" were excluded within the two databases to limit the analysis geographically to European cities.

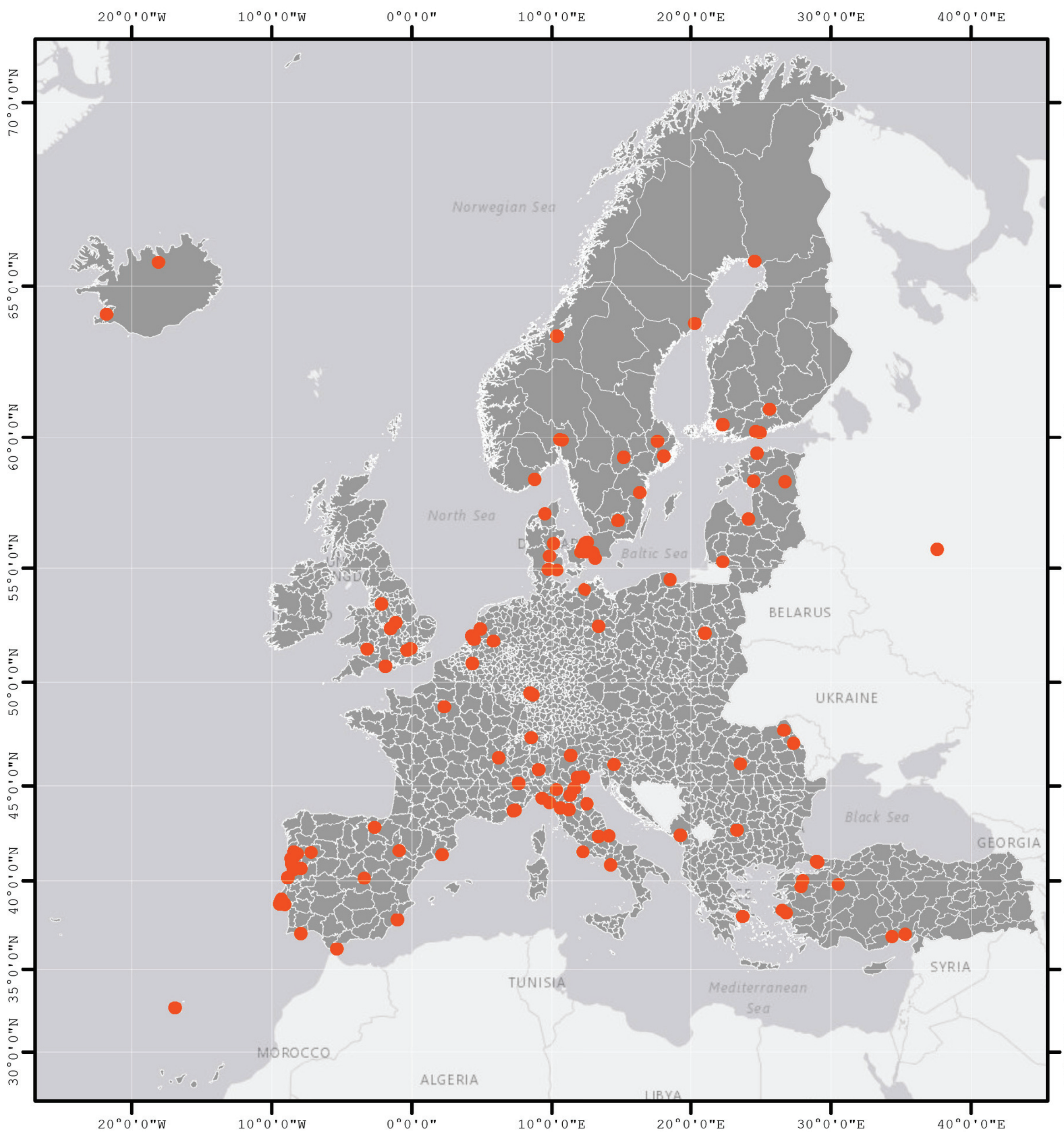
The cities' sample's geographical distribution resulting from this selection is well balanced between Northern and Southern Europe, while it is less balanced between Western and Eastern Europe (Figure 19). In terms of population size, the sample of cities is well balanced and representative of all scales. Table 16 presents the results of applying the OECD classification for European cities (Dijkstra & Poelman, 2012), which divides cities into size classes based on the number of inhabitants. The population ranges are: Extra-small (n° of inhabitants below 50k); Small (n° of inhabitants between 50k and 100k); Medium (between 100k and 250k); Large (between 250k and 500k); Extra-large (between 500k and 1M) and Extra-extra-large (n° of inhabitants above 1M).

Figure 18
Geographical distribution of the sample of cities in the database. Author's elaboration

Table 16
Results of the classification of cities, actions, and average according to the size classes of European cities defined by the OECD.

Population class	N° actions	N° Cities	Action/city (avg.)
XXL	106	16	6,6
XL	98	16	6,1
L	96	16	6,0
M	141	25	5,6
S	87	22	4,0
XS	205	46	4,5
Total	**733**	**141**	**5,2**

Co-benefit area	Action description and implementation progress	Population	Population Year	Last update
Disaster Risk Reduction; Ecosystem preservation and biodiversity improvement; Enhanced climate change adaptation; Enhanced resilience	This measure focuses on one hand on the implementation of green roofs and walls on public buildings, while on the other hand...	1,404,431	2019	2021-03-02 T09:58:35



Results and relations 1 – Understanding the system

Analysis of the first database revealed a wide variety of hazards recorded by cities and their effects on different city systems. The most recorded hazard is the heatwave, with 48 reports drawn across Europe, representing 11.6% of the total reports drawn. Intense precipitation and water hazards are also highly represented, with, for example, Rain Storm 45 records (10.8%) and Flash/surface flood 43 (10.4%). Although the count of these two water-related hazards appears to be coincidental, a cross-check of the 65 cities with records on these two hazards shows that they have been treated differently. According to the classification proposed by (Integrated Research on Disaster Risk, 2014), the hazards were then classified into types and already mentioned in Chapter 1.1 and used in the classification of grey literature in Chapter 1.2. The classification results and the count of the hazards reported in each category are shown in Table 17. First of all, each category's number varies greatly, ranging from only 2 recognised hazards of the Geophysical type to 15 of the Meteorological type. Referring back to what was said in Chapter 1.1 about the types of hazard that the various risk approaches include, we can see a clear majority in the variety and number of hazards covered by both CCA and DRR approaches. These are Climatological (7 hazards, 71 counts), Hydrological (3 hazards, 111 counts) and Meteorological (15 hazards, 170 counts). Hazards that deal exclusively with DRR approaches are less well represented, with Biological (4 hazards, 20 counts) and Geophysical (2 hazards, 14 counts).

Table 17
Reclassification of the hazards in types and their frequency in the database

The severity of hazards

Hazards of biological nature are recognised as having a medium to low severity, with only 5% of cases reported as ‘extremely serious’. It should be noted that the database was collected in 2017, i.e. before the global Covid-19 pandemic. On the other hand, the Climatological, Hydrological and Meteorological hazard types are recognised as having a higher severity on average, with fewer values as a percentage in the “less serious” class: 26.8%, 22.5% and 30.5%, respectively (Table 18). Finally, the Hydrological hazard type recorded the highest percentage (18.0%) in the “extremely serious” class. Hazards with fewer than 5 records were excluded from individual statistics but included in grouped analysis. Overall, the hazards that have been recognised as “extremely serious” most often are Coastal Flood (26.7%), River Flood (23.7%) and Heat Wave (20.8%). These percentages are to be understood as the percentage of times the hazard in question was classified as “extremely serious” out of the total number of times it was classified.

Table 18
Hazard types and their frequency in magnitude

Type	Hazard	Count	%
Biological	Air-borne disease	6	1,4%
	Vector-borne disease	6	1,4%
	Water-borne disease	4	1,0%
	Insect infestation	4	1,0%
	Total	**20**	**4,8%**
Climatological	Drought	32	7,7%
	Forest fire	13	3,1%
	Salt water intrusion	9	2,2%
	Groundwater flood	8	1,9%
	Subsidence	4	1,0%
	Ocean acidification	3	0,7%
	Land fire	2	0,5%
	Total	**71**	**17,1%**
Geophysical	Landslide	10	2,4%
	Rockfall	4	1,0%
	Total	**14**	**3,4%**
Hydrological	River flood	38	9,2%
	Coastal flood	30	7,2%
	Flash/surface flood	43	10,4%
	Total	**111**	**26,7%**
Meteorological	Heat wave	48	11,6%
	Rain storm	45	10,8%
	Extreme hot days	35	8,4%
	Storm surge	17	4,1%
	Severe wind	14	3,4%
	Heavy snow	5	1,2%
	Cold wave	4	1,0%
	Extreme cold days	4	1,0%
	Hail	4	1,0%
	Extreme winter conditions	3	0,7%
	Fog	3	0,7%
	Lightning/thunderstorm	3	0,7%
	Tornado	3	0,7%
	Extratropical storm	1	0,2%
	Tropical storm	1	0,2%
	Total	**190**	**45,8%**
Various	CO_2 concentrations	9	2,2%
	Gran total	**415**	**100%**

	Severity					
Type of hazard	Less Serious		Serious		Extremely serious	
	count	%	count	%	count	%
Biological	9	47,4%	9	47,4%	1	5,3%
Climatological	19	26,8%	44	62,0%	8	11,3%
Geophysical	7	50,0%	5	35,7%	2	14,3%
Hydrological	25	22,5%	66	59,5%	20	18,0%
Meteorological	58	30,5%	109	57,4%	23	12,1%

Relations between sectors and hazards

For each hazard recorded, city administrations had the opportunity to report which sectors they thought were potentially the most affected by the hazard. The questionnaire gave the possibility of reporting a maximum of 3 sectors affected and a minimum of 1, excluding the possibility of recording the same sector twice. For this reason, the total number of sectors reported is 1050 out of a total of 415 registered hazards, with an average of 2.53 sectors reported per hazard. Table 19 gives a picture of the relationship between the impacts grouped into their typologies and the sectors reported. The first column for each type shows the absolute number of relationships reported, while the second column shows the percentage of reports compared to the total number of records for that type of hazard. This is necessary in order to compare the results with each other despite the significantly different number of hazards reported for each type.

The results indicate that overall the sectors recognised as potentially most impacted by the hazards recorded are Public Health with 185 reports reported (17.7% of total records), Residential with 174 reports reported (16.6% of total records) and Transport with 146 reports reported (13.9% of total records). Several sectors were almost not reported as potentially most impacted by the hazards recorded, and these are Community & Culture, Education, Waste Management and Law & Order. By looking at the hazard type results, it is possible to see which sectors were reported as potentially

Table 19
Relations between sectors and hazards' types

Hazards	Biological		Climatological		Geophysical		Hydrological		Meteorological		Total	
Sectors	count	%	count	%	count	%	count	%	count	%	count	%
Commercial	2	5,0%	6	3,5%	1	2,8%	38	12,6%	30	6,0%	77	7,4%
Community & Culture	0	0,0%	1	0,6%	0	0,0%	3	1,0%	1	0,2%	5	0,5%
Education	0	0,0%	0	0,0%	0	0,0%	2	0,7%	3	0,6%	5	0,5%
Emergency Management	3	7,5%	5	2,9%	3	8,3%	12	4,0%	18	3,6%	41	3,9%
Emergency services	1	2,5%	7	4,1%	1	2,8%	15	5,0%	31	6,2%	55	5,3%
Energy	1	2,5%	5	2,9%	1	2,8%	12	4,0%	**66**	**13,2%**	85	8,1%
Environment	**4**	**10,0%**	**24**	**14,1%**	2	5,6%	7	2,3%	19	3,8%	56	5,3%
Food and agriculture	3	7,5%	**34**	**20,0%**	1	2,8%	15	5,0%	38	7,6%	91	8,7%
Industrial	0	0,0%	0	0,0%	1	2,8%	4	1,3%	4	0,8%	9	0,9%
ICT	0	0,0%	0	0,0%	0	0,0%	2	0,7%	6	1,2%	8	0,8%
Law & Order	0	0,0%	0	0,0%	0	0,0%	1	0,3%	0	0,0%	1	0,1%
Public Health	**19**	**47,5%**	**29**	**17,1%**	3	8,3%	26	8,6%	**107**	**21,4%**	**184**	**17,6%**
Residential	3	7,5%	17	10,0%	**10**	**27,8%**	**76**	**25,2%**	**68**	**13,6%**	**174**	**16,6%**
Transport	0	0,0%	7	4,1%	**11**	**30,6%**	**61**	**20,2%**	**67**	**13,4%**	**146**	**13,9%**
Waste Management	0	0,0%	0	0,0%	0	0,0%	2	0,7%	1	0,2%	3	0,3%
Water Supply & Sanitation	**4**	**10,0%**	**35**	**20,6%**	2	5,6%	26	8,6%	40	8,0%	**107**	**10,2%**
Total	40		170		36		302		499		1047	

most impacted by each of these hazard types. All of the biological hazards recorded Public Health as an impacted sector, and this accounts for almost half of the records for this type. Climate hazards also had a high occurrence in this sector (17.1%) along with Food & Agriculture (20.0%) and Water Supply & Sanitation. For Geophysical Hazards, the sectors potentially most impacted are Transport (30.6%) and Residential (27.8%). Both are present in three-quarters of the records for geophysical hazards. Also, for hydrological hazards, the sectors reported as potentially most affected are Residential (25.2%) and Transport (20.2%), with each accounting for just over half of the records. Finally, for meteorological hazards, the Public Health sector is the most reported (21.4%), with an incidence of more than half of the records, Residential (13.6%), Transport (13.4%) and Energy (13.2%).

In terms of the top 6 hazards by the number of entries, Heat Wave and Extreme Hot days both have a high frequency of reports of potential impacts on the Public Health (35.7% and 34.5%) and Energy (18.6% and 16.1%) sectors. Rain Storm, Flash/Surface Flood and River Flood all have a high frequency of reporting potential impacts on the Residential (18.5%; 25.4% and 25.0%) and Transport (24.4%; 22.8% and 20.0%) sectors. Coastal Flood has a high frequency of reporting for the Residential (25.0%) and Commercial (21.4%) sectors. Finally, Drought has a high reporting frequency for the Water Supply & Sanitation (26.5%) and Food & Agriculture (19.3%) sectors.

Results and relations 2 – Intervening in the system

The second database analysis revealed the relationships between actions, the sectors they apply to, and the co-benefits they generate. The first relationships that were examined were those between actions and sectors from two different perspectives.

From the perspective of the sectors, the results that emerge are remarkably uniform. Many sectors are dominated by two actions, which are also the most recurrent throughout the database: "Hazard Mapping & Modelling" and "Crisis management, including warning and evacuation systems". There are also sporadic exceptions, such as the actions related to planting green areas and creating green spaces, which is the most recorded action for the Environment sector, or Nature-based solutions which are often present in the Water sector. However, these exceptions are not surprises because these relationships are well known both in literature and in practice. (Table 20)

Instead, more diversified results emerge from the inverse comparison: by looking at the sectors in which the individual actions have an effect and in which they apply. This perspective allows overcoming the significant recurrence that some actions have in the database and overcoming the previous analysis results' homogeneity. The analysis highlights for each action which are sectors of implementation are more frequently reported. By bringing together the wide variety of responses from the cities, a picture is reconstructed in which it is possible to understand the relationship between actions and sectors of implementation. Table 21 presents the analysis's summary results, listing the main sectors in which each action is most frequently applied. Some sectors are frequently mentioned in many actions: Spatial Planning and Building & infrastructure for many actions of a physical nature, Public Health for actions that are more related to people, and finally Water and Environment for actions that deal with natural resources their efficient use or conservation. Table 23 shows the results for the 6 most recurrent areas in the relationship with actions. This table offers two ways of reading to highlight both which actions are taking place mainly in these areas and which are the main application areas for each action. These two ways of reading are explained later in the part related to co-benefits.

Table 20
Sectors and the most frequent action that apply in each sector

Table 21
Actions and their main sectors of implementation

Actions and their effects: principles for intervention

The database analysis continues by drawing attention to the effects of a specific actions on the system. This aspect picks up on what was observed in Chapter 1.2, which answered the question of how to intervene in the system, and what effects the actions had on the system. In this section, the results that emerged from cross-referencing the local administrations' responses regarding actions underway or planned and the effects that have occurred or are expected from these actions are presented.

The full list of co-benefits reported by cities is: Disaster preparedness; Disaster Risk Reduction; Economic growth; Ecosystem preservation and biodiversity improvement; Enhanced climate change adaptation; Enhanced resilience; Greening the economy; Improved access to and quality of mobility services and infrastructure; Improved access to data for informed decision-making; Improved public health; Improved resource efficiency (e.g. food, water, energy); Improved access to data for informed decision-making. food, water, energy); Improved resource quality (e.g. air, water); Improved resource security (e.g. food, water, energy); Job creation; Poverty reduction/eradication; Promote circular economy; Reduced GHG emissions; Resource conservation (e.g. soil, water); Security of tenure; Shift to more sustainable behaviours; Social community and labour improvements; Social inclusion, social justice.

Sector	More frequent actions that apply to the sector		
Building & Infrastructure	Hazard Mapping & Modelling		
Business and Financial Service	Hazard Mapping & Modelling	Crisis management including warning and evacuation systems	
Energy	Hazard Mapping & Modelling	Crisis management including warning and evacuation systems	
Environment	Tree planting and/or creation of green space		
ICT	Hazard Mapping & Modelling	Crisis management including warning and evacuation systems	
Industrial	Hazard Mapping & Modelling		
Public Health	Hazard Mapping & Modelling	Crisis management including warning and evacuation systems	
Social Services	Hazard Mapping & Modelling	Crisis management including warning and evacuation systems	
Spatial Planning	Hazard Mapping & Modelling	Incorporating climate change into long-term planning documents	Tree planting and/or creation of green space
Transport	Hazard Mapping & Modelling	Crisis management including warning and evacuation systems	Incorporating climate change into long-term planning documents
Water, Supply & Sanitation	Hazard Mapping & Modelling	Nature based solutions for water	

Action	Main sector action applies to		
Air quality initiatives	Environment	Public Health	
Biodiversity monitoring	Spatial Planning	Environment	
Community engagement/education	Spatial Planning		
Crisis management including warning and evacuation systems	Public Health	Transport	
Disease prevention measures	Public Health		
Flood defences – development and operation & storage	Water, Supply & Sanitation	Public Health	
Hazard Mapping & Modelling	Building & Infrastructure	Spatial Planning	
Hazard resistant infrastructure design and construction	Water, Supply & Sanitation	Building & Infrastructure	
Incorporating climate change into long-term planning documents	Spatial Planning		
Nature based solutions for water	Building & Infrastructure	Water, Supply & Sanitation	
Outdoor design for heat reduction	Spatial Planning	Building & Infrastructure	
Projects and policies targeted at those most vulnerable	Public Health	Social Services	
Resilience and resistance measures for buildings	Building & Infrastructure	Spatial Planning	
Storm water capture systems	Water, Supply & Sanitation	Building & Infrastructure	Spatial Planning
Tree planting and/or creation of green space	Spatial Planning	Environment	
Water efficient equipment and appliances	Water, Supply & Sanitation	Building & Infrastructure	
Water use restrictions, standards, incentives and education	Water, Supply & Sanitation	Environment	

Table 22 presents the results of the analysis, listing the main co-benefits for each action. As in the previous section, this approach revealed more fertile results than ranking the most recurrent actions by individual co-benefits. The most recurrent and cross-cutting results are the co-benefits that many actions have in terms of Enhanced Adaptation and Enhanced Resilience: many actions report one or both of these two as co-benefits that the action enables. Disaster risk is another recurring co-benefit, in its Reduction and Preparedness declination. Other co-benefits that have been linked to some types of actions are: Improved Public Health for actions targeting the most vulnerable and disease prevention, Economic Growth and Green Jobs, and several co-benefits linked to the quality, efficiency of use and conservation of resources.

Table 22 – Main cross-cutting co-benefits enabled by each action.

Finally, more in-depth results are reported in Table 24, which shows the interactions of the actions with the 6 most cited co-benefits: Enhanced climate change adaptation; Enhanced resilience; Disaster Risk Reduction; Disaster preparedness; Ecosystem preservation and biodiversity improvement; Improved public health. The table has two levels of legibility. The first is the vertical reading level, where, starting from one of the co-benefits, it is possible to examine the column of absolute numbers and percentages on grey background for each action. Consulting the table in this manner allows understanding which actions are mostly related to that specific co-benefit. The other possible reading level is the horizontal one, where starting from an action, it is possible to read the co-benefits with which it is associated. In addition to the two columns already mentioned, there is also the column of percentages on a yellow background to support this reading. The value in these columns is obtained by dividing the number of the first column, i.e. the absolute number of relationships between action and co-benefit, by the total number of co-benefits recorded for that column. The resulting value indicates how many times, as a percentage, a co-benefit was associated with an action compared to all co-benefits associated with that action. A high value means that the co-benefit is recognised as one of the most frequent co-benefits for a specific action. This process helps to counterbalance the heterogeneous number of actions in the database, which instead emerges in vertical reading.

Action	Main co-benefit that the action enables		
Air quality initiatives	Reduced GHG emissions	Enhanced climate change adaptation	Improved resource quality (e.g. air, water)
Biodiversity monitoring	Ecosystem preservation and biodiversity improvement	Enhanced climate change adaptation	
Community engagement/education	Enhanced resilience	Enhanced climate change adaptation	Shift to more sustainable behaviours
Crisis management including warning and evacuation systems	Disaster preparedness	Enhanced resilience	Disaster Risk Reduction
Disease prevention measures	Improved public health		
Flood defences – development and operation & storage	Enhanced resilience	Enhanced climate change adaptation	Disaster Risk Reduction
Hazard Mapping & Modelling	Enhanced resilience	Enhanced climate change adaptation	Disaster Risk Reduction
Hazard resistant infrastructure design and construction	Enhanced resilience	Enhanced climate change adaptation	Disaster Risk Reduction
Incorporating climate change into long-term planning documents	Enhanced climate change adaptation	Enhanced resilience	Disaster Risk Reduction
Nature based solutions for water	Enhanced climate change adaptation	Enhanced resilience	Ecosystem preservation and biodiversity improvement
Outdoor design for heat reduction	Enhanced resilience	Enhanced climate change adaptation	Improved public health
Projects and policies targeted at those most vulnerable	Improved public health	Social inclusion, social justice	
Resilience and resistance measures for buildings	Disaster preparedness	Economic growth	
Storm water capture systems	Enhanced climate change adaptation	Enhanced resilience	Ecosystem preservation and biodiversity improvement
Tree planting and/or creation of green space	Ecosystem preservation and biodiversity improvement	Improved resource quality (e.g. air, water)	Enhanced resilience
Water efficient equipment and appliances	Resource conservation (e.g. soil, water)	Enhanced climate change adaptation	Enhanced resilience
Water use restrictions, standards, incentives and education	Improved resource efficiency (e.g. food, water, energy)	Enhanced resilience	Shift to more sustainable behaviours

	Spatial Planning			Building & Infrastructure			Public Health		
Action	Count	% in this co-benefit	Out of all %	Count	% in this co-benefit	Out of all %	Count	% in this co-benefit	Out of all %
Air quality initiatives	2	0,9%	11,8%	2	0,9%	11,8%	3	1,6%	17,6%
Biodiversity monitoring	9	4,1%	**25,7%**	3	1,4%	8,6%	3	1,6%	8,6%
Community engagement/education	11	5,1%	13,6%	13	6,0%	16,0%	12	6,5%	14,8%
Crisis management including warning and evacuation systems	12	5,5%	7,2%	21	9,7%	12,6%	33	**17,8%**	19,8%
Disease prevention measures	2	0,9%	11,1%	1	0,5%	5,6%	8	4,3%	44,4%
Flood defences – development and operation & storage	11	5,1%	15,7%	14	6,5%	**20,0%**	15	8,1%	**21,4%**
Hazard Mapping & Modelling	62	**28,6%**	19,6%	62	**28,7%**	19,6%	42	**22,7%**	13,2%
Hazard resistant infrastructure design and construction	6	2,8%	13,3%	12	5,6%	**26,7%**	6	3,2%	13,3%
Incorporating climate change into long-term planning documents	28	**12,9%**	**23,7%**	20	9,3%	16,9%	17	9,2%	14,4%
Nature based solutions for water	13	6,0%	**26,0%**	11	5,1%	**22,0%**	4	2,2%	8,0%
Outdoor design for heat reduction	12	5,5%	**27,3%**	9	4,2%	**20,5%**	7	3,8%	15,9%
Projects and policies targeted at those most vulnerable	2	0,9%	8,0%	4	1,9%	16,0%	9	4,9%	**36,0%**
Resilience and resistance measures for buildings	9	4,1%	15,3%	21	9,7%	**35,6%**	8	4,3%	13,6%
Storm water capture systems	6	2,8%	24,0%	7	3,2%	**28,0%**	3	1,6%	12,0%
Tree planting and/or creation of green space	28	**12,9%**	**32,9%**	10	4,6%	11,8%	10	5,4%	11,8%
Water efficient equipment and appliances	3	1,4%	12,5%	5	2,3%	**20,8%**	4	2,2%	16,7%
Water use restrictions, standards, incentives and education	1	0,5%	6,3%	1	0,5%	6,3%	1	0,5%	6,3%
Total	217	100,0%	293,9%	216	100,0%	298,6%	185	100,0%	287,8%

Table 23
Actions and the 6 main sector they apply to. High percentages highlighted in bold in the grey columns show which are the most frequent actions for a specific action. High percentages highlighted in bold in the red columns means that the specific action is frequently applied in that specific sector.

Water, Supply & Sanitation			Environment			Energy			First 6 Sectors		Total
Count	% in this co-benefit	Out of all %	Count	% in this co-benefit	Out of all %	Count	% in this co-benefit	Out of all %	Total n° of first 6 sectors	% out of all sectors	Total sectors
0	0,0%	0,0%	3	2,9%	17,6%	1	1,4%	5,9%	11	64,7%	**17**
5	3,1%	14,3%	15	**14,4%**	**42,9%**	0	0,0%	0,0%	35	100,0%	**35**
8	4,9%	9,9%	11	**10,6%**	13,6%	4	5,8%	4,9%	59	72,8%	**81**
12	7,4%	7,2%	13	**12,5%**	7,8%	13	**18,8%**	7,8%	104	62,3%	**167**
2	1,2%	11,1%	2	1,9%	11,1%	1	1,4%	5,6%	16	88,9%	**18**
19	**11,7%**	**27,1%**	1	1,0%	1,4%	2	2,9%	2,9%	62	88,6%	**70**
38	**23,5%**	12,0%	12	**11,5%**	3,8%	15	**21,7%**	4,7%	231	72,9%	**317**
8	4,9%	17,8%	0	0,0%	0,0%	9	**13,0%**	**20,0%**	41	91,1%	**45**
12	7,4%	10,2%	12	**11,5%**	10,2%	7	**10,1%**	5,9%	96	81,4%	**118**
17	**10,5%**	**34,0%**	4	3,8%	8,0%	0	0,0%	0,0%	49	98,0%	**50**
2	1,2%	4,5%	4	3,8%	9,1%	2	2,9%	4,5%	36	81,8%	**44**
1	0,6%	4,0%	0	0,0%	0,0%	2	2,9%	8,0%	18	72,0%	**25**
4	2,5%	6,8%	1	1,0%	1,7%	10	**14,5%**	16,9%	53	89,8%	**59**
7	4,3%	**28,0%**	1	1,0%	4,0%	0	0,0%	0,0%	24	96,0%	**25**
9	5,6%	10,6%	21	**20,2%**	**24,7%**	2	2,9%	2,4%	80	94,1%	**85**
10	6,2%	**41,7%**	1	1,0%	4,2%	0	0,0%	0,0%	23	95,8%	**24**
8	4,9%	**50,0%**	3	2,9%	18,8%	1	1,4%	6,3%	15	93,8%	**16**
162	100,0%	289,1%	104	100,0%	178,8%	69	100,0%	95,8%	**953**	**1444,0%**	**1196**

	Disaster preparedness			Disaster Risk Reduction			Ecosystem preservation and biodiversity improvement		
Action	Count	% in this co-benefit	Out of all %	Count	% in this co-benefit	Out of all %	Count	% in this co-benefit	Out of all %
Air quality initiatives	1	0,5%	3,6%	1	0,4%	3,6%	0	0,0%	0,0%
Biodiversity monitoring	4	2,0%	3,9%	13	5,6%	12,7%	18	11,8%	**17,6%**
Community engagement/education	14	6,9%	10,1%	7	3,0%	5,0%	6	3,9%	4,3%
Crisis management including warning and evacuation systems	46	**22,8%**	**19,1%**	37	**15,9%**	**15,4%**	7	4,6%	2,9%
Disease prevention measures	0	0,0%	0,0%	3	1,3%	11,1%	4	2,6%	14,8%
Flood defences – development and operation & storage	12	5,9%	10,3%	21	9,1%	**18,1%**	5	3,3%	4,3%
Hazard Mapping & Modelling	58	**28,7%**	13,1%	63	**27,2%**	14,3%	15	9,9%	3,4%
Hazard resistant infrastructure design and construction	9	4,5%	7,8%	13	5,6%	11,2%	7	4,6%	6,0%
Incorporating climate change into long-term planning documents	16	7,9%	7,2%	29	12,5%	13,1%	17	11,2%	7,7%
Nature based solutions for water	4	2,0%	2,7%	15	6,5%	10,2%	15	9,9%	10,2%
Outdoor design for heat reduction	1	0,5%	1,3%	3	1,3%	4,0%	5	3,3%	6,7%
Projects and policies targeted at those most vulnerable	3	1,5%	5,7%	3	1,3%	5,7%	0	0,0%	0,0%
Resilience and resistance measures for buildings	21	10,4%	**35,6%**	0	0,0%	0,0%	1	0,7%	1,7%
Storm water capture systems	2	1,0%	3,3%	6	2,6%	10,0%	7	4,6%	11,7%
Tree planting and/or creation of green space	4	2,0%	1,7%	12	5,2%	5,0%	39	**25,7%**	**16,3%**
Water efficient equipment and appliances	3	1,5%	5,0%	3	1,3%	5,0%	3	2,0%	5,0%
Water use restrictions, standards, incentives and education	4	2,0%	5,4%	3	1,3%	4,1%	3	2,0%	4,1%
Total	**202**	**100,0%**	**135,8%**	**232**	**100,0%**	**148,4%**	**152**	**100,0%**	**116,7%**

Table 24
Actions and the 6 main co-benefit that they enable. High percentages highlighted in bold in the grey columns show which actions enable that co-benefit most frequently. High percentages highlighted in bold in the red columns show which are the most frequently reported co-benefits that the specific action enable.

Enhanced climate change adaptation			Enhanced resilience			Improved public health			First 6 co-benefits		Total
Count	% in this co-benefit	Out of all %	Count	% in this co-benefit	Out of all %	Count	% in this co-benefit	Out of all %	Total nº of first 6 co-benefits	% out of all co-benefits	Total co-benefits
6	1,7%	**21,4%**	2	0,6%	7,1%	3	2,1%	10,7%	13	46,4%	**28**
14	3,9%	13,7%	12	3,4%	11,8%	8	5,6%	7,8%	69	67,6%	**102**
20	5,5%	14,4%	23	6,5%	**16,5%**	5	3,5%	3,6%	75	54,0%	**139**
30	8,3%	12,4%	39	11,0%	**16,2%**	15	10,6%	6,2%	174	72,2%	**241**
2	0,6%	7,4%	2	0,6%	7,4%	13	9,2%	**48,1%**	24	88,9%	**27**
22	6,1%	**19,0%**	27	7,6%	**23,3%**	4	2,8%	3,4%	91	78,4%	**116**
76	**21,0%**	**17,2%**	80	**22,5%**	**18,1%**	31	**21,8%**	7,0%	323	73,1%	**442**
20	5,5%	**17,2%**	22	6,2%	**19,0%**	3	2,1%	2,6%	74	63,8%	**116**
38	10,5%	**17,2%**	35	9,9%	**15,8%**	11	7,7%	5,0%	146	66,1%	**221**
29	8,0%	**19,7%**	23	6,5%	**15,6%**	5	3,5%	3,4%	91	61,9%	**147**
14	3,9%	**18,7%**	17	4,8%	**22,7%**	8	5,6%	10,7%	48	64,0%	**75**
10	2,8%	**18,9%**	7	2,0%	13,2%	12	8,5%	**22,6%**	35	66,0%	**53**
1	0,3%	1,7%	1	0,3%	1,7%	1	0,7%	1,7%	25	42,4%	**59**
14	3,9%	**23,3%**	14	3,9%	**23,3%**	0	0,0%	0,0%	43	71,7%	**60**
45	12,4%	**18,8%**	34	9,6%	14,2%	16	11,3%	6,7%	150	62,5%	**240**
11	3,0%	**18,3%**	9	2,5%	**15,0%**	3	2,1%	5,0%	32	53,3%	**60**
10	2,8%	13,5%	8	2,3%	10,8%	4	2,8%	5,4%	32	43,2%	**74**
362	**100,0%**	**272,9%**	**355**	**100,0%**	**251,7%**	**142**	**100,0%**	**150,0%**	**1445**	**65,7%**	**2200**

Conclusion

The databases analysed had the peculiarity of being compiled by cities' administrations themselves and having their city as the subject. The point of view that emerges from the analyses in this chapter is that of administrations in full contact with the territory they describe and that understand it through experience. Only a certain number of cities have undertaken vulnerability and risk assessment processes and therefore hold a more rigorous perspective on climate change's impacts and actions on their cities. Therefore, the results that emerge from these analyses are based on practical knowledge of the city, its effects, and the interventions that take place in it.

This perspective is the opposite and complementary to the one examined in Chapter 1.2, where the point of view was external and dealt with cities in a process that starts from the general and is then left to individual cities to bringing to the particular. Here, on the other hand, the information reported is context-related, describing the hazards and risks in more than 140 European cities and their systems and sectors, collecting more than 700 actions in these cities and what co-benefits they have achieved. In analysing and summarising the results, a picture emerges that returns to the general and thus once again speaks the same language as Chapter 1.2 and can be compared with it. The principles for intervening in the system that emerged from that analysis return in this analysis in the form of co-benefit enabled by actions. Among these co-benefits, the most frequent and recurrent concerns concern the three approaches to risk that underlie the previous chapters: climate change adaptation, disaster risk reduction and urban resilience. This result opens up two considerations.

The first tells us that many actions co-benefit from improving one or more of these characteristics and that the actions taking place in Europe are varied, some more frequent than others, but many of them are building resilience, adaptation and risk reduction. The second consideration tells us that few clear-cut actions achieve resilient, adaptive or risk-reduced status alone. Different actions applied in different sectors can contribute to the same goal, and this means that improvement in these aspects takes place in different forms simultaneously and in different ways depending on many factors, one of which is probably geographical contexts.

The hazards considered in the cities' reporting are mainly directly related to climate change and are the subject of all three of the risk approaches described above. The framework in which the questionnaire was inserted and its questions excluded some of the risks that DRR and resilience can deal with, such as earthquakes, wars, economic crises. The hazard types most dealt with belong to the domain of all 3 approaches but coincide with the area that adaptation mainly deals with: hydrological, meteorological and climatological hazards.

The results show that larger cities are shaping more actions than smaller ones. This may be due to greater economic or technical capacity or simply to a larger territory. The interesting fact is that the large number of cities ranked extra small by the OECD are carrying out more than four actions each on average, although some have only a few thousand inhabitants.

Sectors are a field that was common to both databases. They were both in relation to risks, and thus referred to as sectors in which to expect impacts from CC, and in relation to actions, and thus as sectors in which action is implemented. The most commonly cited sectors in both are spatial planning, residential and commercial buildings, Transport, environment and water, and health. These are the sectors that are at the forefront of both impacts and action related to climate change. Moreover, from this analysis and Chapter 1.2's one, it has become clear once again how interrelated they are in both impacts and action.

Chapter 3 - Operative Framework and Methodology

Operative framework

The research aims at positioning between the academic perspective and the policymakers' and practitioners' one. Having an intermediate position, this research attempts to intercept the transfer of knowledge in the science-policy relation in both directions. On the one hand, by investigating the translation of conceptual knowledge into more operational practices, and on the other hand, how experiences and experiments can be generalised and brought back to theory.

The previous chapters have shown that the conceptual framework is rich in sources that consider risk an integral part of contemporary society. The chain of cause and effect is not straightforward, and spreads out in many directions to places and domains far apart. Climate change is one such cause: the effects of which are widespread and disastrous and characterised by uncertainty and unpredictability. This cause has assumed such proportions and importance that it is now being characterised as an emergency, both global and local. The characteristics of this emergency are unique, both in terms of time and space horizons.

Cities are among the most at risk, and this risk is caused by both their vulnerability and their exposure. On the one hand, they are vulnerable to the effects of climate change because their conformation, made of artificial materials and forms, does not provide an efficient response to climate impacts. On the other hand, they are highly exposed due to the density of valuable elements, activities, and populations located in cities. The resulting high risk and the considerable potential to develop adaptive capacities make cities a critical field of experimentation.

Three distinct fields of knowledge and practice address the causes and consequences of climate change and its interactions with the urban context. Climate change adaptation, disaster risk management, and urban resilience have perspectives and modalities that partly differ and partly overlap. Applying these fields of knowledge in the urban context is an evolving practice, and the number of guidelines and tools developed by international organisations is a clear indicator of this. The framework distilled from these documents is an overall representation of how the scientific and conceptual knowledge of the three fields of knowledge is translated into the operational dimension at the city level. This framework has to deal with cities as complex systems, where it is not possible to intervene with certain knowledge of the current state, the effects of an intervention and where stable and static safety is not attainable. The complexity of urban systems, the interactions between their elements, their systems, and climate change require contemplating spaces, times, and relationships of variable geometry simultaneously.

Local governments have declared a state of emergency, where ordinary methods, budgets and tools are no longer sufficient to manage the situation. The urgency of finding short-term responses that also have a long time horizon, the need to act in an emergency and at the same time to act according to a systemic logic, and the uncertainty arising from an ever-changing framework are the challenges with which urban planning must deal. In order to do this, it has at its disposal distinct approaches which, when used in combination, can provide answers capable of dealing with both complexity and climate uncertainty.

Several surveys focusing on European cities have been able to draw a picture of which cities have equipped themselves with planning tools explicitly oriented towards addressing climate change. By classifying these plans into categories, these reviews summarise climate action at the urban level.

The methodology described below is used to combine this summary view with analytical insights. These aim to understand which norms, principles, and techniques shape climate action in some European case studies. Focusing the analytical gaze on individual cities is the way to understand in detail how climate action has related to issues arising from complexity.

Methodology

This thesis takes the form of applied research as it merges academic and practice knowledge. Since the aim is to understand ongoing phenomena and dynamics, the case study approach has been chosen to bring together different sources, databases, and experiences and have a systemic and comprehensive view.

Among the various meanings attributed to the term case study, and among the related research methodologies, in this thesis case study is referred to as the intensive study of a small number of cases. This research method is well suited to understanding the complex dynamics of cities, where it is difficult to apply general theories and make accurate predictions. The case study approach offers context-dependent knowledge, which is useful for understanding a dynamic and evolving context rather than drawing a universal theory (Flyvbjerg, 2006).

In Chapter 1.2 and 2.2, different data sources for a variety of cities were analysed. The results that these analyses give are valid for overall considerations. On the other hand, the case study approach allows close observations to be made at the urban scale, taking into account the context in which they occur, the planning tools used, and the relationships and forms established.

The applied methodology aims to have a systemic understanding of the relations between the system connected to urban action in the fields of CCA, DRR and UR as they are applied in practice. These relations are investigated by analysing relevant documents and plans and then linking them to understand the relation between them.

The first step of the methodology is to understand the variable geometries of the system's boundaries under consideration. For this reason, the case studies are described according to different boundaries, which change the size of the system under study and allow the emergence of subsystems and larger ensembles. Administrative boundaries, for example, are a division of the territory into units that are not necessarily organised according to hierarchical and coinciding logics: different bodies may have authority in the same places and overlap, or be part of the same management body for a common territory. Boundaries are also variable from an urban point of view and are based on the classifications one chooses to use and the systems one wishes to consider. Boundaries can be drawn on the basis of the urban system gravitating on the city in terms of services, work and transport, thus defining the boundaries of the Functional Urban Area. Or based on the proportion of inhabitants living in urban areas, thus defining different boundaries of the continuity of the urban environment. Finally, risk is also a unit of measurement that can classify the territory based on its characteristics. Sets of indicators can lead to the emergence of typologies of territories with similar degrees of climatic risk, defined through indicators of hazard, exposure, vulnerability and adaptive capacity. For this reason, the first sub-chapter of each case study is dedicated to the recognition of systems and typologies of the territory and how it is used to better frame the context and the risk. These chapters are described by collecting relevant and useful materials, maps, and indicators to describe the system's current state.

In order to understand how cities take action to reduce their climate risk, it is important to first understand how they describe and take into account local risks. An important source in this respect are the risk assessments developed within certain planning documents. These can have the form of true risk assessments, with indicators, probabilities and estimates of potential damage, but can also have hybrid forms. Useful elements for understanding local risk may also emerge from descriptive aspects within a plan, observations or spatial conformations. To intercept knowledge derived from experience, it is useful to analyse the local perception of risk by public administrators who implement policies and plans for the city. Analysing their perception of risk also allows the degree of severity and urgency that is attributed to different effects of climate change to emerge, making it possible to understand their priority on the local agenda. This perception is then useful to be compared with the priorities outlined in the risk reduction plans.

The plans are also the fundamental source for understanding how cities intervene in the system to reduce risk. Within the plan documents, a series of relationships and connections emerge between different urban elements and systems in relation to climate impacts. Thus, reading these documents serves as a source for qualitative and quantitive analyses investigating the issues involved in intervening in complex cities. These include, firstly, how the system is described and understood, and the relationships and interconnections that are established between different elements. Secondly, the ways and principles by which action is taken and the role of plans in receiving and implementing these principles. And finally also to understand the co-benefits generated by interventions in other systems and sectors.

Research methods applied

The methodology is a set of different research methods, useful to intercept different data sources, characteristics and experiences.

System's boundaries

In order to understand the boundaries of the analysed systems, documents, information, indicators and spatial data relevant to administrative, morphological, economic and risk aspects were collected. These were critically selected and compared with each other to outline a system with variable geometries and different facets. Depending on the nature of the data, the comparison took place either in a narrative/descriptive manner, through indicator comparison matrices or in the form of cartographic representations. In addition to administrative boundaries, various spatial classifications and divisions were used, including NUTS3, LAU and FUA. NUTS3 is the third level of the classification of the European territory into Statistical Territorial Units set up by Eurostat as a single, coherent system for dividing up the EU's territory in order to produce regional statistics for the Community. NUT3 units divide the territory based on administrative boundaries and on a population threshold between 150000 and 800000 inhabitants. Another classification, also used by Eurostat and OECD, useful to define the system's boundaries divides the territory into Local Administrative Units (LAU), units that are related to local and low level administrative divisions, ranked below a province, region or state. A LAU is classified as a city when the majority of the population lives in an urban centre of at least 50000 inhabitants. The commuting zone contains the surrounding travel-to-work areas of a city where at least 15% of employed residents are working in the city. A functional urban area (FUA) consists of a city and its commuting zone. Functional urban areas therefore consist of a densely inhabited city and a less densely populated commuting zone whose labour market is highly integrated with the city (Dijkstra, Poelman, & Veneri, 2019; Eurostat, 2018; OECD, 2012).

Local risk perception

Two methods were applied to understand local risk perception. If the case study was present in the European risk perception database (Chapter 2.2) at the city level with a fair number of indications then these were examined. If the case studies did not exist or did not have a sufficient number of entries, then ad hoc data collection and analysis was carried out. The data collection took place in the format of multiple-choice and open-ended questionnaires addressed to the staff of the case study municipalities. The completion of the questionnaires was preceded by preparatory meetings and then followed by interviews to validate the results. The content of the questionnaires is presented in the respective chapter and is divided into two co-ordinated levels. The first level of questions is an overall risk assessment, which provides a source of data comparable to the European database, and therefore useful to build a lowest common denominator for all case studies. The second level has a higher level of detail, investigating the relationships between risks and specific sectors and asking for an assessment of the severity, probability and expected time horizon of potential impacts on urban systems. Above all, this second level of data detail allows the results to be analysed quantitatively as well as qualitatively.

The survey took place at a particular stage: the beginning of the SECAP's planning process. Local administrators had first participated in various capacity building and discussion events within the LIFE Veneto Adapt project, aimed at understanding various aspects of the interactions between climate change and urban systems and defining the main hazards for the Central Veneto territory. These capacity building activities were also the place to build a knowledge base of risk assessment terms, in order to have a common and comprehensible vocabulary for subsequent surveys.

Each local authority responded to two surveys: a first overall survey, and a second specific survey investigating the relationships between specific hazards and sectors.

Table 25
Risk-assessment survey example with possible answers.

The first overall survey provides at general considerations as far as certain hazards are concerned and is therefore comparable with the results presented in chapter 2.2 and with the other case study. Hazards identified in the meeting paths with local administrations belong to hydrological, climatological and meteorological categories and are: flash/surface flood, river flood, drought, heat wave, severe wind. For each of these, an overall assessment was requested regarding the current level of risk (low/moderate/high),

Table 26
CC-effects on urban systems survey with indicator example.

