Chapter 6: Cities, Settlements and Key Infrastructure

Coordinating Lead Authors: David Dodman (Jamaica); Bronwyn Hayward (New Zealand); Mark Pelling (United Kingdom)

Lead Authors: Vanesa Castan-Broto (Spain); Winston Chow (Singapore); Eric Chu (United States of America); Richard Dawson (United Kingdom); Luna Khirfan (Canada); Timon McPhearson (United States of America); Anjal Prakash (India); Zheng Yan (China); Gina Ziervogel (South Africa).

Contributing Authors: Diane Archer (Australia/France), Chiara Bertolin (Italy), Shauna Brail (Canada), Anton Cartwright (South Africa), Sarah Colenbrander (Australia/Switzerland), Tapan Dhar (Bangladesh), David Hondula (United States of America), Twan van Hooff (the Netherlands), Hayley Leck (South Africa), Vishal Narain (India), Angelica Ospina (Colombia/Canada), Chao Ren (China), Wan-Yu Shih (Taiwan, Province of China), Gilbert Siame (Zambia), Jennifer Vanos (Canada)

Review Editors: Gian-Carlo Delgado-Ramos (Mexico); Patricia Romero-Lankao (Mexico)

Chapter Scientist: Linda Westman (Sweden)

Date of Draft: 18 October 2019

Notes: TSU Compiled Version

Table of Contents

Executive Summary

Since AR5, cities and settlements (particularly unplanned and informal settlements) have continued to grow at rapid rates and remain crucial both as sites of action on climate change and sites of increased exposure to risk (high evidence, high agreement).

Ensuring the sustainability of cities and settlements, (both formal and informal) and urban infrastructure is key to effective climate change action and reducing exposure to risk (high evidence, high agreement). Another 2.5 billion people are predicted to live in urban areas by 2050, with up to 90 percent of this increase concentrated in the regions of Asia and Africa and in informal settlements, providing an opportunity to build risk reduction into urban development {6.1}.

Systems of social and economic organisation in informal settlements have significant implications for effective climate adaptation, exposure to risk and capacity to adapt particularly in the context of extreme events (medium evidence, high agreement). Communities living in informal settlements have higher exposure to climate risk and lower capacity to adapt {6.1, 6.2}. Most at risk are women and children who make up the majority populations of these settlements {6.1}. Adaptation actions undertaken by and including community actors in informal settlements are critical to resilience outcomes that can reduce risk and enhance wellbeing {6.3, 6.4}.

Changes in international policy architecture, including the Paris Agreement, the 2030 Sustainable Development Agenda, the New Urban Agenda and the Sendai Framework for Disaster Risk Reduction provide a global framework for city action for climate change (medium evidence, medium agreement) {6.1}. City and community level action compliments and at times goes beyond national and international level interventions {6.3}.

The concentration of exposure to risk, loss and damages in cities and settlements has increased since AR5 (strong evidence, high agreement). Observed changes in urban impacts and risks occur directly from changes in climate (e.g. temperature, precipitation and air quality), and indirectly from urbanisation processes interacting with climate systems in multiple, dynamic and complex ways that affect key socio-economic sectors {6.2}.

Few risk management plans and projects in cities, settlements and for key infrastructure have implemented these plans to manage complex interconnected risk, for example in the food energy-water-health nexus or the inter-relationships of air quality and climate risk (medium evidence high agreement). Community based planning and resilience actions are often amongst the most integrated and are able to enhance wellbeing through adaptation and so meet the Sustainable Development Goal ambition of leaving no-one behind (medium evidence, medium agreement) {6.3, 6.4}.

City populations are increasingly exposed to climate impacts in distant rural areas, through national and international commodity flows (medium evidence, high agreement) {6.2}.

Levels of investment in new infrastructure in cities and settlements that explicitly addresses future climate risk have not kept pace with increasing risk and loss (medium evidence, medium agreement). Most innovation in adaptation has been led through advances in social and ecological infrastructures including disaster risk management, social safety nets and green/blue infrastructure (medium evidence, high agreement). Integrated development planning that connects innovation and investment in social, ecological and physical infrastructures can significantly increase the adaptive capacity of urban settlements and cities (medium evidence, high agreement){6.3}.

Adaptation in cities and settlements continues to be largely focussed on climate risk reduction, missing opportunities to enhance inclusive and sustainable development. Pathways for transformative adaptation that enable these multiple goals rest on inclusive and informed decision-making. Transformative adaptation is most commonly observed where community organisations and city authorities collaborate in open decision-making contexts, (medium evidence, high agreement). This has been observed most frequently in larger cities of rich and poor countries, though there have been few scientific studies of smaller settlements {6.3}.

Future scenarios for urbanisation, its associated infrastructure and governance systems point towards a wide range of possibilities for urban futures which could become more inclusive, sustainable and resilient - or accelerate risk and loss, especially for the poorest including disproportionate numbers of women and children. Key to enabling transformative adaptation that can help to transition urban development pathways towards more inclusive, resilient and sustainable futures are trends in governance and dominant modes of development (limited evidence, high agreement).

Multiple forms of urban leadership are key to achieving transformative climate adaptation (high evidence, high agreement). Intersectional, gender-responsive and inclusive leadership is key for climate change adaptation governance in formal and informal settlements (medium evidence, high agreement) {6.3} and {6.4.7}. Institutional, financial, and governance structures can enhance resilience of and enable adaptation in settlements, cities and key infrastructure {6.4}.

Changes of governance approach, finance, and insurance structures and investment in urban infrastructure have not kept pace with new challenges related to climate change and rapid urbanization, especially in small to medium sized cities and informal settlements. (medium evidence, high agreement) {6.4}.

There is insufficient institutional capacity and few urban governance structures are capable of addressing the challenge of integrating mitigation and adaptation strategies. (medium evidence, medium agreement) {6.4}.

Local governments remain the key actors leading climate change adaptation in cities and settlements, and there is little evidence of the presence of private and business sectors driving action. (medium evidence, high agreement) Community adaptation programmes tend to focus on neighbourhood improvements and emphasize incremental infrastructure strategies {6.4}.

6.1 Introduction and Points of Departure

6.1.1 Background and Chapter Outline

Many of the significant global sustainable development initiatives that have been proposed and implemented in the last five years recognise the critical importance of cities, settlements and key infrastructure in responding to climate change. There is widespread acceptance of the effects that climate change will have on these sectors, and of the need for far-reaching responses by actors from the local to the global scales to make human settlements and infrastructure more resilient. There is recognition also of the considerable capacity in settlements to meet climate change challenges, if the governance, financial and social conditions are in place.

Since the publication of AR5, there has been rapid expansion in policy, practice and research related to climate change and human settlements. The 2030 Agenda for Sustainable Development (the Sustainable Development Goals) was agreed in September 2015, followed shortly afterwards by the Paris Agreement (December 2015). These make explicit mention of "sustainable cities and communities" (SDG11) and "cities and subnational authorities" (Paris Agreement) as essential contributors to global goals. The New Urban Agenda (October 2016), with its focus on housing and sustainable urban development, commits its signatories to building resilient and responsive cities that foster climate change mitigation and adaptation.

These changes are reflected in the body of literature assessed for this report. In AR5, the section on 'human settlements, industry, and infrastructure' contained three chapters: urban areas; rural areas; and key economic sectors and services. This chapter therefore covers the full range of human settlements: from small settlements in predominantly rural areas, to large metropolises in both high-income and low-income countries. It also assesses evidence of climate change impacts, vulnerability and adaptation a full range of infrastructures that incorporate social, ecosystem and productive dimensions. It builds on the findings of AR5 which highlighted the concentration of global climate risks in urban areas, the complex causal chains which mediate climate impacts for smaller settlements and rural areas, and the multiple issues shaping and influencing economic sectors and infrastructure. The treatment of these different settings and topics in a single chapter enables a more detailed analysis of the inter-connected drivers of risk that affect human settlements of different sizes, and of the ways in which the inter-connections within and between urban areas, and between different types of infrastructure, accentuate or limit the effects of climate change. The chapter therefore has a significant concentration on the institutional structures that mediate and govern these relationships, as a critical element shaping the potential for adaptation.