Type	Hazard	Current risk	Exp. change in intensity	Exp. change in frequency	Time horizon
Hydrological	**Flash/surface flood**	low; moderate; high	stable; increase	stable; increase	in progress; short-term; medium-term
	River flood				
Climatological	**Drought**				
Meteorological	**Heat wave**				
	Severe wind				

Vicenza											
	Hazard	Sector	Severity			Probability			Time horizon		
			Less serious	Serious	Critical	Rare	Likely	Higly likely	In progress	Short-term	Medium-term
Hydrological	Flash/surface flood	Building & infrastructure		E.g. Flooding from heavy rainfall on private property							
		Transport		E.g. Roads or subways closed to traffic							
		Spatial planning		E.g. Formation of large amounts of runoff in urban areas							
		Agriculture		E.g. Hailstorms in agricultural areas							
		Environment		E.g. Spillage of waste water into water bodies							
		Emergency		E.g. Emergency response							
		Tourism		E.g. Cancellation of public events							
	River flood	Building & infrastructure		E.g. Flooding on private property							
		Transport		E.g. Closure of roads or bridges to traffic							
		Water, supply & sanitation		E.g. Drinking water contamination							
		Waste management		E.g. Increased production of bulky solid waste							
		Spatial planning		E.g. Residential buildings in flood risk zones							
		Environment		E.g. Pollution of water bodies							
		Emergency		E.g. Days of declared emergency							
		Tourism		E.g. Reduced tourist inflow							
Climatological	Drought	Building & infrastructure		E.g. Restriction of water consumption							
		Energy		E.g. Decrease of produced hydro-electric energy							
		Water, supply & sanitation		E.g. Groundwater level							
		Agriculture		E.g. Crop loss							
		Environment		E.g. Minimum vital water flow under guard threshold							
		Emergency		E.g. Interface fires							
Meteorological	Heat wave	Building & infrastructure		E.g. Increased electricity consumption							
		Energy		E.g. Blackouts							
		Water, supply & sanitation		E.g. Increased demand for drinking and irrigation water							
		Spatial planning		E.g. Increased temperatures in urban areas							
		Agriculture		E.g. Loss of crops							
		Environment		E.g. Poor air quality							
		Public health		E.g. Thermal stress							
		Tourism		E.g. Reduction in tourist influx							
	Severe wind	Building & infrastructure		E.g. Detachment of elements from buildings							
		Transport		E.g. Disruption of public services							
		Energy		E.g. Blackouts							
		Agriculture		E.g. Damage to agricultural facilities							
		Environment		E.g. Falling trees							
		Public health		E.g. Damage to persons							
		Emergency		E.g. Days of declared emergency							
		Industrial		E.g. Damage to private movable/immovable property for industrial use							

expected change in intensity and frequency (stable/increase) and time horizon (in progress/short-tem/medium-term) as shown in Table 25.

The second survey is designed to deepen the self-assessment of risk and also to consider the effects that hazards may have on different sectors. Accordingly, for each hazard, local governments were asked to assess its interaction with a list of sectors defined during capacity building meetings. For each sector, a potential impact indicator was given as a non-exhaustive example (Table 26). Administrators assessed the severity of the impact (less serious/serious/critical), probability of occurrence (rare/probable/highly probable) and time horizon (in progress/short-term/mid-term).

The results of these surveys of local risk perception are then analysed and compared in several ways. First, the results of the overall survey are compared with the territorial risk indicators collected in the first chapter of the case study. The aim of this comparison is to understand how well the local perception of risk is aligned with an external risk assessment based on statistical indicators. This first comparison is useful to understand if local administrators are aware of the risks in their territory and which ones they consider as priorities. Secondly, the results of the overall survey and the in-depth survey are compared with each other to see if critical aspects emerge in certain areas that are lost in an overall assessment. Finally, the results of the different surveys are brought together in a system map in order to show which are the risk relationships between hazard and urban systems.

Plan analysis

In order to understand how the municipalities of the case studies intervened, the plans and tools produced by the local administration that were considered most relevant to risk reduction were examined. These documents were analysed according to two methods, both based on reading and understanding the content of the plans.

The first method is to search within some of the planning instruments implemented by the local administration for those modes of intervention that have been attributed to planning in complex contexts in chapter 2.1. These are: planning by masterplanning, planning by coding and planning by development control. This reading and understanding of urban planning tools is returned through the description of the plans' modes of intervention and how they serve to build adaptation, resilience and reduce risk. Understanding how these plans use these modes of intervention, individually or together, serves to highlight how they are acting in practice to govern risk and reduce it.

The second research method examines the planning documents deemed most relevant to understand how the system is described, how action is taken and what co-benefits are generated by the climate action taking place in the case studies. The different documents are read and understood, and then classified within a matrix (Table 27) useful for comparing the plans in the different columns. The first column collects the effects of CC-impacts on urban elements, sectors and systems as described in the documents. The second column collects the ways in which the plan intends to act on the effects described above. The third column summarises the principles of intervention according to the classification constructed in the review of grey literature in chapter 1.2. Finally, the fourth column collects the expected effects of the actions as they are described according to the classification elaborated in chapter 2.2.

The reporting of the results of the reading of the plans in the matrix allows a comparison to be made from two different points of view. The first is temporal, assessing the evolution of these aspects within the plans approved in successive years. This type of comparison is more effective in case studies where there is a certain continuity and experience gained over time in dealing with the effects of climate risks. The second type of comparison is between the different plans and sectors in which they originate, and is therefore a horizontal comparison between different sectors and approaches. This type is effective in case studies where risk reduction aspects take place in different sectors or where sectoral plans pick up actions for mainstreaming in other plans.

Table 27
Example of the matrix used to report the content of the analysed plans.

Effects of CC on urban elements, sectors and systems	Actions for intervention	Principles	Co-Benefits
Description of the effects of CC-impacts on urban elements, sectors and systems	Summary of the ways in which the plan intends to act on the effects previously described	Adaptive Management; Compensatory DRM; Connectivity; Corrective DRM; Diversity and Redundancy; Flexible; Green infrastructure; Grey infrastructure; Inclusion; Inclusive; Integrated; Learning and Innovation; Preparedness; Prospective DRM; Redundant; Reflective; Relocation; Resourceful; Responsiveness; Robust; Self-organisation; Social cohesion; Soft non-structural approaches; Thresholds;	Disaster Risk Reduction; Economic growth; Ecosystem preservation and biodiversity improvement; Enhanced climate change adaptation; Enhanced resilience; Greening the economy; Improved access to and quality of mobility services and infrastructure; Improved access to data for informed decision-making; Improved resource efficiency (e.g. food, water, energy); Improved resource quality (e.g. air, water); Improved resource security (e.g. food, water, energy); Job creation; Reduced GHG emissions; Security of tenure; Shift to more sustainable behaviours; Social inclusion, social justice;

The results that emerge from this analysis are also reported and summarised in the modes of representations elaborated in chapter 1.2. The first one represents a summary of all the interactions cited in the plans analysed for the specific case study and aims to provide a picture of the set of complex relations considered within the data source between the system's elements and the climate change impacts. The second focuses on reporting in a single representation the results related to the principles of intervention contained within the plans considered. This makes it possible to better grasp the similarities and differences between how the various plans intend to intervene.

To complement the research methods presented here, the author had the opportunity to take part in fieldwork, conferences, meetings, focus groups, workshops and research projects in which he explored the themes dealt with in this thesis.

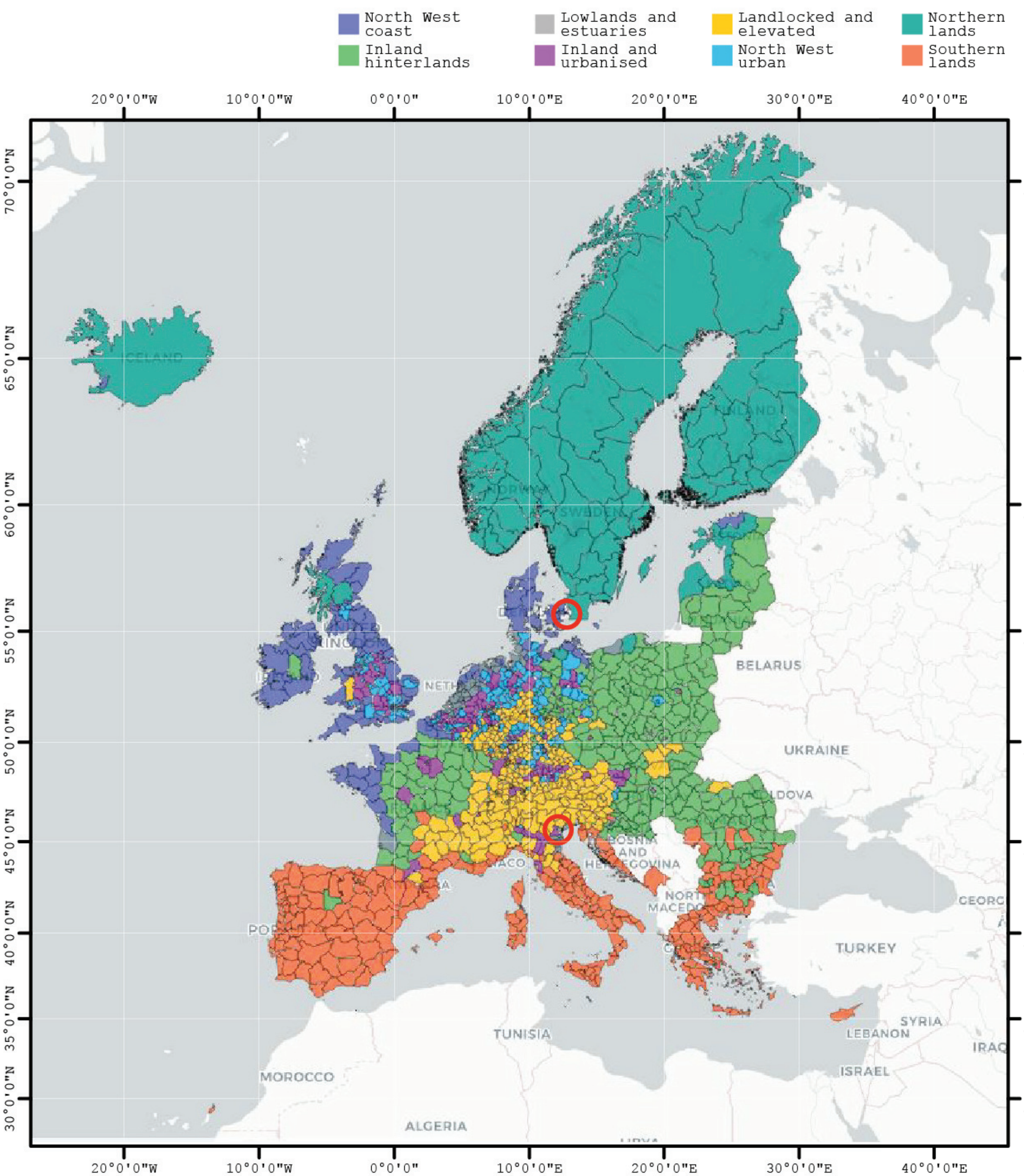
Case studies

In Chapter 2.2 an analysis was conducted that takes into account a large number of European cities, allowing horizontal considerations to be made among a pool of cities potentially representing all European cities. On the other hand, the case study analysis approach chosen allows an intensive study of small numbers of cases to allow close observations to be made at the urban scale. The number of case studies treated according to the case study analysis approach has therefore been limited to two. On the one hand, a larger number of case studies would not have allowed to reach a level of vertical depth that I believe is useful for a comparison with the European horizontal analysis. On the other hand, a single case study would not have allowed a comparison with another case study analysed at the same level of depth.

The two case studies were selected on the basis of a number of criteria including their relation to risk reduction, their size, their geographical representativeness and their belonging to one of the areas most represented in the analysis of chapter 2.2 (Figure 19), and last but not least the possibility of being able to directly observe the contexts within which risk reduction takes place.

The first case study selected is Copenhagen, mainly examined in its municipal boundaries and in systems with varying geometries such as inter-municipal (including Frederiksberg Municipality), metropolitan and regional scale relations. These boundaries are discussed in more detail in the first section (4.1) of the case study. Within the drawn boundaries, Copenhagen is a unitary area in which risk reduction plans and

Figure 20
Location and contextualization of the selected case studie in the European Climate Risk Typology map. Source: Carter, J.G, Hincks, S, Vlastaras, V, Connelly, A and Handley, J. 2018



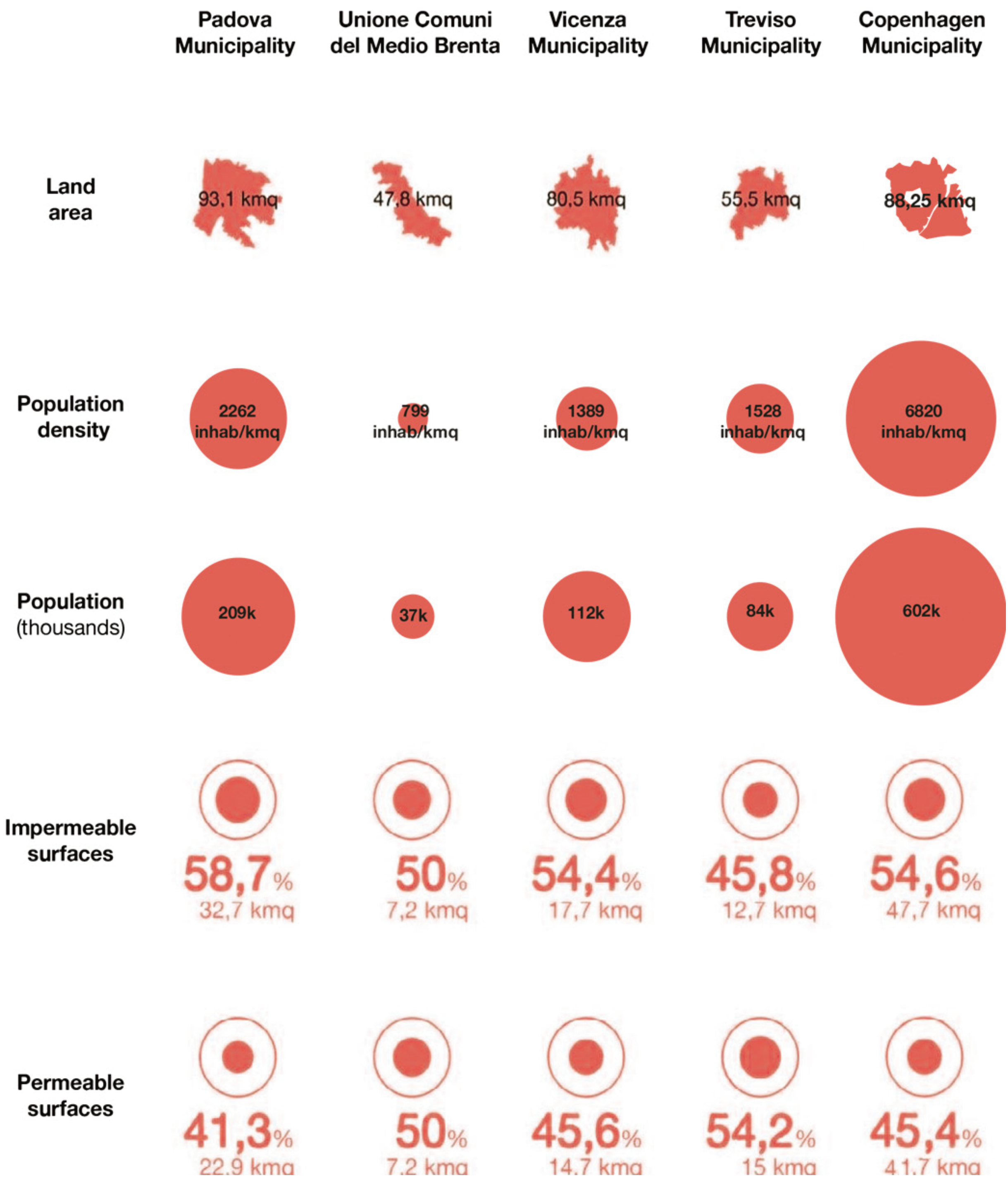
interventions have taken place, especially with regard to water-related risks. It is an excellent case study because of the continuity with which the municipality has developed these policies and was chosen because it allows a reading that accounts for the evolution of these within the system boundaries themselves.

From an urban point of view, Copenhagen is part of a metropolitan system of which it is the centre. The boundaries and extent of this system vary according to the principles by which they are defined, as will be seen below. From a risk point of view, these urban systems are located in the homogeneous risk areas of the North West Coast and the Northern Lands, representing two representative typologies of Central Northern coastal Europe (Hincks, Carter, Connelly, Vlastaras, & Handley, 2018).

The second case study chosen is the Veneto region, in its urban cluster located in the central plain and called Veneto Centrale. The geometry of this cluster varies according to the classifications chosen to define it, and this is deepened in the first paragraph (5.1) of the related case study. In order to analyse this urban cluster, representative urban areas are chosen, which are the Municipalities of Padova, Vicenza and Treviso, all capitals of their respective provinces and medium sized, and the Unione dei Comuni del Medio Brenta, an administrative cluster of small towns. In addition to geographical continuity, Central Veneto is considered a unitary area in this thesis since it is a cluster of cities with similar risks and modes of intervention, where different cities have faced the challenges of climate change through similar planning tools. This allows a cross-sectional reading of the plans produced by individual municipalities, and to draw both punctual and collective considerations. From the point of view of risk, these urban systems are located in the homogeneous risk areas of Lowlands and Estuaries, Inland and Urbanised, Landlocked and Elevated, which represent three typologies representative of a large number of regional areas in Central Europe (Hincks et al., 2018).

The chosen case studies are also a good sample of cities of different sizes according to the OECD classification for European cities (Dijkstra & Poelman, 2012), which divides cities into size classes based on the number of inhabitants (Table 16). The Unione dei Comuni del Medio Brenta falls in the extra-small range, the Municipality of Treviso in the small range, the Municipalities of Padova and Vicenza in the medium range, and the Municipality of Copenhagen in the extra-large range, while the urban cluster of the inner Veneto Central area is in the extra-extra-large range.

Figure 21
Comparison table of municipalities chosen as case studies.


Padova Municipality
Unione Comuni del Medio Brenta
Vicenza Municipality
Treviso Municipality
Copenhagen Municipality
Land area
93,1 kmq
47,8 kmq
80,5 kmq
55,5 kmq
88,25 kmq
Population density
2262 inhab/kmq
799 inhab/kmq
1389 inhab/kmq
1528 inhab/kmq
6820 inhab/kmq
Population (thousands)
209k
37k
112k
84k
602k
Impermeable surfaces
58,7% 32,7 kmq
50% 7,2 kmq
54,4% 17,7 kmq
45,8% 12,7 kmq
54,6% 47,7 kmq
Permeable surfaces
41,3% 22.9 kmq
50% 7.2 kmq
45,6% 14.7 kmq
54,2% 15 kmq
45,4% 41.7 kmq

PART II EMPIRICAL FRAMEWORK: EUROPEAN CASE STUDIES

This part is dedicated to analysing two case studies to better understand the dynamic and evolving context of European cities. In the two chapters, close observations are made at the urban scale, considering the context in which they occur, the planning tools used, and the relationships and forms established. Each of the two chapters follows a common structure, both in terms of the methods used and the reporting of results.

Chapter 4 - Copenhagen

4.1 Context for action

System's boundaries

Administratively, the Municipality of Copenhagen is part, together with 28 other municipalities, of the Capital Region of Denmark (Region Hovedstaden), the easternmost administrative region of Denmark (Figure 22). However, there are several overlapping boundaries in this area, clustering different parts of the territory according to classification and purpose. For example, Copenhagen is also the centre of Metropolitan Copenhagen, an area that includes the Hovedstaden Region and extends into part of the Zealand Region. The boundaries of this area are defined according to what is called the commuter belt, i.e. an area that has a densely populated urban core and its less-populated surroundings but which are united by continuity of economic, people and infrastructure interactions. The boundaries of Metropolitan Copenhagen, albeit with some differences and changes over time, coincide with the mobility infrastructure defined since the Finger Plan of 1947. This shows how the continuity of infrastructure plays a crucial role in defining the boundaries of a metropolitan area, as it is essential for day-to-day exchanges. These areas are also part of the cross-border Øresund Region, also known as Greater Copenhagen, the metropolitan region that comprises eastern Denmark (including Hovestaden and Zealand) and Skåne in southern Sweden. Some classifications also include the Region Halland in Sweden. This area is defined by the continuity of economic interests in the region and a common labour market, facilitated by mobility infrastructure and a shared administrative committee (Figure 23).

In Eurostat's classification, the European Commission's database, within the region there are several urban centres and their associated functional urban areas. This classification is based on the division of the territory in Local Administrative Units (LAU), which are related to local and low level administrative divisions, ranked below a province, region or state. An LAU is classified as a city when the majority of the population lives in an urban centre of at least 50000 inhabitants. The commuting zone contains the surrounding travel-to-work areas of a city where at least 15% of employed residents work in the city. A functional urban area consists of a city and its commuting zone. Therefore, functional urban areas consist of a densely inhabited city and a less densely populated commuting zone whose labour market is highly integrated with the city (Dijkstra et al., 2019; Eurostat, 2018; OECD, 2012). Copenhagen, Malmo, Lund and Helsingborg are the centres in the region, with their functional areas extending through the transport network. (Figure 24)

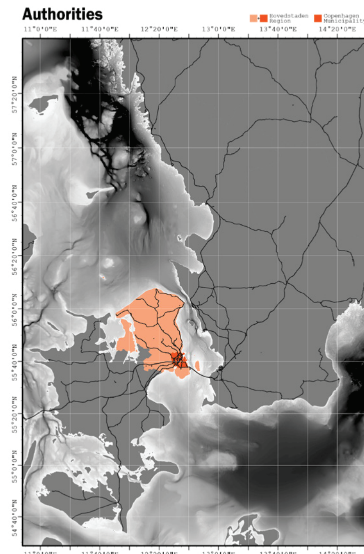


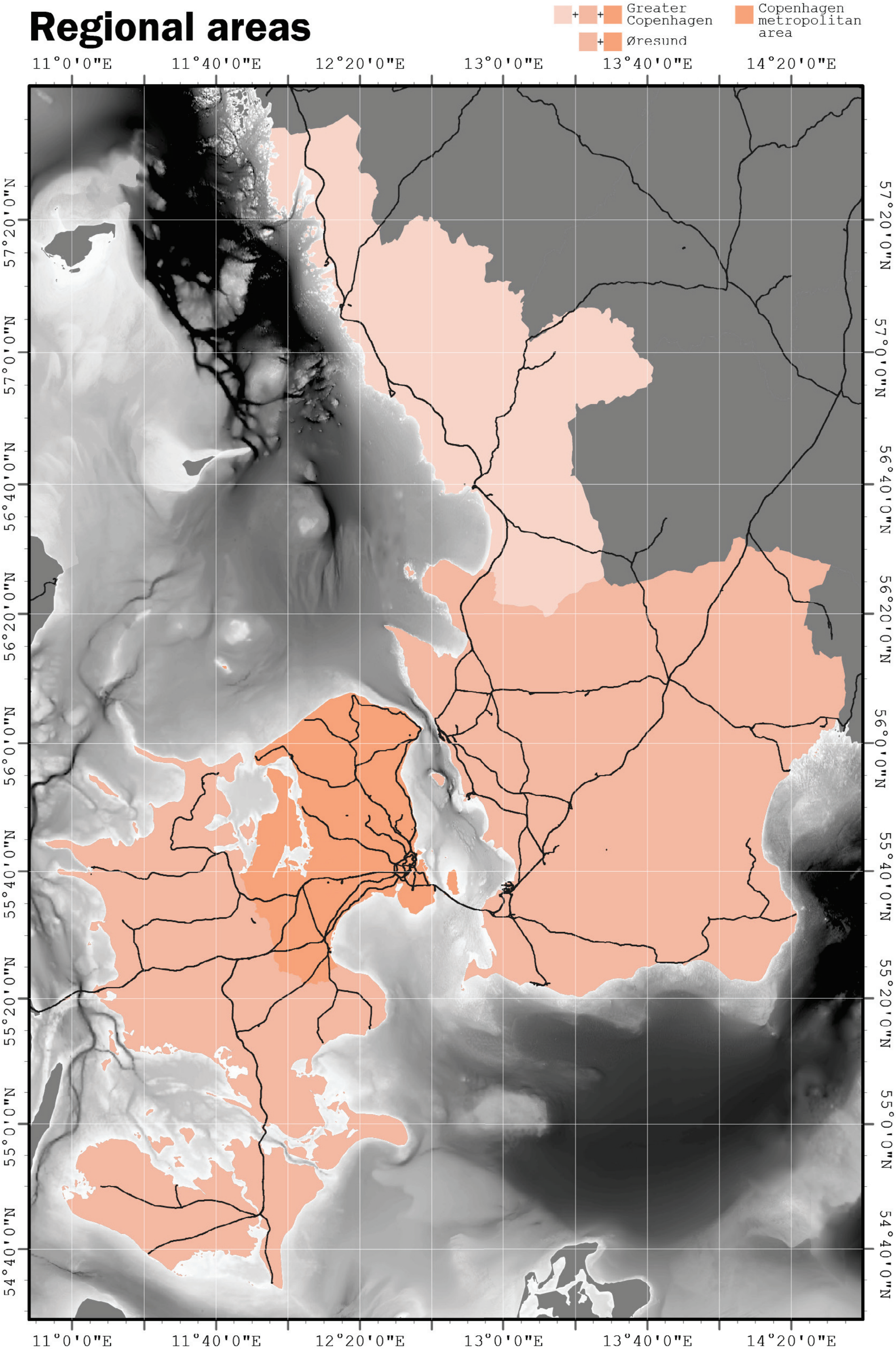
Figure 22
Areas of Hovestaden Region and Copenhagen Municipality

Figure 23
Different regional and transboundary areas. Greater Copenhagen in certain classification includes also the Halland Region. Other classifications recognize only the areas included in the Øresund Region in this map. The Copenhagen Metropolitan Area stretches through the six fingers of the Finger Plan.

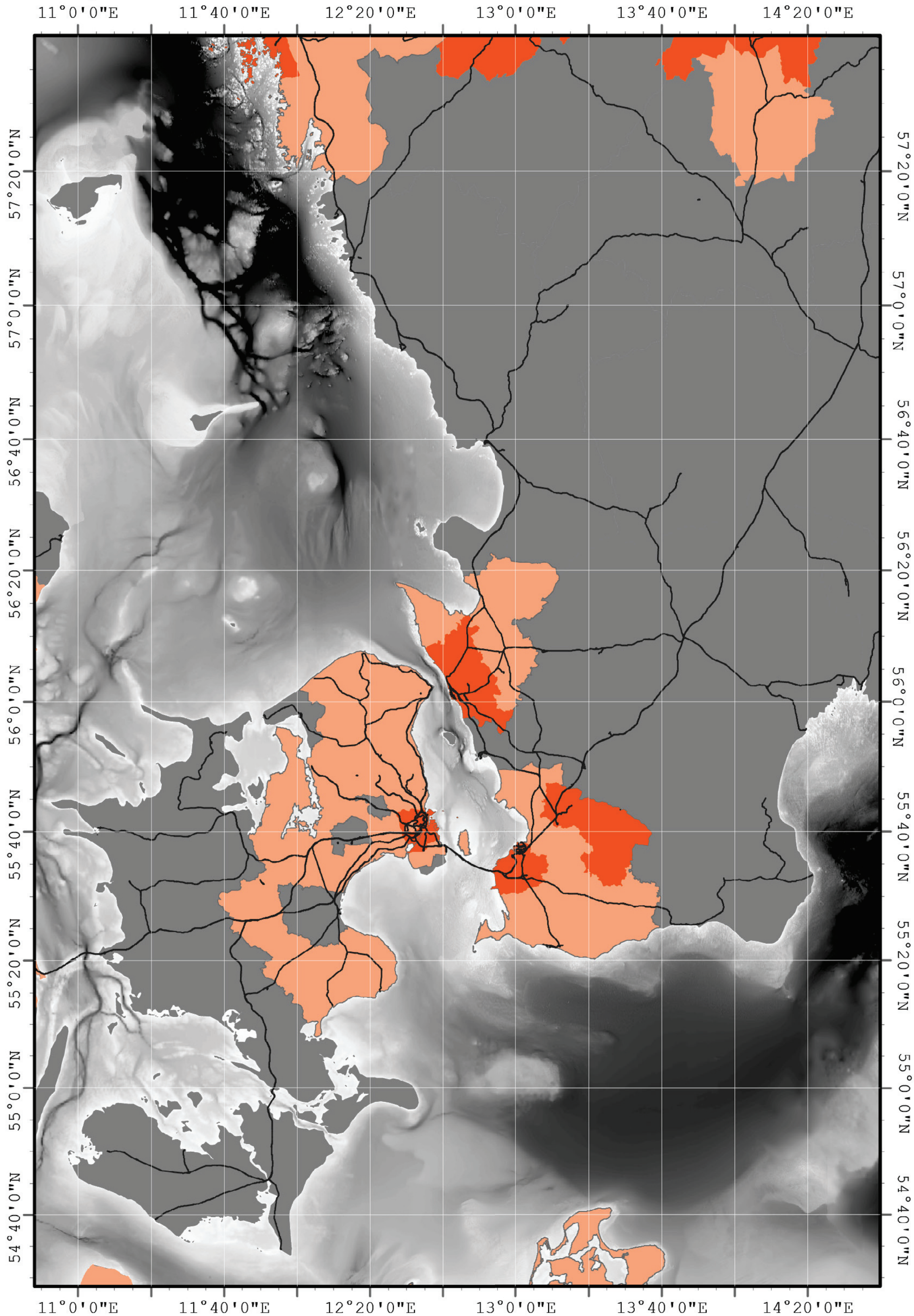
Figure 24
City centres and their Functional Urban Area. Data source: (Urban Audit, 2018)

Figure 25
Degree of urbanization. Data source: (Urban Audit, 2018))

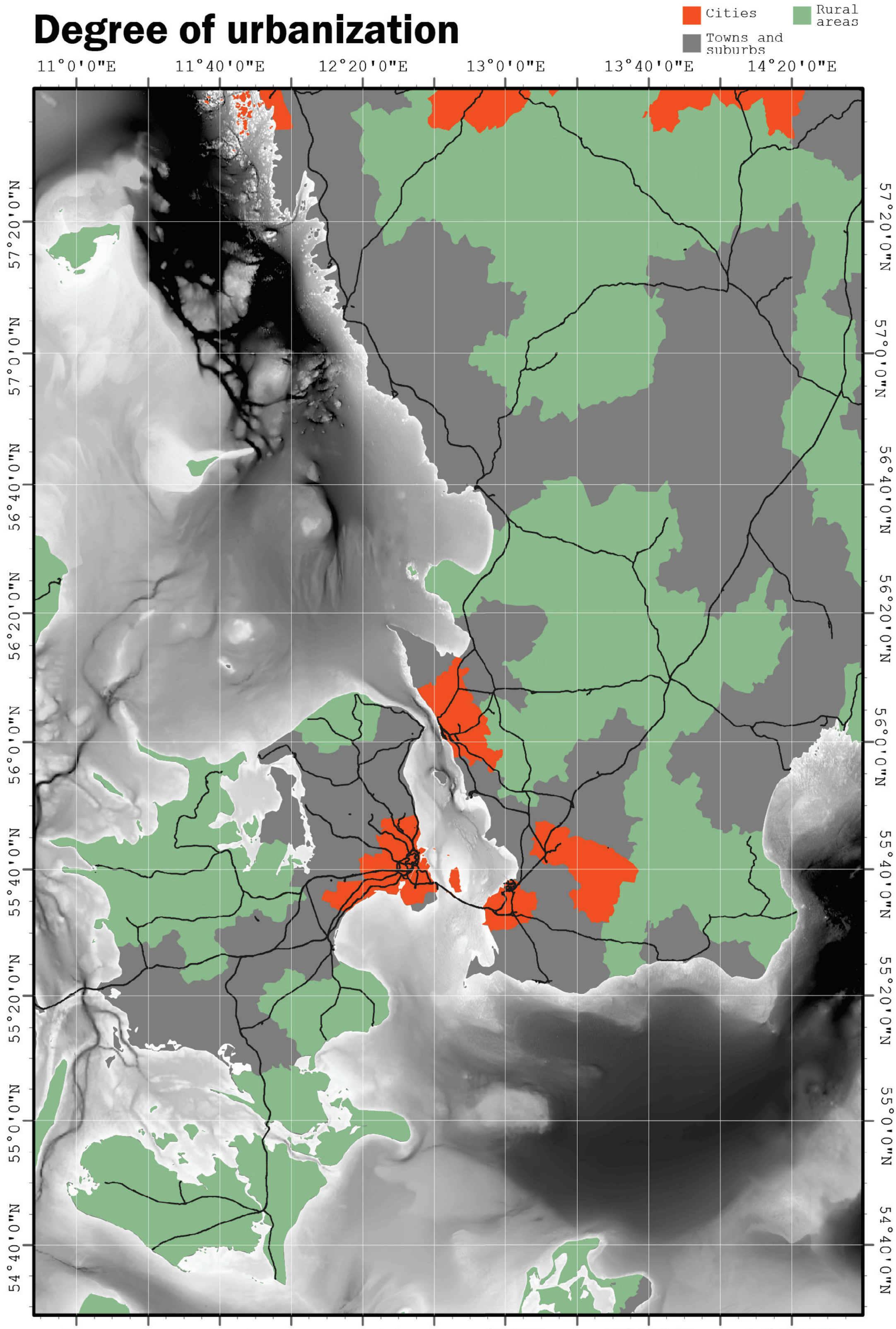
Regional areas



City centres and Functional Urban Area



Degree of urbanization



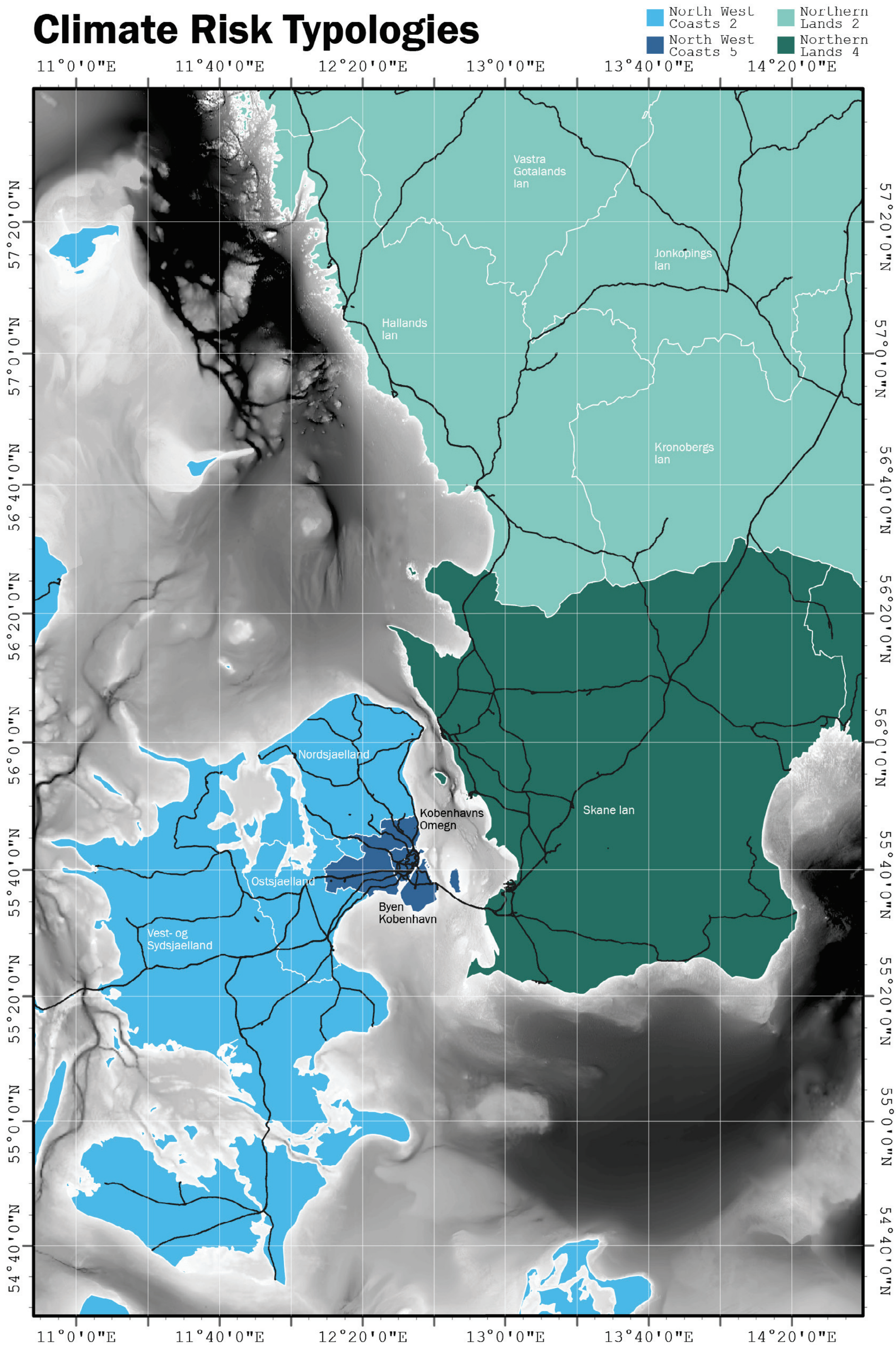
The division into functional urban areas and city centres allows us to understand that cities have an area of influence greater than their administrative boundaries. They are the barycentre of a constellation of neighbouring areas in terms of daily movements. In addition to this functional aspect, urban areas are also larger in terms of the physical dimension of urban space. By classifying areas according to the population living in urban environments, new boundaries of urban continuity can be drawn. Figure 25 represents precisely this continuity of density of urban residents. Densely populated LAUs, i.e. where at least 50% of the population lives in urban centres, are classified as cities. Medium-density LAUs, where less than 50% of the population lives in rural grid cells and less than 50% of the population lives in urban centres, are classified as towns and suburbs. Finally, thinly populated areas where more than 50% of the population lives in rural grid cells are classified as rural areas.

Units of Climate Risk

The boundaries of a system can also be drawn on the basis of homogeneity in terms of risk. The combination of physical, climatic and capacity characteristics allows areas to be aggregated into similar typologies. This typology of climate risk is based on NUTS3 statistical units, which contain a variable number of LAUs. This is the third level of the classification of the European territory into Statistical Territorial Units set up by Eurostat as a single, coherent system for dividing up the EU's territory in order to produce regional statistics for the Community. NUT3 units divide the territory based on administrative boundaries and a population threshold between 150000 and 800000 inhabitants. Based on these units, a comprehensive classification of the whole EU's territory on climate risk has been developed (Hincks et al., 2018). Based on this database (J.G Carter, Hincks, Vlastaras, Connelly, & Handley, 2018), regional and local climate risk characteristics can be drawn in general terms and identify typologies (Figure 26). The following paragraphs summarize the most relevant elements of risk for the regions that are related to Copenhagen. Data and descriptive texts are part of the European Climate Risk Typology (J.G Carter et al., 2018). The classification of regions that share common climate risk components allows a comparison between regions not only in terms of risk but is also the first step in comparing shared modes of response, adaptation and resilience. For this reason, regions are first described textually and according to indicators following the division of the classes and sub-classes to which they belong. Finally, the specific regions are described according to the most significant indicators and compared in Table 28. For a full list of the indicators considered and their values for each of the NUTS3 area in the region, please refer to Annex III.

Figure 26
Climate Risk Typologies for the area. There are two main types of territory in the area: North West Coasts and Northern Lands. These have two subclasses each with different characteristics.

Climate Risk Typologies



North West Coast

The Danish side of the Øresund region belons to the Northern Coast class (Figure 26). This class covers the majority of the coastal zones of the UK, northern France and Denmark. Parts of Belgium, Netherlands and northern Germany are also included. Coastal hazards are a particular feature of these cities and NUTS3 regions (Figure 27). Given the relatively high urban population densities and numbers of transport nodes in these areas, this translates into high levels of exposure of people, settlements and infrastructure to coastal hazards in comparison to other parts of Europe. Conversely, exposure to fluvial flooding and landslide hazards is relatively low from a European perspective. The number of young people is projected to increase as is migration, and there is relatively good access to broadband and high internet bandwidths. These factors can help moderate vulnerability levels to coastal hazards, although the high degree of exposure to this hazard places climate change as a key risk to economic development and health and well-being.

North West Coast 5

The Municipality of Copenhagen and its immediate surroundings are part of the sub-class North West Coast 5, as do many of the principal cities in this class. Relative to cities and NUTS3 regions within the other North West Coast sub-classes (Figure 28), North West Coasts 5 has the following distinguishing features and characteristics: lower fluvial flooding, wildfire and landslide hazard; denser transport infrastructure; higher broadband and NGA provision; lower exposure of people and transport infrastructure to fluvial flooding and landslide hazard; higher exposure of people and transport infrastructure to coastal hazard; higher water consumption pressure; higher projected change in population and numbers of older and younger people; higher urban population density and proportion of built-up urban area. Other indicators are around the average for the North West Coasts class.

North West Coast 2

On the Danish side, the rest of the Øresund region falls into the sub-class of North West Coast 2, as much of Denmark does. This sub-class does not include major cities and urban areas, but its NUTS 3 regions are nevertheless relatively urbanised in nature. Relative to cities and NUTS3 regions within the four other North West Coast sub-classes (Figure 28), North West Coasts 2 has the following distinguishing features and characteristics: higher fluvial flood hazard, lower landslide hazard; higher projected increase in mean temperature; lower projected increase in the number of consecutive dry days; higher projected increase in the number of consecutive wet days; higher provision of critical infrastructure; higher exposure of people and transport infrastructure to fluvial flooding and coastal hazard, and lower exposure to landslide.

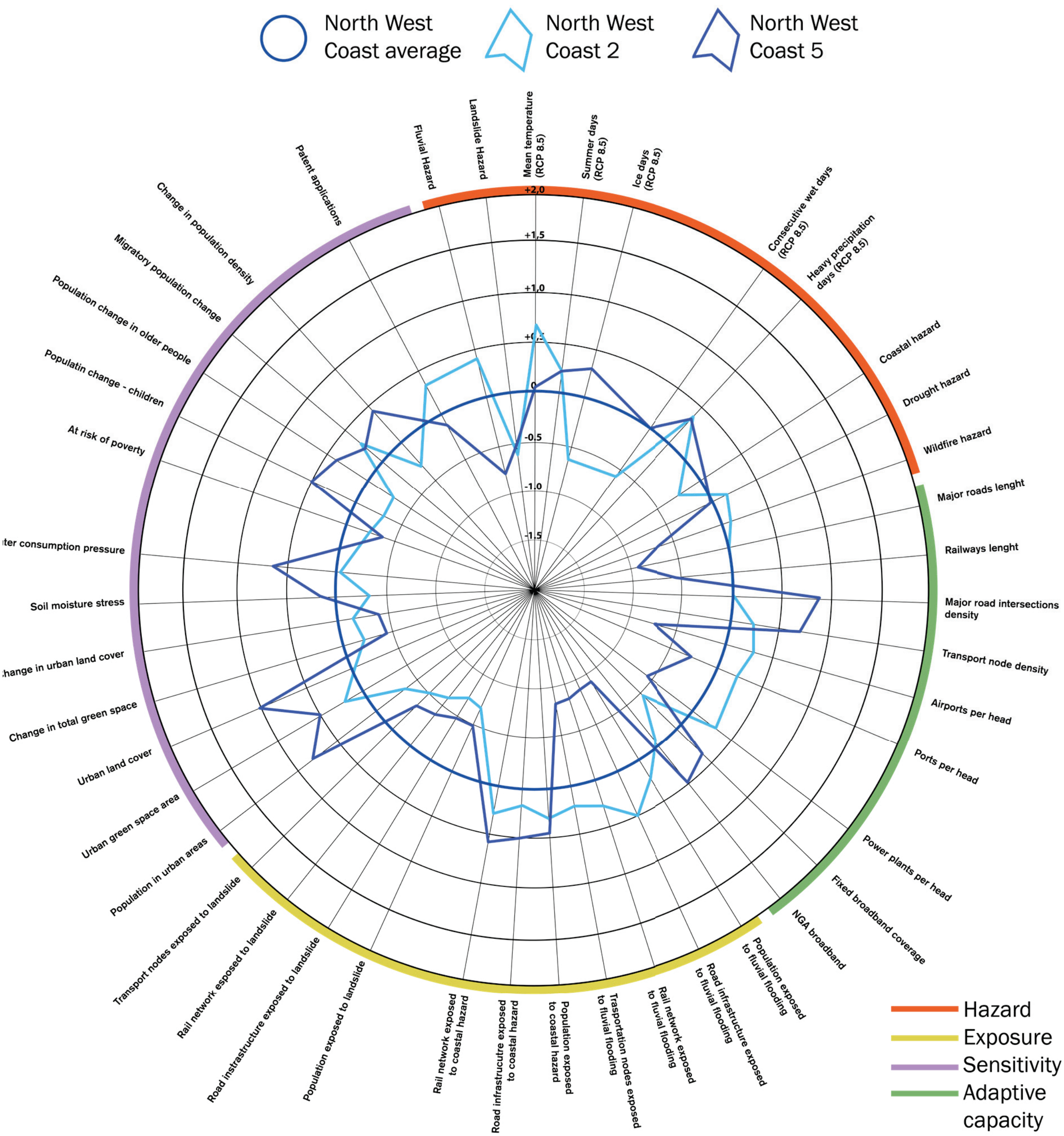


Figure 28

Comparison of the two subclasses belonging to the North West Coasts class. The mean North West Coasts average of all the typologies in this class is kept as the reference level. For each indicator, data is represented compared to this average. Indicators are grouped into four categories, based on risk components: Hazard, Exposure, Sensitivity, Adaptive Capacity. Data source: (Carter et al., 2018).

Northern Lands

The Swedish side of the Øresund region belongs to the Northern land class as most Scandinavia does. Although temperatures are nevertheless rising at a higher than average rate for Europe, these are cool and wet areas, with the number of ice days projected to fall significantly. They are also projected to experience a significant increase in heavy and very heavy precipitation days compared to other European locations, which may increase the chance of surface water flooding in some areas. Coastal hazards are a threat, which results in high exposure of people, settlements and critical infrastructure to this hazard. These are often large areas with relatively low urban population densities and many smaller rural settlements. Urban areas have high levels of green space, and are not densely built up. Broadband and bandwidth capacity are relatively low, as is the density of transport networks with low road intersections and transport nodes. Due to low population densities, the number of critical infrastructure assets per 1000 people (e.g. airports, hospitals) is high from a European perspective. Socio-economically, these are affluent and dynamic places with projected increases in migration and numbers of young people over the coming decades. This increases their capacity to adapt to the changing climate and lessens their level of climate risk.

Northern Lands 4

The Swedish Skane belongs to the sub-class Northern Lands 4, as several Scandinavian capitals (including Stockholm and Helsinki) and key urban areas (including Malmo and Stavanger). All regions are coastal. Relative to cities and NUTS3 regions within the three other Northern Lands sub-classes (Figure 29), Northern Lands 4 has the following features and characteristics: higher fluvial flood and coastal hazard; higher projected increase in the number of summer days and continuous dry days; higher projected increase in the number of very wet days; higher exposure of people and transport infrastructure to coastal hazard; higher density of transport infrastructure; higher broadband coverage and NGA provision; a higher proportion of built-up urban area; greater projected change in older and younger people and migration; higher performance on economic indicators. Other indicators are around the average for the Northern Lands class.

Northern Lands 2

Certain classifications include the Swedish Halstad region in the Greater Copenhagen Region (Nordregio), which belongs to the sub-class Northern Lands 2, as the majority of Sweden. These are generally sparsely populated areas, with significant forest cover punctuated by numerous lakes. Relative to cities and NUTS3 regions within the three other Northern Lands sub-classes (Figure 29), Northern Lands 2 has the following distinguishing features and characteristics: higher fluvial flooding; drought and

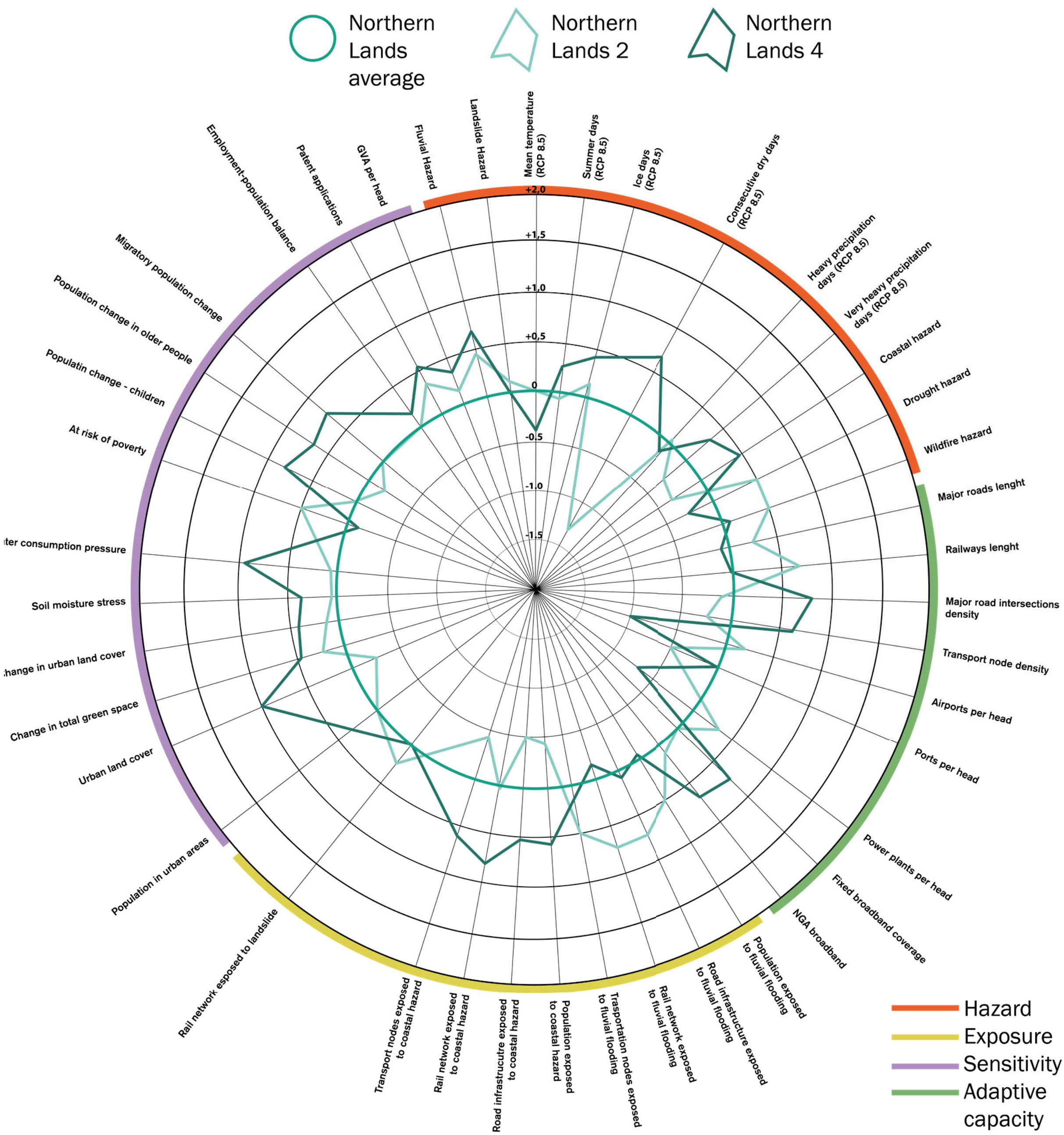


Figure 29

Comparison of the two subclasses belonging to the Northern Lands class. The mean Northern Lands average of all the typologies in this class is kept as the reference level. For each indicator, data is represented compared to this average. Indicators are grouped into four categories, based on risk components: Hazard, Exposure, Sensitivity, Adaptive Capacity. Data source: (Carter et al., 2018).

wildfire hazard; lower projected increase in the number of continuous dry days; higher exposure of people and infrastructure to fluvial flooding; lower exposure of people and transport infrastructure to coastal hazard; a higher proportion of people at risk of poverty; higher performance on economic indicators (including GVA and patent applications). Many of the climate risk indicators are around the average for the Northern Lands class.

Table 28
Most significant risk indicators for the specific NUTS3 regions in the Greater Copenhagen area. Source: (J.G Carter et al., 2018). Please refer to the Annex for complete data on these areas.

Name		Vest- og Sydsjaelland	Ostsjaelland	Nordsjaelland	Kobenhavns Omegn	Byen Kobenhavn	Skane lan	Hallands lan
sub-class		NWC2	NWC2	NWC2	NWC5	NWC5	NL4	NL2
Hazard								
Projected change in mean temperature (RCP 8.5)	°C	1.7	1.7	1.7	1.7	1.7	1.8	1.8
Projected change in maximum temperature (RCP 8.5)	°C	1.6	1.6	1.6	1.7	1.7	1.7	1.7
Projected change in tropical nights (RCP 8.5)	N°	1	1	1	1	2	1	1
Projected change in frost days (RCP 8.5)	N°	-27	-31	-30	-30	-27	-31	-31
Coastal hazard	%	1.2	1.4	1.3	1.1	1.0	1.1	1.5
Drought hazard	%	16.7	18.7	18.2	18.7	3.9	12.3	17.2
Hazard								
Projected change in mean temperature (RCP 8.5)	°C	1.7	1.7	1.7	1.7	1.7	1.8	1.8
Projected change in maximum temperature (RCP 8.5)	°C	1.6	1.6	1.6	1.7	1.7	1.7	1.7
Projected change in tropical nights (RCP 8.5)	N°	1	1	1	1	2	1	1
Projected change in frost days (RCP 8.5)	N°	-27	-31	-30	-30	-27	-31	-31
Coastal hazard	%	1.2	1.4	1.3	1.1	1.0	1.1	1.5
Sensitivity								
Population density	Ratio	90.5	295.0	310.4	1538.5	4129.1	115.1	56.0
Total population living in urban areas /area in km2	Ratio	1119.8	1271.9	1152.0	1949.9	5059.7	1535.6	1006.9
Change in population density in NUTS3 unit between 2017-2050	%	0.0	2.0	0.1	11.0	50.1	0.9	0.5
Migratory population change in NUTS3 unit between 2017-2050	%	0.9	16.1	0.9	37.6	91.9	98.8	28.3
Soil moisture stress	N°	28.5	33.6	31.6	61.0	67.2	51.7	33.7
Water consumption pressure (2030)	mm/ 25km^2	8.3	6.8	6.3	30.1	47.9	7.6	2.9
Adaptive capacity								
Urban area classified as green space	%	2.0	3.4	3.6	11.4	8.5	6.6	5.9
Change in total green space	%	-0.4	-0.0	0.4	0.5	0.4	13.7	6.2
Urban land cover	%	4.4	14.2	21.9	70.2	117.5	5.4	3.9
Change in urban land cover	%	-0.2	-0.0	0.1	0.2	0.2	2.2	2.8

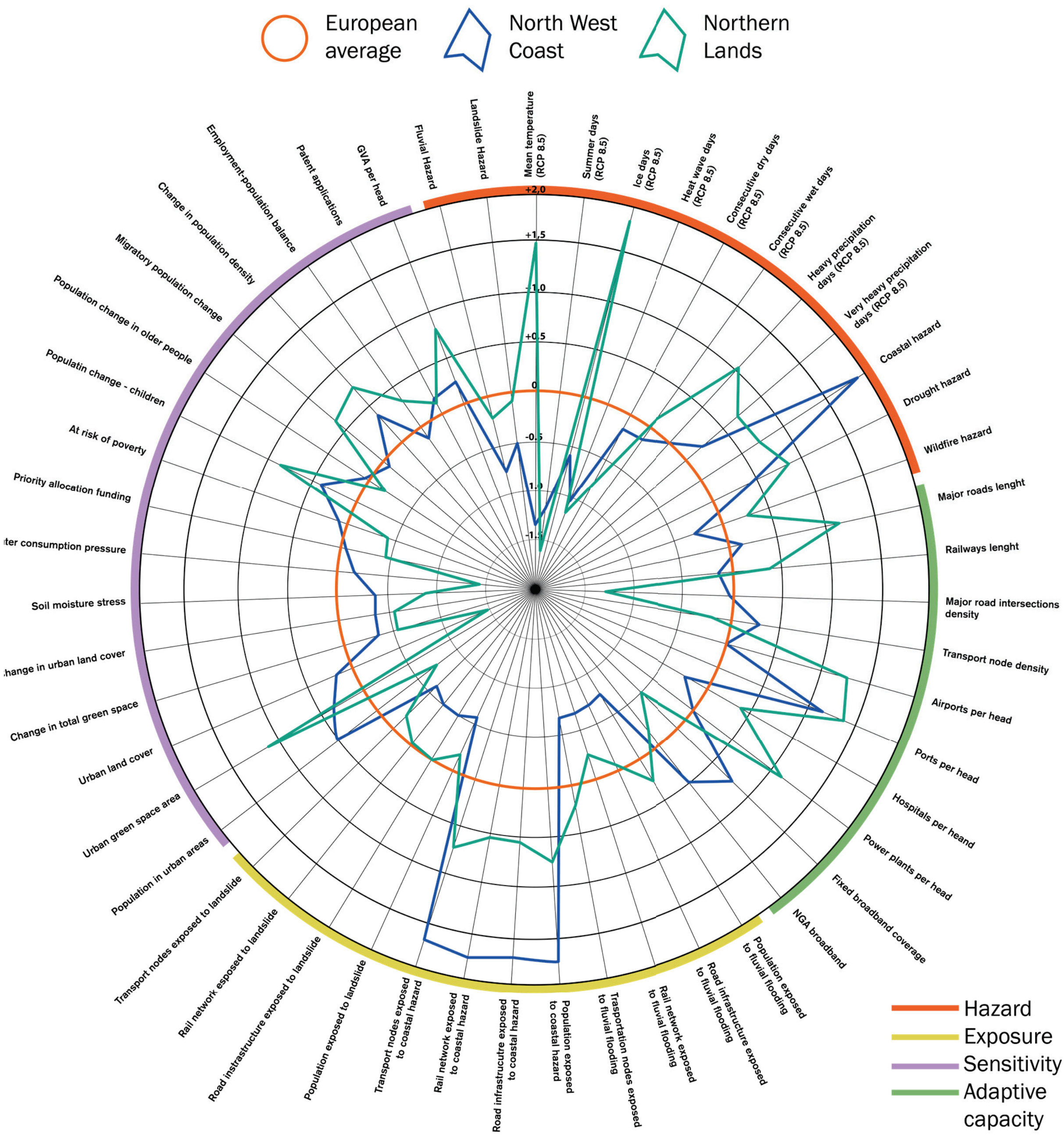


Figure 27

Comparison of North West Coasts and Northern Lands typologies. The mean European average of all the typologies is kept as the reference level. For each indicator, data is represented compared to the European average. Indicators are grouped into four categories, based on risk components: Hazard, Exposure, Sensitivity, Adaptive Capacity. Data source: (Carter et al., 2018).

4.2 System's capacity: planning adaptation

Denmark has a long history of climate awareness. Since the Brundtland report of 1990, Denmark has included these aspects in national and spatial planning, and the 2007 Planning Act set the course for supporting sustainable development in planning at the local level. The Planning Act and its subsequent reviews have updated spatial planning legislation and spatial planning instruments to pursue the sustainable development of cities and the countryside, emphasising strategic planning, spatial regeneration, protection of urban environments from the impacts of climate change and efficient use of resources in line with the Agenda 21 framework. The Planning Act has continued in decentralising and now delegates responsibility for spatial planning to the Minister for the Environment, regional councils and local councils. The government is responsible for ensuring national planning interests, while the regional councils develop general strategic plans for each of the 5 regions. Local councils are responsible for planning in both town and country, this means that local authority planning is the main type of planning for development and land use at the local level (NST, 2012). Local Authorities are called upon to shape planning at local level through a strategy document, which they must publish within two years of the elections, and a Local Authority Plan to which guidelines, local plans and sectoral plans then refer. Finally, through Local Plans, Local Authorities concretise strategies and objectives by defining the rules according to which land can be used and developed. They regulate how future development can take place by controlling various aspects, from ratios to architectural features. In defining the rules for development and in defining the areas and the forms these must have - each Local Plan must contain at least one map - this type of plan uses planning approaches that are both code-based and design-based.

The planning by development control approach is employed for the Environmental Impact Assessment (EIA) mainly as part of local authority planning and in compliance with Denmark's rules based on the EU Directive previously described. The local council generally carries out this assessment as well as the Ministry of the Environment for certain types of construction (e.g. main infrastructure, tall wind turbines), or if they deem it necessary they can ask private developers to submit an EIA. An EIA is a thorough assessment of the impacts that the project may have on several systems, the main one being the environment but also taking into account people, landscape, resources and not least the climate. This assessment then allows us to understand if there are alternatives or modifications to the project that can improve it from this perspective, reducing the impact on the

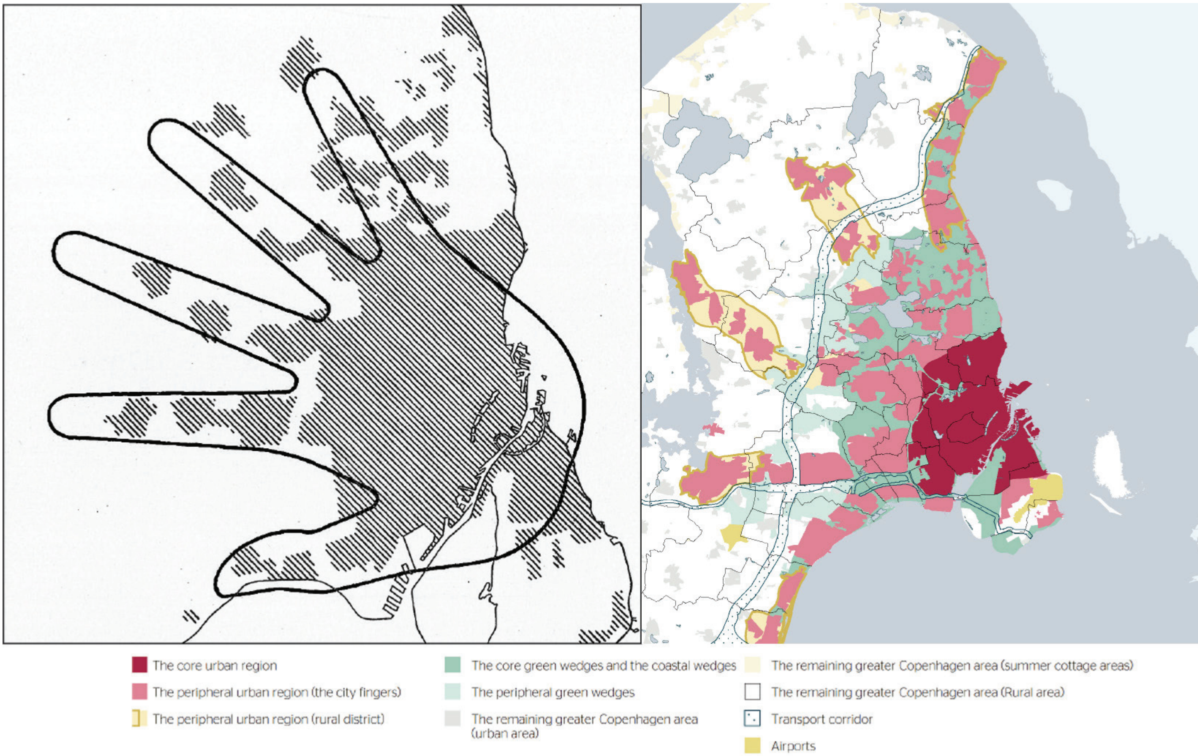


Figure 30
Greater Copenhagen Finger Plan. On the left the 1948's concept, on the right the 2019 map of the different areas in the contemporary Finger Plan: the core urban region; the peripheral urban region (the city fingers and the rural districts); the core green wedges and the coastal wedges, the peripheral green wedges. Source: (Ministry of the Environment, 2019)

environment or exploiting favourable synergies. This process is open to the public, and the documents are open for comment, encouraging participation and giving citizens a voice. An EIA generally consists of an overview of the project alternatives that have been assessed, a description of the effects that the project may have on sensitive elements (flora and fauna, people, climate, soil, air, water, landscape), an assessment of the short- and long-term effects on the environment, and finally the presentation of measures within the project to reduce the impact. The overall environmental assessment and the results of the public consultation give the local council a good background for deciding on the project and any conditions attached to the approval. Through this development control process, project applicants are asked to modify their proposal in order to provide benefits to the applicants, their neighbours, the climate and the environment. (NST, 2012)

With the areal distinctions before mentioned, the area around Copenhagen is one cohesive housing and labour market. The Ministry of the Environment prepares the plan for this metropolitan area. The structure of the metropolitan plan lays its foundations on the principles set since the first finger plan adopted in 1948, and these aim to ensure a clear demarcation between town and country and combine urban development with public transport. The following reviews of the plan, including the latest Finger Plans (Ministry of the Environment, 2015, 2019), continued on this approach in concentrating urban development in Copenhagen in the fingers created by the railway network and the radial road network and leaving the green areas between the fingers undeveloped. This continuous structure has now been developed further, stretching the green areas also in the dense urban centre of Copenhagen, providing recreational green and cycle accessibility. In these green wedges, climate change adaptation projects are also eligible, provided they are in continuity with the recreational purpose of these areas.

Copenhagen has placed sustainable development at the heart of its strategies, becoming one of the models for experimentation and innovation in these areas. For several years, Copenhagen has been recognised as a leading city in this sector, thanks to the remarkable results achieved in green mobility, adaptation to climate change, and mitigation policies, which have earned it numerous awards, including that of European Green Capital 2014.

Municipal Planning

The foundations for these achievements have been laid through various planning instruments, starting from the 2007 update of the New Sustainable Copenhagen strategy, which the 2009 Municipal Plan then followed up. The sustainability principles developed in this strategy which then took shape in the plan, included promoting Copenhagen as highly environmentally sustainable, aligning with the path set out in the national Planning Act. In addition, through the Municipal Plan, the Municipality of Copenhagen sets out guidelines for developing land, services, and built environment by applying local planning regulations and strict development control managed by the City.

The municipal plan establishes the combined regulation of expansion of housing, transport, services, open spaces. In addition, the Municipal Plan contains binding guidelines for the municipality's administration on several topics laid down in the Planning Act. The municipal plan is primarily concerned with designating areas for urban development. If areas are judged to be particularly at risk from groundwater, seawater or stormwater flooding, they can be kept clear of buildings and designated for purposes where there is no water vulnerability. Requirements can also be set for building development on elevated terrain or protected against flooding, even if this is typically implemented in local plans.

The municipal plan can reserve areas for technical facilities, for example, collecting and retarding basins for stormwater or dikes and locks for floods from the sea. The plan can also regulate how watercourses, lakes and seas are to be used and designate the areas in the Municipality where permission can be given for local infiltration of stormwater.

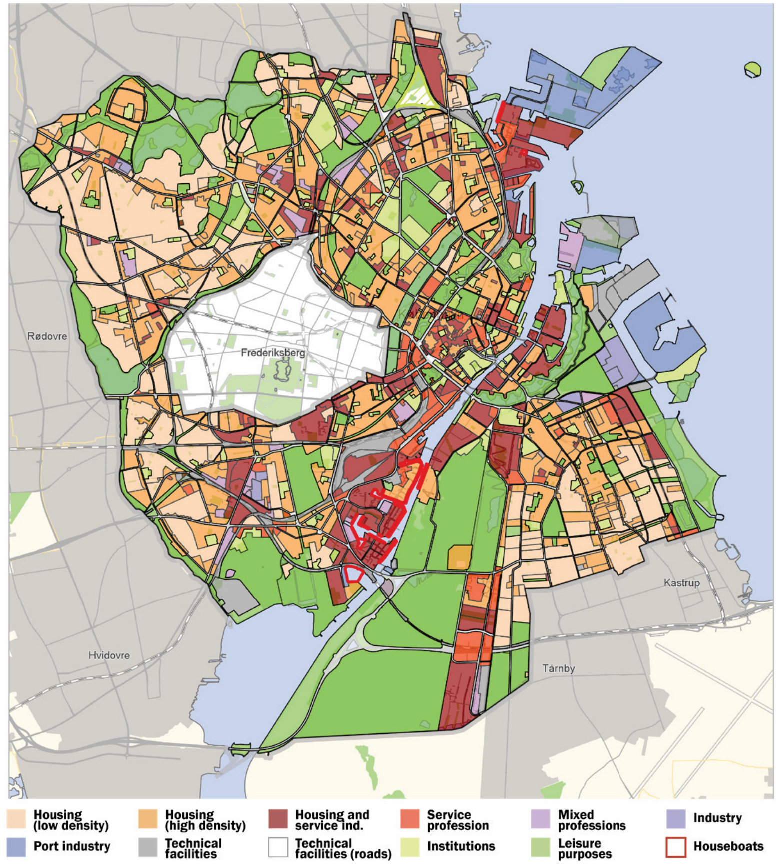


Figure 31
Areas defined by Municipal Plan 2019.

Despite the municipal plan stipulating this, it does not entail a duty to act. In other words, the municipal plan opens up the possibility of use of the areas, but that the plan does not make this use compulsory. In connection with the planning of building work, 'expansion agreements' can be entered into with landowners, which can contribute, for example, to increasing the capacity for local drainage. An expansion agreement expands the options contained in the municipal plan and contains specific, mutually obliging agreements between the planning authority and the landowner.

The municipal plan can counteract high temperatures in the city by controlling land use and open spaces provision. This can be achieved by designating land for green and blue uses, counterbalancing development, or designating development in areas like the harbour, where green and blue spaces mitigate temperature. Buildings with canals, as in Sydhavnn for example, are well protected against local warming. The municipal plan requirement for open spaces ensures access to areas where the temperatures will be lower. In addition, the designation of spaces for leisure purposes and nature protection ensures a high proportion of undeveloped areas in the city, which counteracts warming.

Local planning and building/planning permits

The frameworks for development and land use in the Municipal Plan are created among other planning tools through local plans. The local plan is legally binding on the individual landowner. Local plans cannot, however, regulate everything. The Planning Act indicates what conditions a local plan can regulate on future development, but it cannot oblige to act, and it has limited authority to influence existing urban areas unless they undergo changes that are subject to local planning requirements.

Through local planning, the City of Copenhagen has the option of requiring that construction and open spaces are designed in such a way as to counteract and reduce the impact of climate. To avoid flooding from groundwater or the sea, the Municipality has an option connected with local planning to ensure that new building work is done on higher ground or prevent development in areas at risk. On the other hand, for areas where the water table is expected to fall, the plan may, after verifications, provide for areas of rainwater infiltration. Local planning can designated areas and require SUDS to be integrated in new developments to reduce flooding, improve water quality, and reduce water consumption. Local plans can also set new developments to include trees in open spaces as shading and cool spots and to consider strong wind in designing open spaces.

In compliance with the Building Act, one of the building regulation purposes is to ensure that buildings are safe and healthy and can withstand the effects of future climate. Building regulations act predominantly as functional requirements, which means that the developer can choose the methods that are best suited, provided they fulfil the requirements in practical use.

The city of Copenhagen can set requirements in its building permits for documentary evidence that the proposed design fulfils specific standards and principles. Buildings are to be constructed so that water and moisture from rain, snow, surface water and air humidity do not lead to damage or inconvenience in use, for example impaired durability and poor health conditions. The building regulations contain requirements on how facilities that drain stormwater away from buildings are to be designed, and the guidelines can be adapted to increased volumes of rain.

In new construction, the building can be protected by choice of materials and execution against penetrating water, minor floods, and groundwater's upward force. However, these requirements do not prevent damages in the event of large floods and storm surges.

The regulation also requires buildings to be fairly orientated and windows to be sun screened to ensure comfortable temperature during summer high-temperature days. It also requires buildings to be designed to withstand effects that occur from average wind, while not for the exceptional.

City of Copenhagen Sustainability tool

The City of Copenhagen uses the local planning process to control development through binding regulations and requirements related to the municipal and sectorial plans' different policies. It also uses Copenhagen uses local planning as a valuable tool to ensure that environmental impacts are adequately handled. During the process of defining and approving the transformation and development of several large urban areas, the Municipality of Copenhagen together with private and public institutions, developed the Sustainability Assessment Tool. The tool is a set of questions and criteria for use by developers and project proponents. Through questions and indicators, the Municipality, on the one hand, allows developers to include in their proposal the standards and objectives that the Municipality has set as priorities.

On the other hand, it gives the Municipality a way of assessing transformation proposals and requesting additions during the approval process. The tool serves mainly as a dialogue tool in negotiations (Alkhani, 2020), has no normative value and has no minimum score to reach. However, from the list of questions that the Municipality regularly updates, it is possible to trace the relationships that the project establishes with the context - economic, environmental, social and energy - that the Municipality assesses as

Table 29
Full list of indicators of the Sustainability assessment tool. Source: (Realdania by, 2013). Continues in next page

Environment and resources ELEMENT	INDICATOR	KEY QUESTIONS
Energy	1. Energy consumption for building operation	To what extent will energy consumption for building operation be reduced compared to expected standard requirements in the project period?
	2. CO2 emissions from electricity consumption	To what extent will the CO2 emissions from the district's electricity consumption be reduced compared to the baseline, where all consumption is covered by electricity from the grid?
	3. CO2 emissions from heat consumption	To what extent will the CO2 emissions from the district heating consumption be reduced compared to the baseline, where the otherwise relevant supply mode is used?
Transport	4. Facilities for pedestrians and cyclists	To what extent are solutions in place to encourage people to walk or cycle in the district?
	5. Incentives to use public transport	To what extent is the district designed to facilitate the use of public transport?
	6. Traffic solution	What traffic solution is established and what traffic distribution is prioritised?
Waste and water and waste	7. Rainwater management	How is rainwater managed and what measures are taken to prevent rainwater from being discharged into the sewerage system?
	8. Waste management	How is waste managed and what measures are used to reduce waste and optimise waste sorting?

a priority. This is also a form of planning that serves to define the characteristics of new urban transformations. The complete list of indicators and questions in version 2.0 of the tool is presented in Table 29. Several climate change issues can be recognised in it, both from the perspective of mitigation and adaptation. For mitigation, indicators 1-2-3 and 22-23 are directly related to reducing energy consumption and emissions, and indicators related to transport are indirectly related. For adaptation, indicator 7 concerns rainwater management and the measures put in place to separate it from wastewater, which is one of the main objectives of the Cloudburst Management Plan. Indicator 9 relates to the consideration of local climatic conditions, and is linked to indicator 10, which concerns future climatic conditions and the measures put in place to adapt to them. Finally, indicator 12 concerns the integration of green and blue infrastructure and measures to maximise biodiversity into the project. The appropriate answer to these questions varies according to context and project size. However, a list of what relationships the Municipality considers valuable for a project is a track that ensures clarity between the parties and ensures the municipal agenda's priorities are applied in each new transformation project.

The single standing adaptation plan

The government's 2008 strategy for adaptation to climate change (The Danish Government, 2008) added to sustainable development and reducing greenhouse gas emissions, the need to think about local measures that could deal with the consequences of future climate change. UN Climate Change Conference COP15 hosted by Copenhagen in 2009 marked a turning point in the city's approach to sustainability, energy transition and dealing with climate risks. On that occasion, the Copenhagen Climate Plan was launched to achieve zero carbon emissions by 2025, and the city's initiative to equip itself with tools to adapt to extreme weather events was announced (City of Copenhagen, 2009).

Following this, the Copenhagen Climate Adaptation Plan was developed and published in 2011, which focuses on the relations between the effects of climate change and the urban environment. The aim is the to enhance protection of these areas against climate threats, setting up a knowledge framework that outlines the challenges the city faces in the short and medium terms as a result of expected changes in the future climate. The primary challenges it identifies are the intensification and increased frequency of heavy rainfall events and the progressive rise in sea level combined with exceptional tidal events such as storm surges. Other challenges that the plan includes are rising maximum temperatures and heat island phenomena, the impact of climate change on groundwater, and a range of

Social and health		
Physical	9. Local climate conditions	To what extent have local climatic conditions been taken into account?
	10. Adaptation to changing climate conditions	To what extent are changing local climatic conditions due to climate change taken into account and adapted to?
	11. Security	To what extent has the experience of safety and accessibility in, to and from the district been taken into account?
	12. Green and blue elements in the cityscape	To what extent are green spaces and blue elements an integral part of the urban landscape and how can the highest possible biodiversity be ensured in the city?
Urban life	13. Variation in urban functions	To what extent is variation and diversification in the functions of the city envisaged?
	14. Urban spaces and meeting places	To what extent have urban spaces, meeting places, ground floor functions, etc. been created that encourage people to stay and spontaneous activity and that create communities and local urban life and coherence with surrounding areas?
Health	15. Unorganised physical activity	To what extent are there opportunities for unorganised leisure and sporting activities, both within the district and in interaction with the surrounding area?
	16. Health promotion measures and activities (in addition to sport)	To what extent are there opportunities for health promotion and activities (other than sport) in the district that promote public health?
Diversity	17. Variation in resident segments	To what extent does the district contain structures that provide for an appropriate variety of housing in the city of which the development area forms part?
	18. Activities and space for all	To what extent does the city and urban environment provide activities, space and inclusiveness for all?

Economy		
Economy	19. Pollution and foundations in land development	How are contaminated soil and groundwater and foundations managed, and what significant measures are used to minimise the costs of contamination and extra foundations as part of development?
	20. Infrastructure for development and operation	Which essential solutions in planning, building and operating infrastructure contribute to good overall economy?
	21. Construction and operating costs of future construction	What essential solutions optimise construction and operating costs of future construction?
	22. Socio-economics of the electricity supply solution	To what extent does the electricity supply solution represent a wise use of scarce social resources?
	23. Socio-economics of the heat supply solution	To what extent does the heat supply solution represent a wise use of scarce social resources?

Table 29
Full list of indicators of the Sustainability assessment tool. Source: (Realdania by, 2013). Continues from previsous page

Level 1	The aim is to reduce the likelihood of the event happening, preferably to prevent it completely. At this level is the establishment of dikes, building higher above sea level, local adaptation of sewer capacity, local management of stormwater etc. If measures can be implemented effectively at this level, measures at levels 2 and 3 will not be taken.
Level 2	The aim is to reduce the scale of the event. At this level are warning systems for rain, the establishment of watertight basements, sandbags, adaptation of public spaces so that they can store rainwater etc. If measures at this level can be taken effectively, measures at level 3 will not be applied.
Level 3	The aim is to reduce vulnerability to the event by taking measures that make it easier and cheaper to clear up after an event. At this level are extensive utilisation of basements, emergency preparedness with pumps, etc.

Table 30
Guiding principles for adaptation intervention. Source: (City of Copenhagen, 2011)

indirect consequences related to health, biodiversity, and air quality. How the plan deals with the relationship of these hazards with the urban environment is discussed in more detail in the following chapter 4.3. The plan sets up a roadmap for research, capacity development, and actions, distinguishing different geographical scales of action from regional to building level (Table 30). The uncertainty of impacts due to an evolving framework is recognised, but with this plan the city wants to start to work the earliest possible, to have the time to analyse challenges, identify possible solutions, value opportunities and avoid maladaptation.

Although the plan is based on the disciplinary approach of adaptation to climate change, it also has a risk reduction component. This is present both in the assessment of risks and in the definition of intervention methods. The risk is defined by multiplying the probability by the expected cost of the impact. From this equation, the result is a classification of the risk into intensities that extend from tolerable to non-tolerable risk. In defining how to intervene, the plan provides principles to guide future risk reduction interventions' choice and objectives. This logic is organised into three distinct levels, which are organised according to a preference logic. The first level is the preferred guiding principle for each intervention, if this is not applicable for technical or economic reasons then the choice falls to the second principle, and finally if this also has insurmountable obstacles for application, then the third guiding principle will be the one applied. These principles to guide the intervention approach are shown in Table 30.

These principles are then applied at different scales of intervention and with different purposes, as Table 31, Table 32, and Table 33 show. These tables intersect the different scales of intervention with the different thematic axes of intervention. For intervention geographies, the scales present are regional, municipal, district or neighbourhood, street and building. They include the impacts of heavy precipitations, sea-level rise and storm surge, high temperature and urban heat island, groundwater floods and water scarcity, and a greener city's objective with enhanced biodiversity.

Table 31 presents measures that aim to reduce the likelihood of impacts occurring. These measures mainly concern protection and mitigation approaches, such as building dykes to contain impacts from the sea or establishing green corridors to reduce the heat island effect. The implementation of these intervention principles is aimed at reducing the occurrence of impacts.

Table 32 summarises the measures that aim to reduce the scale of impacts. These measures mainly concern approaches aimed at preparing for and containing the adverse effects of a phenomenon. To this category belong emergency interventions of water containment with sandbags of particularly exposed elements, the provision of groundwater pumps or the establishment of early warning systems. The implementation of these intervention principles is aimed at reducing the severity of an impact.

Finally, Table 33 brings together measures that aim to reduce vulnerability to an impact. These measures mainly concern approaches aimed at relocating elements exposed to impacts. To this category belong interventions aimed at displacing vulnerable functions and installations such as cabins or switchboards. Due to relocation interventions' complex nature, planning is often seen as one of the most appropriate tools.

Other plans/regulations

Several circumstances of significance to adaptation to climate change are governed by special legislation. This applies, for instance, to the drainage of water or the protection against coastal erosion and floods.

The wastewater plan of the City of Copenhagen is drawn up following the Environmental Protection Act. The wastewater plan lays out the division of rainwater and wastewater, storage structures for stormwater during heavy precipitations, and stormwater infiltration options. The Environmental Protection Act requires the plan to be updated under climate change projections.

The law on payment rules for wastewater treatment plants provides some mechanisms to incentivise SUDS practices for both new and existing buildings. For example, if a private individual or building manages rainwater locally and disconnects it from the sewerage system, up to 40% of the connection fee can be reimbursed.

The Floods Act regulates the possibility of compensation in the event of floods and sea storms in the case of events with a return time of more than 20 years. This means that these public reimbursements do not cover the most frequently occurring events, and the individual private owner is encouraged to take out private insurance or to put in place protection systems for these minor events.

Theme Geography	Heavy precipitation	Sea level rise and storm surge	High temperature and urban heat island	Groundwater floods and water scarcity	Greener city and biodiversity
Region	Establishment of retarding basins on separate rain runoffs	Establishment of dikes	Establish green corridors/network with links to green finger plan		Establish green corridors/network with links to green finger plan
Municipality	Disconnection of stormwater using SUDS. Establishments of pumps on runoffs		Establishment of green, continuous structures, preserve and add to the existing green structure and include SUDS solutions	Mapping future groundwater levels.	Establish green continuous networks, preserve and add to existing green structure
District / neighbourhood	Decoupling of stormwater using SUDS. Plan B-solutions on central squares/ sport facilities/ parks	Raised building elevation, dikes	Establishment of green, continuous structures, establish stormwater basins etc., plant trees, preserve and add to the green structure		Establish green continuous networks, establishment of stormwater basins, plant trees, preserve and add to existing green structure by establishing green walls and other green elements, water gardens etc.
Street	Plan B solutions separation of stormwater from sewer		Establishment of green, continuous structures, establish green walls and other green elements, rain gardens, green roofs etc.		Establish green continuous networks, establish stormwater basins, water gardens and similar, green roofs and walls, trees
Building	Disconnection of stormwater from sewer	Raised building elevation		Sealing of basements and foundations.	

Table 31
Protection (level 1) or reduce probability measures in the Copenhagen Climate Adaptation Plan, divided by theme and geography. Source: (City of Copenhagen, 2011)

<table>
<tr><th>Theme

Geography</th><th>Heavy precipitation</th><th>Sea level rise and storm surge</th><th>High temperature and urban heat island</th><th>Groundwater floods and water scarcity</th><th>Greener city and biodiversity</th></tr>
<tr><td>Region</td><td>Protection of vulnerable infrastructure Metro, S-trains, tunnels, cultural assets</td><td>Establishment of warning system for high waters</td><td></td><td></td><td rowspan="2">Planning</td></tr>
<tr><td>Municipality</td><td>Disconnection of stormwater using SUDS Planning</td><td>Planning, warning</td><td>"Promote district cooling of buildings. Planning."</td><td>Pipe sealing and regular maintenance</td></tr>
<tr><td>District / neighbourhood

Street</td><td>Decoupling of rainwater using SUDS. Emergency Management, sandbags etc.</td><td>Preparedness, sandbags etc.</td><td rowspan="2">Planning. Incorporate green solutions into private and public initiatives</td><td rowspan="2">Groundwater pumps</td><td rowspan="2">Planning and specific private and public initiatives</td></tr>
<tr><td>Building</td><td>Backwater valves, sealed basements, Preparedness, sandbags etc.</td><td>Backwater valves, sealed basements, preparedness, sandbags etc.</td></tr>
</table>

Table 32
Preparedness (level 2) or reduce scale measures in the Copenhagen Climate Adaptation Plan, divided by theme and geography. Source: (City of Copenhagen, 2011)

Table 33
Relocation (level 3) or reduce vulnerability measures in the Copenhagen Climate Adaptation Plan, divided by theme and geography. Source: (City of Copenhagen, 2011)

<table>
<tr><th>Theme

Geography</th><th>Heavy precipitation</th><th>Sea level rise and storm surge</th><th>High temperature and urban heat island</th><th>Groundwater floods and water scarcity</th><th>Greener city and biodiversity</th></tr>
<tr><td>Region</td><td colspan="2">Protection of vulnerable infrastructure Metro, S-trains, tunnels, cultural assets</td><td></td><td rowspan="2"></td><td rowspan="2">Planning</td></tr>
<tr><td>Municipality</td><td>Planning</td><td>Planning, preparedness</td><td>Planning</td></tr>
<tr><td>District / neighbourhood

Street</td><td>Moving electrical cabinets for light regulation, pumping stations etc. from low-lying points</td><td rowspan="2">Moving of vulnerable functions and installations</td><td rowspan="2">Planning. Incorporate green solutions into private and public initiatives</td><td rowspan="2">Moving of vulnerable functions and installations</td><td rowspan="2">Planning and specific private and public initiatives</td></tr>
<tr><td>Building</td><td>Move vulnerable functions away from basement level (service rooms, electrical panels etc.)</td></tr>
</table>

The Municipal District Cooling Act gave the Municipality the framework to provide building's cooling through centralised units that distribute cooling to multiple buyers through a heating or cooling medium via a grid. This could prevent the multiplication of individual air conditioners, which expel heat into the city and contribute to the heat island effect.

Cloudburst Management Plan

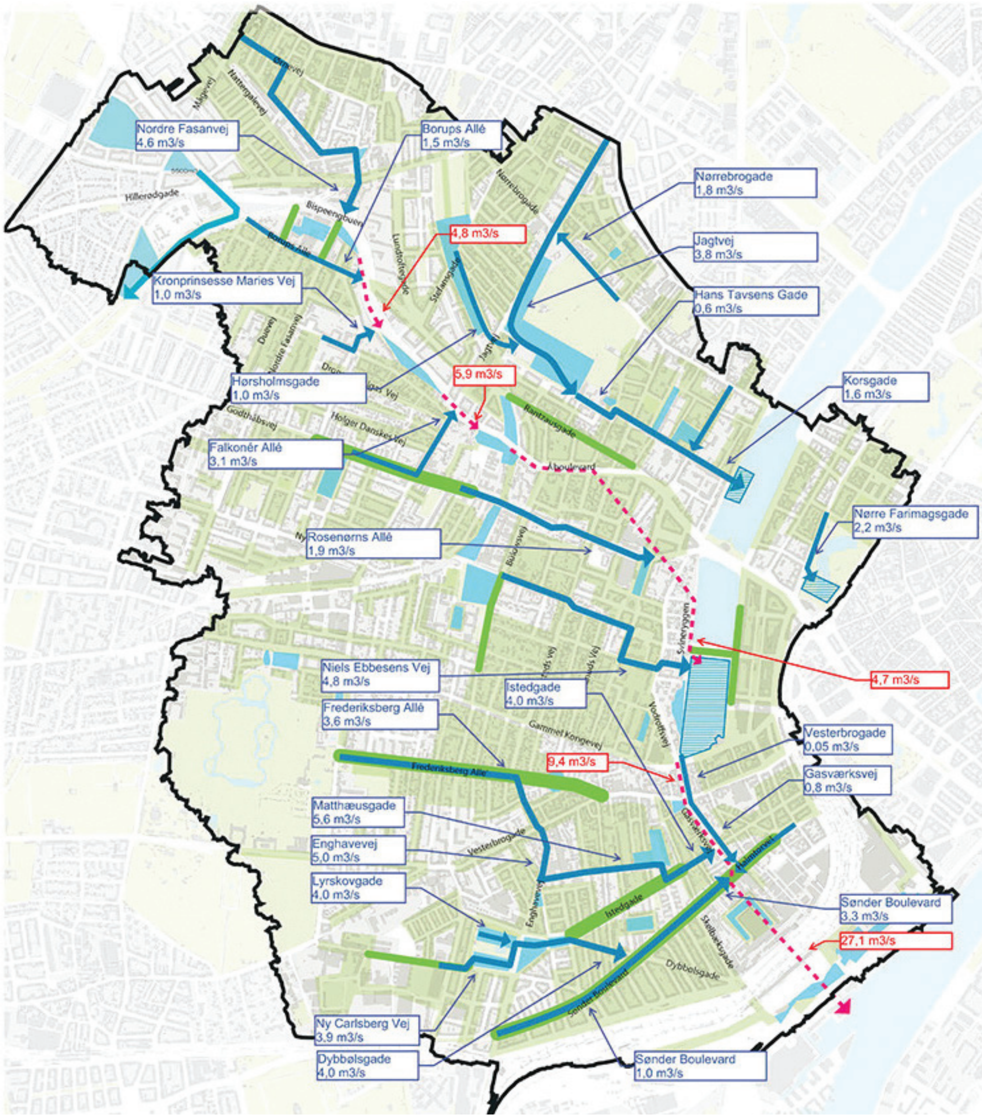
The Cloudburst Management Plan (CMP) is a stand-alone plan addressing specific impacts of climate change related to heavy precipitation. This plan is in continuity with the Climate Adaptation Plan framework and applies its principles to stormwater management. The CMP addresses the challenges of managing large amounts of stormwater in urban settings in an integrated manner, including physical, economic, and social challenges. Principles of action are outlined in the plan, but these are further defined and develop in the two supporting documents to the plan published in 2016: parts I and II of the Climate Change Adaptation and Investment Statement. (City of Copenhagen, 2015a, 2015b).

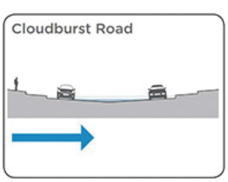
The plan is based on a thorough understanding of the relationships between the urban environment and the hydrography, both free surface and forced underground. Some local characteristics, including the proximity to the sea and the relative size of rivers, allow the local water system to be treated as a bounded and concluded system. This allows the flow of rainwater to be traced from where it originates to the outlet. Based on this understanding, integrated water management in the context of the City has been able to reach a level of capillary definition.

The methods of intervention are gathered in 5 types of solutions. Of these, the purposes, fields of application and general characteristics are made explicit, but deliberately the details are not defined to allow them to be better adapted to the context they apply. The application of these typologies is described and defined by a master plan that includes Copenhagen and Frederiksberg's municipalities and defines the main hydraulic functions desired. This master plan allows applying the intervention modes to the seven water catchment areas following one coherent design. The general master plan is then divided into local sub-catchments where the types of intervention are defined with a local master plan and a specific schedule. These sub-catchments are sub-systems defined by water flow and do not necessarily coincide with the standard administrative divisions. The solutions articulated here are thought of as parts of a continuous hydraulic solution.

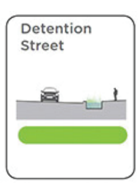
As stated in the plans, these documents are not per se legally binding for property owners, the utility company, or the City Administration. To have an effect, the contents of these plans need incorporating into the Administration's general planning process: primarily the Municipal Master

Figure 33
Cloudburst management plan. Local masterplan outlining strategies and typologies of interventions. Source: (City of Copenhagen, 2015a)



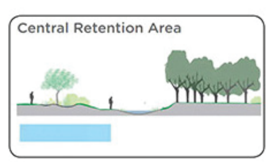


Cloudburst roads are used to channel and direct cloudburst water. These streets can be formed with a unique V-shaped profile and raised kerbs to ensure water will flow in the middle of the road, away from the buildings - contrary to standard engineering practice. Channels and swales can be established along road edges so that water runs in urban rivers or green strips. Cloudburst roads may also be combined with Cloudburst piping below the surface to create tool synergies.

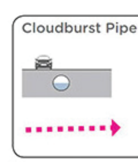


Detention streets are streets that are typically located slightly upstream of vulnerable low-points. In these streets there should be a detention volume established to handle stormwater before reaching the more vulnerable points downstream.

Green streets are proposed as upstream conections to all Cloudburst roads. The green streets should be established with a combination of small-scale channels and stormwater planters or permeable paving. Stormwater should be collected, delayed and then channeled towards the Cloudburst roads.



Central retention areas are proposed in the squares and parks where it is possible to delay stormwater, so that Cloudburst roads can be established in smaller dimensions. The central retention elements can be, for example, open depressions in the parkland or lowered seating areas. Alternatively, they can be established as underground storage such as soak-away crates or rain gardens. Central retention elements will typically be placed in connection with adjacent Cloudburst roads.



A Cloudburst pipe handles rainwater in the same way as Cloudburst roads. This is placed just below street level to ensure connection to other surface solutions. This solution is used if there is no useable space for aboveground solutions.

Figure 32
Stormwater flooding levels of a storm with annual chance of 1%.

Plan, sectoral plans (Wastewater Plan) and local master plans. Furthermore, urban renewal plans and local neighbourhood facelift schemes should incorporate the Cloudburst Management Plan into their drafting (City of Copenhagen, 2012). However, the ways in which it defines space and interventions are specific to planning and are cleverly used in an integrated way. The intervention typologies define the hydraulic functions that interventions should have and, although they do not carry binding indices and conditions at this level of definition, they are an example of planning by coding. The general master plan and especially its local derivations act according to the mode of planning by design. These define in space a series of relationships that the plan wants to establish between the urban environment and water management, foreshadowing the fully realised plan's final state. Finally, incorporating the recommendations in this plan within local plans can constitute a planning mode by development control. In fact, defining the types of intervention according to their principles, and not all the details, leaves the possibility for developers to develop local solutions through the techniques and synergies they consider most appropriate.