This chapter has five main sections. The first elaborates on changes in the international policy architecture since 2014, highlighting the implications that this has for responses to climate change in cities, settlements and key infrastructure. Section 6.2 is focused on climate risks, paying particular attention to the ways in which these are created through processes of urbanization and infrastructural investment. Section 6.3 takes an integrated and holistic approach to adaptive actions undertaken by key infrastructures that form the material basis for resilience in cities and settlements, drive economies, and are essential for human wellbeing. The enabling environment and leadership qualities associated with adaptation processes that can also meet the equity agenda of the Sustainable Development Goals – to leave no-one behind is assessed through institutional, finance and governance structures in Section 6.4. Several case studies are used to highlight how climate and other issues are inter-related in the creation (and reduction) of urban (climate) risk – as such, these are not linked specifically to any particular risk or adaptation pathway. They also exemplify how risk production/reduction plays out across a range of urban typologies, such as larger cities, unequal cities, and networks of cities.

6.1.2 Points of Departure

The AR5 conceptualised cities and settlements as complex interdependent systems that could be engaged in supporting climate change adaptation (Revi et al., 2014 8.8.2). Effective municipal governance systems and cooperative multilevel governance supported adaptation action. The AR5 report expressed medium confidence that governance interventions can help develop synergies across geographical and institutional scales, because when urban areas already grapple with challenges such as infrastructure investment and maintenance, land use management, livelihood creation, and ecosystem services protection. Further, the report highlights that adaptation in urban locations provide openings for incremental and transformative changes to the developmental processes to build resilience and sustainable development. Multilevel urban risk governance, alignment of policies and incentives, strengthening of local government and community adaptation capacity, synergies with the private sector, and appropriate financing and institutional development were some of the tools proposed. The assessment identified an opportunity in delivering action in rapidly growing cities where institutions and infrastructure are still not established to meet the growing demands of the cities. However, there was medium confidence that this is actually happening.

The framing of 'key economic sectors and services' in AR5 focused primarily on three infrastructural areas (energy, water services, transport) and on primary and secondary economic activities (including recreation and tourism, insurance and financial services). This chapter addresses risk and adaptation pathways in these same sectors, but positions them alongside a wider range of infrastructures (as described below).

Cities, settlements and key infrastructure are also referred to in the special reports released since AR5. The Special Report on Global Warming of 1.5°C makes widespread and far-reaching mention of urban systems and infrastructure. It particularly highlights the risks facing residents of unplanned and informal urban settlements, many of which are exposed to a range of climate-related hazards (Sections 3.4.8 and 4.4.1.3). It identifies green infrastructure, sustainable land use and planning, and sustainable water management as key adaptation options that can reduce risks in urban areas (SPM). Innovative governance arrangements that go beyond formal 'government' and political arrangements and that include other actors, networks and informal institutions are seen as being critical for addressing climate change and implementing responses to 1.5°C-consistent pathways (Section 4.4.1 and 5.6.2). The report mentions, with high confidence, that the increase in global warming, as projected, will negatively affect urban population via urban heat islands effects, heatwaves and increasing risks from some vector-borne diseases, such as malaria and dengue fever.

The special report on oceans and cryosphere emphasises that effective governance helps reducing disaster risk, considering relevant exposure factors such as planning, zoning, and urbanization pressures, as well as vulnerability factors such as poverty, which can challenge efforts towards resilience and sustainable development for communities. The report shows that the emerging challenges due to climate change are changing the accessibility and availability of vital resources and the blurring of public and private boundaries of risk and responsibility. According to the report, new governance arrangements are emerging to address these challenges, including participatory and networked structures, and institutions linking formal and informal networks and involving the state, the private sector, indigenous and civil society actors in different configurations. The conclusion is a call for place-specific action because there is no single climate governance panacea for the ocean, coasts, and cryosphere, although some examples emerge that suggest the importance of inclusivity, fairness, deliberation, reflexivity, responsiveness, social learning, the co-production of knowledge, and respect for ethical and cultural diversity.

An additional bridge between AR5 and AR6 was the CitiesIPCC Cities and Climate Change Science conference in March 2018. This generated a 'Global Research and Action Agenda on Cities and Climate Change Science' (Prieur-Richard, 2018), which highlights six topical research areas where more evidence is needed to inform action: finance; informality; uncertainty; urban planning and design; built and green/blue infrastructure; and sustainable consumption and production. While this chapter does not adopt this structure in its entirety (and, indeed, some elements are more appropriately covered in Working Group 3), all the key themes are addressed either in specific sections (finance; urban planning and design; built and green/blue infrastructure) or as cross-cutting themes (informality).