The control of the adequacy of the proposed solutions and its continuity with the local and general master plan can be an efficient planning mode to ensure coherence in the plan's implementation.

4.3 Interactions between CC and the urban system in Copenhagen's planning

Introduction

The following section aims to analyse the content of climate-related plans implemented by the City of Copenhagen. The thematic questions guiding this analysis aimed to compare the knowledge that emerges from the City's body of plans with that reconstructed from the conceptual and practical framework of Chapters 1.2 and 2.2. The questions are oriented to understand which relations are treated in the plans between CC-impacts and the urban environment and which intervention modalities are contained in the plans. The plans' content analysis is articulated to bring out how the Copenhagen plans are: 1) considering the CC interdependencies; 2) intervening in the system; 3) and according to which principles; and finally 4) the co-benefits generated by the plan interventions.

Based on the framework elaborated in chapter 1.2, the various relationships present in a selected body of plans of the City of Copenhagen are collected. The plan's list has been elaborated based on the survey carried out in the previous chapter and integrated by following the cross-references within the plans (Table 34). All the documents in the list were read and analysed by looking for descriptions and references to the relationships between CC and the urban environment and the proposed interventions. The relations found during the reading of the plans are presented in the next paragraph

Table 35
City of Copenhagen's CC-risk self-assessment

Copenhagen						
Type	Hazard	Current risk	Exp. change in intensity	Exp. change in frequency	Time horizon	Most impacted sectors
Hydrological	**Flash/surface flood**	high	increase	increase	in progress	Commercial, Residential, Transport
	Coastal flood	moderate	increase	increase	medium-term	Residential, Transport, Commercial
Meteorological	**Heat wave**	low	increase	increase	medium-term	Energy, Public health, Residential
	Storm surge	moderate	increase	increase	medium-term	Residential, Transport, Commercial

through two modalities: a descriptive narrative and a graphic matrix. Both of these two modes are applied to answer the previously listed questions.

In addition, the local perception of risk levels is reported to contextualise the level of local awareness and the administration's priorities. As in chapter 2.2 and 5.3 below, the survey intercepts the perceptions of the city's local administrators and is a form of risk self-assessment.

Figure 34
Plans considered in the qualitative plan review

Results

The city's local administrators recognised four main risks for the city of Copenhagen (Table 35). The highest level of risk is recognised as the risk of flash flooding. Unfortunately, this is already widely in-progress, with disastrous events occurring in 2011, 2014 and 2015. The risk from the sea has a current level that is perceived as medium, and takes the form of coastal flooding and storm surge. However, it is expected to increase in intensity and frequency in the medium-term, raising the risk level considerably.

Finally, heatwaves are perceived to have a low risk level, although the changing scenario is expected to increase in intensity and frequency. The sectors most affected by heatwave impacts are energy, public health and residential. For all other impacts, commercial, transport and residential are perceived as most exposed.

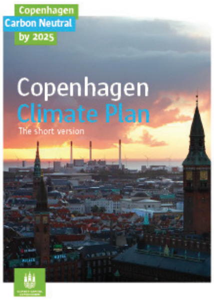
Climate adaptation plan

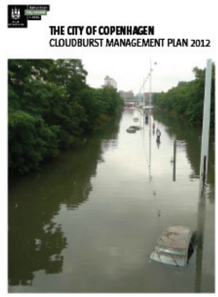
The climate adaptation plan addresses the challenges that the effects of climate change pose or will pose in the future for the city. The primary challenges it identifies are the intensification and increased frequency of heavy rainfall events and the progressive rise in sea level combined with exceptional tidal events such as storm surges. Other challenges that the plan includes are rising maximum temperatures and heat island phenomena, the impact of climate change on groundwater, and a range of indirect consequences related to health, biodiversity, and air quality.

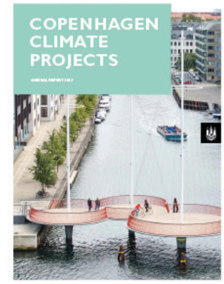
The plan highlights the need for intervention to provide a high value of secondary gains and synergies with other planning. Together with the risk reduction, interventions must also improve the citizens' quality of life and provide secondary gains as more recreational spaces, new jobs, and enhanced environment and biodiversity.

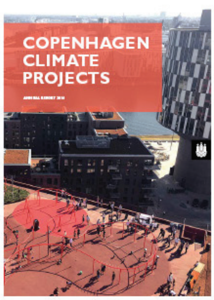
The responsibility for implementing the interventions belongs to several public and private actors. The utility company, which has both public and private shares, is responsible for urban water management interventions. The City of Copenhagen has responsibility for all ancillary components of these projects, which are not directly related to water management. Finally, private individuals also have the responsibility to implement waterproofing measures in their buildings at their own expense. As concerning

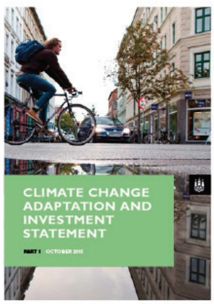
Table 34
List of the selected plans for this review, year, leading developer, central theme and reference.











Plan title	Year	Main Developer	Main theme		Reference
Copenhagen Climate Plan	2009	City of Copenhagen	Mitigation		(City of Copenhagen, 2009)
Copenhagen Climate Adaptation Plan	2011	City of Copenhagen	Adaptation		(City of Copenhagen, 2011)
Cloudburst Management Plan	2012	City of Copenhagen	Stormwater management	Adaptation	(City of Copenhagen, 2012a)
Copenhagen Climate Projects 2014	2014	City of Copenhagen	Mitigation	Adaptation	(City of Copenhagen, 2014)
Copenhagen Climate Projects 2015	2015	City of Copenhagen	Mitigation	Adaptation	(City of Copenhagen, 2015a)
Copenhagen Climate Projects 2016	2016	City of Copenhagen	Mitigation	Adaptation	(City of Copenhagen, 2016)
Urban nature in Copenhagen. Strategy 2015-2025	2015	City of Copenhagen	Greening	Adaptation	(City of Copenhagen, 2015b)
Climate Change Adaptation and Investment Statement - Part 1	2015	City of Copenhagen	Stormwater management	Adaptation	(City of Copenhagen, 2015c)
Climate Change Adaptation and Investment Statement - Part 2	2015	City of Copenhagen	Stormwater management	Adaptation	(City of Copenhagen, 2015d)
Storm surge Plan	2017	City of Copenhagen	Storm surge	Disaster risk reduction	(City of Copenhagen, 2017)
Nyt liv til jeres gård?	2018	City of Copenhagen	Greening	Adaptation	(City of Copenhagen, 2018)

the coastal risk, protection facilities are covered by the Coastal Protection Act, which foresees that the Municipality can require landowners to implement specific coastal protection measures. Landowners can intervene on their own by applying for a permit to the Municipality. The Act also regulates the financing of the facilities, this is based on the rule that the landowners who benefit from a facility have to finance it, which also applies to public authorities.

An example of the understanding between the urban system and climate effects is represented by the relationships described in the plan regarding buildings, roads and the various climate impacts. These are described as follows: "*Buildings are vulnerable to changes in the climate, which may lead to water penetration, more storm, snow and subsidence damage, poorer indoor climate and a shorter life for building structures. The consequences of damage to buildings range from loss of life and health to expenditure on repairs and increased operating costs or loss of value. Roads and tunnels are vulnerable to floods and a rising groundwater level, and drainage of roads is important to avoid damage to roads, surroundings buildings and installations*". While some of these risk, such as groundwater change and sea-level rise, are not currently of primary importance, the plan recognises that impacts and damages will be substantial later.

Cloudburst management plan

The Cloudburst management plan focuses on managing the effects of heavy rainfall in relation to the urban environment. At this stage, the issue is addressed from a very sectoral perspective, and interactions with other climate change impacts are not considered in the plan. The effects of heavy rainfall flooding on the urban system are multiple and affect the following systems and elements: sewerage system, canals, basins, lakes, sea, water quality, green areas, treatment plants, roads, tunnels, park, open spaces, buildings and infrastructure.

The plan intervenes in the management of rainwater in two main ways. The first, more traditional and in continuity with the existing intervention methods, is linked to removing rainwater from neighbourhoods through underground tunnels that discharge the water into the sea. The second involves the widespread construction of SUDS which can manage rainwater locally and in a decentralised manner through storage and infiltration. This second mode of intervention involves a wide range of co-benefits for the urban environment typical of blue and green infrastructure. Overall, this plan's implementation contributes to improving preparedness for extreme events, system resilience to intense shocks, and general adaptation to climate change.

Plan title	Effects of CC on urban elements, sectors and systems	Actions and ways of intervention	Principles	Co-Benefits
Copenhagen Climate Plan	Dry summers with intensive rain events, wetter winters, higher temperatures and rising water levels. Risk from stormwater flooding and storm surges. Built environment, citizens and business are exposed.	It calls for a comprehensive adaptation plan to face CC-risk in an integrated manner. Drafts area of intervention: safeguarding against flooding and storm surges, heat-proof measures (sun-shades, ventilation and insulation) for retrofitting buildings and stardards for new buildings, green areas and green roofs/walls to reduce risk of runoff, green/grey infrastructure for conveying stormwater from heavy downpours.	Green infrastructure, Grey Infrastructure, Diversity and redundancy	Reduced GHG emissions, Economic growth, Improved resource efficiency (e.g. food, water, energy),
Copenhagen Climate Adaptation Plan	How impacts interact with the socio-economic structure of the city, infrastructure, citizen, environment, activities. Heavy precipitations and storm surges have several effects on pipes, sewers, treatment plants, energy sector, infrastructures including metro, residential, commercial, roads, water quality, public health (water bourne diseases). High temperatures have effects on energy consumption, health (allergies, UV skin cancer, strokes), environemnt and have negative interdependecies with drought and high building development. Wind, heat and traffic can have negative relations with air quality. Many of the impacts affect biodiversity too.	Development of methods to discharge during heavy downpours. Establishment of green solutions to reduce the risk of flooding. Increased use of passive cooling of buildings. Protection against flooding from the sea. Levels of intervention divided in: protection, preparation and relocation.	Integrated, Flexible, Adaptive management, Learning and innovation, Preparedness, Early warning, Relocation.	More recreational opportunities, New green jobs, Enhanced environment and biodiversity, Enhanced climate change adaptation
Cloudburst Management Plan	The plan is dedicated to stormwater management to avoid flooding from heavy precipitation, and doesn't address directly any other CC-impact. The plan highlights relations with the following urban elements and systems: sewerage system, canals, basins, lakes, sea, water quality, green areas, treatment plants, roads, tunnels, park, open spaces, buildings and infrastructure.	There are two types of stormwater management interventions. The first involves draining water out to sea through new or enlarged tunnels. The second involves storage and infiltration by SUDS located throughout the city.	Integrated, Green infrastructure, Grey infrastructure, Diversity and redundancy, Robust, Thresholds, Preparedness.	Enhanced climate change adaptation, Enhanced resilience, Disaster Risk Reduction, Disaster preparedness.
Urban nature in Copenhagen. Strategy 2015-2025 + "Nyt liv til jeres gård?" 2018	The strategy aims at enhancing the quantity and quality of urban green in the City. In relation toclimate change, urban green is used to reduce the impacts of heavy precipitations, heat waves and poor air and water quality. It is mainly related to urban elements and systems connected to: residential buildings, roads, parks, rivers, harbours, courtyards.	The strategy aims at enhancing urban green to enhance ecosystem services, to adapt to future climate changes, stop the decline in biodiversity and secure a pleasant micro-climate in the city. To have a positive effect on temperature, air quality and noise and to create shade, light and air circulation.	Green infrastructure, Self-organisation, Inclusion, Social cohesion, Diversity and redundancy.	Ecosystem preservation and biodiversity improvement, Enhanced climate change adaptation, Enhanced resilience, Improved public health, Improved resource quality (e.g. air, water), Social inclusion.

Table 36

Summary of the results of the plan analysis. Columns focus on the effects of CC on urban elements, sectors and systems, principles of intervention and co-benefits generated. Continues in next page

Copenhagen climate projects

The three editions of the annual reports collect the actions and projects developed in those years related to climate, both from the mitigation and adaptation perspectives. In this review, these projects' relationships with the goals and objectives of reducing the impact of climate change on the city were taken into account, including those related to CCA, DRR and UR approaches. As a result, actions related to energy efficiency, energy production and mobility are also taken into account, but only to the extent of their contribution to improving these aspects.

The three reports considered bringing together the actions developed in implementing the adaptation framework defined by the Copenhagen Adaptation Plan and the Cloudburst Management Plan. Few relationships are established between the actions and most of the impacts identified by these plans. Drought and storm surge impacts are not even mentioned in the three reports. Few indirect references are made to heatwaves, mainly aimed at reducing the energy demand for summer cooling. Actions are mainly aimed at reducing the impacts and magnitude of flooding from heavy precipitations. How this objective is applied in projects opens up numerous co-benefits that have positive effects on the local reduction of summer temperatures, water quality and the quantity and health of green areas.

Climate Change Adaptation and Investment Statement

The different interventions are designed both for hydraulic efficiency and numerous co-benefits that exploit different contexts and applications' opportunities. In general terms, these are disaster risk reduction, enhanced adaptation and improved resource quality.

The documents then go into the specifics of the various urban neighbourhoods where the actions occur and identify local characteristics that can work in synergy with the projects and develop a more significant number of local co-benefits. This is the case, for example, in the Indre-by district, where the actions aim to enhance and protect buildings of historical value and preserve the high degree of connectivity. Alternatively, the case of Norrebro, where the interventions enhance the numerous shopping streets and integrate with the district's green heritage. Or the case of the Sydhavn neighbourhood in transformation, where interventions can be in synergy with the request to extend recreational and green spaces and in synergy with the harbour.

Plan title	Effects of CC on urban elements, sectors and systems	Actions and ways of intervention	Principles	Co-Benefits
Copenhagen Climate Projects 2014, 2015, 2016	Despite the wide framework for adaptation provided in the climate adaptation plan, projects from these annual reports do mention very few relations with heat waves, storm surges, wind storm and droughts. Main projects implemented establish strong relations with stormwater management and roads, commercial, water quality, infrastructure, sewers, historic building, urban green, rivers,	Realization of projects based on the principles of infiltration, filtration and storage of stormwater. Centralized cooling for the district with seawater	Green infrastructure, Grey infrastructure, Diversity and redundancy, Social cohesion, Reflective	More recreational opportunities, Job creation, Ecosystem preservation and biodiversity improvement, Improved access to and quality of mobility services and infrastructure, Reduced GHG emissions, Improved resource quality (e.g. air, water)
Climate Change Adaptation and Investment Statement - Part 1 + Part 2	It refers to the Cloudburst management plan and therefore it mainly orientated to stormwater management to avoid flooding. It does however include the relation of the solutions proposed with other issues and impacts such as heat waves, air quality, water quality. The relations of these impacts with the urban environement are describe in the document in their relation to the following elements: rivers, river banks pipes, roads, railway tracks, residential buildings, historical buildings, parks, green spaces, cementery, bathing sites and soil.	Intervention are mainly physical intervention that relate to the previously cited urban elements. Intervention have the following main objetives: retain water, reduce inflow, block water, channel water, discharge water, avoid flooding.	Green infrastructure, Grey infrastructure, Diversity and Redundancy	Disaster Risk Reduction, Enhanced climate change adaptation, Improved resource quality (e.g. air, water)
Storm surge Plan	The plan is dedicated to the hazard coming from the combination of sea level rise, storm surges and waves. It includes their potential for large-scale destruction of houses, roads, harbours, railway and metro lines, water and power supplies, energy production, wastewater treatment plants, and posing a danger to human life.	Intervention is foreseen through the main principle of protection by rising barriers, dikes and floodgates in the outer coastline	Integrated, Grey infrastructure, Robust	Disaster preparedness, Disaster Risk Reduction, Improved resource security (e.g. food, water, energy)

Table 36

Summary of the results of the plan analysis. Columns focus on the effects of CC on urban elements, sectors and systems, principles of intervention and co-benefits generated. Continues from previous page.

Urban nature in Copenhagen

The strategy to increase the amount of urban green space in the city considers its role in increasing biodiversity, providing ecosystem services, and counteracting the impacts of climate change such as flooding, heatwaves, poor air and water quality. In doing so, the plan considers the interaction of green spaces with many urban systems and elements, including residential buildings, roads, parks, rivers, harbours and courtyards. Furthermore, the plan addresses the types of places where urban green spaces can be increased, from interventions on municipal land to new developments and retrofits in established contexts. The plan also sets up several ways to spread greenery in private spaces, leaving private individuals to self-organise. This is the case of the policy for redeveloping the inner courtyards of residential buildings, where the Municipality intervenes with incentives and tax relief for specific performances achieved in terms of greenery and locally managed rainwater.

Storm surge Plan

The storm surge plan focuses on the hazard coming from the sea and considers the combined action of sea-level rise, storm surge and waves in the form of an acute shock. It does not take into account long-term stresses on the coast, such as erosion for example. The described relationships of this acute shock to urban systems are many and catastrophic. These are the destruction of physical elements including buildings and infrastructure, the disruption of essential transport services and water and energy supplies, and the possible disruption of other infrastructure critical to urban systems (Figure 35). Therefore, the relationship with urban systems is to be avoided at all costs, so the plan provides robust and continuous protection on the outer coastline. The co-benefits for this mode of intervention are mainly quantifiable in avoided damage and the prevention of protective structures within the city.

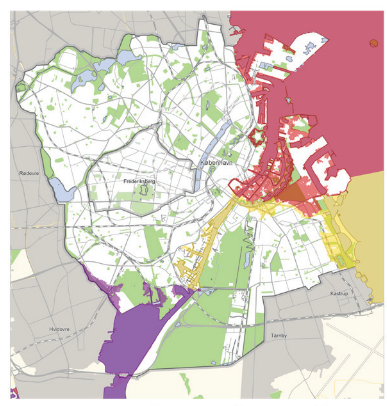


Figure 35
Storm surge flooding map, based on 3 different scenarios

Conclusions

In the previous paragraph, results have been reported individually for the different plans of the Municipality of Copenhagen. Table 36 summarises the results of the content analysis of the plans based on the research questions. Some documents were grouped into clusters because they were considered very similar or parts of the same plan. The first column contains the titles of the clustered plans. The second column contains some of the critical effects addressed within the plans regarding the interaction climate change has with urban elements, sectors and systems. The third column summarises the mode of action and intervention descriptively, while the fourth column contains the principles of intervention addressed within the

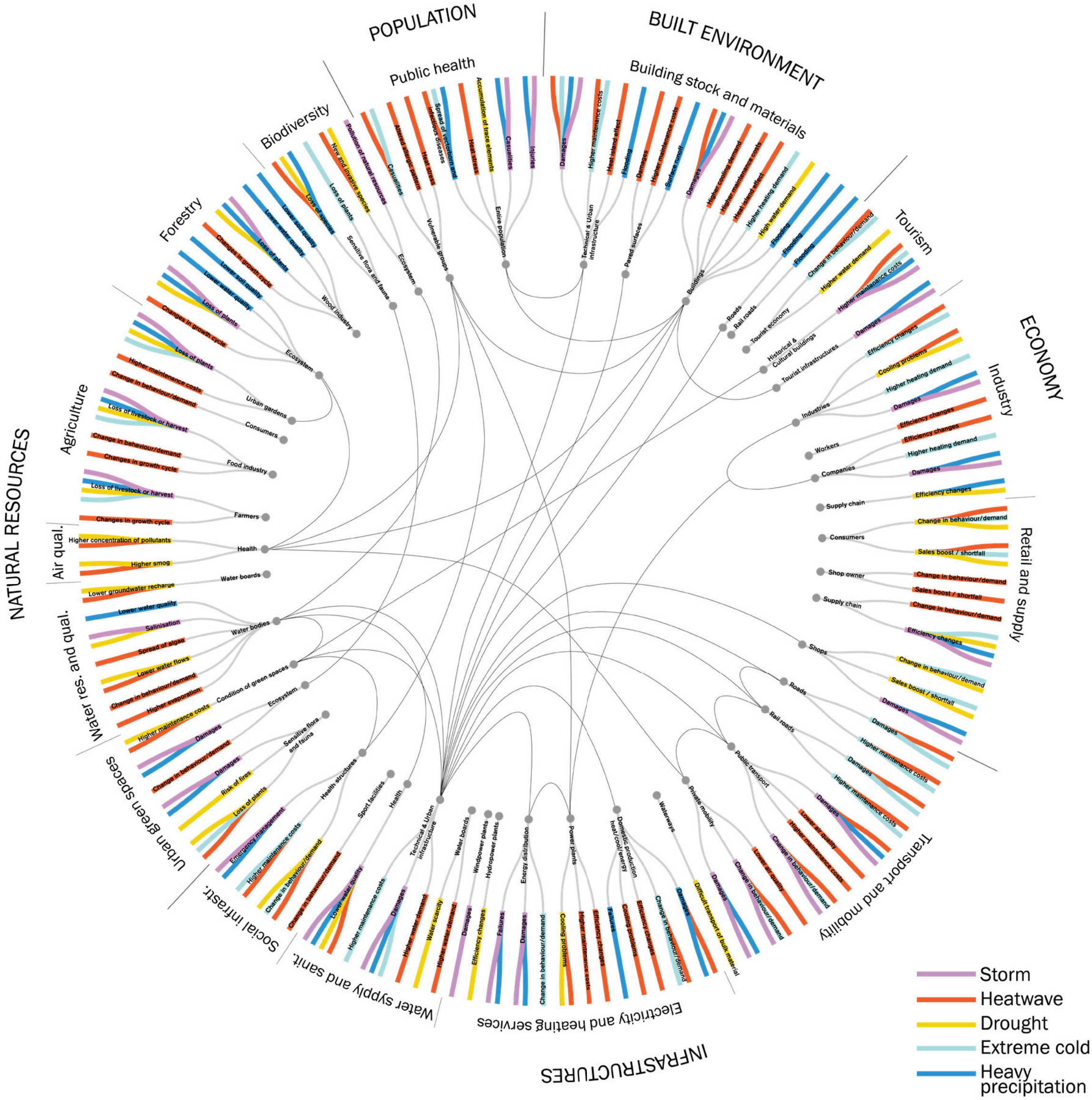


Figure 36

Map of the interdependencies in Copenhagen. Author's interpretation of the interdependencies (lines in the middle) between the impacts that CC and urban systems and elements emerged from the plan analysed. Starting from the outside, there are Sectors and Sub-sectors. Then, each colour represents an impact between: drought, heatwave, extreme cold, heavy precipitation, and storm. These impacts cause an effect, specified above the coloured line, on certain system elements, where the grey dot is. These elements are connected between them based on the relations and cascading effects cited in the plans.

plan according to the classification that emerged in Chapter 1.2. Finally, the fifth column contains the co-benefits of the interventions described in the plans and classified according to the categories emerged in Chapter 2.2.

A clear picture of the effects of climate change on Copenhagen's urban systems emerges from the analysed plans of the different municipalities. Figure 36 summarises the potential impacts of climate events with urban elements and the cascading effects that may occur, drawing the local picture of interdependencies. In this diagram, the clusters of the most recurrent elements addressed in the plans and their interactions were identified. The first cluster in importance is related to technical and urban infrastructures for water supply and sanitation. This, together with water bodies, is the core of many interactions with other urban systems and a recurring theme in many plans. Another recurring system in the interactions is biodiversity, reflecting the attention in many plans. The transport system also emerges and is treated as an interconnected network where the different transport modes are connected and dependent on each other.

The diagram in Figure 37 traces the primary connections between the clusters of plans analysed and the principles of intervention. The yellow plans are based on climate change adaptation, while the blue plan is based on disaster risk reduction approaches. The most common principles are green and grey infrastructure, both of which are present in most plans. In the analysed plans, adaptation principles are more frequent than resilience and disaster risk reduction.

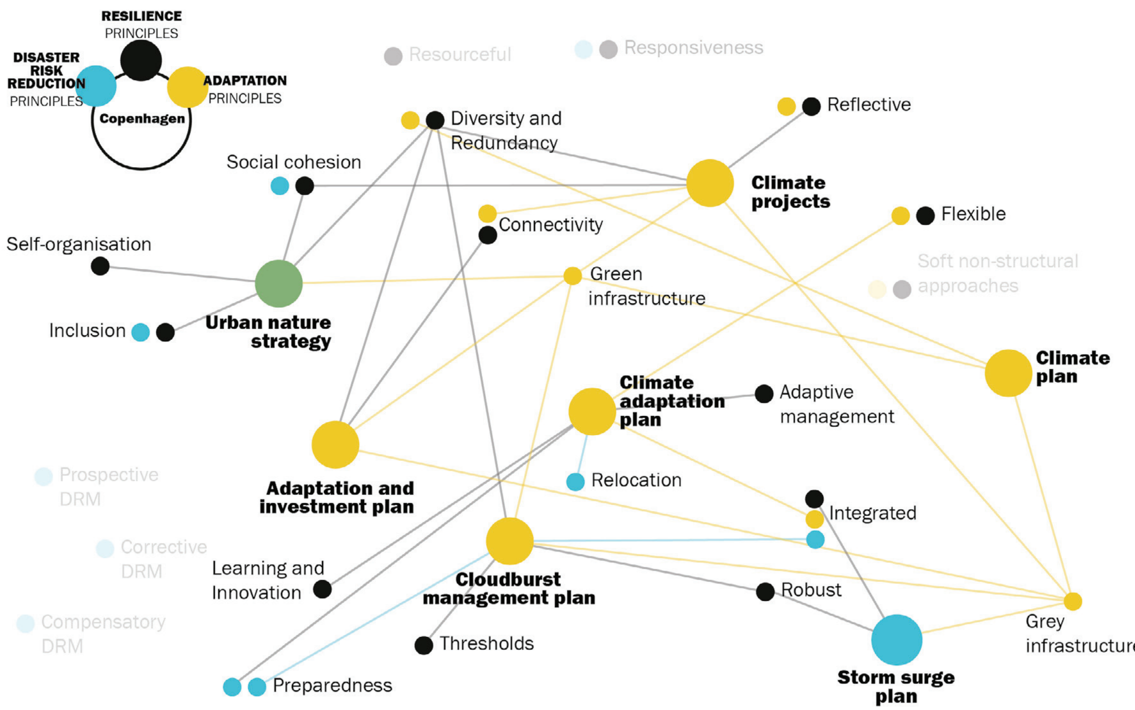


Figure 37
Overall picture of the principles applied in the cluster of plans considered for Copenhagen

Chapter 5 - Central Veneto
5.1 Context for action

System's boundaries

The Veneto Region is administratively divided into seven provinces, one of which is represented by the Metropolitan City of Venice. The set of documents that create the main regional planning framework is contained within the Regional Territorial Coordination Plan (Veneto Region, 2020). Each province has well-defined geographical and administrative boundaries, which are represented in Figure 38. Beyond the administrative divisions, several divisions of the territory share homogeneous characteristics according to the aspects considered. Central Veneto is not an administratively recognised classification but belongs to a distinct geographical area compared to the other two main geographical realities recognisable in Veneto, namely the coastal and mountain areas. In addition to geographical continuity, Central Veneto is considered a unitary area in this thesis since it is a cluster of cities with similar risks and modes of intervention, where different cities have faced the challenges of climate change through similar planning tools. The geometry of this area is variable, and the boundaries cannot be traced univocally and clearly in the provincial boundaries. For the purposes of this thesis, it was decided to draw the area in which the Central Veneto straddles the provinces of Vicenza, Padova, Treviso and the Metropolitan City of Venezia.

In the classification of Eurostat, the European Commission database, within the region, there are several urban centres and their associated functional urban areas. This classification is based on the division of the territory in Local Administrative Units (LAU), units that are related to local and low-level administrative divisions, ranked below a province, region or state. An LAU is classified as a city when the majority of the population lives in an urban centre of at least 50000 inhabitants. The commuting zone contains the surrounding travel-to-work areas of a city where at least 15% of employed residents work in the city. A functional urban area consists of a city and its commuting zone. Therefore, functional urban areas consist of a densely inhabited city and a less densely populated commuting zone whose labour market is highly integrated (Dijkstra et al., 2019; Eurostat, 2018; OECD, 2012).

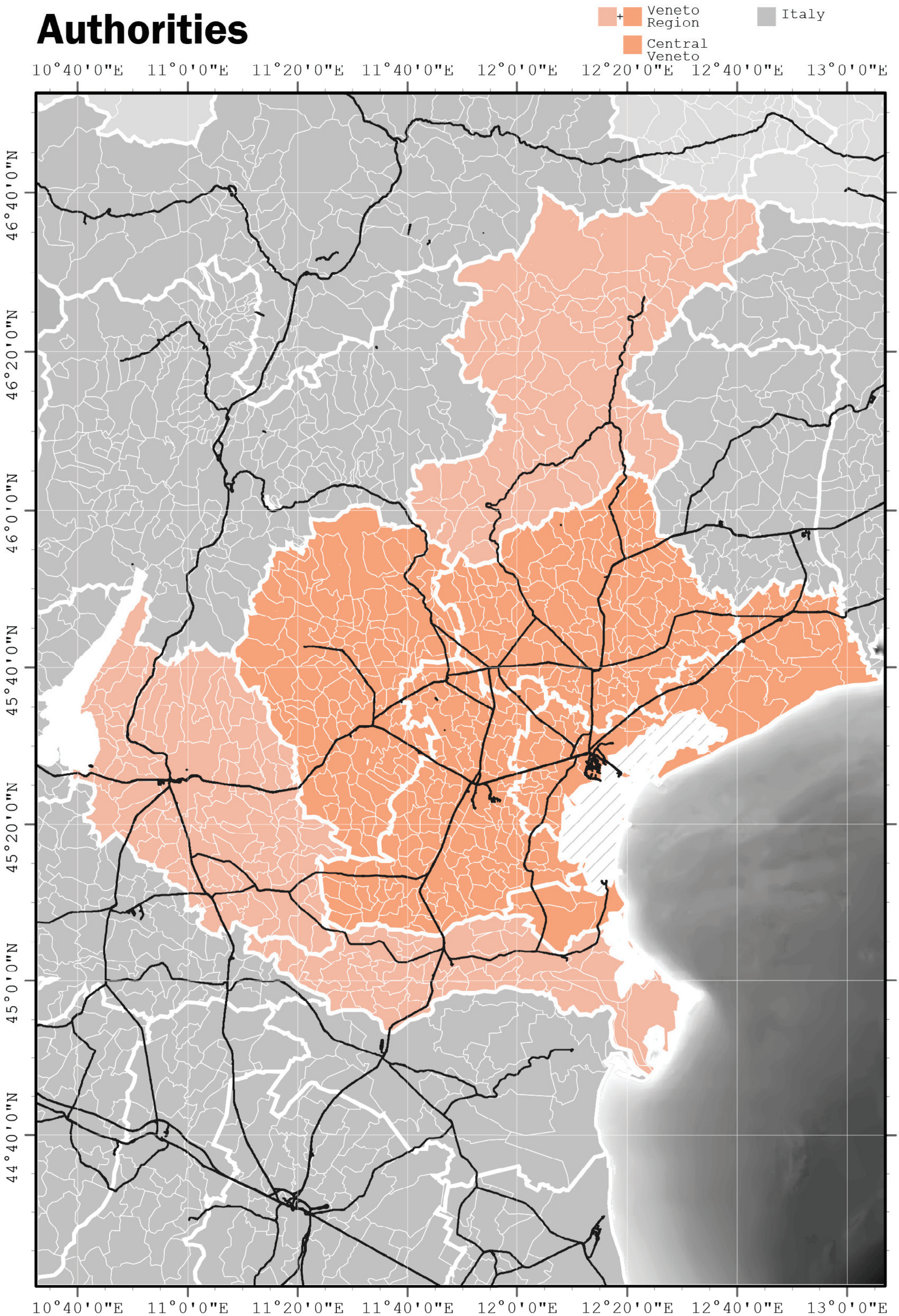
Applied to the context of Veneto and neighbouring territories, this classification of the territory reveals that there are clusters of cities and functional areas that are in continuity with each other and create an extended sphere of territories belonging to the same system (Figure 39). The cluster of cities and functional areas linked to the Via Emilia is clearly recognisable

Figure 38
North-eastern part of Italy, highlighting the area of the Veneto Region. The boundaries of the 7 regional provinces are highlighted in thick white, with darker filling for those which constitute the central area. Thin white lines mark the boundaries of Local Administrative Units, in this case mostly coinciding with Municipalities.

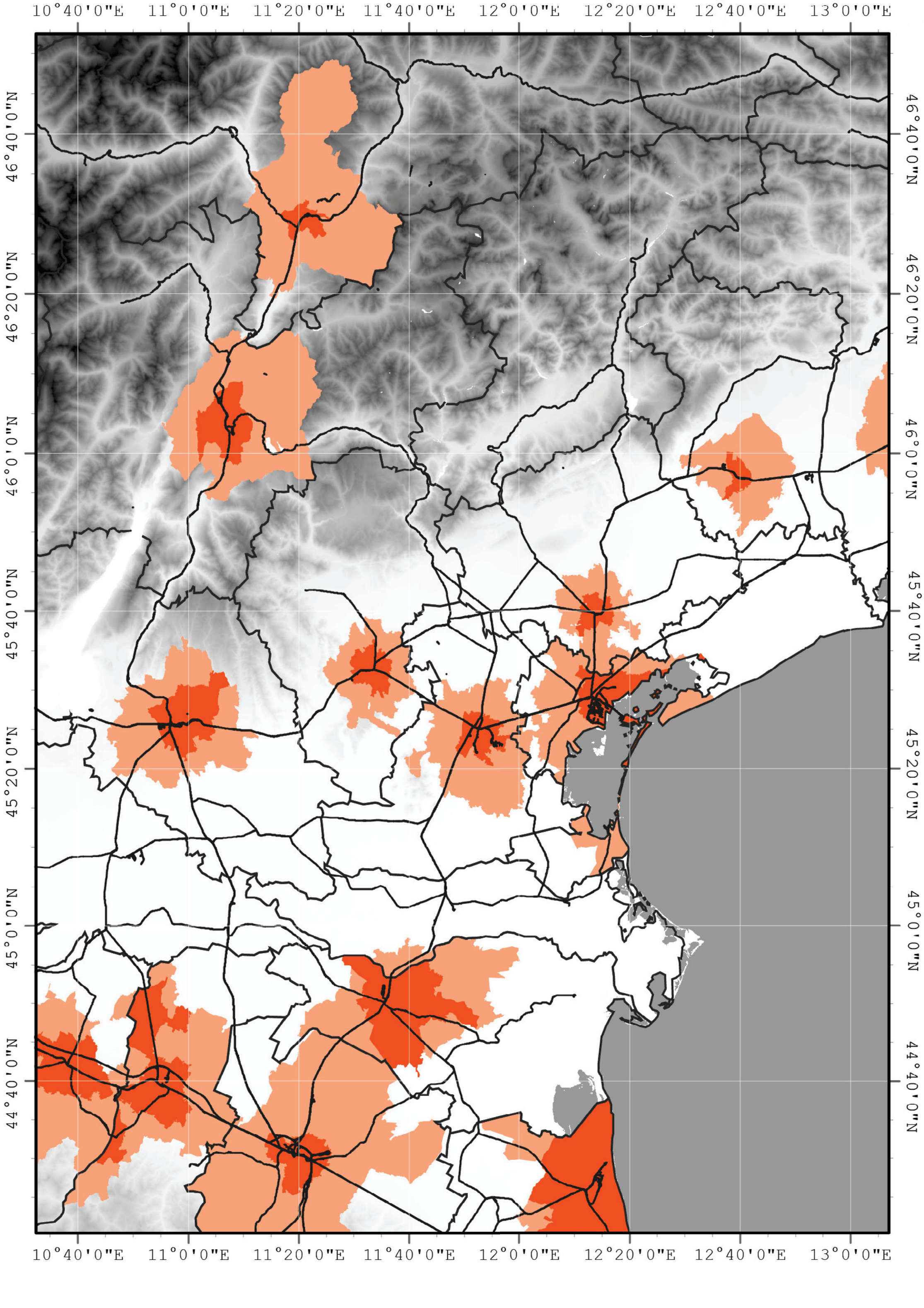
Figure 39
City centres and their Functional Urban Area in the Veneto Region and surrounding territories. Data source: (Urban Audit, 2018)

Figure 40
Degree of urbanisation of the Veneto Region and surrounding territories. Data source: (Urban Audit, 2018)

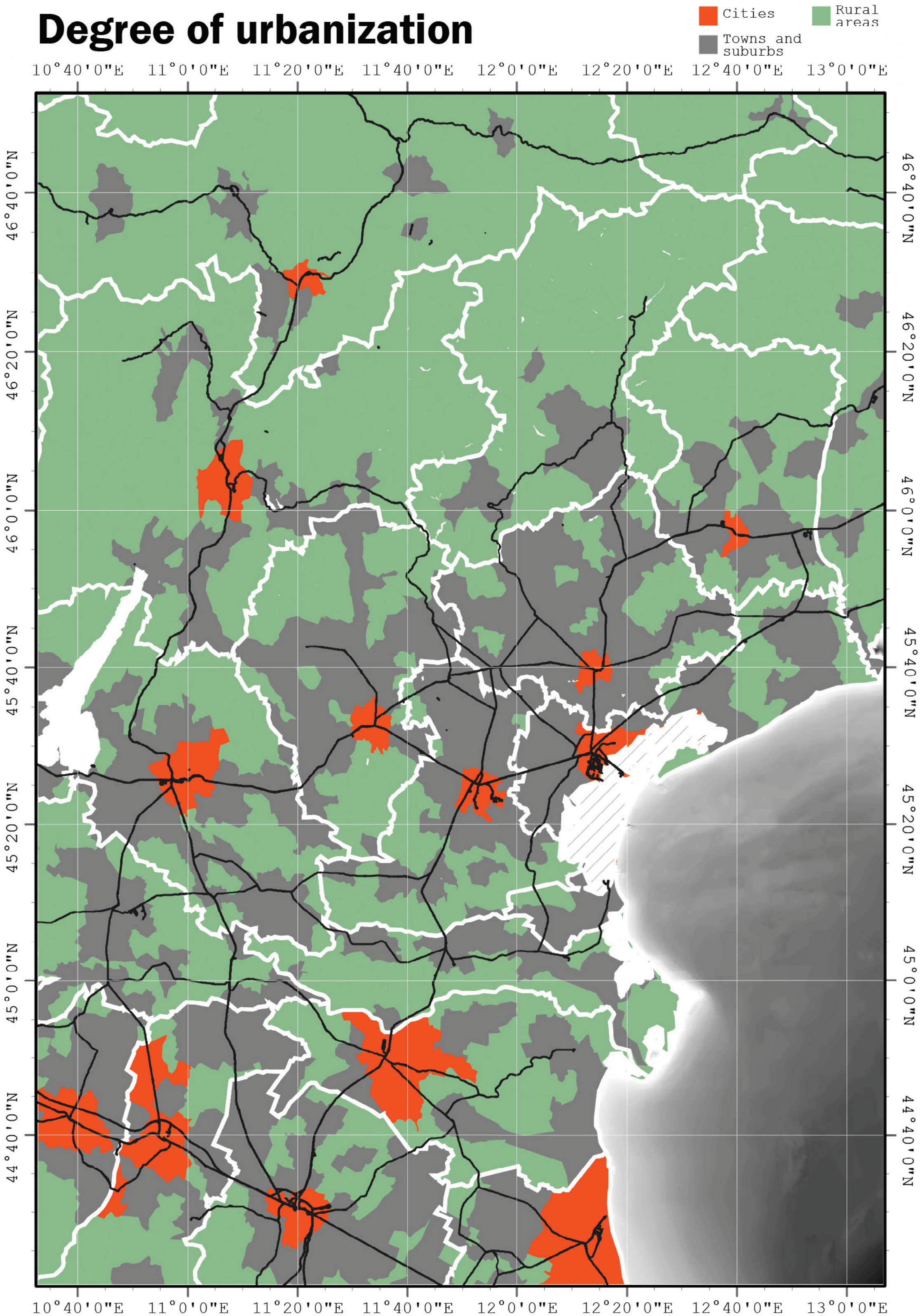
Authorities



City centres and Functional Urban Areas



Degree of urbanization



and cuts across the map to the South. To the West, it is possible to recognise the cluster linked to the Adige Valley, which, although less dense, is articulated around the North-South hydrographic axis. Finally, it is also possible to recognise the dense area of urban centres in Central Veneto, including Venice, Treviso, Padua, and Vicenza. The functional areas of these centres are adjacent, defining a single and continuous territorial system.

The division into functional urban areas and city centres allow understanding that cities have an area of influence larger than their administrative boundaries. They are the barycentre of a constellation of neighbouring areas in terms of daily movements. In addition to this functional aspect, urban areas are also more extensive in terms of urban space's physical dimension. New urban continuity boundaries can be drawn by classifying areas according to the percentage of the population living in urban environments.

Figure 40 represents precisely this continuity of density of urban residents. Densely populated LAUs, i.e. where at least 50% of the population lives in urban centres, are classified as cities. Medium-density LAUs, where less than 50% of the population lives in rural grid cells, and less than 50% of the population lives in urban centres, are classified as towns and suburbs. Finally, thinly populated areas where more than 50% of the population lives in rural grid cells are classified as rural areas.

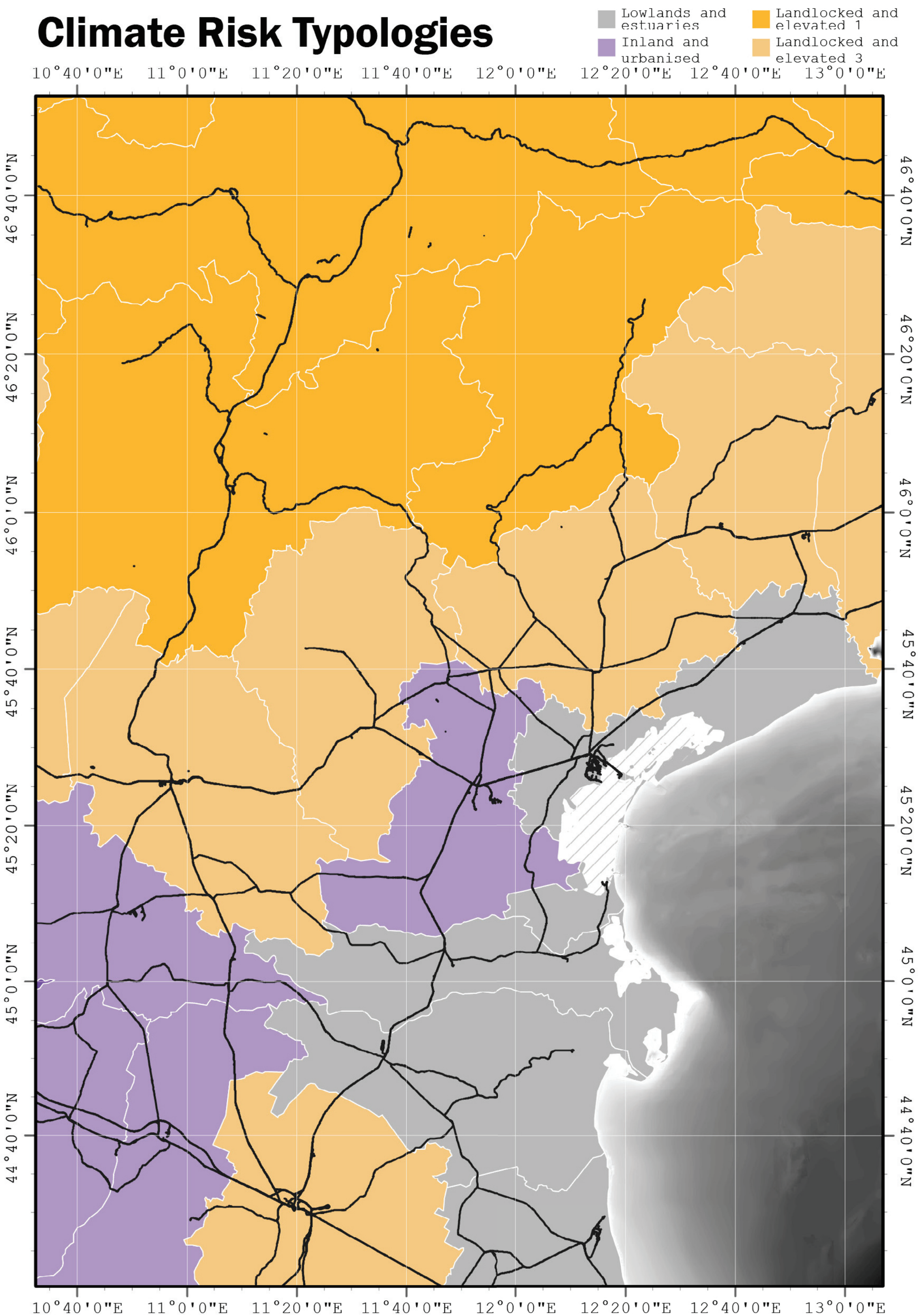
Whereas the previous classification of functional areas emphasised continuity for work-related travel, and thus which territorial area gravitated around urban centres, this index focuses on the degree of urbanisation of each LAU. Figure 40 shows the LAUs divided according to the three classifications. In Veneto's central part, a strongly urbanised territory emerges, where cities, towns and suburbs alternate seamlessly. Within this fabric, few and circumscribed interruptions of territory classified as rural coincide with local hills.

Units of Climate Risk

The boundaries of a system can also be drawn based on homogeneity in terms of risk. The combination of physical, climatic and capacity characteristics allows areas to be aggregated into similar typologies. This typology of climate risk is based on NUTS3 statistical units, which contain a variable number of LAUs. This is the third level of the classification of the European territory into Statistical Territorial Units set up by Eurostat as a single, coherent system for dividing up the EU's territory to produce regional statistics for the Community. NUT3 units divide the territory based on administrative boundaries and a population threshold between 150000 and 800000 inhabitants. Based on these units, a comprehensive classification of the whole EU's territory on climate risk has been developed

Figure 41
Climate Risk Typologies in the Veneto region and surrounding territories. There are three main types of risk typologies in the area: lowlands and estuaries, inland and urbanised, and landlocked and elevated. Each of these share similar characteristics and risks with the other areas of the same typology.

Climate Risk Typologies



(Hincks et al., 2018). Based on this database (J.G Carter et al., 2018), regional and local climate risk characteristics can be drawn in general terms and identify typologies (Figure 41). The following paragraphs sum the most relevant elements of risk for the Veneto region. Data and descriptive texts are part of the European Climate Risk Typology (J.G Carter et al., 2018).

The classification of regions that share common climate risk components allows a comparison between regions in terms of risk (Figure 42) and the first step in comparing shared modes of response, adaptation, and resilience. For this reason, regions are first described textually and according to indicators following the division of the classes and sub-classes to which they belong. Finally, the specific regions are described according to the most significant indicators and compared in Table 37. For a full list of the indicators considered and their values for each of the NUTS3 area in the region, please refer to Annex III.

Lowlands and estuaries

The Lowlands and Estuaries class encompasses a relatively small number of cities and NUTS3 regions sited in low lying and estuarine locations, particularly in the Netherlands and Denmark. Other regions sharing these characteristics are in North Eastern Italy and Northern Germany, which also fall within this class.

The critical hazards that they face are fluvial flooding and coastal hazards, well above the European average. Exposure of people, settlements and critical infrastructure to these hazards is also exceptionally high in a European context. There are relatively few people at risk of poverty, and migration levels are projected to increase. GDP, employment prospects, and patent applications indicators show values that these areas sit above the average for Europe's cities and NUTS3 regions from an Economic perspective. These locations also have relatively high critical infrastructure provision and broadband access, and high bandwidths. This suggests that the capacity to adapt to hazards is relatively high and sensitivity relatively low. However, the severity of the hazards faced by these areas, and the high level of exposure to fluvial flooding and coastal hazards, highlights that climate change stands out as a major risk factor.

In the specific, Venice and Rovigo areas belong to the Lowlands and Estuaries 3 subclass, as cities such as Bordeaux, Rotterdam, Bremen, and Utrecht. These regions are located on or close to the estuaries and deltas of major rivers: the Po river for Rovigo and a network of rivers for Venice. Relative to other cities and regions classified as Lowlands and Estuaries, this subclass has the following distinguishing features and characteristics: higher fluvial flooding hazard; higher coastal and drought hazard; higher projected increase in summer days, heatwave days and continuous dry days; higher

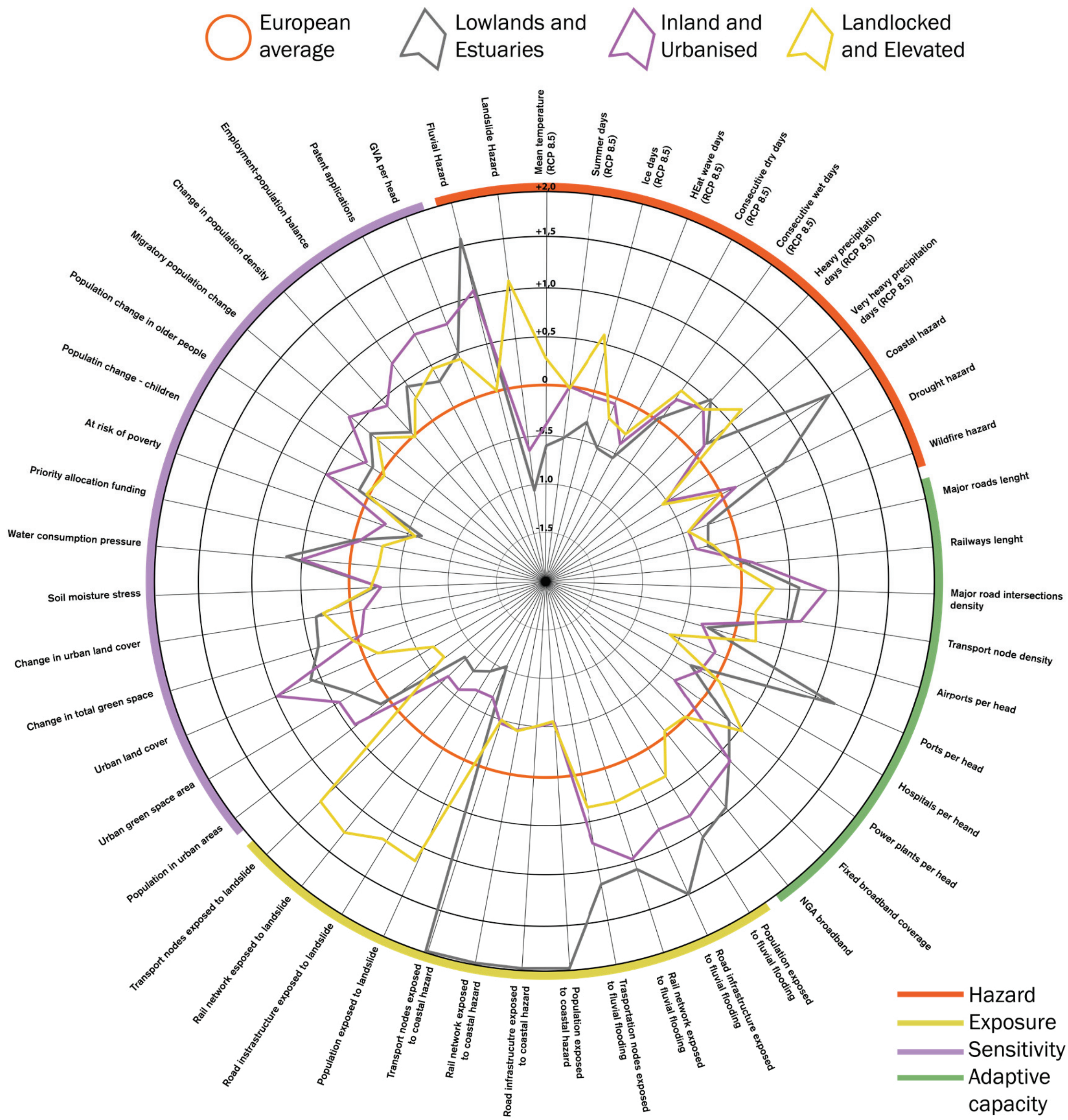


Figure 42

Comparison of Lowlands and Estuaries, Inland and Urbanised, Landlocked and Elevated typologies. The mean European average of all the typologies is kept as the reference level. For each indicator, data is represented compared to the European average. Indicators are grouped into four categories, based on risk components: Hazard, Exposure, Sensitivity, Adaptive Capacity. Data source: (Carter et al., 2018).

projected water consumption pressure; higher exposure of people to fluvial flooding; lower exposure of people and rail network to coastal hazard; longer road and rail length; greater projected change in total population, migration and numbers of older and younger people; higher number of patent applications. Other indicators are around the average for the Lowlands and Estuaries class. The most significant risk indicators for the Venice and Rovigo areas are present in Table 37 in comparison with the other Veneto Region NUTS 3 areas.

Table 37
Most significant risk indicators for the specific NUTS3 regions in the Veneto Region. Source: (J.G Carter et al., 2018) Please refer to the Annex for complete data on these areas.

Inland and urbanised

Cities and NUTS3 regions in the Inland and Urbanised class are predominantly located in Central and Western Europe. Several capital cities are included. Fluvial flooding from rivers is the crucial climate hazard facing these areas. There is also the potential for more significant surface water flooding arising from the projected increase in heavy rainfall events over the coming decades. Exposure of people, settlements and critical infrastructure to fluvial flooding is currently relatively high in a European context. Due to their low lying topography, exposure to landslides is relatively low. These are relatively affluent and innovative areas and are projected to experience increased migration and numbers of young people. They also have well-developed road networks and high broadband access and bandwidth capacity. For reasons such as these, they have relatively low sensitivity to climate change hazards and high adaptive capacity, and their vulnerability to climate change is therefore relatively low. However, given that exposure to fluvial flooding is high, climate change and extreme weather are crucial challenges.

Padova and its NUTS 3 region belong to the Inland and Urbanised 1 sub-class with other major cities (e.g. Milan, Vienna, Budapest, Lyon, Zurich, Prague) and NUTS 3 regions immediately surrounding major cities (e.g. Paris and Frankfurt). Relatively to the other Inland and Urbanised sub-classes, this subclass has the following distinguishing features and characteristics: higher projected increase in the number of heatwave days; lower projected increase in the number of wet days; higher soil moisture stress and pressure on water resources; greater projected change in total population, migration and the number of older and younger people; higher number of patent applications. The most significant risk indicators for the Padova area are present in Table 37 compared to the other Veneto Region NUTS 3 areas. From this comparison, it emerges that Padova has high fluvial flood hazards, with consequently high exposure of its road network (30,1%), rail network (47,6%) and transport nodes (14,9%). In addition, a considerable percentage of its population (12,5%) lives in settlement exposed to fluvial flooding. Finally, the high population density and migratory projections can bring additional pressure to the already high water consumption.

	name	Venezia	Padova	Treviso	Vicenza	Verona	Belluno	Rovigo
	sub-class	LES3	IU1	LEL3	LEL3	LEL3	LEL1	LES3
Hazard								
Projected change in mean temperature (RCP 8.5)	°C	1.9	1.9	1.9	1.9	1.9	2.1	1.9
Projected change in maximum temperature (RCP 8.5)	°C	1.8	1.9	1.8	1.9	1.9	2.1	1.8
Projected change in tropical nights (RCP 8.5)	N°	26	24	19	14	21	2	27
Projected change in heat wave days (RCP 8.5)	N°	6	9	7	5	8	0	9
Coastal hazard	%	1.2	1.2	1.2	0.0	0.0	0.0	1.0
Drought hazard	%	0.9	2.1	1.1	1.9	2.7	-2.6	3.9
Fluvial hazard	%	23.7	14.3	5.1	1.5	9.7	2.4	80.1
Landslide hazard	%	0.0	4.2	16.2	45.2	22.7	86.8	0.0
Exposure								
Population in settlements exposed to fluvial flooding	%	7.4	12.5	2.9	1.5	6.9	0.9	39.8
Population in settlements exposed to coastal hazard	%	10.2	1.0	0.0	0.0	0.0	0.0	10.2
Population in settlements exposed to landslide	%	0.0	1.9	6.0	19.0	8.2	45.7	0.0
Road infrastructure exposed to fluvial flooding	%	16.8	30.1	4.9	8.3	13.2	4.7	75.0
Rail network exposed to fluvial flooding	%	27.5	47.6	5.1	6.0	27.6	4.8	74.3
Road infrastructure exposed to coastal hazard	%	11.9	3.1	0.0	0.0	0.0	0.0	1.7
Rail network exposed to coastal hazard	%	9.3	0.0	0.0	0.0	0.0	0.0	2.2
Transport nodes exposed to fluvial flooding	%	1.2	14.9	0.5	2.7	7.9	1.6	42.4
Transport nodes exposed to coastal hazard	%	23.2	0.4	0.0	0.0	0.0	0.0	5.9
Ports exposed to coastal hazard	%	50.0	0.0	0.0	0.0	0.0	0.0	100.0
Sensitivity								
Population density	Ratio	367.3	437.2	360.4	319.6	304.1	57.6	137.7
Total population living in urban areas /area in km2	Ratio	960.8	914.5	750.4	1035.5	1068.2	779.9	976.2
Change in population density in NUTS3 unit between 2017-2050	%	3.4	3.7	1.2	1.4	1.9	0.0	0.6
Migratory population change in NUTS3 unit between 2017-2050	%	67.2	77.7	30.4	37.7	58.5	1.3	9.2
Soil moisture stress	N°	48.0	48.4	69.5	77.5	72.6	64.6	50.5
Water consumption pressure (2030)	mm/25km^2	210.7	238.7	194.5	123.6	79.3	6.8	207.9
Adaptive capacity								
Urban area classified as green space	%	0.6	0.1	0.1	0.0	0.5	0.3	0.9
Change in total green space	%	4.7	5.0	5.2	1.8	5.1	0.4	4.3
Urban land cover	%	13.6	12.7	11.3	10.2	9.5	1.9	6.4
Change in urban land cover	%	1.7	1.9	1.9	0.6	1.7	0.5	4.0

Landlocked and elevated

This Landlocked and Elevated class covers the Alps, upland areas of Germany, parts of the Carpathian Mountains and France's Massif Central and Eastern mountain ranges. Aside from several areas in Italy, all cities and NUTS 3 regions are inland. The topography and high rainfall levels contribute to landslides standing out as a critical hazard. The exposure of people, settlements and critical infrastructure to landslides is high from a European perspective. High transport infrastructure densities (road intersections, transport nodes) stand out as a particular issue, although population densities are relatively low. Exposure to fluvial flooding is also relatively high. Projections for climate-change-induced intensification of extreme rainfall may drive exposure levels higher still. In addition, these areas are projected to experience increasing migration in the future. Climate change poses a range of risks to these regions over the coming decades, although their relatively high levels of adaptive capacity may help to lessen levels of risk.

In the specific, Treviso, Vicenza and Verona NUTS 3 regions belong to the Landlocked and Elevated 3 sub-class, as a chain of cities and NUTS 3 regions running along the southern side of the Alps, through France, Italy, Slovenia and Austria do. Relative to cities and NUTS3 regions within the other Landlocked and Elevated sub-classes, these NUTS 3 regions have the following distinguishing features and characteristics: higher projected increase in the number of summer days, heatwave days and consecutive dry days; higher soil moisture stress and projected water consumption pressure; greater projected change in the number of young people and migration. Other indicators are around the average for the Landlocked and Elevated class. The most significant risk indicators for the Treviso, Vicenza, Verona and Belluno areas are present in Table 37 compared to the other Veneto Region NUTS 3 areas. As part of these regions lies on flat topography and part on hills mountains, the % of areas exposed to landslide varies from region to region, ranging from 16,2% for Treviso to 86,6% for Belluno. This characteristic also leads to a high percentage of the population living in landslide risk areas, with high values for Belluno (86.8%) and Vicenza (45.2). On the other hand, there is some risk from rivers and a large increase in expected heat-related impacts in lowland areas. In RCP 8.5 scenario, the increase of tropical nights is very high for Treviso (+19) and Verona (+21) areas and the increase of heatwave days, with +7 days per year for Treviso and +8 for Verona.

5.2 System's capacity: plans dealing with CC-impacts.

Coding and development control for water management

The approach in Veneto to urban drainage is linked to the concept of hydraulic invariance (Pistocchi, 2001). This principle states that any transformation of the land use of an area must not cause an aggravation of the flood capacity of the water body receiving the surface flows originating from the area itself (flow attenuation). Hydraulic invariance, therefore, provides for the quantification and artificial availability of the minimum volumes of reservoir necessary to compensate for those suppressed by urbanisation. In essence, it requires those proposing a transformation to take on the responsibility for the soil sealing, according to the "user pays" principle. However, the provision of these volumes of storage is not aimed at retaining the flows on site, but to maintain unchanged the formation of floods at the catchment scale. Since the hydraulic protection of the territory is the primary purpose of this invariance approach, it is mainly implemented through the construction of underground lamination tanks and oversized sewerage networks.

The Veneto Region was one of the first Italian administrations to introduce forms of hydraulic regulation applied to urban planning and construction interventions in its territory, followed by other regional and provincial administrations (Pasi et al., 2019). In Veneto, as in most cases, the promoters of urban plans and/or building interventions are required to assess hydraulic compatibility through studies in which the impact of the proposed interventions is analysed. The necessary compensatory volumes are then calculated included in the project.

The methods for sizing compensatory volumes do not change between new construction and restructuring/requalification interventions: the tendential objective remains to limit surface runoff from any area subject to transformation to that typical of a non-urbanised context. Methods and values to be used are then differentiated according to a combination of size thresholds and levels of potential waterproofing. In this way, an increasing complexity of analyses is required as the importance of the transformation interventions increases.

The parameters required by the hydraulic invariance approach in Veneto tend to conform the interventions to a mere compensation logic, not allowing to highlight other possible and necessary benefits. In the hydraulic field, these benefits include water quality, infiltration on site and hydrogeological invariance, which are applied in the Lombardy Region regulations. Solutions that can bring co-benefits indirectly linked to water management do not find proper regulatory support either. These include the support of habitats and biodiversity, the recharging of water tables, the reduction of vulnerability due to heat island phenomena, the quality of urban spaces and the multifunctionality that sustainable urban drainage solutions (SuDS) can develop compared to conventional solutions (Musco, 2018).

The coding approach chosen by the Veneto Region in the field of hydraulics does not sufficiently support, in contrast to the British approach dealt with in Chapter 2.1, a water management planning that can enter into synergy with the policies of reducing land consumption and adapting to climate change. The former, for example, dealt with in Veneto's L.R. n.14/2017 contains relevant references to mitigation, ecological compensation and hydraulic invariance, to which is added the protection of the environment and people from the effects of climate change. In section 5.3, we will see how this theme recurs in the Regional Planning Plans examined.

5.3 Interaction between CC and urban systems in Central Veneto

The following section aims to analyse the content of two typologies of plans implemented by the Municipalities of the Central Veneto area. The thematic questions guiding this analysis aimed to compare the knowledge that emerges from the body of local plans reconstructed from the conceptual and practical framework of Chapters 1.2 and 2.2. The questions are oriented to understand which relations are treated in the plans between CC-impacts and the urban environment and which intervention modalities are contained in the plans. The plans' content analysis is articulated to bring out how the plans are: 1) considering the CC interdependencies, 2) intervening in the system 3) and according to which principles, and finally 4) what are the co-benefits generated by the plan interventions.

Table 38
List of the selected plans for this review, year, main developer, main theme and reference.

The two types of plans examined are Sustainable Energy and Climate Action Plans (SECAPs) and Piano di Assetto Territoriale (PAT). SECAPs are an example of a Local Climate Plan of the "Comprehensive and stand-alone" type according to the classification presented in Chapter 2.1 (D. Reckien et al., 2019). They are plans dedicated to mitigation and adaptation, developed within the Covenant of Mayors.

The PAT is a territorial instrument at the municipal scale that is strategic and falls into the "Mainstreamed and inclusive" category of Local Climate Plans. It can interact with climate impacts through different modalities, including: land use definition and management, local transformation

Plan title	Year	Main Developer	Main theme		Reference
Piano di assetto del territorio (PAT)	2010	Municipality of Vicenza	Planning	Strategic	(Comune di Vicenza, 2010)
Piano di assetto del territorio intercomunale (PATI)	2010	Municipality of Cadoneghe and Vigodarzere	Planning	Strategic	(Comune di Cadoneghe & Comune di Vigodarzere, 2010)
Piano di assetto del territorio (PAT)	2014	Municipality of Padova	Planning	Strategic	(Comune di Padova, 2014)
Piano di assetto del territorio (PAT)	2015	Municipality of Treviso	Planning	Strategic	(Comune di Treviso, 2015)
Sustainable Energy and Climate Action Plan (SECAP)	2021	Municipality of Padova	Mitigation	Adaptation	(Comune di Padova, 2021)
Sustainable Energy and Climate Action Plan (SECAP)	2021	Municipality of Treviso	Mitigation	Adaptation	(Comune di Treviso, 2021)
Sustainable Energy and Climate Action Plan (SECAP)	2021	Municipality of Vicenza	Mitigation	Adaptation	(Comune di Vicenza, 2021)
Sustainable Energy and Climate Action Plan (SECAP)	2021	Muncipality of Curtarolo	Mitigation	Adaptation	(UCMB, 2021)
Sustainable Energy and Climate Action Plan (SECAP)	2021	Muncipality of Cadoneghe	Mitigation	Adaptation	(UCMB, 2021)
Sustainable Energy and Climate Action Plan (SECAP)	2021	Muncipality of Vigodarzere	Mitigation	Adaptation	(UCMB, 2021)

management, local service provision planning, application of urban and environmental quality standards and application of rules for implementation planning. The analysis within this typology of plans aims to identify components related to climate change impacts even if these are not explicitly stated. Table 38 shows the list of the documents analysed in this chapter.

The analysis of these documents is supported by a questionnaire addressed to the municipalities aimed at collecting their perception of climate risks in their territory. The questionnaire is designed to collect knowledge based on the administrators' direct experience concerning climate risks and their effects on local sectors. The questionnaire was carried out in 2019 as part of a process of assisting municipalities in the construction of their SECAP within the VenetoAdapt LIFE project in which the author took part. The results of this questionnaire are presented below in the section dedicated to each Municipality, and they give a picture of the local perception of the probability, intensity and time horizon that specific CC-related hazards may have on different local sectors.

Results

This section presents the results of the analysis of the data and plans previously presented. The results are organised according to the different Municipalities: Vicenza, Padova, Treviso and UCMB. For each municipality is presented the analysis of the overall perception of risk, the main local planning document (PAT or PATI) and finally, the most recent sectoral planning document related to climate change (SECAP). The relations found during the reading of these plans and survey analysis will be presented in this paragraph through two modalities: a descriptive narrative (Table 47) and a graphic matrix (Figure 47)

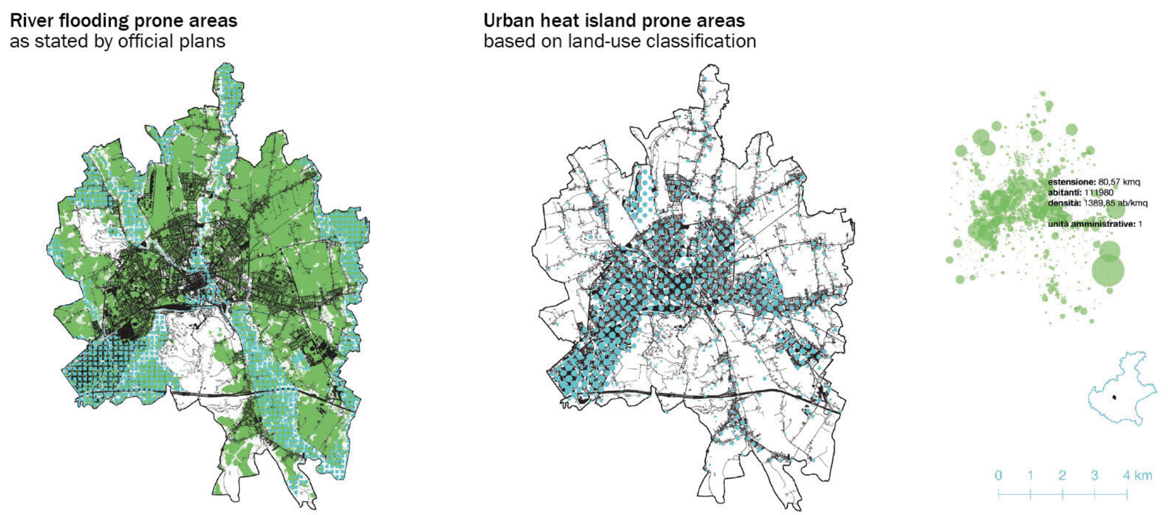


Figure 43
Vicenza Municipality's river flood and urban heat island prone areas, based on planning documents and land-use classification. Source: (Veneto Adapt, 2019)

Municipality of Vicenza

The city of Vicenza is located in the Landlocked and Elevated typology for climate risk (Chapter 5.1). Comparing the risk indicators presented in Table 37 of that chapter with the local perception of risks shows a high degree of correspondence between the two. Table 39 shows the self-assessed level of risks, change in intensity and frequency, and time horizon based on the knowledge and experience of the Municipality administration. The most severe risks with an in-progress time horizon are hydrological risks in the form of both surface and river overbank flooding. The other high risk is recognised in heat waves, whose expected change increases both in intensity and frequency. The local perception is consistent with the specific indicators for the NUTS3 of Vicenza, with considerable increases expected in mean temperature, maximum temperature, tropical nights and heatwave days. On the other hand, the risks perceived as moderate, with an increasing scenario but in the medium term, arise from droughts and severe winds.

Self-assessed CC-effects on the urban systems

The survey on local perceptions of the effects that hazards may have on urban systems goes into more detail about the potential impacts perceived by the local administration of Vicenza (Table 40). The impacts of hydrological hazards are perceived as the most severe, although they have critical effects only on the water, environment and spatial planning sectors. The probability of their occurrence is generally perceived as medium, except for spatial planning that are perceived as already in progress. Potential impacts on other sectors are instead perceived with a longer time horizon, linked to the expected increase in frequency and intensity of impacts.

Drought-related responses reveal a very uniform picture of moderate-intensity, likelihood and long term, even for sectors such as agriculture that have high vulnerability and exposure to this impact. This is likely a consequence of still uncertain knowledge of the sector-specific impacts of drought, perceived as a distant scenario with uncertain effects.

In contrast, the effects of meteorological events are more differentiated, with critical severity points for the energy, agriculture and public health sectors. The effects of heatwaves on sectors are considered very likely, and for agriculture are even already in progress. In an interview commenting on the survey with the Administration, it emerged that the time horizon is marked medium-term in its most critical effects, such as blackouts for the energy sector, although impacts of lesser severity are already underway.

PAT

The PAT of the Municipality of Vicenza (Comune di Vicenza, 2010), in its different documents, contains several relations between the urban environment and climate impacts. The plan focuses on water-related impacts: hydraulic risk from river flooding, surface water areas, localised flooding from intense rainfall and embankment and resurgence areas. The relations that these impacts have with urban systems are concentrated on three main axes: the built environment, green areas and the hydrographic network. The relations with the former are of vulnerability, where buildings and infrastructures are mainly seen as assets exposed to risks. The plan intervenes in vulnerable areas through modalities that follow the “robust” principle. These aim to limit building development, protect undeveloped areas, and regulate new interventions with waterproofing parameters, elevation, and prohibition of specific building conformations. In non-at-risk areas, both new constructions and those subject to restoration are required to compensate for their impact on the water response of the territory with lamination and storage measures, at both building and urban level. The protection of vulnerable areas intersects with the axes linked to the ecological and water network. In these areas, the plan prohibits new buildings, and the permitted recovery and enhancement interventions can only occur with

Vicenza					
Type	Hazard	Current risk	Exp. change in intensity	Exp. change in frequency	Time horizon
Hydrological	**Flash/surface flood**	high	increase	increase	in progress
	River flood	high	increase	stable	in progress
Climatological	**Drought**	moderate	increase	increase	medium-term
Meteorological	**Heat wave**	high	increase	increase	short-term
	Severe wind	moderate	increase	increase	medium-term

Table 39
Municipality of Vicenza's CC-Risk self-assessment

Table 40
Municipality of Vicenza's CC-effects on urban systems self-assessment

Vicenza											
Type	Hazard	Sector	Severity			Probability			Time horizon		
			Less serious	Serious	Critical	Rare	Likely	Higly likely	In progress	Short-term	Medium-term
	Flash/surface flood	Building & infrastructure		x				x		x	
		Transport		x			x				x
		Spatial planning		x			x		x		
		Agriculture		x			x				x
		Environment		x			x				x
		Emergency		x			x			x	
		Tourism	x			x					x
Hydrological	River flood	Building & infrastructure		x			x			x	
		Transport		x		x				x	
		Water, supply & sanitation			x	x					x
		Waste management		x				x		x	
		Spatial planning			x		x		x		
		Environment			x			x		x	
		Emergency		x			x			x	
		Tourism	x				x				x
total hydrological			**2**	**10**	**3**	**3**	**9**	**3**	**2**	**7**	**6**

Table 40 (continued)
Municipality of Vicenza's CC-effects on urban systems self-assessment

Vicenza											
Type	Hazard	Sector	Severity			Probability			Time horizon		
			Less serious	Serious	Critical	Rare	Likely	Higly likely	In progress	Short-term	Medium-term
Climatological	Drought	Building & infrastructure		x			x				x
		Energy		x			x				x
		Water, supply & sanitation		x			x				x
		Agriculture		x			x				x
		Environment		x		x					x
		Emergency		x		x					x
Total climatological			**0**	**6**	**0**	**2**	**4**	**0**	**0**	**0**	**6**
Meteorological	Heat wave	Building & infrastructure		x				x		x	
		Energy			x		x				x
		Water, supply & sanitation		x				x		x	
		Spatial planning		x				x		x	
		Agriculture			x			x	x		
		Environment		x			x				x
		Public health		x			x				x
		Tourism	x			x					x
	Severe wind	Building & infrastructure	x				x				x
		Transport	x				x				x
		Energy		x		x					x
		Agriculture		x			x				x
		Environment		x			x				x
		Public health			x	x					x
		Emergency	x			x					x
		Industrial	x			x					x
total meteorological			**5**	**8**	**3**	**5**	**7**	**4**	**1**	**3**	**12**

eco-compatible and naturalistic engineering techniques, compatible with the "green infrastructure" intervention principle. The protection of some of these areas, such as resurgence zones, is also important for preserving water quality. Finally, the protection of ecological networks, rural areas, wooded areas, urban greenery and vegetation also mitigates summer heat-related impacts, although these are not explicitly stated.

SECAP

SECAP of Vicenza Municipality (Comune di Vicenza, 2021) combines the aims of mitigation and adaptation in an integrated way. The plan considers numerous interactions between urban elements and different hazards. Hydrological hazards are the most considered, with numerous interactions with the built environment, transport, environment and minor hydrographic systems. Together with health and agriculture, they are also the sectors with numerous interactions with other hazards, including drought and heatwaves.

The modes of intervention are organised in actions, and for the adaptation part, they are composed of three main types. One is integrating adaptation and risk reduction principles and standards in the revision or construction of new plans. Another is the definition of information and knowledge dissemination systems to improve the response and adaptation to climate impacts. Finally, the implementation of physical interventions, primarily to manage the risk of the hydrographic network.

This SECAP effectively integrates each sectoral action into a broader context, addressing several critical territorial issues at a time and tackling several impacts. One example is hydraulic interventions, which are designed and implemented to contribute to the improvement of water quality, habitats, and ecosystems. Precisely because of this integrated perspective, each action has numerous areas in which it produces co-benefits. The most frequent are the sectors of water and buildings and infrastructures, which benefit from improved management of water quantity and quality and consequent risk reduction with benefits for the health and emergency management sector. Improved hydraulic risk management also benefits the transport sector, and with it many related economic sectors. Finally, agriculture, the environment and biodiversity benefit from improved water quality and the numerous renaturation measures included in the hydraulic works.

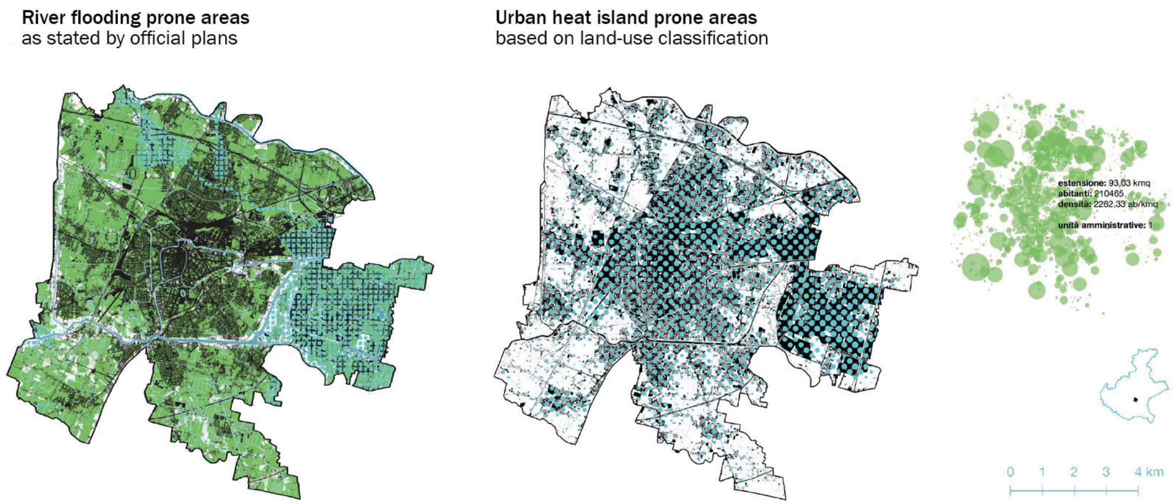


Figure 44
Padova Municipality's river flood and urban heat island prone areas, based on planning documents and land-use classification. Source: (Veneto Adapt, 2019)

Municipality of Padova

The city of Padova is located in the Inland and Urbanised typology for climate risk (Chapter 5.1). Comparing the risk indicators presented in Table 37 of that chapter with the local perception of risks shows a moderate degree of correspondence between the two. Table 41 shows the self-assessed level of risks, change in intensity and frequency, and time horizon based on the knowledge and experience of the Municipality administration. In this overall consideration of risk, the local perception is that the risks from climate change are of significant intensity and with an increasing trend of change. The risk from heatwaves is classified as high and ongoing, and is expected to intensify and become more frequent. This is in line with the area-wide indicators, which in the RCP8.5 scenario predict a substantial increase in average and maximum temperatures (+1,9°C), with one of the most significant increases in tropical nights (+24) and heat wave days (+9). The high risk is also exacerbated by highly urbanised local conditions, with urban areas covering 12,7% of the territory and growing at one of the highest rates in the region. The climatological hazard driven by drought is considered to have a moderate risk in a short-term scenario. The perception aligns with the spatial indicators, which record an intense pressure on water consumption and moderate soil water stress.

The spatial indicators indicate a high hydrological risk, which affects a large proportion of land area (14,3%), road infrastructure (30,1%) and rail network (47,6%). The percentage of the population in settlements exposed to river hazards is also very high (12,5%). However, this high exposure is not directly reflected in the local perception, which instead classifies the risk of river floods as moderate and with a medium-term time horizon. On the other hand, flash/surface floods with a more local scope are perceived as in progress and of high risk.

Self-assessed CC-effects on the urban systems

The survey on local perceptions of the effects that hazards may have on urban systems goes into more detail about the potential impacts perceived by the local administration of Padova (Table 42). As emerged from the overall risks survey, meteorological and hydrological hazards are perceived to be the most critical.

The sectors that are perceived to be the most exposed in the short term, both in severity and likelihood, to flooding impacts are transport, building & infrastructure and spatial planning. This perception aligns with the indicators presented earlier, showing that the transport system and urbanised spaces are in areas perceived to be at risk for a considerable proportion. In addition, other critical effects are considered ongoing for the agriculture sector and expected in the medium-term for the environment and water supply & sanitation sectors.

The effects of heatwaves are perceived locally as critical in most sectors, except the buildings and water sectors. Half of the sectors considered have a high probability of these effects occurring in a short time horizon if not already ongoing. These include the spatial planning and environment sectors, with critical severity. Surprisingly, the sectors related to public health and energy - which are generally recognised as being among the most negatively affected by these events - have a medium-term time horizon in administrators' perception.

The effects of drought on urban systems are considered likely but with a more indefinite medium-term horizon. The agriculture and environment sectors are perceived to be the only ones exposed at a critical level, while surprisingly the impacts on the water sector are considered minor.

Intense wind impacts are also considered risks that may occur in the medium term with a medium probability. Only in the environment sector is the risk perceived as in progress, very likely and critical. Based on local experience, the main damage occurred on urban and regional tree stock following recent high wind events. Other significant effects are expected on buildings and public health in the form of potential casualties, a consideration that has led to a critical severity rating in these sectors, albeit with a medium-term time horizon.

PAT

In Padova Municipality's PAT (Comune di Padova, 2014) there are numerous relationships between urban systems and the impacts of climate change. The most treated and regulated relations concern the impacts deriving from water, and the impacts that human activities have on water quality. The risk of river flooding and urban flooding are treated concerning the built environment and infrastructure. The plan in this report acts mainly by regulating the areas in which protection standards are to be applied, in which new development is to be prohibited and in which special investigations are to be required before authorisation to intervene. In areas not considered vulnerable, the plan sets standards and techniques for hydraulic compensation of sealing interventions.

The quality of surface and groundwater is protected by a series of regulations and technical standards required where there are uses and functions particularly at risk, such as industrial, agricultural and road use. In addition, the protection and extension of ecological networks and green areas are explicitly linked to the reduction of heat island phenomena, air quality and biodiversity.

The main co-benefits of the plan are related to land safety. This occurs both in vulnerable areas, reducing the risk of disaster, and in other areas, where a better relationship between built-up areas and water management is aimed at increasing the system's resilience.

SECAP

SECAP of Padova Municipality (Comune di Padova, 2021) combines the attention for mitigation aspects with hydrological and meteorological risks. The relationships most considered within the plan are those that relate primarily to the built and urban environment. In fact, the various hydrological and meteorological impacts are related to public and private buildings, urban spaces and industrial areas. Another system very much present in the plan is the environmental one, specifically the minor hydrographic network and its relationship with heavy rainfall.

The principles of intervention are numerous and cover different modalities. For new private buildings, regulations are foreseen for aspects of building design and spatial planning. For existing private buildings, knowledge and incentives are provided for retrofits towards local rainwater management, water consumption reduction, and vulnerability to heatwaves. Numerous interventions on the building stock of both the municipality and other public bodies are also planned. These measures also concern urban open spaces and industrial buildings. For the risk of flooding, both physical and organisational interventions are foreseen for the basin-wide management of river water. In order to cope with water consumption, and thus also with the risk of water scarcity, interventions on the water supply network are planned for monitoring and resilience. Finally, to cope with emergencies, the plan provides for organisational and real-casting interventions.

Padova					
Type	Hazard	Current risk	Exp. change in intensity	Exp. change in frequency	Time horizon
Hydrological	Flash/surface flood	high	increase	increase	in progress
	River flood	moderate	increase	increase	medium-term
Climatological	Drought	moderate	increase	increase	short-term
Meteorological	Heat wave	high	increase	increase	in progress
	Severe wind	moderate	increase	stable	short-term

Table 41
Municipality of Padova's CC-Risk self-assessment

Table 42
Municipality of Padova's CC-effects on urban systems self-assessment

Padova											
Type	Hazard	Sector	Severity			Probability			Time horizon		
			Less serious	Serious	Critical	Rare	Likely	Higly likely	In progress	Short-term	Medium-term
	Flash/surface flood	Building & infrastructure		x			x			x	
		Transport			x			x		x	
		Spatial planning			x			x		x	
		Agriculture			x			x	x		
		Environment			x		x				x
		Emergency		x				x		x	
		Tourism		x			x				x
Hydrological	River flood	Building & infrastructure			x		x				x
		Transport			x		x			x	
		Water, supply & sanitation			x	x					x
		Waste management		x				x		x	
		Spatial planning			x			x		x	
		Environment		x			x				x
		Emergency			x			x		x	
		Tourism		x			x				x
total hydrological			**0**	**6**	**9**	**1**	**7**	**7**	**1**	**8**	**6**

Table 42 (continued)
Municipality of Padova's CC-effects on urban systems self-assessment

Padova											
Type	Hazard	Sector	Severity			Probability			Time horizon		
			Less serious	Serious	Critical	Rare	Likely	Higly likely	In progress	Short-term	Medium-term
Climatological	Drought	Building & infrastructure	x				x				x
		Energy		x			x				x
		Water, supply & sanitation		x			x				x
		Agriculture			x		x				x
		Environment			x		x				x
		Emergency	x			x					x
Total climatological			**2**	**2**	**2**	**1**	**5**	**0**	**0**	**0**	**6**
Meteorological	Heat wave	Building & infrastructure		x				x	x		
		Energy			x		x				x
		Water, supply & sanitation		x				x		x	
		Spatial planning			x			x	x		
		Agriculture			x		x			x	
		Environment			x			x	x		
		Public health			x		x				x
		Tourism			x		x				x
	Severe wind	Building & infrastructure			x		x				x
		Transport		x		x					x
		Energy		x			x				x
		Agriculture		x			x				x
		Environment			x			x	x		
		Public health			x		x				x
		Emergency		x		x					x
		Industrial		x			x			x	
total meteorological			**0**	**7**	**9**	**2**	**9**	**5**	**4**	**3**	**9**

Through these modes of intervention, the plan foresees a wide range of co-benefits in many sectors. As adaptation actions have also been developed with mitigation in mind, the sector with the most co-benefits is energy. The focus on the built environment throughout the plan includes numerous co-benefits in buildings and infrastructures and spatial planning. There are also essential co-benefits in the areas of health, emergency management and environment and biodiversity.

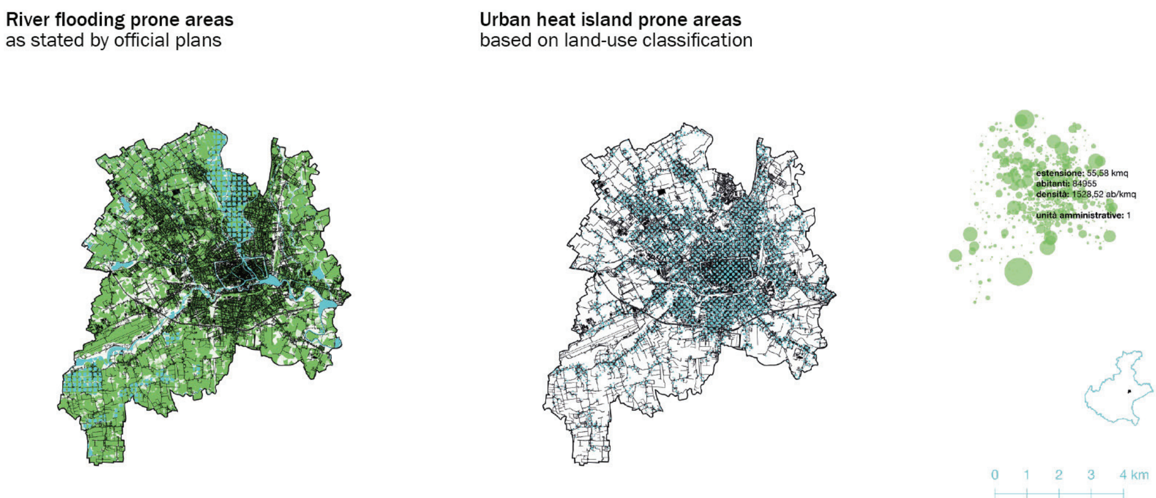


Figure 45
Treviso Municipality's river flood and urban heat island prone areas, based on planning documents and land-use classification. Source: (Veneto Adapt, 2019)

Municipality of Treviso

The city of Treviso is located in the Landlocked and Elevated typology for climate risk (Chapter 5.1). Comparing the risk indicators presented in Table 37 of that chapter with the local perception of risks shows a moderate degree of correspondence between the two. Table 43 shows the self-assessed level of risks, change in intensity and frequency, and time horizon based on the knowledge and experience of the Municipality administration. In this overall consideration of risk, the local perception is that the risks from climate change are of a low-moderate level. The changing trend of this risk is considered partially stable for frequency and increasing for intensity, with a long and distant time horizon.

The perception of the Administration is that the only moderate risks are aspects of hydrological and meteorological risks. The first ones are confirmed by Treviso NUTS3 indicators, which show that only a small portion of the territory is subject to fluvial hazard (5,1%), but also that the high percentage of urban land cover (11,3%) in consistent annual increase (+1,9%) implies vulnerability to flash/surface flood events.

Heatwaves are the only locally recognised hazard with a short-term horizon. This is in line with the area-wide indicators, which in the RCP8.5 scenario predict a substantial increase in average and maximum temperatures (+1,9°C), with a significant increase in tropical nights (+19) and heat wave days (+7).

The risk from droughts is considered the lowest in the long term and with a stable scenario. This local assessment is based on the richness of resurgent waters in the territory, but it seems an underestimation of the risk in comparison with regional indicators. In fact, the percentage of territory at risk of drought is low (1,1%), but the effects of this impact can reverberate throughout the system, especially considering the high water consumption pressure expected in 2030 and a high soil moisture stress. Intense wind phenomena are another risk that is considered low, long-term and only increasing in intensity.

Self-assessed CC-effects on the urban systems

The survey on local perceptions of the effects that hazards may have on urban systems goes into more detail about the potential impacts perceived by the local administration of Treviso (Table 44). As emerged from the overall risks survey, climatological and hydrological hazards are perceived to have a long time horizon, while meteorological ones are perceived to have a shorter time horizon.

The effects of hydrological hazards on urban systems are considered to have a medium-high severity, with acute effects on the agriculture, water, environment and emergency sectors. However, the probability of these occurring is generally perceived as medium-low.

As emerged from the overall risk perception, drought is another hazard considered to have a medium-term time horizon, and therefore distant in time. However, assessing the interaction of this hazard with sectors allows us to go into detail on impacts and highlight that there are already important interactions in some sectors. The agricultural sector is critically exposed to this impact, with a reasonable probability of these impacts occurring. The water supply & sanitation and environment sectors are also considered to be seriously exposed to this impact. The rest of the sectors are rated as less serious, with rare probability and medium-term horizon, which is the lowest possible rating.

In the perception of Treviso administrators, heatwaves severely interact with many urban sectors. Only the tourism sector seems to be considered as less relevant. Interactions of this hazard are perceived as short term, and in the case of the environment sector also as in progress, in countertendency to the medium-term evaluation assigned to most of the other hazards. The likelihood of heatwaves interacting severely or critically with the

Treviso					
Type	**Hazard**	**Current risk**	**Exp. change in intensity**	**Exp. change in frequency**	**Time horizon**
Hydrological	Flash/surface flood	moderate	increase	stable	medium-term
	River flood	low	increase	increase	medium-term
Climatological	Drought	low	stable	stable	medium-term
Meteorological	Heat wave	moderate	increase	increase	short-term
	Severe wind	low	increase	stable	medium-term

Table 43
Municipality of Treviso's CC-Risk self-assessment

Table 44
Municipality of Treviso's CC-effects on urban systems self-assessment

Treviso											
Type	Hazard	Sector	Severity			Probability			Time horizon		
			Less serious	Serious	Critical	Rare	Likely	Higly likely	In progress	Short-term	Medium-term
Hydrological	Flash/surface flood	Building & infrastructure		x			x				x
		Transport	x			x					x
		Spatial planning	x			x					x
		Agriculture			x		x				x
		Environment		x			x				x
		Emergency		x			x				x
		Tourism		x		x					x
	River flood	Building & infrastructure		x			x				x
		Transport		x		x					x
		Water, supply & sanitation			x		x				x
		Waste management		x		x					x
		Spatial planning			x		x				x
		Environment			x	x					x
		Emergency			x	x					x
		Tourism		x		x					x
total hydrological			**2**	**8**	**5**	**8**	**7**	**0**	**0**	**0**	**15**

Table 44 (continued)
Municipality of Treviso's CC-effects on urban systems self-assessment

Treviso											
Type	Hazard	Sector	Severity			Probability			Time horizon		
			Less serious	Serious	Critical	Rare	Likely	Higly likely	In progress	Short-term	Medium-term
Climatological	Drought	Building & infrastructure	x			x					x
		Energy	x			x					x
		Water, supply & sanitation		x			x				x
		Agriculture			x		x				x
		Environment		x		x					x
		Emergency	x			x					x
Total climatological			**3**	**2**	**1**	**4**	**2**	**0**	**0**	**0**	**6**
Meteorological	Heat wave	Building & infrastructure		x				x			x
		Energy		x		x					x
		Water, supply & sanitation		x			x			x	
		Spatial planning			x			x			x
		Agriculture			x			x		x	
		Environment		x				x	x		
		Public health			x		x			x	
		Tourism	x			x					x
	Severe wind	Building & infrastructure		x		x					x
		Transport		x		x				x	
		Energy	x			x					x
		Agriculture		x			x			x	
		Environment			x		x			x	
		Public health			x	x				x	
		Emergency	x			x					x
		Industrial	x			x					x
total meteorological			**4**	**6**	**5**	**7**	**4**	**4**	**1**	**6**	**8**

buildings, spatial planning, agriculture and environment sectors is assessed as very likely. Surprisingly, the energy sector, which suffers typically during heatwaves, is considered to have a rare medium-term probability of being negatively affected.

Finally, the effects of severe wind events are considered to be generally rare, except for the agriculture and environment sectors. Together with the effects on public health, these sectors are assessed with a short-term horizon and high severity. These considerations are in line with the perception that the other Administrations considered in this survey have recorded, where severe wind events interact mainly with vegetation, buildings and, as a consequence, with the safety of people close to these elements.

PAT

The PAT of the Municipality of Treviso (Comune di Treviso, 2015) contains some relations between urban systems and climate change impacts. Even if the latter is not explicitly mentioned, the hydraulic risk deriving from flooding or water stagnation is extensively treated and related to it. Hydraulic compensation works are treated in several aspects, specifically in their relation to new buildings, riverbanks, and floodplain areas. The particularity of resurgence areas leads to some interesting interactions regarding the protection and quality of water, which is seen as particularly vulnerable in its interaction with buildings, some agricultural and industrial uses. Impacts due to high temperatures and heat island phenomena are not explicitly addressed, but the plan provides measures related to ecological corridors and the water network that can help to reduce their impact.

SECAP

SECAP of Treviso Municipality (Comune di Treviso, 2021) combines the attention for mitigation aspects with risks deriving from the hydrographic system. The most considered relations inside the plan are those between surface water management and minor hydrographic network with built-up areas, embankments, agricultural areas, energy production, urban areas, sewerage and main hydrographic network. The heat island is mentioned in relation to air quality, urban green areas and public health. As for other impacts, the plan merely lists them and does not address the possible effects and interactions they may have on the territory.

The intervention methods of this plan take shape through distinct actions oriented towards three main types of intervention: the adoption or revision of sectoral plans, the integration of adaptation issues into territorial plans and their technical regulations, and the implementation of some punctual interventions. All these types of intervention are mainly focused on hydraulic defence and urban green, acting according to principles aiming at increasing the system's thresholds, diversity and redundancy of the hydrographic system, and some grey and green infrastructures interventions to be included in the revision of some plans. The sectors with the most co-benefits from these interventions are water, buildings and infrastructures and the environment. The main co-benefits are disaster risk reduction, enhanced climate change adaptation, enhanced resilience and improved resource quality.

River flooding prone areas
as stated by official plans

Urban heat island prone areas
based on land-use classification

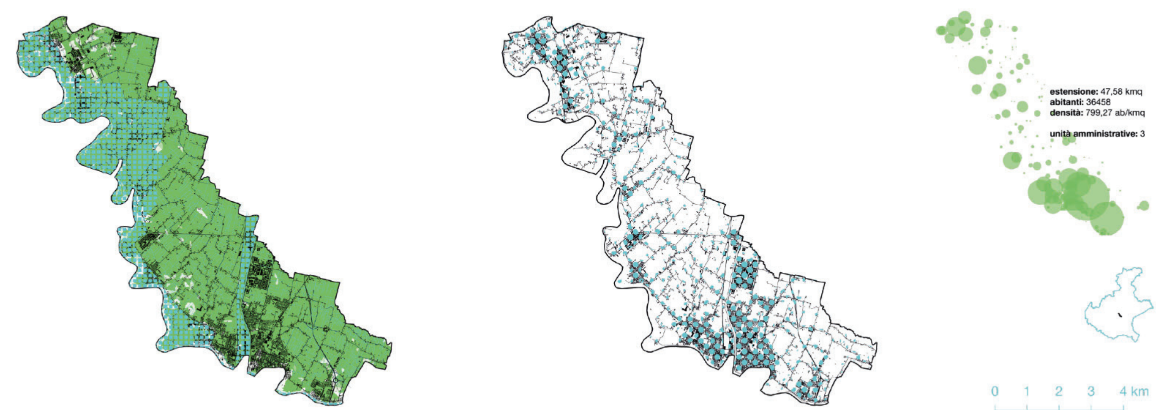


Figure 46
UCMB's river flood and urban heat island prone areas, based on planning documents and land-use classification. Source: (Veneto Adapt, 2019)

Medio Brenta Union of Municipalities

The Medio Brenta Union of Municipalities (UCMB) is located in the Inland and Urbanised typology for climate risk (Chapter 5.1). Comparing the risk indicators presented in Table 37 of that chapter with the local perception of risks shows a moderate degree of correspondence between the two. Table 45 shows the self-assessed level of risks, change in intensity and frequency, and time horizon based on the knowledge and experience of the Municipality administration. In this overall consideration of risk, the local perception is that the risks from climate change are of moderate-high intensity, with a clear increasing trend of change for intensity and frequency, although in a medium-term time horizon. Hydrological risks are the only ones perceived as high at the moment, both in terms of local flooding and the risk of river flooding. This risk is high because the Union of Municipalities lies along the course of the Brenta, a river prone to flooding and with a problematic hydraulic flow. This territory falls within the NUTS3 region of Padova and therefore shares its territorial indicators. The UCMB's differences are rooted in the lower density of population and built-up area compared to the Municipality of Padova. This drives a lower perception of heat island risk. The other consideration on drought and severe wind reported for Padova apply similarly to UCMB.

Self-assessed CC-effects on the urban systems

The survey on local perceptions of the effects that hazards may have on urban systems goes into more detail about the potential impacts perceived by the local administration of UCMB (Table 46). As emerged from the overall risks survey, all hazards considered are perceived to have a long time horizon, except for severe wind with some short-term implications. Although only hydrological hazards were classified with a high risk level in the overall consideration, the severity and probability of interaction with urban systems show that meteorological hazards also carry a high risk.

These hazards involve acute and very likely effects in buildings & infrastructure, water supply & sanitation, spatial planning, agriculture, environment and public health. The latter two also have shorter time horizons than all other classified interactions. Interactions with tourism are considered to be insignificant as tourist flows in these areas are negligible.

Hydrological hazards, as already mentioned, have a high probability of occurrence, despite being classified with a medium-term time horizon. The sector that has critical interactions with both hazards is the transport sector. The building & infrastructure and agriculture sectors have critical severity interactions with flash floods, while surprisingly both these and spatial planning are considered to have modest interactions with the river flood hazard. The water and environment sectors are considered more vulnerable to this hazard.

For the drought hazard, the most likely interactions are with the water and agriculture sectors, with a shorter time horizon for the former and a higher criticality for the latter.

PATI

The PATI of Cadoneghe and Vigodarzere municipalities (Comune di Cadoneghe & Comune di Vigodarzere, 2010) represents the UCMB territory and contains some relationships between exposed systems and climate change impacts. Mainly the plan addresses the effects of water risks, both in its abundance and lack. The sectors that are mainly affected by these impacts are buildings and infrastructures, agriculture, transport and industry. The plan intervenes in these sectors through regulation of new construction, incentives for retrofitting, land-use changes, and promotion of sustainable behaviour. The plan also provides compensation for relocating buildings in at-risk areas, and requires even CO2-emitting industries to compensate with measures that may also have heatwave relevance. Other actions considered for this impact are building construction practices that reduce albedo, including green roofs. Impacts related to intense wind are only mentioned and do not find space in this plan.

SECAP

The SECAPs of the three municipalities that are part of the Union have been adopted in three separate documents, one for each municipality, but they have been realised and constructed in a shared process that has common approaches and many actions (Comune di Cadoneghe, 2021; Comune di Curtarolo, 2021; Comune di Vigodarzere, 2021). These SECAPs mainly address the hydraulic risks arising from the proximity of the Brenta River and the flat orography of their territory. These impacts are related to buildings and infrastructures, specifically residential buildings, public buildings, productive areas and the transport system, with consequences on public health and the local economy. They are also related to possible impacts on the agricultural system, biodiversity and water quality. Furthermore, agriculture is considered to be exposed to the impacts of droughts and public health to heatwaves. Finally, the intense wind is related to potential damage to residential and productive buildings and trees.

The methods of intervention of this plan take shape through distinct actions oriented towards three main types of intervention: the adoption or revision of sectoral plans, the integration of adaptation issues into territorial plans and their technical regulations, and the implementation of some punctual interventions aimed at hydraulic defence and urban green areas. The former adopts principles of adaptive management, preparedness, and green areas self-organisation. In contrast, punctual interventions and building regulations rely on grey and green infrastructures to build adaptation.

The sectors with the most co-benefits from these interventions are water, buildings and infrastructures, spatial planning and environment. The main co-benefits are disaster preparedness, disaster risk reduction, enhanced climate change adaptation, ecosystem preservation and biodiversity improvement.

Medio Brenta union of Municipalities					
Type	**Hazard**	**Current risk**	**Exp. change in intensity**	**Exp. change in frequency**	**Time horizon**
Hydrological	Flash/surface flood	high	increase	stable	medium-term
	River flood	high	increase	increase	medium-term
Climatological	Drought	moderate	increase	increase	medium-term
Meteorological	Heat wave	moderate	increase	increase	medium-term
	Severe wind	moderate	increase	increase	short-term

Table 45
UCMB's CC-Risk self-assessment

Table 46
UCMB's CC-effects on urban systems self-assessment

Medio Brenta union of Municipalities											
Type	Hazard	Sector	Severity			Probability			Time horizon		
			Less serious	Serious	Critical	Rare	Likely	Higly likely	In progress	Short-term	Medium-term
Hydrological	Flash/surface flood	Building & infrastructure			x			x			x
		Transport			x			x			x
		Spatial planning		x				x			x
		Agriculture			x			x			x
		Environment		x			x				x
		Emergency		x			x				x
		Tourism		x			x				x
	River flood	Building & infrastructure		x			x				x
		Transport			x			x			x
		Water, supply & sanitation			x	x					x
		Waste management		x				x			x
		Spatial planning	x				x				x
		Environment			x			x			x
		Emergency		x			x				x
		Tourism	x			x					x
total hydrological			**2**	**7**	**6**	**2**	**6**	**7**	**0**	**0**	**15**

Table 46 (continued)
UCMB's CC-effects on urban systems self-assessment

Medio Brenta union of Municipalities											
Type	Hazard	Sector	Severity			Probability			Time horizon		
			Less serious	Serious	Critical	Rare	Likely	Higly likely	In progress	Short-term	Medium-term
Climatological	Drought	Building & infrastructure		x			x				x
		Energy		x			x				x
		Water, supply & sanitation		x				x		x	
		Agriculture			x			x			x
		Environment		x			x				x
		Emergency		x			x				x
Total climatological			**0**	**5**	**1**	**0**	**4**	**2**	**0**	**1**	**5**
Meteorological	Heat wave	Building & infrastructure		x				x			x
		Energy		x		x					x
		Water, supply & sanitation			x			x			x
		Spatial planning			x			x			x
		Agriculture			x			x			x
		Environment		x			x				x
		Public health		x			x				x
		Tourism	x			x					x
	Severe wind	Building & infrastructure		x				x			x
		Transport		x			x				x
		Energy		x		x					x
		Agriculture			x			x			x
		Environment			x			x		x	
		Public health			x			x		x	
		Emergency		x			x				x
		Industrial			x		x				x
total meteorological			**1**	**8**	**7**	**3**	**5**	**8**	**0**	**2**	**14**

Plan title	Effects of CC on urban elements, sectors and systems	Actions and ways of intervention	Principles	Co-Benefits
Municipality of Vicenza - Piano di assetto del territorio (PAT)	The flood risks covered in the plan are groundwater, fluvial and heavy rainfall flooding. Numerous relationships with buildings, water network, sealed areas, embankments, wetlands, lakes and green areas are described in the plan. Heat-related impacts have a relationship with the protection of green areas, ecological corridors and nature areas.	In areas classified as vulnerable, only naturalistic engineering interventions and environmentally friendly techniques are allowed. In general, in rehabilitation or new construction projects, the plan obliges hydraulic compensation interventions both at building and urban level. There are construction standards for building in vulnerable areas and principles of intervention on the hydrographic and natural network.	Grey infrastructure, Green infrastructure, Integrated, Robust, Relocation	Disaster Risk Reduction, Ecosystem preservation and biodiversity improvement, Improved resource quality (e.g. air, water).
Municipality of Vicenza - Sustainable Energy and Climate Action Plan (SECAP)	The plan considers numerous interactions between urban elements and different hazards. Hydrological hazards are the most considered, with numerous interactions with the built environment, transport, environment and minor hydrographic systems. Together with health and agriculture, they are also the sectors that have numerous interactions with other hazards, including drought and heat waves.	The main interventions that have the value of adaptation and disaster risk reduction are related to the water system, environment, biodiversity and buildings & infrastructures. The way in which the plan intervenes is linked both to the mainstreaming of adaptation principles within sectoral plans and to the implementation of physical works of risk reduction. The plan contains integrated intervention principles, which involve many municipal planning tools and have co-benefits in many sectors.	Grey infrastructure, Green infrastructure, Diversity and Redundancy, Integrated, Preparedness, Responsiveness, Prospective DRM	Disaster preparedness, Disaster Risk Reduction, Ecosystem preservation and biodiversity improvement, Enhanced climate change adaptation, Improved public health, Improved resource quality (e.g. air, water)
Municipality of Padova - Piano di assetto del territorio (PAT)	Relationships with water-related impacts are numerous within the plan. River and heavy rainfall flooding are the most dealt with because of the risk they bring mainly to buildings and infrastructure. The quality and quantity of surface water and groundwater is also very much dealt with, especially in its relation to industrial, agricultural and road areas. Heat island phenomena are mentioned in relation to urban areas, green corridors, urban green areas and buildings.	The principles of intervention are mostly prescriptive in nature and linked to land transformation. Hydraulic land management is the main area of intervention, to regulate both new urbanisation and interventions on existing buildings. Rainwater storage is widely addressed, and compensation is required to ensure a low runoff volume and high quality. Measures are mainly physical and transformative in nature, but also include protection and enhancement. Those in the ecological and hydrographic network have the most positive effects on the heat island phenomenon, the quality and quantity of groundwater and biodiversity.	Grey infrastructure, Green infrastructure, Corrective DRM	Ecosystem preservation and biodiversity improvement, Improved resource quality (e.g. air, water), Disaster Risk Reduction, Enhanced resilience
Municipality of Padova - Sustainable Energy and Climate Action Plan (SECAP)	The plan considers numerous interactions between the impacts of climate change and urban systems. Impacts related to heavy rainfall and heat waves are related to buildings and infrastructure, industry, health and spatial planning. The secondary water system is also included in the relationships with these impacts and water scarcity.	The principles of intervention are numerous and cover different modalities. For new private buildings, regulations are foreseen for aspects of building design and spatial planning. For existing private buildings, knowledge and incentives are provided for retrofits towards local rainwater management, reduction of water consumption and reduction of vulnerability to heat waves. Numerous interventions on the building stock of both the municipality and other public bodies are also planned. These measures also concern urban open spaces and industrial buildings. For the risk of flooding, both physical and organisational interventions are foreseen for the basin-wide management of river water. In order to cope with water consumption, and thus also with the risk of water scarcity, interventions on the water supply network are planned for monitoring and resilience. Finally, to cope with emergencies, the plan provides for organisational and real-casting interventions.	Green infrastructure, Diversity and Redundancy, Soft non-structural approaches, Learning and Innovation, Adaptive Management, Robust, Responsiveness, Inclusion.	Disaster preparedness, Disaster Risk Reduction, Ecosystem preservation and biodiversity improvement, Enhanced climate change adaptation, Enhanced resilience, Improved access to and quality of mobility services and infrastructure, Improved resource efficiency (e.g. food, water, energy).

Municipality of Treviso - Piano di assetto del territorio (PAT)	The main impact considered within the plan is the hydraulic risk from flooding or waterlogging, and is mainly related to built-up areas and industries. Other interactions dealt with are resurgence areas and water quality with buildings, agricultural and industrial uses.	The principles of intervention are geared towards regulating building construction and rehabilitation, relocation of functions and buildings in vulnerable areas, environmental protection and restoration, and hydraulic land management.	Grey infrastructure, Relocation, Corrective DRM	Disaster Risk Reduction, Ecosystem preservation and biodiversity improvement, Improved resource quality (e.g. air, water)
Municipality of Treviso - Sustainable Energy and Climate Action Plan (SECAP)	The relationships that are most considered within the plan are those between surface water management and the minor hydrographic network with buildings, embankments, agricultural areas, energy production, urban areas, sewers and the main hydrographic network. The heat island is mentioned in relation to air quality, urban green areas and public health.	The main interventions that have adaptation implications are related to surface water management. This includes: channel excavation, creation of reservoirs, maintenance of ditches and sewerage network, realcasting of rivers, monitoring. For air quality and heat island adaptation, the plan focuses primarily on urban and private green space.	Grey infrastructure, Green infrastructure, Adaptive Management, Thresholds, Diversity and Redundancy	Disaster Risk Reduction, Enhanced climate change adaptation, Enhanced resilience, Improved resource quality (e.g. air, water)
Medio Brenta union of Municipalities (Ca-Vi) - Piano di Assetto del Territorio Intercomunale (PATI)	The relations that are mainly addressed within the plan concern water-related risks. The risk of flooding is related to spatial planning, buildings and transport. The effects of heavy rainfall mainly concern secondary hydrography, and with it damage to agricultural land, damage to buildings and infrastructure, disruption of transport and chemical contamination of the industrial sector. Finally, drought is related to residential buildings and consumption, agriculture and industry.	The principles of intervention for this risk plan are related to reducing the environmental impact of certain activities and urban elements and to reducing the vulnerability of the territory. These are carried out in a regulatory, incentive, communication, relocation and building guideline manner. The principles are generally oriented towards a more local management of water runoff, a conscious use of water resources and the reduction of building exposure.	Grey infrastructure, Integrated, Corrective DRM, Relocation	Disaster Risk Reduction, Ecosystem preservation and biodiversity improvement, Improved resource quality (e.g. air, water), Improved resource security (e.g. food, water, energy), Shift to more sustainable behaviours
Medio Brenta union of Municipalities - Sustainable Energy and Climate Action Plan (SECAP)	Hydraulic risks, both from flooding and local flooding, are related to building and infrastructures, specifically residential buildings, public buildings, productive areas and transport system, with consequences on public health and local economy. They are also related to possible impacts on the agricultural system, biodiversity and water quality. Agriculture is considered to be exposed to drought impacts and public health to heat waves. Finally, intense wind is related to potential damage to residential and productive buildings and tree stock.	The main interventions with adaptation implications are related to water systems, with land use and building regulation, health, agriculture, environment and emergency management. The main modes of intervention involve the adoption or updating of plans and organizational documents - such as the water plan, building regulations or emergency plan - with some hydraulic and urban forestation interventions.	Grey infrastructure, Green infrastructure, Self-organisation, Adaptive Management, Preparedness	Disaster preparedness, Disaster Risk Reduction, Ecosystem preservation and biodiversity improvement, Enhanced climate change adaptation

Table 47
Summary of the results of the plan analysis

Conclusions

This chapter presented analyses carried out at the local level for several municipalities in central Veneto. The results have been reported individually for each municipality in the previous section, while a summary of the various results is presented in these conclusions. From this unified picture, various aspects emerge that outline a common profile of Central Veneto. The boundaries drawn in chapter 5.1 describe a territory with a solid urban continuity and with similar geographical and risk characteristics. In this paragraph, the differences and similarities are discussed in-depth to outline the collective profile of Central Veneto.

A relatively uniform picture of the effects of climate change on the urban systems of the Central Veneto Region emerges from the plans analysed. Figure 47 summarises the potential impacts of climate events on urban elements and the cascading effects that may take place, drawing a local picture of interdependencies. This diagram focuses on the most recurrent elements treated in the plans and their interactions can be recognised. The first cluster is on buildings, particularly residential buildings, exposed to most direct and indirect impacts. Another cluster includes industry, exposed to the effects of service and transport disruptions and the cause of potential environmental effects. The water system cluster is both a driver of exposure and a vulnerable element. And the environmental and agricultural system, linked to the other clusters both in terms of risk and risk reduction effects.

PAT

Analysing the main local planning document, the PAT, has been useful to understand which adaptation approaches were already present and rooted in ordinary planning, even if not labelled and recognised as such. In general terms, the PAT can intervene in the system to reduce risk with a limited number of principles (Figure 48). All the analysed PATs include grey infrastructures as structural solutions to reduce vulnerability, the most frequent being hydraulic works of various sizes. Only half of the PATs include indications for green infrastructures as solutions to manage rainfall flows locally or to intervene with hydraulic purposes in naturalistic contexts. Only a few PATs give indications and prescriptions that work in an integrated way and that interventions are mutually effective for risk reduction. Since the PAT is a spatial planning tool, it can preclude building in some risk areas and possibly move buildings and functions outside of them. This mode of intervention includes the principle of relocation and corrective DRM.

SECAP

SECAPs, on the other hand, provided a picture of the climate-related actions that the various municipalities have developed explicitly to cope with the effects of climate change. SECAPs are used to mainstream actions in other plans and regulation, therefore they dispose of a broader range of

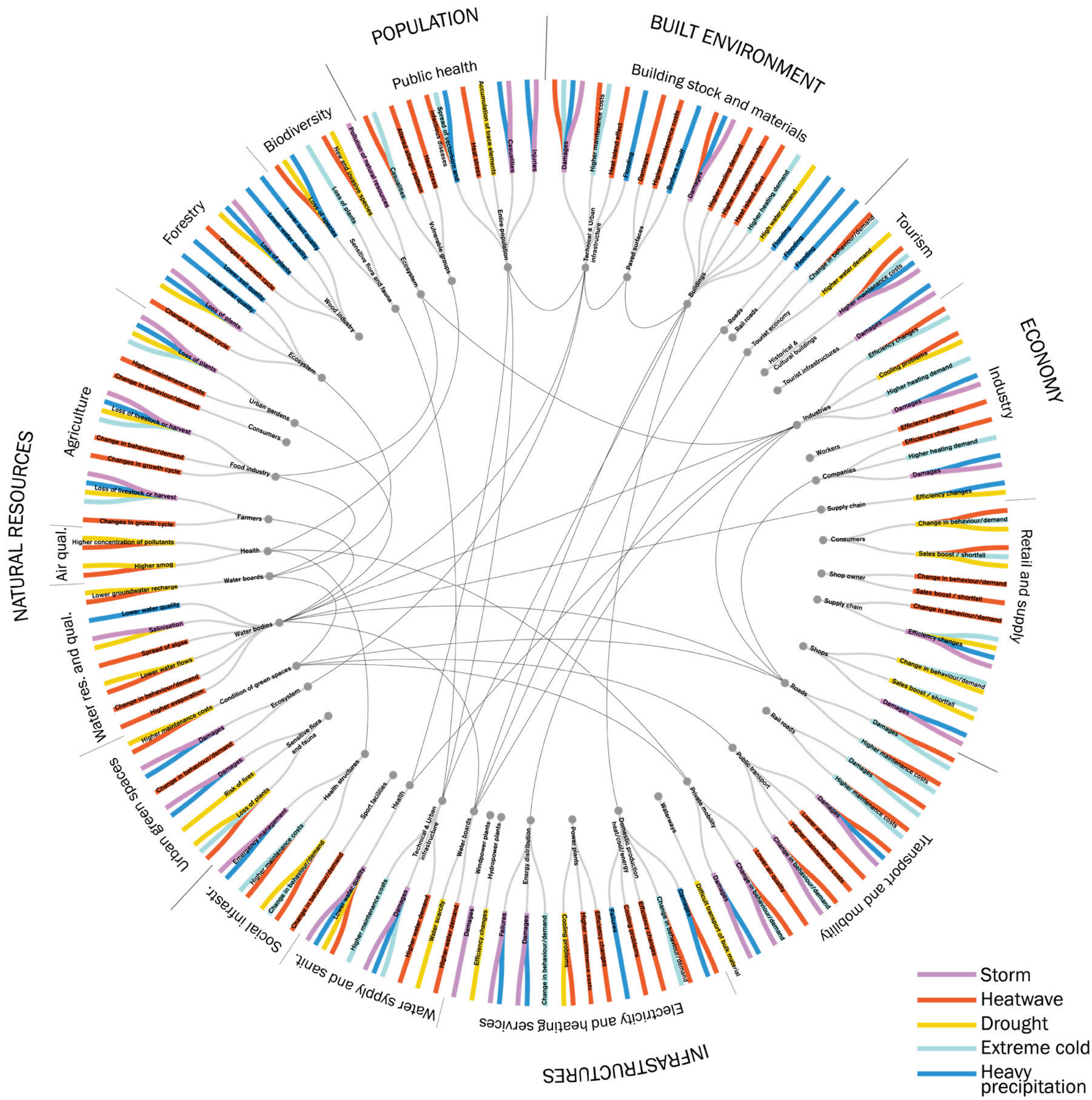


Figure 47
Map of the interdependencies in Central Veneto. Author's interpretation of the interdependencies (lines in the middle) between the impacts that CC and urban systems and elements emerged from the plan analysed. Starting from the outside, there are Sectors and Sub-sectors. Then, each colour represents an impact between: drought, heatwave, extreme cold, heavy precipitation, and storm. These impacts cause an effect, specified above the coloured line, on certain system elements, where the grey dot is. These elements are connected between them based on the relations and cascading effects cited in the plans.

intervention principles (Figure 49). All the SECAPs analysed use both grey and green infrastructures as a mode of physical intervention in the territory. These interventions are organised according to the principles of diversity, i.e. using several types of solutions, and redundancy, i.e. intervening with solutions working in parallel. The principle of adaptive management is also applied extensively within SECAPs, providing flexibility and the ability to adapt to changing contexts and including aspects of prospective DRM. All SECAPs considered include a review of the municipal emergency plan, thus applying the principles of responsiveness and preparedness. Other principles are included in individual SECAPs, such as inclusiveness in decision-making, self-organisation of citizens, learning and innovation.

Figure 48
Visualisation of the principles found within the PATs of the municipalities considered in Central Veneto. The initial list is based on the results that emerged in the GL review on “How to intervene in the system to reduce risk”.

The risk perception questionnaire addressed to Administrations is instead based on empirical knowledge of CC effects on urban systems and sectors. This brings out local perspectives in terms of the priority and severity accorded to specific impacts. The differences between the different CC-risk self-assessments are in part due to different local probabilities and vulnerabilities, as emerges from the Climate risk typology (Chapter 5.1). However, they can also be linked to local knowledge, capacity and political will to recognise CC-related impacts as proximate, likely and severe.

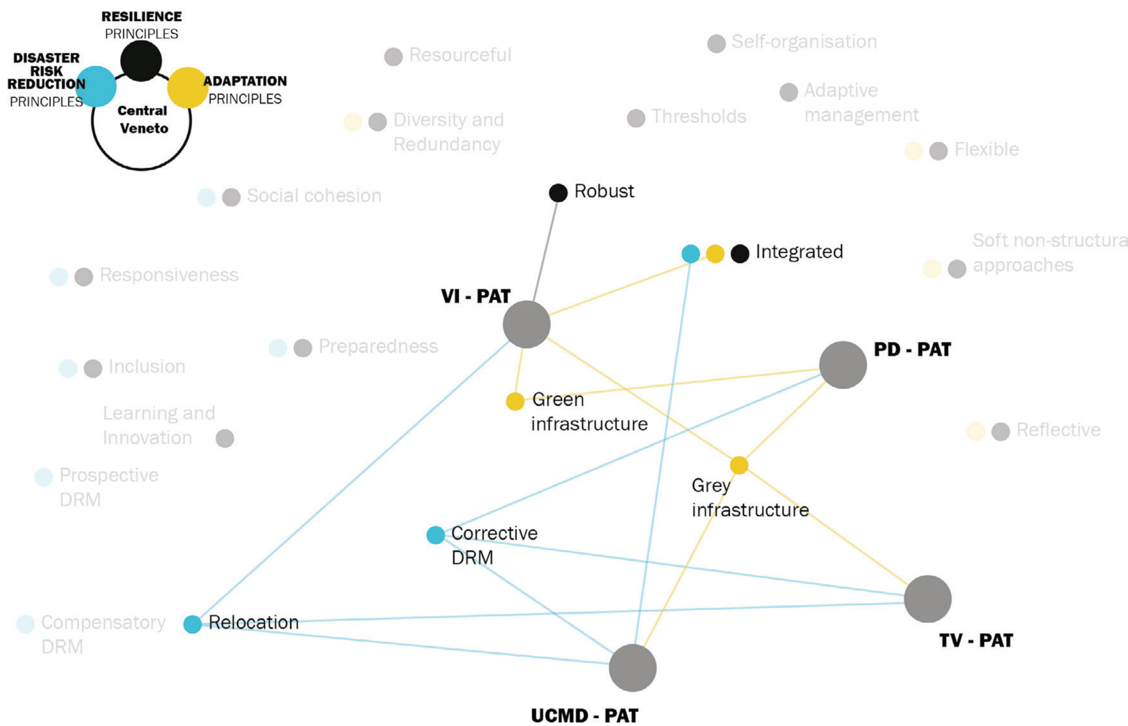
This picture of local perceptions, represented jointly in Figure 50, is particularly interesting compared with the SECAPs adopted by municipalities and how they intervene in the system to build adaptation.

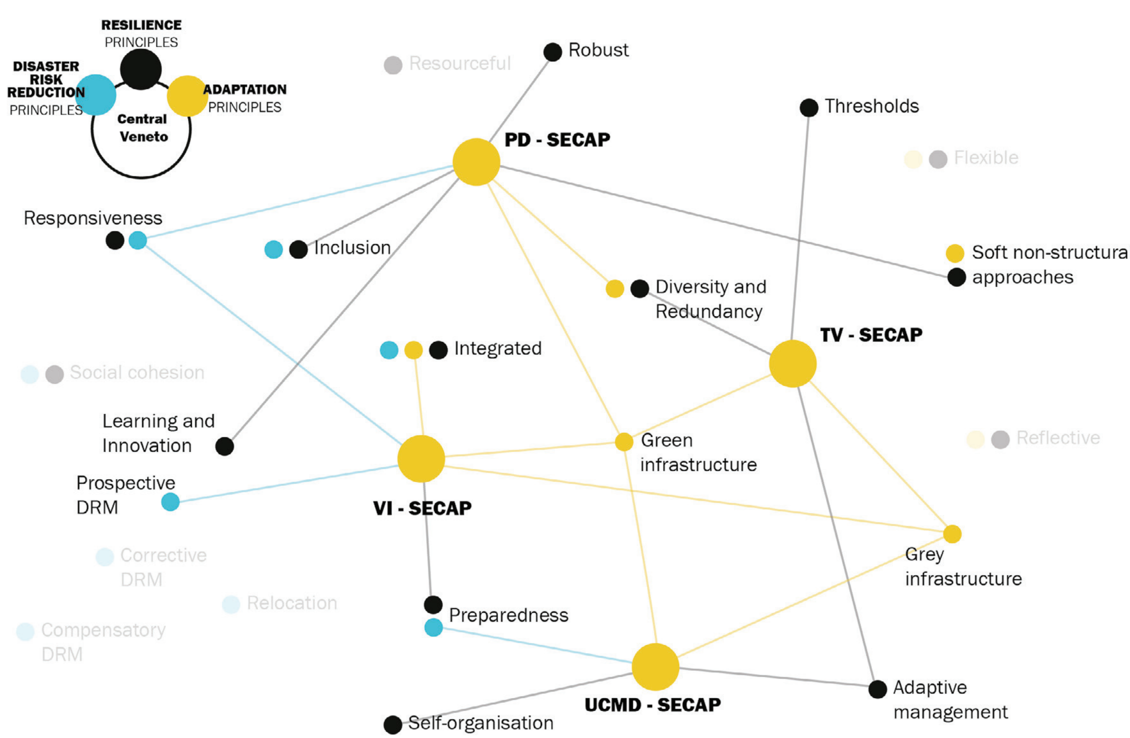
Flash flooding

The flash flooding hazard is perceived to have a medium to high current risk, with increasing intensity and an acknowledged time horizon in progress or medium-term. The sectors recognised as most adversely affected by this hazard across the municipalities are the agricultural and transport sectors, both in terms of severity and probability of impact. Other important impacts concern the sectors of buildings & infrastructure, spatial planning, and environment.

From the actions contained in the analysed SECAPs, it is possible to summarise all municipalities in which ordinary planning instruments are mainstreamed actions addressing flash flooding hazard. Piano di Assetto del Territorio (PAT) and the Interventions Plan (PI) are the most cited for mainstreaming. These are two of the most versatile tools available to municipalities. The first one draws the strategic framework, while the second one the development of specific areas. As far as sectoral plans are concerned, mainstreaming is mainly indicated in the water plan, the emergency plan and the urban green plan. On the other hand, the regulations that

Figure 49
Visualisation of the principles found within the SECAPs of the municipalities considered in Central Veneto. The initial list is based on the results that emerged in the GL review on “How to intervene in the system to reduce risk”.


RESILIENCE PRINCIPLES
DISASTER RISK REDUCTION PRINCIPLES
ADAPTATION PRINCIPLES
Central Veneto
Resourceful
Self-organisation
Adaptive management
Diversity and Redundancy
Thresholds
Flexible
Social cohesion
Robust
Integrated
Soft non-structural approaches
Responsiveness
VI - PAT
Preparedness
PD - PAT
Inclusion
Green infrastructure
Learning and Innovation
Reflective
Prospective DRM
Grey infrastructure
Corrective DRM
Compensatory DRM
Relocation
TV - PAT
UCMD - PAT


RESILIENCE PRINCIPLES
DISASTER RISK REDUCTION PRINCIPLES
ADAPTATION PRINCIPLES
Central Veneto
Resourceful
Robust
Thresholds
PD - SECAP
Flexible
Responsiveness
Inclusion
Soft non-structural approaches
Diversity and Redundancy
TV - SECAP
Integrated
Social cohesion
Learning and Innovation
Green infrastructure
Reflective
Prospective DRM
VI - SECAP
Corrective DRM
Grey infrastructure
Relocation
Preparedness
Compensatory DRM
Adaptive management
UCMD - SECAP
Self-organisation

are indicated as the most relevant to include risk reduction aspects of this hazard are the building code, the hydraulic police code and partly also the landscape code.

River flooding

All the municipalities perceive the hazard of river flooding as in a scenario of increasing intensity and frequency. Although the current overall risk level is perceived differently across the municipalities, there is an agreement on the sectors critically exposed to this impact. All of them ranked as critical the impacts on the water supply & sanitation sector, and three of them also the spatial planning and environment sectors. Transport and emergency are also recognised as having a high level of potential severity. In terms of likelihood, there is a good level of agreement on the high likelihood of impacts on the waste management and environment sectors. Except for spatial planning, no sector was assessed as having an impact in progress, which confirms the overall perception.

The river flooding risk-reducing actions contained in the SECAPs are mainstreamed in the following ordinary planning instruments. The planning instrument most involved in adaptation actions is the Interventions Plan (PI), which together with the Piano di Assetto del Territorio (PAT) holds many competencies for land transformation. Frequent mainstreaming is foreseen in the water plan, and to a lesser extent in the emergency and urban green plan. In addition to these sectoral plans, there is mainstreaming in municipal codes concerning buildings, hydraulic police and, to a lesser extent, landscaping.

Drought

Municipalities perceive the drought hazard as having a low to medium level of current risk, although in a scenario of increasing intensity and frequency in the medium term. Impacts in sectors are also considered not severe, except for the agricultural and environmental sectors, which are also perceived to have a higher probability of being negatively affected.

In order to face the drought risk, the actions contained in the analysed SECAPs have few mainstreaming effects in ordinary planning. The instrument most involved in adaptation actions is the building regulation, where consumption reduction actions are the most frequent. Some of the SECAPs also indicate some sectoral plans as possible receivers, these are the water plan, the emergency plan and the urban green plan. Single actions are indicated as potentially mainstreamable in the Operational Plan (PO), the Interventions Plan (PI) and the landscape regulation. It should be noted that there are far fewer measures addressing drought hazards than hydrological hazards. This reflects the local perception of this hazard as minor and distant.

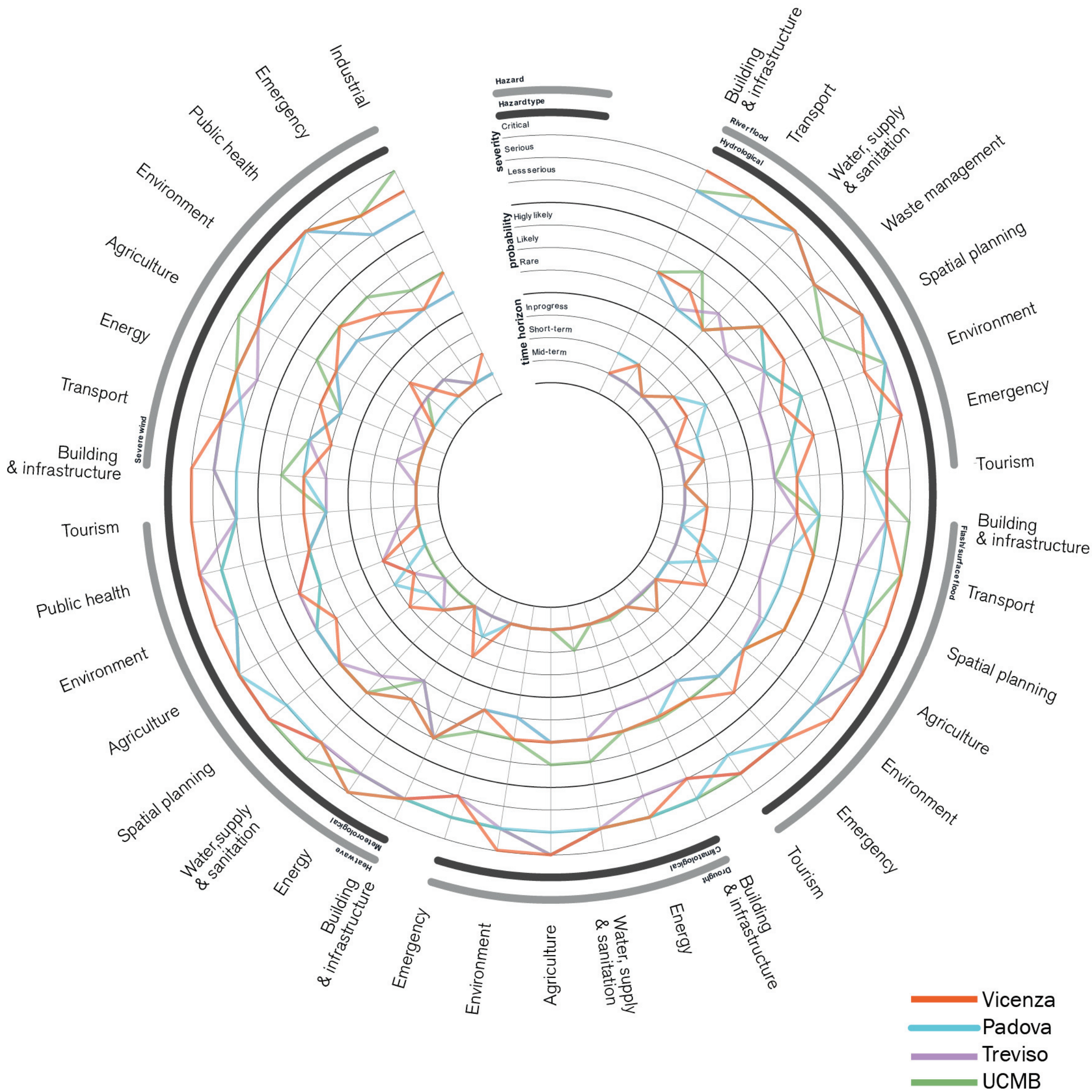


Figure 50
Joint representation of Central Veneto's Municipalities self-assessment on CC-effects on urban system

Heatwave

The municipalities perceive heatwave hazard with a medium-high current risk and with a scenario of increasing intensity and frequency in the short term. From the point of view of critical impact severity, the most exposed sectors are agriculture and spatial planning in the first place, together with energy, environment, and public health. The likelihood is considered high for the building & infrastructure sector and spatial planning, and there is strong concordance for the water, agriculture and environment sectors. These impacts are viewed with an in-progress or short-term time horizon.

In line with the local perception scenario, the analysed SECAPs contain a good number of actions that have mainstreaming effects in ordinary planning. The most frequent modes of intervention to face the heatwave hazard concern vegetation and population preparedness. Therefore, the two main mainstreaming receviers are the urban green plan and the landscape and building regulation. While in terms of preparedness, the recognised tools for implementing actions are the emergency plan and institutional communication. Traffic, sustainable mobility and water plans are also indicated as possible receivers of mainstreaming.

Severe wind

Municipalities perceive severe wind hazard with a current medium risk level, assessed with a scenario of increasing intensity but stable frequency. All municipalities agree that the potential impact on the public health sector, as well as on the environment, is critical. The latter is also the only one with a considered ongoing time horizon and a high probability of occurrence.

With the main perceived effects in the areas of environment and public health, the actions contained in SECAPs are mainly oriented towards safeguarding those elements that may be exposed to the risk of severe wind and protecting citizens. These actions are implemented through a number of planning instruments in which they are mainstreamed. The sectoral plans involved are the emergency plan, the urban green plan and the building regulation.

PART III
ADVICE FOR LOCAL ACTION IN THE CLIMATE EMERGENCY

This Part focuses on comparing the various results and insights that have emerged from the previous parts to reach a synthesis in which potential advice for local action in the climate emergency is highlighted. The comparison is between Part I's conceptual and operational framework and the empirical framework of Part II, as well as internal comparisons between chapters and case studies analysed.

Part III consists of two chapters: conclusion and discussion. The conclusion chapter compares the previously discussed chapters to highlight insights and valuable advice for the operationalisation of climate emergency action in the local context. The discussion chapter is dedicated to reviewing the whole document focusing on research aspects, key facts, limitations of the approaches, and future research areas.

Chapter 6 - Conclusions: Lessons learned and transferability potential

This chapter reinterprets the results presented in the previous chapters to highlight helpful directions and insights for shaping climate action at the local level. These conclusions are based on comparing different sources of information and approaches dealt with within this research, the frameworks built, and the results obtained. The comparison between the parts aims to find points of contact and difference between the different scales on how the three approaches to addressing climate change impacts are operationalised and which aspects have the potential to be further developed in local climate action.

The conclusions presented in this chapter are addressed to those who are operationally involved in translating risk management, adaptation and resilience approaches into local climate actions. This category of beneficiaries can potentially include global agencies, city networks, local policymakers, and various practitioners involved in shaping sustainable and resilient development.

CCA, DRR and UR as appropriate approaches for European climate action

The various aspects arising from CC effects are firmly in the top global risk rankings in terms of both likelihood and impact (Chapter 1.1). The effects of these risks are not limited to the environmental aspect but are closely intertwined with economic, social and geopolitical risks, creating a complex and diffuse risk network.

The grey literature documents developed by global agencies provide a comprehensive operational framework to counter climate risks at the local level through CCA, DRR and UR approaches. When analysed together, the CC-related hazards treated as priorities in all documents are heatwave, heavy precipitation, storm, drought and extreme cold (chapter 1.2). There is a good correspondence between this list of hazards and what are perceived to be the most frequent hazards in the experience of local administrators in Europe (chapter 2.2). The administrators' perception is that these are the most relevant hazards to their cities, with the only exclusion being severe cold which is not mentioned frequently. These hazards belong to the field of action common to all three approaches to risk management. This correspondence between the scope of these risk approaches and the priorities reported by local administrators means that CCA, DRR and UR are the appropriate approaches for climate risk management on the European continent.

Risk spreads through urban systems

The effects that these hazards have on urban systems are numerous and vary according to context. Analysis of the grey literature has revealed a wide range of impacts that each hazard considered has within urban systems (chapter 1.2). These are shown in the outer layer of Figure 10, where the impacts that hazards have on urban systems and related sectors are highlighted. The documents show that each sector is exposed to a different range of impacts, and that while for some elements the hazards have similar effects, for others their effects are different.

Local administrators' perceptions of which sectors are most affected by the various hazards reveal a consistent picture between the European-level survey (chapter 2.2) of a representative pool of all European cities, and the case study survey (chapter 5.3) of a cluster of administrations representative of an urban system. In general terms, the sectors most affected by a wide range of impacts are public health, built environment & infrastructures, and transportation. The following are the main sectors exposed by hazard:

- → Flash and riverine flooding are related in Europe mainly to impacts in buildings and transportation sectors. The case study inquiry highlights that water supply & sanitation, spatial planning, and the environment can be severely impacted.
- → Heatwaves are related in Europe mainly to impacts in public health and energy sectors. The case study inquiry highlights that also agriculture, spatial planning and environment sectors are are highly exposed to this hazard.
- → Droughts are related in Europe mainly to impacts in the water supply & sanitation, and agriculture sectors. However, the case study inquiry highlights that the environment sector is also affected, even if the severity is generally perceived as lower than the other hazards.

Urban elements are interdependent

Climate change risks do not only affect the urban elements on which hazards have a direct impact. A dense network of relationships interconnects urban systems through which risk is spread across many distinct sectors. The World Economic Forum report (Figure 4) highlighted how risks from climate change are interconnected to other risks through relationships that run in both directions. The survey of the main grey literature dealing with risk in an operational manner revealed a wide range of interdependencies between urban elements that spread the risk of individual impacts to elements in other sectors. Based on the grey literature, a system map of these interdependencies has been developed for the wider urban environment.

This systemic mapping approach was also applied to record all the interactions present within the planning documents analysed for the individual case studies. Figure 50 is an overlay of the maps of interdependencies that emerge from these three different sources, comparing a generic city emerging from grey literature, the city of Copenhagen, and the cities of Central Veneto. This analysis deepens the understanding of risk on urban systems to include the urban elements belonging to the various sectors and the risk interconnections between these elements. The mapping is not intended to be a definitive representation of risk propagation as it is based on interpretations of the included documents. Although it is not exhaustive, this representation allows to appreciate the dense network of relationships on which the functioning of the urban environment is based. This network of relationships and dependencies allows two main considerations to be made. The first is that integrated risk management cannot limit itself to intervening only in specific sectors but must consider the urban system as complex and interdependent. This entails also assessing the importance of certain elements for the system. Key elements exposure value, the risk component that generally puts a price on potential damage from a hazard, must also take into account the systemic effects of disrupting the proper functioning of that element. The second consideration is that even sectors whose risk perception is assessed as less severe are exposed to the indirect effects of climate hazards. Planning in these sectors should involve addressing these indirect effects and understanding how to reduce risk systematically.

Cross-cutting co-benefits for intervention on urban systems

Just as risk is spread through the network of relationships, interventions in the system can also generate cross-cutting benefits in other sectors than the one they are implemented in.

Throughout Europe's cities, spatial planning and building & infrastructures are two of the main sectors in which climate-related actions are implemented, particularly for physical transformation. The other main sectors of implementation are public health, for measures that are more related to people, and water and the environment, for measures that deal with efficient use and conservation of natural resources.

Although most European cities' actions are implemented in the sectors just described, the generated co-benefits extend throughout the urban system. The most recurrent and cross-cutting co-benefits that many actions have, are enhanced adaptation and enhanced resilience: many actions report one or both of these two as co-benefits that the action enables. Disaster risk

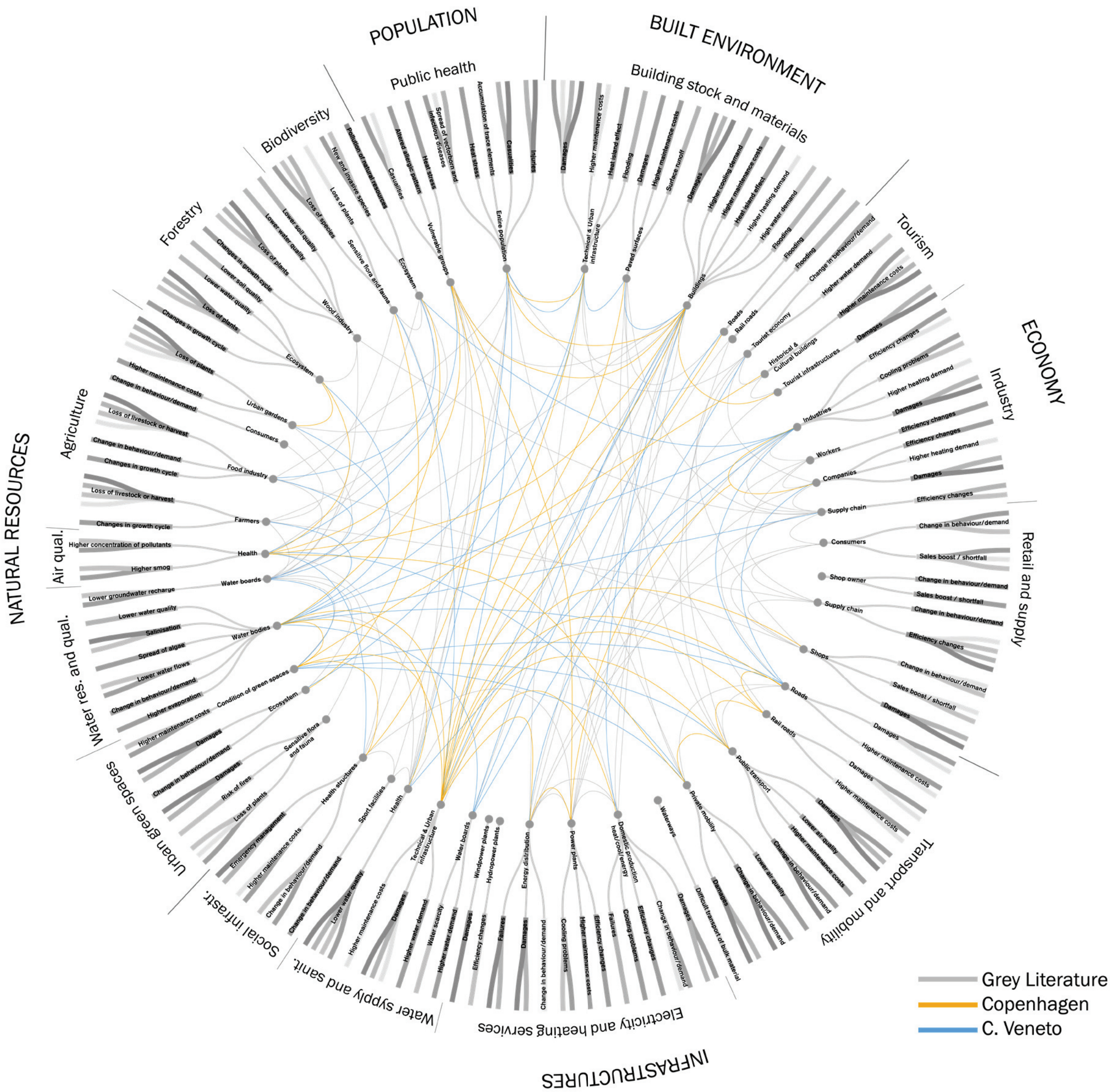


Figure 51
Map of interdependencies. Author's interpretation of the interdependencies (lines in the middle) cited in the grey literature documents (grey lines), Copenhagen's documents (yellow lines) and Central Veneto's documents (blue lines) between the impacts that CC and urban systems and elements. These elements are connected between them based on their relations and cascading effects.

is another recurring co-benefit in its reduction and preparedness declination. Other co-benefits that have been linked to some types of actions are: improved public health for actions targeting the most vulnerable and disease prevention, economic growth and green jobs, and several co-benefits linked to the quality, efficiency of use and conservation of resources.

The case studies are partially in continuity with the co-benefit framework generated by actions in European cities but have some noteworthy local peculiarities. Almost all the plans examined for the Central Veneto region generate co-benefits of disaster risk reduction, ecosystem preservation, biodiversity improvement and improved resource quality. This shows that climate action in this region has its roots in the environmental protection planning culture. Central Veneto SECAPs also generate numerous benefits of enhanced climate change adaptation and resilience, and disaster preparedness. Only a few other co-benefits were recognised in individual plans. In contrast, the plans analysed for Copenhagen have a wide variety of co-benefits generated. The most frequent ones correspond to those recognised in the central Veneto region, which are also added to reduced GHG emissions and recreational opportunities. This is representative of a climate action culture that has reached spatial planning and urban design and is now embedded in a wide range of physical transformation projects of the city.

As expected, the sectors in which more risk reduction actions are implemented are also those in which the risk is perceived as more severe. The co-benefits generated by actions implemented in other peripheric sectors can positively affect the urban system and most exposed sectors. Implementing risk reduction actions in these peripheric sectors is one way to manage risk systemically and contribute to an integrated resilience, especially if these include specific principles.

Principles at the heart of intervention

In the operational documents of the grey literature, there are numerous principles of intervention to shape local climate action. The full range of recommended principles spans the three approaches to risk management and is collected in Chapter 2.1 . According to the extent of the analysed grey literature, the system map of principles visually represents the set of these principles and which approach they correspond to. Through a qualitative interpretation, these principles were searched for within the planning documents of the analysed case studies, which recognised a substantial number of principles used at the local level (chapter 4.3 and 5.3). The most frequently used ones aim to transform the physical environment and are green infrastructures and grey infrastructures, with applications mainly in the buildings & infrastructures sector where the robust principle is also often applied. Another principle that finds frequent application in the plans analysed is diversity and redundancy, both in the transformation of the physical environment and governance and services. The principle of integration and alignment between city systems is applied transversally both for decision-making and action-design to ensure that risk is addressed between different sectors and scales. And in this note, adaptive management is also applied to ensure enough flexibility to adapt to changing needs and uncertainty. Finally, the principles of responsiveness and preparedness are used in some specific organisational aspects of disaster risk reduction, with implications for coping, early warning and emergency response.

Although recognising these principles has been done on a one-to-one basis, isolating the principle and taking it out of context, patterns have emerged in planning documents where certain principles are applied together. One example is the combination of grey infrastructures with the principle of robustness, used to reduce the vulnerability of specific elements through protection and securing essential parts of the system. Instead, the green infrastructures have been operationalized through the principle of redundancy and diversity, used to reduce the risk through interventions that manage the system's vulnerability in parallel and whose eventual interruption of the service does not have consequences on the whole system.

The possibility of combining these principles is the direction to take in order to intervene in an integrated way and maximise the benefits of risk reduction interventions. There are many possible combinations of these principles. Those emerged from the case studies are probably just the tip of the iceberg of all the experimentation that is taking place. These principles are, in my opinion, the most easily transferable unit of intervention for mainstreaming and transferability of experiences between cities, as will be further elaborated in the discussion.

Types of planning for integrated intervention

Finally, the aspects described so far need to find a regulatory instrument that can make them operational. The different modes of planning by design, by coding and by development control are used within the case studies to shape climate action according to their specific purpose and normative framework.

Planning by design is used in the main planning documents to regulate land use and city development. The masterplan is the primary way of defining the framework within which the rest of the local planning is articulated. Therefore, the resulting plan is a series of modifications of the current state and an imagination of how the system can be represented in the future once the plan is implemented. The city of Copenhagen uses this type of planning not only in its Municipal Plan but also effectively within one of its sectoral plans, the Cloudburst Management Plan. Here, the masterplan is used to define the hydrological functions that each element and part of the city must perform in order to achieve the plan's objectives and realise the pre-conceived final state. Although not a binding instrument, this masterplan defines some future or desirable characteristics of the urban system and spatialises each intervention, flexibly regulating the space. Furthermore, the spatialisation of intervention typologies is followed by indications that refer to the type of planning by coding, where generic specifications of allowable and necessary components or (un)desired relationships between the city's elements are traced. This second mode of planning has common elements with the English SUDS system of priorities and principles mentioned in chapter 2.1.

Planning by coding mode is applied in the Veneto regional legislation on hydraulic invariance, although with some differences to the planning modes used for stormwater management in the Danish case and the English SUDS. The Veneto legislation does not use a succession of preferable principles but instead requires the achievement of a definitive parameter through some possible modalities. This parameter is applied indiscriminately to all the territory subject to transformation and lacks a reference master plan that is able to identify priority areas of intervention and local needs. For large projects with a potentially high impact, the legislation delegates the approval opinion to a competent body based on a local hydraulic study and assessing the project's impact on it. Only in this case, planning by development control is contemplated, capable of assessing and modifying the project proposal once it has been formulated and submitted.

The SECAPs applied within the cities of the Central Veneto instead do not include the type of planning by design, limiting themselves to defining some physical actions and giving indications for future updates of the sector plans. Therefore, there is no representation of the desired future state of the system, neither in the form of a master plan nor in any other form. The other planning modalities are not applied in these plans either, as the plan does not have a clear coding dimension for future interventions and does not give useful parameters for development control. The mainstreaming dimension that the plan should have in order to include climate risk management aspects in the various local government plans takes the form of a collection of isolated actions. Plans made in this way do not succeed in creating a framework for guiding future choices or in constituting a vision to strive for. One example of this is the revisions of sectoral plans, which are included as actions in the SECAP, but the minimum objectives and risk aspects to be addressed in the plans are not defined. This is a significant missed opportunity to coordinate the plans and give each a precise role in systemically reducing risk.

SECAPs have great potential for dissemination thanks to the solid network they rely on, facilitated by the widespread dissemination of SEAPs of which they are an update, and the relatively simple way of constructing the plan. In my opinion, there are opportunities to make this type of plan more effective in managing climate risk and building local climate action, bringing it closer to a plan than to a collection of isolated actions. The first opportunity concerns the use of the planning by design modality, where the vision of the system's future is outlined, including the spatial dimension of the city and giving the places the desired characteristics/functions. In this, Copenhagen's Cloudburst Management Plan is a very effective example. The second opportunity regards the use of planning by coding to outline which relationships between elements within the urban system to strengthen or prevent. Based on these, the sector plans that develop later can regulate within their sector following indications of a coordinated framework that embraces the whole urban system and its functioning. Having defined these two aspects, there is also the opportunity to make some of the indications emerged as parameters or characteristics proper to approve/reject a project in the development control phase, requiring single projects to further align themselves with the indications of the master plan or with the relations defined by the codes. An example of this is the way in which the Sustainability Tool has incorporated some indications from the Copenhagen Climate Adaptation Plan. This mainstreaming was possible because the Copenhagen Adaptation Plan sets out a clear vision of how to intervene, giving a succession of principles and methods of intervention to be applied at the various scales and in the various sectors. Once these aspects were defined and an overall framework was created, Copenhagen's mainstreaming of adaptation principles reached many sectoral plans, comprehensive masterplans, tools, and even private projects. Regarding the implementation of the plan by the Municipality of Copenhagen, each year it is defined which interventions will be addressed to implement the various aspects of the plan (City of Copenhagen, 2015a, 2015b). As described above, the SECAPs analysed are used directly as a collector of actions without succeeding in creating a coordination framework or giving clear indications that can be included in other plans. Ultimately, the planning methods used in the Copenhagen local climate plan allow it to be mainstreamed more effectively and extensively than SECAPs, which instead focus only on collecting actions.

Chapter 7 - Discussion

On methods and findings

My research is motivated by the desire to understand how the challenges of risks that the climate emergency brings to cities can be addressed in an integrated way.

This research aims to build an operational framework that can support different actors in developing plans and policies for cities in managing the complexity of interactions between climate and urban systems that generate risk. This is important because integrated and resilient risk management must find contact points and strengthen the complementarity of the different approaches and sectors currently addressing climate risk in city planning. The overarching question of this research is *How can Planning and Design contribute to adapting complex urban environments to shocks and stresses of the climate emergency?*

As climate emergency is an ongoing and evolving issue, there is no single, definitive answer to this question, especially in an environment as complex as the urban one. In this research, the answers to this question were investigated by taking multiple perspectives using multiple methods to investigate the available sources of knowledge, data and experience. The sources used to understand the conceptual framework within which the research question applies are literature, both scientific in the form of books and articles and operational in the form of grey literature. The data that were interrogated and analysed to understand how the conceptual themes are implemented in practice are EU databases and the corpus of local planning documents. Finally, empirical knowledge emerging from practice was intercepted through the experience and perception of city officials.

The research was divided into three main parts, where in each part these different sources of knowledge are analysed and compared. Part I develops an operational framework within which conceptual, practical and methodological knowledge is embedded. Part II is dedicated to bringing out the empirical knowledge of the two case studies investigated through the points of view elaborated in the operative framework. Finally, these two parts are synthesised in Part III, which is dedicated to comparing the results emerging from the various sources of knowledge and to the discussion.

Part I establishes several key elements that can be framed in the fact that the climate emergency potentially concerns the whole complex urban system and that its management is rooted in the three approaches that deal with risk.

Key findings that emerged:

→ Climate risk has direct and indirect effects on a multitude of interconnected urban systems, and interactions with one of these have repercussions on the others.
→ The three approaches related to climate risk have their own particularities and declensions, but they also have numerous points of contact in both concept and practice.
→ The operationalisation of these three approaches in the complex urban system occurs according to some common principles and others specific to a single approach.
→ The disciplines of planning and urban design have valuable tools for shaping risk and complexity management locally.
→ European local city officials consider meteorological and hydrological hazards as the most frequent and essential to address, with effects across numerous urban systems.
→ Local climate action that is taking place in Europe foresees enhanced adaptation and resilience as the most cross-cutting co-benefits.
→ Hazard mapping and modelling are the most cross-cutting actions in urban sectors, showing that city officials desire to understand better local risk.
→ Building regulation, spatial planning and environmental protection are the sectors in which more climate action is implemented.

Part I has outputs that are represented in the form of system maps, which visually present certain aspects that emerged from the operational framework. The purpose of these maps is twofold: on the one hand, they present the results of the various forms of knowledge in a clear and more accessible form; on the other hand, they are methodological tools that are subsequently applied in Part II in order to deepen the case studies and compare the two parts. The first of these diagrams represents all the different interactions between climate change and the urban environment that have emerged, portraying the interdependencies recorded between the different urban systems. This system map summarises the framework of direct and indirect climate-city interactions as described within the analysed documents, which in Part I are the grey literature documents and in Part II are the local planning documents. The second scheme collects and represents the set of principles available to intervene in the urban system through planning, summarising the intervention principles of the three different approaches to risk management.

Part I brings together different types of knowledge that emerge from the types of sources available, describing the operationalisation of the three different approaches to risk management within the planning and urban design disciplines. The desire to bring together different types of data and knowledge necessarily had to limit the scope of the investigation to the points of contact between these sources while maintaining a horizontal point of view, limiting the possibilities of delving vertically into individual types of knowledge. Nevertheless, there is still much we need to learn about the complex interactions between climate and cities, and the framework constructed in this part is not intended to be unambiguous and definitive, but a basis for comparison with Part II.

Part II shifts the focus of the investigation to two European case studies, to explore how the issues raised in the conceptual framework are operationalized within the plans and actions of these cities. The key findings of this part are:

→ Cities belong to numerous variable geometry systems, whose boundaries change according to the aspects taken into account.
→ Risk is one of the criteria according to which boundaries can be defined, and types of territories with comparable characteristics can be recognised.
→ There is a wider perception of risk and its effects than what is currently dealt with and contemplated within the field of action.
→ Sectoral and mainstreaming plans have a greater breadth of intervention principles than ordinary planning.

Planning by design, coding and development control are methods that are included in different local plans and which in some cases are used in complementary modalities. In Part II the issues and tools developed in Part I are addressed. The representation of the results in system maps based on Part I allows comparing the local picture of the case studies with the global picture previously reconstructed. This comparison method is based on qualitative aspects recognised within local planning and constitutes a complementary approach to the numerous resilience indices based on quantitative indicators used extensively today to describe local realities. Unlike the latter, which measure the level of resilience of different cities to compare them, system maps provide an overview of how cities are operationalising resilience and climate risk management in general.

Part III, of which this discussion is a part, has served to compare the various results, distil some aspects of interest and outline considerations for future research.

Principles and codes as the replication unit

Principles and codes are the elements that have a high potential for replication, for being applied elsewhere and transfer adaptation to other contexts and sectors. While best practices are fundamentally great stories that have the power to inspire, they result from one particular process grounded in a local context. They are disseminated as a finished result, which is also composed of spatial and normative particularities specific only to the context they apply to. Not all local municipalities have the human capacities to discern the particular forms from the general function, and have difficulties imagining or apply them in their local context. As a result, best practices may be discarded based on certain specific aspects that may not be fundamental for the objectives or principles behind them. On the other hand, principles and codes have a broader field of application and are a flexible tool that - while regulating certain aspects and desired performances - allow different applications in time, space and scale. From a complexity perspective, codes and principles do not envision a single possible future and can embrace uncertainty. It is this characteristic that makes principles an effective unit of replication between different urban systems.

In the parallel with genetics, freely inspired by the book The Selfish Gene (Dawkins, 1976) and its inversion of perspectives, I interpret principles as genes and best practices as individuals. Genes are the units of replication, which find in individuals the form through which they express themselves and give them the characteristics and functions we recognise in the individual. A different mix of a few genes is able to manifest itself in individuals with very different forms and characteristics, enabling them to adapt to different contexts, conditions and functions. On the other hand, single individuals have a range of survival conditions, outside of which they cannot adapt. Similarly, I see best practices as intimately linked to the places, times and conditions in which they are applied. Repeating a best practice outside its range of conditions may preclude its desired effectiveness. On the contrary, the principles of intervention that define how the best practice has been constituted are adaptable and modular in applications that manifest themselves in different forms, and constitute the unit of replication that can be adapted to different conditions.

I am aware of the partiality of this parallel with genetics, and that it has also been used to express other nuances related to urbanism (Kropf, 2012). I believe that the term adaptation, declined in relation to climate change and urban environments, carries a strong temptation of mental association with the theory of evolution of the species and biology in general. The latter is also present in the interpretation of cities as complex systems (Batty & Marshall, 2017; Marshall, 2012a; Salat, 2017). Although I have desisted from including terminologies, methodologies, and quotations from other scientific fields within this research work, I believe that they can provide interesting insights to bring out alternative points of view for understanding contemporary cities.

Limitations as research opportunities

One of the limitations of this research is linked to the language and interpretation of the contents of the grey literature and the plans analysed. The meaning attributed to some terms changes according to variables that can be traced back to different contexts, disciplines and cultures. If this difference is negligible for some terms - as for example in the elements of urban systems - for others, it has been an obstacle to the uniformity of results. This is the case with intervention principles, where complex concepts are expressed in the synthetic form of a single word. The definition of this principle varies within the different operational documents, and recognising when and how it is applied within the plans is a process of interpretation that necessarily has an arbitrary component. The list of these principles itself is not exhaustive and cannot describe the entire set of principles that shape the objectives of different approaches to risk. Instead, this list, and the system maps derived from it, are a way of constructive comparison, which aims to be used more for understanding than for exhaustive explanation, and which is most effective when used in parallel with other tools for understanding.

As already described within this thesis, the boundaries within which risk approaches (CCA, DRR and UR) operate are not easily traceable. Some principles and objectives belong to more than one of these approaches, while others are mainly rooted in one. For others, how they are applied determines whether they have aims that fall more within one approach than another. However, the fact that these boundaries are not clear-cut is a limitation that has positive aspects that can be exploited in the perspective of greater integration. In shaping these principles of intervention, one can include those non-exclusive aspects that allow the aims of several approaches to be pursued, thus designing an integrated local climate action.

Another limitation arises from the need to draw boundaries to the analysed systems in order to move between the different scales. The global dimension is taken into account through the conceptual approaches, global agendas and operational documents of the leading agencies dealing with risk at a global level. As the analysis unfolded, it was necessary to reduce the scope of action to the European level, and then move into two regional areas to analyse local documents. In doing so, it was necessary to leave out other areas that could have revealed other results and given greater depth and breadth to considerations of urban systems. Even at the European level alone, the existing Climate Risk Typologies provide a classification of homogeneous risk zones requiring further comparative analysis to maximise the transferability of results to all European contexts. Other national and local regulatory frameworks are further factors that can be taken into account to enrich the research questions' framework. The necessary choices and exclusions are limitations due to the time available, but they also constitute an interesting starting point for further research that can intercept the aims of European agencies, applied research projects, national, regional and local policymakers.

Therefore, an interesting area for future research is related to creating further connections and relationships between European CRTs and intervention patterns to reduce climate risk. As CRTs are territorial units that classify territories according to their risk characteristics, they could also be preferential frameworks for identifying patterns of intervention between different European areas that transcend the geographical division and are instead united by similar risk-determining components. Due to legislative and cultural differences, linking similar units of risk with the collection and systematisation of how they intervene can pave the way for a valuable database in several respects. Firstly, it can be an interesting area of research to bring out common patterns of intervention. Secondly, such a classification can also be helpful to support a European mainstreaming of intervention modes in contexts with similar risk types.

Another limitation concerns the approach used to survey the existing body of scientific literature on the topics discussed. In order to intersect the various perspectives on com-plexity sciences, climate change adaptation, urban resilience, disaster risk reduction and urban planning, it was necessary to focus only on the most significant texts to build a common conceptual framework. Through this selection and extraction process, some top-ics may be more limited than the broad scope with which the scientific community treats them. The process of understanding served as an introduction to these disciplines, neces-sary for constructing a conceptual framework that would find points in common, but which does not end with this thesis. The framework has also served to interpret and un-derstand the knowledge that is not produced in the academic sphere, but that emerges from the multitude of actors confronted with the urban context and its interaction with climate change. The desire to address the gap between these two worlds of knowledge un-derlies the path chosen for this thesis. Its limitations of time, methods, means and experi-ence have necessarily led to the exclusion of certain aspects, but these constitute an excit-ing area to continue my future research.

Final note

The integration of different approaches to risk is in my view more urgent and fertile at the operational level than at the conceptual level. Even if differences still exist at the conceptual level, it is in operationalisation that the approaches must find convergence and complementarity. The urgency is that what is included in the plans, in the local actions and in the urban systems can at the same time pursue different goals and maintain an operational dimension while giving clear indications to intervene in the system.

In conclusion, it seems that to understand local climate action within urban planning, it is necessary to consider the different approaches that deal with climate risk in an integrated way. The ways these approaches are operationalised have notable common features both at the conceptual and urban planning levels. Once the principles through which they are applied were acknowledged, it emerged that these approaches are not only not exclusive, but that their integration is the key to responding effectively to different risks such as climate change and other unforeseen events. Master plans, codes and development control are planning tools that allow local climate action to be rooted in the organisation of the complex city as long as they are used in a complementary and coordinated manner. The operationalisation of the principles of intervention within these planning tools is an exciting challenge for researchers and policymakers to overcome the logic of sectorial actions and systemically address climate risk.

APPENDIX

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ANNEX I
EUROPEANS CITIES' SELF-ASSESSMENT ON PERCEIVED CLIMATE RISKS DATA-BASE

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
Albania	City of Tirana	Heat wave	Extremely serious	Public health	Water Supply & Sanitation	Environment
Albania	City of Tirana	Drought	Serious	Water Supply & Sanitation	Environment	Public Health
Albania	City of Tirana	Rain storm	Extremely serious	Transport	Energy	Water Supply & Sanitation
Bulgaria	Burgas Municipality	River flood	Serious	Residential	Food and agriculture	Public health
Bulgaria	Burgas Municipality	Rain storm	Serious	Residential	Transport	
Bulgaria	Stara Zagora	Extreme hot days	Serious	Emergency services	Public Health	Water Supply & Sanitation
Bulgaria	Stara Zagora	Drought	Serious	Water Supply & Sanitation	Food and agriculture	
Bulgaria	Stara Zagora	Forest fire	Extremely serious	Public Health	Emergency services	
Croatia	City of Zagreb	Extreme hot days	Serious	Public Health	Emergency services	
Croatia	City of Zagreb	River flood	Serious	Food and agriculture	Public Health	Transport
Croatia	City of Zagreb	Landslide	Serious	Energy	Water Supply & Sanitation	Transport
Czech Republic	Brno City Council	Extreme hot days	Serious	Public Health	Water Supply & Sanitation	Food and agriculture
Denmark	City of Ærøskøbing	Rain storm	Serious	Food and agriculture	Food and agriculture	Food and agriculture
Denmark	City of Copenhagen	Rain storm	Extremely serious	Residential	Commercial	Public Health
Denmark	City of Copenhagen	Heat wave	Less serious	Public Health	Residential	Commercial
Denmark	City of Copenhagen	Storm surge	Serious	Residential	Transport	Commercial
Denmark	City of Copenhagen	Coastal flood	Serious	Residential	Transport	Commercial
Denmark	City of Hvidovre	Coastal flood	Extremely serious	Residential	Industrial	Transport
Denmark	City of Hvidovre	Rain storm	Serious	Residential	Transport	
Denmark	City of Hvidovre	River flood	Serious	Residential		
Denmark	Egedal Municipality	Heavy snow	Less serious	Food and agriculture	Residential	
Denmark	Egedal Municipality	Flash/surface flood	Serious	Transport	Food and agriculture	Residential
Denmark	Egedal Municipality	Rain storm	Serious	Transport	Food and agriculture	Residential
Denmark	Egedal Municipality	Atmospheric CO2 concentrations	Serious	Transport	Food and agriculture	Residential
Denmark	Egedal Municipality	Groundwater flood	Serious	Residential	Food and agriculture	
Denmark	Elsinore Municipality	Coastal flood	Serious	Residential	Environment	Commercial
Denmark	Elsinore Municipality	Rain storm	Less serious	Residential	Transport	Commercial
Denmark	Elsinore Municipality	Severe wind	Less serious	Residential	Environment	Transport
Denmark	Fredensborg Kommune	Rain storm	Less serious	Water Supply & Sanitation	Transport	Residential
Denmark	Fredensborg Kommune	Coastal flood	Less serious	Transport	Commercial	Residential
Denmark	Frederikshavn Kommune	Rain storm	Serious	Water Supply & Sanitation	Energy	Energy
Denmark	Frederikshavn Kommune	River flood	Extremely serious	Water Supply & Sanitation	Food and agriculture	Transport
Denmark	Frederikshavn Kommune	Coastal flood	Serious	Water Supply & Sanitation	Food and agriculture	Transport
Denmark	Frederikshavn Kommune	Storm surge	Serious	Residential	Environment	Emergency Management
Denmark	Gladsaxe Kommune	Flash/surface flood	Serious	Commercial	Transport	Residential
Denmark	Hillerød Kommune	Rain storm	Serious	Residential	Transport	Emergency Management

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
Denmark	Hoeje-Taastrup Kommune	Groundwater flood	Less serious	Residential		
Denmark	Hørsholm Kommune	Rain storm	Serious	Water Supply & Sanitation	Residential	Commercial
Denmark	Hørsholm Kommune	Flash/surface flood	Serious	Water Supply & Sanitation	Residential	Commercial
Denmark	Hørsholm Kommune	River flood	Serious	Water Supply & Sanitation	Residential	Commercial
Denmark	Hørsholm Kommune	Coastal flood	Serious	Transport	Residential	Commercial
Denmark	Jammerbugt Kommune	Groundwater flood	Serious	Transport	Food and agriculture	Residential
Denmark	Jammerbugt Kommune	Coastal flood	Serious	Food and agriculture	Residential	Transport
Denmark	Jammerbugt Kommune	Rain storm	Serious	Commercial	Transport	Residential
Denmark	Jammerbugt Kommune	River flood	Serious	Food and agriculture	Residential	
Denmark	Lejre Kommune	Flash/surface flood	Less serious	Residential	Food and agriculture	Water Supply & Sanitation
Denmark	Middelfart Kommune	Rain storm	Serious	Residential	Commercial	Emergency services
Denmark	Middelfart Kommune	Coastal flood	Serious	Residential	Commercial	Emergency services
Denmark	Middelfart Kommune	Storm surge	Serious	Residential	Commercial	Emergency services
Denmark	Middelfart Kommune	Flash/surface flood	Serious	Residential	Commercial	
Denmark	Odder Kommune	Flash/surface flood	Serious	Residential	Transport	Commercial
Denmark	Odder Kommune	Rain storm	Serious	Residential	Transport	Commercial
Denmark	Odder Kommune	Coastal flood	Serious	Residential	Transport	Commercial
Denmark	Ringkøbing-Skjern Kommune	Rain storm	Less serious	Water Supply & Sanitation		
Denmark	Sonderborg Kommune	Rain storm	Serious	Transport	Residential	Industrial
Denmark	Sonderborg Kommune	Severe wind	Less serious	Transport	Residential	Public health
Denmark	Sonderborg Kommune	Flash/surface flood	Serious	Environment	Transport	Residential
Denmark	Sonderborg Kommune	Coastal flood	Serious	Residential	Community & Culture	Industrial
Denmark	Sonderborg Kommune	Groundwater flood	Less serious	Water Supply & Sanitation	Food and agriculture	Environment
Denmark	Sonderborg Kommune	Storm surge	Serious	Residential	Industrial	Transport
Denmark	Sonderborg Kommune	Salt water intrusion	Serious	Water Supply & Sanitation	Food and agriculture	Environment
Denmark	Sonderborg Kommune	Landslide	Less serious	Transport	Residential	Food and agriculture
Denmark	Sonderborg Kommune	Subsidence	Less serious	Transport	Residential	Food and agriculture
Denmark	Vejle Kommune	Groundwater flood	Serious	Residential	Water Supply & Sanitation	Environment
Denmark	Vejle Kommune	Landslide	Serious	Residential	Transport	Environment
Denmark	Vejle Kommune	Coastal flood	Serious	Residential	Transport	Water Supply & Sanitation
Denmark	Vejle Kommune	Storm surge	Extremely serious	Residential	Industrial	Water Supply & Sanitation
Denmark	Vejle Kommune	Flash/surface flood	Serious	Public health	Residential	Water Supply & Sanitation
Denmark	Vejle Kommune	Rain storm	Extremely serious	Public health	Residential	Water Supply & Sanitation
Denmark	Vejle Kommune	River flood	Extremely serious	Residential	Transport	Water Supply & Sanitation
Estonia	City of Johvi	Atmospheric CO2 concentrations	Less serious	Public Health		
Estonia	Pärnu City Government	Landslide	Less serious	Residential		

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
Estonia	Pärnu City Government	Coastal flood	Serious	Water Supply & Sanitation	Energy	Emergency Management
Finland	City of Espoo	Coastal flood	Less serious	Residential	Industrial	
Finland	City of Espoo	Heat wave	Less serious	Residential	Public health	
Finland	City of Espoo	River flood	Less serious	Residential	Industrial	Environment
Finland	City of Espoo	Extreme cold days	Less serious	Residential	Public health	
Finland	City of Espoo	Extreme winter conditions	Less serious	Water Supply & Sanitation		
Finland	City of Helsinki	Extreme hot days	Less serious	Public health		
Finland	City of Helsinki	Heat wave	Less serious	Public health	Energy	
Finland	City of Helsinki	Drought	Less serious	Public Health	Environment	
Finland	City of Helsinki	Water-borne disease	Less serious	Public Health	Environment	
Finland	City of Helsinki	Rain storm	Serious	Water Supply & Sanitation	Transport	
Finland	City of Helsinki	Flash/surface flood	Less serious	Transport	Energy	ICT
Finland	City of Helsinki	Tornado	Less serious	Transport	Energy	ICT
Finland	City of Helsinki	Coastal flood	Less serious	Residential		
Finland	City of Lahti	Flash/surface flood	Serious	Residential	Water Supply & Sanitation	Transport
Finland	City of Lahti	Heat wave	Serious	Public Health	Emergency services	Energy
Finland	City of Turku	Rain storm	Serious	Water Supply & Sanitation	Residential	Transport
Finland	City of Turku	Severe wind	Serious	Energy	Public Health	Transport
France	City of Paris	River flood	Extremely serious	Emergency Management	Energy	Transport
France	City of Paris	Heat wave	Extremely serious	Public health	Energy	Transport
France	City of Paris	Extreme hot days	Serious	Residential	ICT	Water Supply & Sanitation
France	City of Paris	Drought	Extremely serious	Water Supply & Sanitation	Food and agriculture	Environment
France	City of Paris	Rain storm	Serious	Transport	Environment	Water Supply & Sanitation
France	City of Paris	Extreme cold days	Less serious	Public health	Transport	Energy
France	City of Paris	Subsidence	Serious	Residential	Transport	Commercial
France	City of Paris	Severe wind	Less serious	Transport	Residential	Environment
France	City of Paris	Cold wave	Serious	Public health	Energy	Transport
France	City of Paris	Forest fire	Serious	Environment	Food and agriculture	Emergency Management
France	City of Paris	Vector-borne disease	Extremely serious	Public health	Emergency Management	Water Supply & Sanitation
Georgia	Tbilisi City	Flash/surface flood	Serious	Public Health	Residential	Transport
Georgia	Tbilisi City	Drought	Serious	Public health	Environment	
Georgia	Tbilisi City	Heat wave	Serious	Public health	Environment	
Germany	City of Cologne	Extreme hot days	Serious	Public health		
Germany	City of Cologne	Heat wave	Serious	Public health		
Germany	City of Cologne	Flash/surface flood	Serious	Residential	Transport	
Germany	City of Hamburg	Storm surge	Serious	Water Supply & Sanitation	Residential	Emergency services

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
Germany	City of Hamburg	Heat wave	Serious	Public Health	Environment	Water Supply & Sanitation
Germany	City of Hamburg	Flash/surface flood	Serious	Water Supply & Sanitation	Residential	Commercial
Germany	City of Hamburg	Drought	Serious	Environment	Water Supply & Sanitation	Food and agriculture
Germany	Landeshauptstadt Magdeburg	River flood	Serious	Residential	Public Health	Transport
Germany	Landeshauptstadt Magdeburg	Heat wave	Serious	Public Health	Residential	Emergency services
Germany	Stadt Heidelberg	Extreme hot days	Serious	Public health	Residential	Food and agriculture
Germany	Stadt Heidelberg	River flood	Less serious	Emergency services	Residential	Transport
Germany	Stadt Heidelberg	Flash/surface flood	Serious	Residential	Transport	Food and agriculture
Germany	Stadt Heidelberg	Extratropical storm	Serious	Emergency services	Residential	Public health
Gibraltar	City of Gibraltar	Extreme hot days	Serious	Public Health	Residential	Energy
Gibraltar	City of Gibraltar	Flash/surface flood	Serious	Emergency services	Transport	Public Health
Gibraltar	City of Gibraltar	Storm surge	Serious	Water Supply & Sanitation	Public Health	Emergency services
Gibraltar	City of Gibraltar	Coastal flood	Serious	Residential	Commercial	Transport
Gibraltar	City of Gibraltar	Heat wave	Serious	Energy	Public Health	Residential
Greece	City of Athens	Extreme hot days	Extremely serious	Energy	Public health	
Greece	City of Athens	Heat wave	Extremely serious	Energy	Public health	Commercial
Greece	City of Athens	Flash/surface flood	Serious	Emergency Management	Public Health	Residential
Greece	City of Athens	Drought	Serious	Water Supply & Sanitation	Public health	Residential
Greece	City of Athens	Heat wave	Extremely serious	Energy	Public health	Commercial
Greece	City of Athens	Extreme hot days	*Extremely serious*	*Energy*	Public health	
Iceland	City of Reykjavík	Coastal flood	Less serious	Residential	Commercial	
Iceland	City of Reykjavík	Ocean acidification	Serious	Food and agriculture	Environment	
Italy	Comune di Bolzano	Rockfall	Less serious	Transport	Residential	
Italy	Comune di Ferrara	Heat wave	Extremely serious	Public Health	Food and agriculture	Energy
Italy	Comune di Ferrara	Rain storm	Serious	Transport	Residential	Emergency services
Italy	Comune di Ferrara	Drought	Serious	Food and agriculture	Water Supply & Sanitation	Energy
Italy	Comune di Firenze	Extreme hot days	Serious	Public health	Energy	
Italy	Comune di Firenze	Flash/surface flood	Serious	Transport	Environment	Emergency Management
Italy	Comune di Firenze	Heavy snow	Less serious	Transport	Emergency Management	
Italy	Comune di Firenze	Insect infestation	Less serious	Public health	Water Supply & Sanitation	Environment
Italy	Comune di Firenze	River flood	Extremely serious	Emergency Management	Transport	
Italy	Comune di Genova	River flood	Serious	Residential	Commercial	Transport
Italy	Comune di Genova	Forest fire	Less serious	Environment	Transport	
Italy	Comune di Genova	Heat wave	Less serious	Public health		
Italy	Comune di Genova	Landslide	Less serious	Residential	Transport	Industrial
Italy	Comune di Milano	River flood	Less serious	Transport	Residential	Education

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
Italy	Comune di Milano	Heat wave	Less serious	Public health	Energy	Environment
Italy	Comune di Milano	Rain storm	Less serious	Transport	Environment	
Italy	Comune di Monza	Atmospheric CO2 concentrations	Serious	Residential	Public health	Transport
Italy	Comune di Monza	River flood	Serious	Residential	Commercial	Emergency Management
Italy	Comune di Monza	Tropical storm	Serious	Environment	Food and agriculture	Commercial
Italy	Comune di Napoli	Atmospheric CO2 concentrations	Extremely serious	Environment	Public health	Emergency Management
Italy	Comune di Napoli	Coastal flood	Serious	Water Supply & Sanitation	Transport	Residential
Italy	Comune di Napoli	Heat wave	Extremely serious	Public health	Emergency Management	Energy
Italy	Comune di Napoli	Rockfall	Serious	Transport	Water Supply & Sanitation	Emergency Management
Italy	Comune di Oristano	Land fire	Less serious	Food and agriculture		
Italy	Comune di Padova	Atmospheric CO2 concentrations	Serious	Public health	Community & Culture	Emergency Management
Italy	Comune di Padova	Air-borne disease	Less serious	Public health	Emergency Management	
Italy	Comune di Padova	Drought	Serious	Food and agriculture	Commercial	Community & Culture
Italy	Comune di Padova	Heat wave	Serious	Public health	Emergency Management	Energy
Italy	Comune di Padova	Rain storm	Less serious	Environment		Commercial
Italy	Comune di Parma	Heat wave	Serious	Food and agriculture	Environment	Emergency Management
Italy	Comune di Parma	Hail	Less serious	Food and agriculture	ICT	Transport
Italy	Comune di Parma	Rain storm	Serious	Food and agriculture	Energy	ICT
Italy	Comune di Parma	Drought	Serious	Food and agriculture	Environment	Emergency Management
Italy	Comune di Parma	River flood	Serious	ICT	Law & Order	Emergency Management
Italy	Comune di Ravenna	Heat wave	Serious	Public Health	Energy	
Italy	Comune di Ravenna	River flood	Less serious	Food and agriculture	Transport	Emergency services
Italy	Comune di Ravenna	Coastal flood	Extremely serious	Commercial	Food and agriculture	
Italy	Comune di Reggio Emilia	Extreme hot days	Serious	Residential	Emergency services	
Italy	Comune di Reggio Emilia	Rain storm	Serious	Water Supply & Sanitation	Transport	
Italy	Comune di Rimini	Atmospheric CO2 concentrations	Serious	Transport	Transport	Transport
Italy	Comune di Torino	River flood	Serious	Transport	Commercial	Public Health
Italy	Comune di Torino	Extreme hot days	Serious	Energy	Public Health	Residential
Italy	Comune di Torino	Heat wave	Serious	Energy	Public Health	Residential
Italy	Comune di Torino	Air-borne disease	Serious	Public Health		
Italy	Comune di Torino	Drought	Serious	Water Supply & Sanitation	Energy	Food and agriculture
Italy	Comune di Venezia	Rain storm	Serious	Transport	Food and agriculture	Emergency Management
Italy	Comune di Venezia	Hail	Less serious	Transport	Food and agriculture	Emergency Management
Italy	Comune di Venezia	Tornado	Serious	Transport	Food and agriculture	Residential
Italy	Comune di Venezia	Fog	Less serious	Transport	Public health	Emergency Management
Italy	Comune di Venezia	Heat wave	Serious	Public health	Residential	Energy

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
Italy	Comune di Venezia	Extreme hot days	Serious	Public health	Residential	Energy
Italy	Comune di Venezia	Flash/surface flood	Extremely serious	Transport	Water Supply & Sanitation	Emergency Management
Italy	Comune di Venezia	Coastal flood	Extremely serious	Commercial	Residential	Waste Management
Italy	Comune di Venezia	Storm surge	Extremely serious	Commercial	Residential	Waste Management
Italy	Comune di Venezia	Air-borne disease	Serious	Public health	Environment	
Italy	Comune di Venezia	Subsidence	Less serious	Food and agriculture		
Italy	Comune di Verbania	Flash/surface flood	Less serious	Environment	Energy	
Italy	Comune di Verbania	Landslide	Extremely serious	Transport		
Italy	Comune di Verbania	Lightning/thunderstorm	Extremely serious	Energy	Water Supply & Sanitation	
Kosovo	Pristina Municipality	Extreme hot days	Serious	Food and agriculture		
Latvia	Riga City	Heavy snow	Less serious	Transport	Environment	
Latvia	Riga City	River flood	Less serious	Environment	Transport	
Lithuania	Šiauliai City Municipality	Extreme hot days	Less serious	Food and agriculture	Emergency services	
Lithuania	Vilnius City Municipality	Flash/surface flood	Less serious	Residential	Transport	
Lithuania	Vilnius City Municipality	Heat wave	Serious	Public Health		
Lithuania	Vilnius City Municipality	Storm surge	Serious	Public Health	Energy	
Lithuania	Vilnius City Municipality	Vector-borne disease	Serious	Public Health		
Lithuania	Vilnius City Municipality	Drought	Serious	Public Health	Energy	
Lithuania	Vilnius City Municipality	Air-borne disease	Serious	Public Health	Residential	Energy
Monaco	Ville de Monaco	Heat wave	Serious	Energy	Water Supply & Sanitation	Public Health
Monaco	Ville de Monaco	Rain storm	Serious	Water Supply & Sanitation	Transport	Emergency services
Monaco	Ville de Monaco	Flash/surface flood	Serious	Transport	Energy	Emergency services
Monaco	Ville de Monaco	Storm surge	Less serious	Energy	Transport	Emergency services
Monaco	Ville de Monaco	Coastal flood	Serious	Residential	Emergency services	Commercial
Monaco	Ville de Monaco	Cold wave	Less serious	Energy		
Monaco	Ville de Monaco	Extreme hot days	Serious	Energy	Public Health	Emergency services
Monaco	Ville de Monaco	Drought	Serious	Water Supply & Sanitation		
Monaco	Ville de Monaco	Groundwater flood	Serious	Transport	Emergency services	Energy
Monaco	Ville de Monaco	Heat wave	Serious	Energy	Public Health	Emergency services
Monaco	Ville de Monaco	Ocean acidification	Serious	Residential		
Monaco	Ville de Monaco	Salt water intrusion	Serious	Water Supply & Sanitation		
Netherlands	City of Amsterdam	Heat wave	Less serious	Public Health	Energy	Residential
Netherlands	City of Amsterdam	Coastal flood	Extremely serious	Public Health	Energy	Emergency services
Netherlands	City of Amsterdam	Drought	Serious	Residential	Commercial	Water Supply & Sanitation
Netherlands	City of Amsterdam	Salt water intrusion	Serious	Water Supply & Sanitation		
Netherlands	City of Amsterdam	Rain storm	Serious	Transport	Commercial	Residential

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
Netherlands	City of Amsterdam	River flood	Extremely serious	Public Health	Energy	Emergency services
Netherlands	Gemeente Groningen	Heat wave	Less serious	Public health	Residential	Commercial
Netherlands	Gemeente Groningen	Flash/surface flood	Serious	Commercial	Residential	Public health
Netherlands	Gemeente Nijmegen	Water-borne disease	Less serious	Public Health		
Netherlands	Gemeente Nijmegen	Extreme hot days	Less serious	Public Health	Commercial	
Netherlands	Gemeente Nijmegen	Rain storm	Serious	Water Supply & Sanitation	Public Health	Residential
Netherlands	Gemeente Nijmegen	Drought	Less serious	Food and agriculture	Public Health	
Netherlands	Gemeente Nijmegen	River flood	Extremely serious	Water Supply & Sanitation	Residential	Public Health
Netherlands	Gemeente Rotterdam	Flash/surface flood	Serious	Public Health	Residential	Commercial
Netherlands	Gemeente Rotterdam	River flood	Serious	Food and agriculture	Public Health	Residential
Netherlands	Gemeente Rotterdam	Storm surge	Serious	Public Health	Commercial	Residential
Netherlands	Gemeente Rotterdam	Heat wave	Less serious	Energy	Public Health	Food and agriculture
Netherlands	Gemeente Rotterdam	Drought	Serious	Water Supply & Sanitation	Transport	Food and agriculture
Netherlands	Gemeente Rotterdam	Salt water intrusion	Serious	Water Supply & Sanitation	Public Health	Food and agriculture
Netherlands	Gemeente Rotterdam	Rain storm	Serious	Public Health	Commercial	Residential
Netherlands	Gemeente Rotterdam	Extreme hot days	Serious	Energy	Water Supply & Sanitation	Public Health
Netherlands	Gemeente Rotterdam	Subsidence	Serious	Public Health	Residential	Commercial
Netherlands	Gemeente Rotterdam	Water-borne disease	Less serious	Public Health	Water Supply & Sanitation	Food and agriculture
Netherlands	The Hague	Rain storm	Less serious	Transport	Commercial	Residential
Netherlands	The Hague	Severe wind	Serious	Transport		
Netherlands	The Hague	Heat wave	Serious	Public health		
Netherlands	The Hague	Coastal flood	Extremely serious	Public health	Residential	Transport
Netherlands	The Hague	Groundwater flood	Less serious	Residential		
Netherlands	The Hague	Drought	Less serious	Environment		
Norway	Bærum Kommune	Flash/surface flood	Less serious	Transport	Residential	Water Supply & Sanitation
Norway	City of Oslo	Flash/surface flood	Serious	Residential	Water Supply & Sanitation	Transport
Norway	City of Oslo	Storm surge	Serious	Residential	Commercial	Transport
Norway	City of Oslo	Rockfall	Less serious	Residential	Transport	Emergency Management
Norway	City of Oslo	Heavy snow	Less serious	Transport	Emergency Management	Energy
Norway	City of Oslo	Forest fire	Serious	Emergency Management	Public health	Environment
Norway	City of Oslo	Vector-borne disease	Serious	Public health	Residential	Emergency Management
Norway	City of Oslo	Landslide	Serious	Emergency Management	Residential	Transport
Norway	City of Oslo	Water-borne disease	Serious	Public health	Water Supply & Sanitation	Residential
Norway	Municipality of Arendal	Heavy snow	Serious	Transport	Public health	
Norway	Municipality of Arendal	Storm surge	Less serious	Water Supply & Sanitation		
Norway	Municipality of Arendal	River flood	Less serious	Residential	Transport	

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
Norway	Municipality of Arendal	Rain storm	Serious	Water Supply & Sanitation	Transport	
Norway	Municipality of Arendal	Drought	Less serious	Water Supply & Sanitation	Food and agriculture	
Poland	City of Gdynia	Extreme cold days	Less serious	Public Health	Transport	Energy
Poland	City of Gdynia	Extreme hot days	Less serious	Public Health	Transport	Energy
Poland	City of Gdynia	Storm surge	Less serious	Public Health	Transport	Energy
Poland	City of Gdynia	Atmospheric CO2 concentrations	Less serious	Public Health	Transport	Energy
Poland	City of Gdynia	Coastal flood	Less serious	Public Health	Transport	Energy
Poland	City of Warsaw	Extreme hot days	Serious	Energy	Public Health	Emergency services
Poland	City of Warsaw	Rain storm	Serious	Emergency services	Water Supply & Sanitation	Public Health
Poland	City of Warsaw	Drought	Serious	Water Supply & Sanitation	Public Health	Food and agriculture
Poland	City of Warsaw	River flood	Less serious	Emergency Management		
Poland	City of Warsaw	Flash/surface flood	Serious	Residential		
Poland	City of Wroclaw	Rain storm	Extremely serious	Transport	Residential	Food and agriculture
Poland	City of Wroclaw	Cold wave	Less serious	Transport	Public Health	Energy
Poland	City of Wroclaw	Extreme cold days	Less serious	Transport	Public Health	Energy
Poland	City of Wroclaw	Heat wave	Extremely serious	Public Health	Energy	Food and agriculture
Poland	City of Wroclaw	Extreme hot days	Extremely serious	Public Health	Energy	Food and agriculture
Poland	City of Wroclaw	River flood	Less serious	Residential	Transport	Public Health
Poland	City of Wroclaw	Flash/surface flood	Serious	Transport	Residential	Water Supply & Sanitation
Poland	City of Wroclaw	Drought	Serious	Public Health	Water Supply & Sanitation	Food and agriculture
Poland	City of Wroclaw	Lightning/thunderstorm	Serious	Residential	Transport	Energy
Poland	Gdansk	Extreme hot days	Serious	Public health	Water Supply & Sanitation	
Poland	Gdansk	Severe wind	Serious	Energy	Emergency Management	Public health
Poland	Gdansk	Fog	Less serious	Transport		
Poland	Gdansk	Rain storm	Serious	Energy	Transport	
Poland	Gdansk	Flash/surface flood	Extremely serious	Residential	Public health	
Poland	Gdansk	Salt water intrusion	Less serious	Food and agriculture		
Portugal	Barreiro	River flood	Serious	Residential	Transport	Public Health
Portugal	Barreiro	Flash/surface flood	Serious	Residential	Transport	Public Health
Portugal	Barreiro	Heat wave	Serious	Public Health	Emergency services	Water Supply & Sanitation
Portugal	Barreiro	Severe wind	Serious	Public Health	Emergency services	Transport
Portugal	Cascais	Heat wave	Serious	Energy	Public Health	Emergency services
Portugal	Cascais	Drought	Serious	Water Supply & Sanitation		Public Health
Portugal	Cascais	River flood	Serious	Residential	Emergency services	
Portugal	Cascais	Forest fire	Serious	Food and agriculture		
Portugal	Cascais	Coastal flood	Serious	Water Supply & Sanitation	Emergency services	Commercial

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
Portugal	City of Lisbon	Heat wave	Serious	Public Health	Residential	Energy
Portugal	City of Lisbon	Flash/surface flood	Serious	Transport	Commercial	Residential
Portugal	City of Lisbon	Drought	Less serious	Public Health	Energy	Environment
Portugal	City of Lisbon	Severe wind	Serious	Public Health	Emergency services	Transport
Portugal	City of Lisbon	Rain storm	Extremely serious	Emergency services	Transport	
Portugal	City of Porto	Coastal flood	Serious	Transport	Residential	Commercial
Portugal	City of Porto	Heat wave	Less serious	Energy	Public Health	Emergency services
Portugal	City of Porto	Rain storm	Less serious	Energy	Public Health	
Portugal	City of Porto	Flash/surface flood	Less serious	Transport	Commercial	Residential
Portugal	City of Porto	River flood	Less serious	Commercial	Residential	
Portugal	City of Porto	Landslide	Serious	Public Health	Residential	Transport
Portugal	Faro	Land fire	Serious	Emergency services	Water Supply & Sanitation	Public Health
Portugal	Faro	Salt water intrusion	Less serious	Water Supply & Sanitation	Food and agriculture	Public Health
Portugal	Faro	Coastal flood	Extremely serious	Emergency services	Commercial	
Portugal	Município de Braga	River flood	Serious	Water Supply & Sanitation	Residential	
Portugal	Município de Braga	Flash/surface flood	Serious	Food and agriculture	Community & Culture	
Portugal	Município de Braga	Extreme hot days	Serious	Public health	Food and agriculture	Community & Culture
Portugal	Município de Braga	Severe wind	Less serious	Food and agriculture		
Portugal	Município de Guimarães	Drought	Extremely serious	Environment	Water Supply & Sanitation	Public health
Portugal	Município de Guimarães	Heat wave	Extremely serious	Public health	Emergency Management	Food and agriculture
Portugal	Município de Guimarães	Landslide	Extremely serious	Transport	Environment	Residential
Portugal	Município de Guimarães	Severe wind	Extremely serious	ICT	Energy	Commercial
Portugal	Município de Guimarães	Extreme winter conditions	Serious	Transport	Food and agriculture	Emergency Management
Portugal	Município de Guimarães	Rain storm	Serious	Transport	Water Supply & Sanitation	Food and agriculture
Portugal	Município de Guimarães	River flood	Extremely serious	Transport	Water Supply & Sanitation	Food and agriculture
Portugal	Município de Guimarães	Forest fire	Extremely serious	Public health	Food and agriculture	Water Supply & Sanitation
Portugal	Município de Ovar	Forest fire	Serious	Emergency services	Residential	
Portugal	Município de Ovar	Flash/surface flood	Serious	Residential	Commercial	Transport
Portugal	Município de Ovar	Rain storm	Less serious	Water Supply & Sanitation	Residential	Transport
Portugal	Município de Ovar	Severe wind	Less serious	Residential	Public Health	
Portugal	Município de Ovar	Coastal flood	Extremely serious	Commercial	Residential	Education
Portugal	Município de Ovar	Salt water intrusion	Extremely serious	Food and agriculture	Public Health	
Portugal	Município de Ovar	Storm surge	Less serious	Residential	Commercial	
Portugal	Município de Ovar	Ocean acidification	Less serious	Water Supply & Sanitation	Public Health	
Portugal	Vila Nova de Famalicão	Atmospheric CO2 concentrations	Less serious	Industrial	Transport	Food and agriculture
Portugal	Santarém	Heat wave	Serious	Food and agriculture	Public Health	Water Supply & Sanitation

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
Portugal	Santarém	Extreme hot days	Serious	Food and agriculture	Public Health	Water Supply & Sanitation
Portugal	Santarém	Tornado	Less serious	Energy	Emergency services	Residential
Portugal	Santarém	Forest fire	Serious	Water Supply & Sanitation	Public Health	Residential
Portugal	Torres Vedras Municipality	Rockfall	Less serious	Residential	Commercial	Public Health
Portugal	Torres Vedras Municipality	Flash/surface flood	Serious	Energy	Food and agriculture	Public Health
Portugal	Torres Vedras Municipality	Severe wind	Serious	Energy	Food and agriculture	Public Health
Portugal	Torres Vedras Municipality	Storm surge	Serious	Commercial	Residential	Public Health
Portugal	Torres Vedras Municipality	Forest fire	Less serious	Food and agriculture	Public Health	
Portugal	Torres Vedras Municipality	Insect infestation	Less serious	Public Health	Food and agriculture	
Portugal	Torres Vedras Municipality	Coastal flood	Serious	Commercial	Community & Culture	Environment
Romania	City of Alba-Iulia	Rain storm	Less serious	Food and agriculture		
Romania	City of Alba-Iulia	River flood	Less serious	Residential		
Russia	Moscow Government	Extreme hot days	Serious	Transport	Public Health	
Russia	Moscow Government	Forest fire	Serious	Public Health	Food and agriculture	Emergency services
Slovenia	City of Ljubljana	River flood	Serious	Residential	Public Health	Commercial
Spain	Ajuntament de Barcelona	Heat wave	Serious	Public Health	Emergency services	Residential
Spain	Ajuntament de Barcelona	Rain storm	Serious	Emergency services	Water Supply & Sanitation	Transport
Spain	Ajuntament de Barcelona	Drought	Extremely serious	Water Supply & Sanitation	Residential	Environment
Spain	Ajuntament de Barcelona	Forest fire	Less serious	Emergency services	Environment	
Spain	Ajuntament de Barcelona	Air-borne disease	Less serious	Public Health		
Spain	Ajuntament de Barcelona	Extreme hot days	Serious	Public Health	Emergency services	Residential
Spain	Ayuntamiento de Madrid	Drought	Serious	Water Supply & Sanitation	Residential	Public Health
Spain	Ayuntamiento de Madrid	Extreme hot days	Serious	Public Health	Energy	Residential
Spain	Ayuntamiento de Madrid	Heat wave	Serious	Public Health	Energy	Residential
Spain	Ayuntamiento de Madrid	Rain storm	Less serious	Water Supply & Sanitation	Emergency services	Transport
Spain	Ayuntamiento de Murcia	Drought	Extremely serious	Water Supply & Sanitation	Food and agriculture	Commercial
Spain	Ayuntamiento de Murcia	Extreme hot days	Serious	Energy	Public Health	Food and agriculture
Spain	Ayuntamiento de Murcia	Heat wave	Extremely serious	Energy	Public Health	Environment
Spain	Ayuntamiento de Murcia	Vector-borne disease	Less serious	Public Health	Emergency services	
Spain	City of Zaragoza	Air-borne disease	Serious	Public health	Public health	
Spain	City of Zaragoza	Extreme hot days	Serious	Environment	Public health	
Spain	City of Zaragoza	Insect infestation	Serious	Public health		
Spain	City of Zaragoza	Drought	Serious	Environment		
Spain	City of Zaragoza	Forest fire	Serious	Environment	Emergency Management	
Sweden	City of Stockholm	River flood	Extremely serious	Transport	Water Supply & Sanitation	Energy
Sweden	City of Stockholm	Heat wave	Less serious	Public health		

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
Sweden	City of Stockholm	Salt water intrusion	Extremely serious	Water Supply & Sanitation		
Sweden	City of Stockholm	Flash/surface flood	Extremely serious	Energy	Water Supply & Sanitation	Residential
Sweden	Umeå municipality	Heat wave	Serious	Public health	Water Supply & Sanitation	Residential
Switzerland	Basel-Stadt	Heat wave	Serious	Public health	Environment	Industrial
Switzerland	Basel-Stadt	Extreme hot days	Serious	Public health	Commercial	Education
Switzerland	Basel-Stadt	Drought	Serious	Commercial	Environment	Residential
Switzerland	Basel-Stadt	River flood	Less serious	Water Supply & Sanitation	Commercial	Residential
Switzerland	Basel-Stadt	Lightning/thunderstorm	Less serious	Education	Commercial	Food and agriculture
Switzerland	Basel-Stadt	Vector-borne disease	Serious	Public health	Commercial	Environment
Switzerland	Stadt Zürich	Heat wave	Serious	Public Health	Energy	Water Supply & Sanitation
Switzerland	Stadt Zürich	Rain storm	Serious	Public Health	Residential	Food and agriculture
Switzerland	Stadt Zürich	Drought	Serious	Public Health	Water Supply & Sanitation	Food and agriculture
Switzerland	Stadt Zürich	River flood	Serious	Public Health	Residential	Emergency services
Switzerland	Stadt Zürich	Landslide	Less serious	Public Health	Emergency services	
Switzerland	Stadt Zürich	Extreme hot days	Less serious	Public health	Environment	Public health
Switzerland	Stadt Zürich	Flash/surface flood	Serious	Transport	Water Supply & Sanitation	
Switzerland	Stadt Zürich	Vector-borne disease	Serious	Public health	Environment	
Switzerland	Stadt Zürich	Hail	Less serious	Residential	Commercial	
Switzerland	Ville de Nyon	Flash/surface flood	Less serious	Emergency services	Residential	Water Supply & Sanitation
Switzerland	Ville de Nyon	Atmospheric CO2 concentrations	Serious	Public Health	Transport	
Switzerland	Ville de Nyon	Heat wave	Serious	Public Health	Emergency services	Water Supply & Sanitation
Switzerland	Ville de Nyon	Drought	Serious	Water Supply & Sanitation	Food and agriculture	Environment
Turkey	stanbul Metropolitan Municipalit	Cold wave	Less serious	Transport	Energy	Emergency Management
Turkey	stanbul Metropolitan Municipalit	Extreme hot days	Serious	Energy	Water Supply & Sanitation	Food and agriculture
Turkey	stanbul Metropolitan Municipalit	Drought	Serious	Water Supply & Sanitation	Food and agriculture	Public health
Turkey	stanbul Metropolitan Municipalit	Rain storm	Serious	Environment	Water Supply & Sanitation	Public health
Turkey	stanbul Metropolitan Municipalit	Fog	Less serious	Transport	Emergency Management	Environment
Turkey	stanbul Metropolitan Municipalit	Flash/surface flood	Serious	Water Supply & Sanitation	Public health	Residential
Turkey	stanbul Metropolitan Municipalit	Forest fire	Less serious	Environment	Emergency Management	Public health
Turkey	Seferihisar municipality	Hail	Serious	Food and agriculture	Commercial	Public Health
Turkey	Seferihisar municipality	Insect infestation	Less serious	Food and agriculture	Commercial	Public Health
Turkey	Seferihisar municipality	Salt water intrusion	Less serious	Water Supply & Sanitation	Food and agriculture	Public Health
Turkey	Village of Kadiovacik	Extreme hot days	Serious	Food and agriculture	Food and agriculture	Food and agriculture
United Kingdom	City of Bournemouth	Heat wave	Extremely serious	Residential	Public Health	Transport
United Kingdom	City of Bournemouth	Flash/surface flood	Serious	Transport	Emergency services	Commercial
United Kingdom	City of Bournemouth	Groundwater flood	Serious	Residential	Transport	Emergency services

Country	Organization	Climate Hazards	Magnitude of Impact	Assets or services that may be most impacted		
United Kingdom	City of Bournemouth	Extreme winter conditions	Serious	Transport	Residential	Public Health
United Kingdom	City of Bournemouth	Severe wind	Serious	Emergency services	Transport	Energy
United Kingdom	City of Bournemouth	Coastal flood	Less serious	Commercial	Public Health	Emergency services
United Kingdom	City of Cardiff	Flash/surface flood	Less serious	Transport	Emergency Management	Waste Management
United Kingdom	City of Cardiff	River flood	Serious	Transport	Residential	Public health
United Kingdom	City of Cardiff	Storm surge	Extremely serious	Energy	Commercial	Emergency Management
United Kingdom	City of Cardiff	Heat wave	Less serious	Commercial	Residential	Education
United Kingdom	Glasgow City Council	Rain storm	Serious	Transport		
United Kingdom	Glasgow City Council	Flash/surface flood	Serious	Transport		
United Kingdom	Greater London Authority	River flood	Serious	Transport	Commercial	Residential
United Kingdom	Greater London Authority	Heat wave	Serious	Public health	Residential	Transport
United Kingdom	Greater London Authority	Flash/surface flood	Serious	Residential	Commercial	Transport
United Kingdom	Greater London Authority	Drought	Serious	Public health	Water Supply & Sanitation	Environment
United Kingdom	Greater London Authority	Coastal flood	Extremely serious	Transport	Residential	Commercial
United Kingdom	Greater Manchester	Heat wave	Less serious	Public health	Emergency management	
United Kingdom	Greater Manchester	Extreme hot days	Less serious	Public health		
United Kingdom	Greater Manchester	Flash/surface flood	Serious	Transport	Energy	Emergency management
United Kingdom	Greater Manchester	Severe wind	Serious	Energy	Emergency Management	ICT
United Kingdom	Greater Manchester	River flood	Extremely serious	Transport		Emergency management

ANNEX II
DATABASE OF CLIMATE RISK TYPOLOGY FOR GREATER COPENHAGEN AND VENETO REGION

NUTS 3 regions in Greater Copenhagen

		Vest- og Sydsjaelland NWC2		Ostsjaelland NWC2		Nordsjaelland NWC2		Kobenhavns Omegn NWC5		Byen Kobenhavn NWC5		Skane lan NL4		Hallands lan NL2	
Hazard	Unit	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization
Projected change in mean temperature (RCP 8.5)	°C	**1.7**	-0.26	**1.7**	-0.26	**1.7**	-0.26	**1.7**	-0.26	**1.7**	-0.26	**1.8**	0.16	**1.8**	0.16
Projected change in maximum temperature (RCP 8.5)	°C	**1.6**	-0.42	**1.6**	-0.42	**1.6**	-0.42	**1.7**	-0.02	**1.7**	-0.02	**1.7**	-0.02	**1.7**	-0.02
Projected change in summer days (RCP 8.5)	N°	**5**	-1.15	**5**	-1.15	**5**	-1.15	**6**	-1.03	**5**	-1.15	**5**	-1.15	**4**	-1.29
Projected change in tropical nights (RCP 8.5)	N°	**1**	-1.05	**1**	-1.05	**1**	-1.05	**1**	-1.05	**2**	-0.43	**1**	-1.05	**1**	-1.05
Projected change in heat wave days (RCP 8.5)	N°	**0**	-1.15	**0**	-1.15	**0**	-1.15	**0**	-1.15	**0**	-1.15	**0**	-1.15	**0**	-1.15
Projected change in minimum temperature (RCP 8.5)	°C	**1.8**	-0.09	**1.8**	-0.09	**1.8**	-0.09	**1.8**	-0.09	**1.8**	-0.09	**1.9**	0.38	**1.9**	0.38
Projected change in frost days (RCP 8.5)	N°	**-27**	-0.01	**-31**	-0.73	**-30**	-0.48	**-30**	-0.48	**-27**	-0.01	**-31**	-0.73	**-31**	-0.73
Projected change in ice days (RCP 8.5)	N°	**-10**	0.13	**-12**	0.42	**-12**	0.42	**-12**	0.42	**-11**	0.26	**-14**	0.74	**-15**	0.87
Projected change in total wet-day precipitation (RCP 8.5)	mm	**62**	0.29	**53**	-0.00	**58**	0.13	**54**	0.02	**60**	0.20	**65**	0.42	**71**	0.71
Projected change in consecutive wet days (RCP 8.5)	N°	**0**	-0.07	**0**	-0.07	**0**	-0.07	**0**	-0.07	**0**	-0.07	**0**	-0.07	**0**	-0.07
Projected change in heavy precipitation days (RCP 8.5)	N°	**3**	0.60	**3**	0.60	**3**	0.60	**3**	0.60	**3**	0.60	**3**	0.60	**4**	1.86
Projected change in very heavy precipitation days (RCP 8.5	N°	**1**	0.08	**1**	0.08	**1**	0.08	**1**	0.08	**1**	0.08	**1**	0.08	**2**	1.78
Projected change in consecutive dry days (RCP 8.5)	N°	**-1**	-1.64	**-1**	-1.64	**-1**	-1.64	**-1**	-1.64	**-1**	-1.64	**0**	-0.26	**-1**	-1.64
Wildfire hazard	%	**0.1**	1.10	**0.0**	0.28	**0.0**	-0.03	**0.0**	-0.31	**0.0**	-1.68	**0.0**	0.39	**0.0**	0.11
Coastal hazard	%	**1.2**	1.17	**1.4**	1.22	**1.3**	1.20	**1.1**	1.12	**1.0**	1.04	**1.1**	1.11	**1.5**	1.28
Drought hazard	%	**16.7**	1.94	**18.7**	2.62	**18.2**	2.38	**18.7**	2.57	**3.9**	-0.17	**12.3**	1.40	**17.2**	2.16
Fluvial hazard	%	**0.3**	-0.95	**0.0**	-1.57	**0.0**	-1.57	**0.0**	-1.57	**0.0**	-1.57	**2.3**	-0.18	**3.3**	0.10
Landslide hazard	%	**0.1**	-0.46	**0.0**	-1.17	**0.0**	-1.17	**0.0**	-1.17	**0.0**	-1.17	**0.1**	-0.41	**0.3**	-0.31
Exposure	Unit	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization
Population in settlements exposed to fluvial flooding	%	**0.1**	-0.89	**0.0**	-1.52	**0.0**	-1.52	**0.0**	-1.52	**0.0**	-1.52	**0.8**	-0.34	**2.4**	0.17
Population in settlements exposed to coastal hazard	%	**5.4**	1.61	**9.5**	1.80	**5.1**	1.59	**4.5**	1.56	**8.6**	1.76	**0.6**	0.98	**1.7**	1.20
Population in settlements exposed to landslide	%	**0.0**	-0.51	**0.0**	-1.13	**0.0**	-1.13	**0.0**	-1.13	**0.0**	-1.13	**0.0**	-0.41	**0.1**	-0.25
Road infrastructure exposed to fluvial flooding	%	**0.2**	-0.89	**0.0**	-1.43	**0.0**	-1.43	**0.0**	-1.43	**0.0**	-1.43	**1.1**	-0.52	**8.2**	0.76
Rail network exposed to fluvial flooding	%	**0.4**	-0.70	**0.0**	-1.36	**0.0**	-1.36	**0.0**	-1.36	**0.0**	-1.36	**1.7**	-0.29	**11.0**	0.70
Road infrastructure exposed to coastal hazard	%	**1.8**	1.50	**0.8**	1.31	**1.6**	1.45	**2.6**	1.58	**32.5**	2.61	**0.7**	1.26	**0.0**	-0.52
Road infrastructure exposed to landslide	%	**0.0**	-0.97	**0.0**	-0.97	**0.0**	-0.97	**0.0**	-0.97	**0.0**	-0.97	**0.0**	-0.97	**0.0**	-0.09
Rail network exposed to coastal hazard	%	**2.4**	1.65	**16.7**	2.43	**10.4**	2.23	**6.1**	1.96	**23.3**	2.52	**0.5**	1.35	**0.0**	1.17
Rail network exposed to landslide	%	**0.0**	-0.88	**0.0**	-0.88	**0.0**	-0.88	**0.0**	-0.88	**0.0**	-0.88	**0.0**	-0.09	**0.0**	0.07
Transport nodes exposed to fluvial flooding	%	**0.7**	-0.48	**0.0**	-1.27	**0.0**	-1.27	**0.0**	-1.27	**0.0**	-1.27	**1.0**	-0.38	**4.5**	0.38
Transport nodes exposed to coastal hazard	%	**12.8**	1.93	**5.1**	1.59	**3.5**	1.46	**1.9**	1.27	**13.6**	1.95	**1.2**	1.18	**1.5**	1.20
Transport nodes exposed to landslide	%	**0.0**	-0.94	**0.0**	-0.94	**0.0**	-0.94	**0.0**	-0.94	**0.0**	-0.94	**0.0**	-0.21	**0.0**	-0.94
Airports exposed to fluvial flooding	%	**0.0**	-0.36	**0.0**	-0.36	**0.0**	-0.36	**0.0**	-0.36	**0.0**	-0.36	**5.9**	1.93	**0.0**	-0.36
Airports exposed to coastal hazard	%	**28.6**	4.24	**0.0**	-0.20	**0.0**	-0.20	**0.0**	-0.20	**0.0**	-0.20	**0.0**	-0.20	**0.0**	-0.20
Airports exposed to landslide	%	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18
Power plants exposed to fluvial flooding	%	**0.0**	-0.82	**0.0**	-0.82	**0.0**	-0.82	**0.0**	-0.82	**0.0**	-0.82	**5.2**	0.26	**29.0**	1.46
Power plants exposed to coastal hazard	%	**6.1**	2.37	**0.0**	-0.33	**2.7**	2.14	**0.0**	-0.33	**13.6**	2.60	**1.0**	2.07	**0.0**	-0.33
Power plants exposed to landslide	%	**0.0**	-0.68	**0.0**	-0.68	**0.0**	-0.68	**0.0**	-0.68	**0.0**	-0.68	**0.0**	-0.68	**0.0**	-0.68
Ports exposed to fluvial flooding	%	**0.0**	-0.30	**0.0**	-0.30	**0.0**	-0.30	**0.0**	-0.30	**0.0**	-0.30	**0.0**	-0.30	**0.0**	-0.30
Ports exposed to coastal hazard	%	**17.4**	2.24	**0.0**	-0.33	**50.0**	2.81	**33.3**	2.48	**0.0**	-0.33	**16.7**	2.22	**0.0**	-0.33
Ports exposed to landslide	%	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18
Hospitals exposed to fluvial flooding	%	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18	**0.0**	-0.18
Hospitals exposed to coastal hazard	%	**8.0**	4.41	**0.0**	-0.19	**75.0**	5.96	**0.0**	-0.19	**0.0**	-0.19	**0.0**	-0.19	**0.0**	-0.19
Hospitals exposed to landslide	%	**0.0**	-0.41	**0.0**	-0.41	**0.0**	-0.41	**0.0**	-0.41	**0.0**	-0.41	**0.0**	-0.41	**0.0**	-0.41

NUTS 3 regions in Greater Copenhagen (continued)

		Vest- og Sydsjaelland NWC2		Ostsjaelland NWC2		Nordsjaelland NWC2		Kobenhavns Omegn NWC5		Byen Kobenhavn NWC5		Skane lan NL4		Hallands lan NL2	
Sensitivity	Unit	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization
Population density	Ratio	90.5	-0.42	295.0	0.52	310.4	0.55	1538.5	1.33	4129.1	1.91	115.1	-0.18	56.0	-0.92
Total population living in urban areas /area in km2	Ratio	1119.8	-0.31	1271.9	-0.01	1152.0	-0.24	1949.9	0.91	5059.7	2.06	1535.6	0.40	1006.9	-0.66
Change in population density in NUTS3 unit between 2017-2050	%	0.0	-0.77	2.0	-0.13	0.1	1.16	11.0	1.88	50.1	2.50	0.9	1.81	0.5	1.34
Migratory population change in NUTS3 unit between 2017-2050	%	0.9	-0.03	16.1	0.80	0.9	-0.04	37.6	1.39	91.9	2.05	98.8	2.14	28.3	1.17
Population change - children (> 15 years) in NUTS3 unit between 2017-2050	%	-31.8	-0.81	-19.3	-0.41	24.2	1.89	26.0	2.02	31.1	2.42	24.3	1.90	19.8	1.45
Population change in older people (> 70 years) in NUTS3 unit between 2017-2050	%	29.2	-0.58	41.6	0.50	25.4	-0.84	36.8	0.02	59.9	2.19	38.5	0.19	31.4	-0.43
Soil moisture stress	N°	28.5	-0.86	33.6	-0.65	31.6	-0.73	61.0	0.22	67.2	0.39	51.7	-0.01	33.7	-0.65
Water consumption pressure (2030)	mm/25km²	8.3	-0.34	6.8	-0.42	6.3	-0.47	30.1	0.24	47.9	0.52	7.6	-0.36	2.9	-0.99
At risk of poverty	%	12.0	-0.68	9.9	-1.79	9.9	-1.79	12.0	-0.68	20.0	1.03	20.0	1.03	12.0	-0.68

Adaptive capacity	Unit	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization
GVA at basic prices per head of population	Euro	27.2	0.46	28.4	0.59	32.1	0.87	61.8	1.84	57.6	1.76	34.0	0.99	31.8	0.85
Employment-population balance	%	0.4	-0.51	0.4	-0.23	0.4	-0.27	0.6	1.44	0.7	1.55	0.5	0.26	0.4	0.17
Length of major road network	Km	907.8	1.00	259.8	-0.22	290.9	-0.12	357.3	0.07	102.7	-1.22	2079.8	2.17	600.6	0.63
Length of railway network	Km	748.9	1.11	222.0	-0.18	322.8	0.17	266.9	-0.01	303.1	0.11	1419.3	1.97	514.7	0.67
Density of major road intersections	Ratio	1.2	-1.13	1.7	-0.63	2.1	-0.21	2.5	0.14	4.0	1.26	1.5	-0.84	1.2	-1.14
Density of transport nodes	Ratio	0.3	-0.95	0.4	-0.67	0.8	-0.30	1.2	0.05	2.2	0.70	1.6	0.32	0.4	-0.80
Airports per head of population	N°	0.0	0.86	0.0	-0.04	0.0	0.77	0.0	-1.21	0.0	-0.59	0.0	0.98	0.0	0.67
Ports per head of population	N°	0.0	2.60	0.0	-0.62	0.0	1.03	0.0	1.16	0.0	0.81	0.0	1.06	0.0	-0.62
Hospital sites per head of population	N°	0.0	0.81	0.1	2.69	0.0	-0.09	0.0	0.12	0.0	-0.00	0.0	-0.64	0.0	-1.22
Power plants per head of population	N°	0.2	1.43	0.0	-0.07	0.1	0.57	0.0	-0.30	0.0	-0.46	0.1	0.46	0.3	1.88
Fixed broadband coverage	%	99.6	0.30	99.5	0.27	99.8	0.40	99.8	0.40	99.9	0.56	97.3	-0.36	95.8	-0.65
Patent applications to the EPO	N°	40.1	0.59	53.6	0.78	227.7	1.92	194.8	1.81	151.4	1.61	464.4	2.37	48.4	0.72
Urban area classified as green space	%	2.0	0.67	3.4	1.02	3.6	1.08	11.4	2.36	8.5	2.00	6.6	1.64	5.9	1.50
Priority allocation funding	%	0.0	0.41	0.0	0.11	0.0	-0.28	0.0	0.06	0.0	0.50	0.0	0.68	0.0	-0.15
Change in total green space	%	-0.4	-1.49	-0.0	-1.34	0.4	-0.70	0.5	-0.66	0.4	-0.72	13.7	1.17	6.2	0.51
Urban land cover	%	4.4	-0.44	14.2	0.59	21.9	0.78	70.2	1.46	117.5	1.70	5.4	-0.23	3.9	-0.57
Change in urban land cover	%	-0.2	-1.44	-0.0	-1.34	0.1	-0.97	0.2	-0.83	0.2	-0.89	2.2	0.10	2.8	0.22
Next Generation Access (NGA) - broadband	%	86.1	0.24	91.5	0.53	98.6	1.44	99.8	1.58	98.5	1.42	81.5	-0.02	77.6	-0.21

NUTS 3 regions in Veneto

		Venezia		Padova		Treviso		Vicenza		Verona		Belluno		Rovigo	
		LES3		IU1		LEL3		LEL3		LEL3		LEL1		LES3	
Hazard	Unit	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization
Projected change in mean temperature (RCP 8.5)	°C	1.9	0.60	1.9	0.60	1.9	0.60	1.9	0.60	1.9	0.60	2.1	1.47	1.9	0.60
Projected change in maximum temperature (RCP 8.5)	°C	1.8	0.34	1.9	0.71	1.8	0.34	1.9	0.71	1.9	0.71	2.1	1.49	1.8	0.34
Projected change in summer days (RCP 8.5)	N°	23	1.18	21	0.92	21	0.92	19	0.74	21	0.92	9	-0.59	21	0.92
Projected change in tropical nights (RCP 8.5)	N°	26	1.61	24	1.46	19	1.21	14	0.97	21	1.30	2	-0.43	27	1.68
Projected change in heat wave days (RCP 8.5)	N°	6	0.97	9	1.34	7	1.09	5	0.86	8	1.21	0	-1.15	9	1.34
Projected change in minimum temperature (RCP 8.5)	°C	1.9	0.38	1.9	0.38	1.9	0.38	2.0	0.86	1.9	0.38	2.2	1.60	1.9	0.38
Projected change in frost days (RCP 8.5)	N°	-20	0.85	-22	0.59	-23	0.49	-27	-0.01	-23	0.49	-32	-1.06	-20	0.85
Projected change in ice days (RCP 8.5)	N°	-2	-1.11	-2	-1.11	-3	-0.89	-8	-0.14	-4	-0.67	-24	1.67	-1	-1.36
Projected change in total wet-day precipitation (RCP 8.5)	mm	71	0.71	45	-0.20	52	-0.03	37	-0.37	40	-0.32	62	0.29	52	-0.03
Projected change in consecutive wet days (RCP 8.5)	N°	0	-0.07	0	-0.07	0	-0.07	0	-0.07	0	-0.07	0	-0.07	0	-0.07
Projected change in heavy precipitation days (RCP 8.5)	N°	2	-0.31	1	-0.77	1	-0.77	0	-1.02	1	-0.77	1	-0.77	2	-0.31
Projected change in very heavy precipitation days (RCP 8.5	N°	2	1.78	1	0.08	1	0.08	1	0.08	1	0.08	1	0.08	1	0.08
Projected change in consecutive dry days (RCP 8.5)	N°	0	-0.26	0	-0.26	0	-0.26	0	-0.26	0	-0.26	-1	-1.64	0	-0.26
Wildfire hazard	%	0.0	0.62	0.2	1.23	0.2	1.36	0.3	1.45	0.3	1.57	0.0	0.41	0.0	0.40
Coastal hazard	%	1.2	1.12	1.2	1.13	1.2	1.13	0.0	-0.60	0.0	-0.60	0.0	-0.60	1.0	1.07
Drought hazard	%	0.9	-0.63	2.1	-0.48	1.1	-0.59	1.9	-0.50	2.7	-0.40	-2.6	-0.98	3.9	-0.21
Fluvial hazard	%	23.7	1.63	14.3	1.29	5.1	0.46	1.5	-0.48	9.7	1.00	2.4	-0.13	80.1	2.60
Landslide hazard	%	0.0	-1.17	4.2	0.15	16.2	0.63	45.2	1.44	22.7	0.85	86.8	2.24	0.0	-1.17

Exposure	Unit	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization	Absolute value	Europe normalization
Population in settlements exposed to fluvial flooding	%	7.4	1.09	12.5	1.60	2.9	0.30	1.5	-0.09	6.9	1.04	0.9	-0.30	39.8	2.66
Population in settlements exposed to coastal hazard	%	10.2	1.83	1.0	1.09	0.0	0.70	0.0	-0.59	0.0	-0.59	0.0	-0.59	10.2	1.83
Population in settlements exposed to landslide	%	0.0	-1.13	1.9	0.22	6.0	0.62	19.0	1.37	8.2	0.77	45.7	2.20	0.0	-1.13
Road infrastructure exposed to fluvial flooding	%	16.8	1.31	30.1	1.88	4.9	0.31	8.3	0.77	13.2	1.15	4.7	0.30	75.0	2.97
Rail network exposed to fluvial flooding	%	27.5	1.34	47.6	1.83	5.1	0.23	6.0	0.30	27.6	1.35	4.8	0.20	74.3	2.18
Road infrastructure exposed to coastal hazard	%	11.9	2.22	3.1	1.63	0.0	-0.52	0.0	-0.52	0.0	-0.52	0.0	-0.52	1.7	1.48
Road infrastructure exposed to landslide	%	0.0	-0.97	0.0	-0.23	0.0	0.49	0.0	1.23	0.0	0.84	0.0	2.72	0.0	-0.97
Rail network exposed to coastal hazard	%	9.3	2.15	0.0	-0.46	0.0	-0.46	0.0	-0.46	0.0	-0.46	0.0	-0.46	2.2	1.62
Rail network exposed to landslide	%	0.0	-0.88	0.0	0.25	0.0	0.42	0.0	0.96	0.0	0.67	0.0	2.21	0.0	-0.88
Transport nodes exposed to fluvial flooding	%	1.2	-0.32	14.9	1.56	0.5	-0.56	2.7	0.07	7.9	0.88	1.6	-0.22	42.4	2.68
Transport nodes exposed to coastal hazard	%	23.2	2.33	0.4	0.99	0.0	-0.52	0.0	-0.52	0.0	-0.52	0.0	-0.52	5.9	1.64
Transport nodes exposed to landslide	%	0.0	-0.94	3.1	0.34	3.6	0.39	11.0	0.85	9.4	0.77	75.8	2.79	0.0	-0.94
Airports exposed to fluvial flooding	%	0.0	-0.36	100.0	3.39	0.0	-0.36	0.0	-0.36	33.3	2.29	0.0	-0.36	0.0	-0.36
Airports exposed to coastal hazard	%	0.0	-0.20	0.0	-0.20	0.0	-0.20	0.0	-0.20	0.0	-0.20	0.0	-0.20	0.0	-0.20
Airports exposed to landslide	%	0.0	-0.18	0.0	-0.18	0.0	-0.18	0.0	-0.18	0.0	-0.18	100.0	6.51	0.0	-0.18
Power plants exposed to fluvial flooding	%	7.7	0.42	0.0	-0.82	0.0	-0.82	4.3	0.21	2.7	0.10	4.1	0.18	41.2	1.84
Power plants exposed to coastal hazard	%	7.7	2.45	0.0	-0.33	0.0	-0.33	0.0	-0.33	0.0	-0.33	0.0	-0.33	11.8	2.54
Power plants exposed to landslide	%	0.0	-0.68	5.0	0.51	2.6	0.42	59.4	2.02	5.4	0.52	83.7	2.60	0.0	-0.68
Ports exposed to fluvial flooding	%	0.0	-0.30	0.0	-0.30	0.0	-0.30	0.0	-0.30	0.0	-0.30	0.0	-0.30	100.0	3.78
Ports exposed to coastal hazard	%	50.0	2.81	0.0	-0.33	0.0	-0.33	0.0	-0.33	0.0	-0.33	0.0	-0.33	100.0	3.90
Ports exposed to landslide	%	0.0	-0.18	0.0	-0.18	0.0	-0.18	0.0	-0.18	0.0	-0.18	0.0	-0.18	0.0	-0.18
Hospitals exposed to fluvial flooding	%	0.0	-0.18	0.0	-0.18	0.0	-0.18	0.0	-0.18	0.0	-0.18	0.0	-0.18	0.0	-0.18
Hospitals exposed to coastal hazard	%	33.0	5.03	0.0	-0.19	0.0	-0.19	0.0	-0.19	0.0	-0.19	0.0	-0.19	0.0	-0.19
Hospitals exposed to landslide	%	0.0	-0.41	0.0	-0.41	0.0	-0.41	25.0	2.04	14.3	1.78	33.3	2.25	0.0	-0.41

NUTS 3 regions in Veneto (continued)

Sensitivity	Unit	Venezia LES3 Absolute value	Venezia LES3 Europe normalization	Padova IU1 Absolute value	Padova IU1 Europe normalization	Treviso LEL3 Absolute value	Treviso LEL3 Europe normalization	Vicenza LEL3 Absolute value	Vicenza LEL3 Europe normalization	Verona LEL3 Absolute value	Verona LEL3 Europe normalization	Belluno LEL1 Absolute value	Belluno LEL1 Europe normalization	Rovigo LES3 Absolute value	Rovigo LES3 Europe normalization
Population density	Ratio	**367.3**	0.66	**437.2**	0.74	**360.4**	0.64	**319.6**	0.57	**304.1**	0.54	**57.6**	-0.89	**137.7**	-0.02
Total population living in urban areas /area in km2	Ratio	**960.8**	-0.87	**914.5**	-1.01	**750.4**	-1.67	**1035.5**	-0.57	**1068.2**	-0.45	**779.9**	-1.53	**976.2**	-0.79
Change in population density in NUTS3 unit between 2017-2050	%	**3.4**	0.70	**3.7**	0.92	**1.2**	0.76	**1.4**	0.85	**1.9**	0.90	**0.0**	0.36	**0.6**	0.45
Migratory population change in NUTS3 unit between 2017-2050	%	**67.2**	1.77	**77.7**	1.88	**30.4**	1.23	**37.7**	1.40	**58.5**	1.69	**1.3**	0.00	**9.2**	0.50
Population change - children (> 15 years) in NUTS3 unit between 2017-2050	%	**15.6**	1.05	**13.8**	0.91	**7.9**	0.63	**9.5**	0.70	**10.8**	0.76	**12.5**	0.82	**16.1**	1.10
Population change in older people (> 70 years) in NUTS3 unit between 2017-2050	%	**36.8**	0.02	**43.7**	0.69	**44.3**	0.74	**44.3**	0.75	**42.8**	0.61	**29.1**	-0.59	**33.8**	-0.26
Soil moisture stress	N°	**48.0**	-0.12	**48.4**	-0.11	**69.5**	0.45	**77.5**	0.58	**72.6**	0.49	**64.6**	0.33	**50.5**	-0.06
Water consumption pressure (2030)	$mm/25km^2$	**210.7**	2.23	**238.7**	2.41	**194.5**	2.08	**123.6**	1.49	**79.3**	0.97	**6.8**	-0.41	**207.9**	2.17
At risk of poverty	%	**12.0**	-0.68	**9.9**	-1.79	**9.9**	-1.79	**12.0**	-0.68	**9.9**	-1.79	**20.0**	1.03	**15.0**	0.19

Adaptive capacity	Unit	Venezia LES3 Absolute value	Venezia LES3 Europe normalization	Padova IU1 Absolute value	Padova IU1 Europe normalization	Treviso LEL3 Absolute value	Treviso LEL3 Europe normalization	Vicenza LEL3 Absolute value	Vicenza LEL3 Europe normalization	Verona LEL3 Absolute value	Verona LEL3 Europe normalization	Belluno LEL1 Absolute value	Belluno LEL1 Europe normalization	Rovigo LES3 Absolute value	Rovigo LES3 Europe normalization
GVA at basic prices per head of population	Euro	**26.5**	0.38	**28.4**	0.59	**26.5**	0.38	**27.7**	0.50	**28.1**	0.56	**27.1**	0.45	**22.1**	-0.10
Employment-population balance	%	**0.4**	0.08	**0.5**	0.40	**0.5**	0.29	**0.5**	0.27	**0.5**	0.28	**0.4**	0.06	**0.4**	-0.39
Length of major road network	Km	**578.6**	0.59	**632.6**	0.67	**714.7**	0.77	**783.0**	0.86	**904.7**	1.00	**491.8**	0.42	**295.3**	-0.10
Length of railway network	Km	**1224.7**	1.74	**890.9**	1.34	**752.5**	1.11	**469.6**	0.56	**1326.6**	1.84	**220.8**	-0.18	**337.7**	0.22
Density of major road intersections	Ratio	**2.4**	0.04	**2.5**	0.11	**2.7**	0.29	**2.4**	0.04	**2.1**	-0.20	**1.7**	-0.57	**1.8**	-0.50
Density of transport nodes	Ratio	**1.4**	0.18	**1.9**	0.49	**0.5**	-0.56	**1.1**	-0.03	**0.6**	-0.49	**0.9**	-0.21	**0.4**	-0.77
Airports per head of population	N°	**0.0**	-0.38	**0.0**	-0.62	**0.0**	-0.40	**0.0**	-0.15	**0.0**	-0.17	**0.0**	0.05	**0.0**	-1.21
Ports per head of population	N°	**0.0**	0.74	**0.0**	-0.62	**0.0**	-0.62	**0.0**	-0.62	**0.0**	-0.62	**0.0**	-0.62	**0.0**	0.99
Hospital sites per head of population	N°	**0.0**	0.31	**0.0**	0.57	**0.0**	0.55	**0.0**	0.97	**0.0**	0.95	**0.0**	1.71	**0.0**	0.50
Power plants per head of population	N°	**0.0**	-0.46	**0.0**	-0.80	**0.0**	-0.10	**0.1**	0.53	**0.0**	-0.19	**0.2**	1.56	**0.1**	0.37
Fixed broadband coverage	%	**99.0**	0.08	**99.6**	0.30	**95.3**	-0.72	**99.0**	0.07	**98.0**	-0.19	**99.1**	0.09	**97.1**	-0.39
Patent applications to the EPO	N°	**50.9**	0.75	**112.3**	1.35	**141.8**	1.53	**151.5**	1.61	**81.1**	1.07	**11.9**	-0.15	**12.9**	-0.10
Urban area classified as green space	%	**0.6**	-0.06	**0.1**	-0.58	**0.1**	-0.59	**0.0**	-1.19	**0.5**	-0.20	**0.3**	-0.36	**0.9**	0.09
Priority allocation funding	%	**0.0**	-1.29	**0.0**	-1.29	**0.0**	-1.29	**0.0**	-1.29	**0.0**	-1.29	**0.0**	-1.29	**0.0**	-1.29
Change in total green space	%	**4.7**	0.33	**5.0**	0.36	**5.2**	0.40	**1.8**	-0.15	**5.1**	0.38	**0.4**	-0.74	**4.3**	0.26
Urban land cover	%	**13.6**	0.57	**12.7**	0.53	**11.3**	0.46	**10.2**	0.40	**9.5**	0.34	**1.9**	-1.14	**6.4**	-0.02
Change in urban land cover	%	**1.7**	-0.03	**1.9**	0.00	**1.9**	-0.00	**0.6**	-0.45	**1.7**	-0.03	**0.5**	-0.54	**4.0**	0.46
Next Generation Access (NGA) - broadband	%	**92.8**	0.63	**90.8**	0.48	**68.2**	-0.53	**77.2**	-0.23	**92.4**	0.59	**55.6**	-0.76	**62.8**	-0.62