6.1.3 Terminology and Definitions

This chapter covers both 'cities and settlements' and 'key infrastructure'.

The chapter identifies 'cities and settlements' as referring urban to centres (whether small or large) that exist along a continuum from unambiguously 'rural' to clearly 'urban' (Figure 6.1) and that are fundamentally inter-connected to other urban centres and to rural areas as 'nodes' within broader urban networks (Figure 6.2). Key infrastructure therefore provides much of the material basis of cities and settlements, as well as the mechanisms for enabling flows of people, goods, data and capital between these. A more sophisticated framing for planetary urbanization is provided in Box 6.1 "Understanding climate change risks and adaptation actions in the global urban hinterland".

RURAL	AMBIGUOUS	URBAN
Unambiguously rural settlements with most of the inhabitants deriving a living from farming and/or forestry or fishing	'Large villages', 'small towns' and 'small urban centres'. The proportion of the population in rural and urban areas is influenced by each nation's definition of 'urban areas'	Unambiguously urban centres with much of the economically active population deriving their living from manufacturing or services
Populations of rural settlements range from farmsteads to a few hundred inhabitants	Populations range from a few hundred to 20,000 inhabitants	In virtually all nations, settlements with 20,000+ inhabitants are considered as urban
→ Increasing population size Increasing importance of non-agricultural economic activities		

Figure 6.1: Defining rural and urban areas [Source: (Satterthwaite, 2016)]

Figure 6.2: The interconnected nature of cities, settlements and infrastructure. [PLACEHOLDER FOR SECOND ORDER DRAFT: to be re-drawn]

The chapter takes a broad and holistic approach to understanding 'key infrastructure'. This is based on a framing of cities as complex entities where social, ecological and physical systems interact in planned and unplanned ways. The chapter therefore builds on the AR5 chapter 10 conception of key economic sectors and services (e.g. energy, water, transport) by positioning these within three major categories of infrastructure: social, ecological and physical. This approach allows an understanding of adaptation that is not constrained to the administrative boundaries of cities and settlements, but that includes the networks and flows that link these together and with peri-urban and rural places. Both formal provision by government and informal provision by communities and individuals are considered as objects at risk from climate change and as components of adaption pathways and actions.

The IPCC 1.5 Degrees Report commented that "The extent of risk depends on human vulnerability and the effectiveness of adaptation for regions (coastal and non-coastal), informal settlements, and infrastructure sectors (energy, water, and transport) (high confidence)." We take this statement as a starting point for assessing the risks to cities, settlements and key infrastructure. Risks to climate change are understood as the product of climate change associated hazards impacting on exposed and susceptible assets where adaptation can reduce exposure and susceptibility and enable recovery and scope for transformation. Risks can be used to describe present conditions but also future prospects. Direct attribution of hazards to climate change remains limited to temperature extremes and sea-level rise, though we consider all hydrometeorological hazards as systems associated with climate change processes.

The complexity of cities, settlements and key infrastructure where multiple functional systems continuously interact makes it difficult to distinguish risks. The literature often resolves this by offering discrete assessments for specific sectors. This fragmented approach to understanding climate change associated impacts and risks is then reflected also in siloed risk management and adaptation financing. Recent literature, and increasingly resilience planning, have begun to overcome this tendency by presenting climate change impacts, losses and damages, and urban processes, as unfolding together in interacting pathways. The chapter reflects this change in the literature by presenting climate change impacts through a series of risk assessments, including by hazard type, through indirect impacts on agriculture and food security, through impacts on key infrastructure systems, on land-use and human mobility. The integrated quality of urbanization and risk production and reduction processes emphasises the contributions to adaptation made from hazard and risk specific as well as more generic actions. The chapter assesses in detail the enabling environment for adaptation options. This includes incremental and transformative adaptation. Transformative adaptation is understood to be that which addresses fundamental systems attributes. In the context of the Sustainable Development Goals mission to leave-no-one behind, transformative adaptation is that which addresses fundamental systems functions to enable enhanced social and ecological wellbeing. Adaptation that seeks only to defend existing development status will not contribute to enhanced wellbeing and is not transformative, even if fundamental engineering or legislative systems are changed to maintain the status quo in the face of increasing risk. Incremental and transformative adaptation are then both important, but serve distinct roles in the interaction of urban systems, climate risk and risk management.

6.1.4 Global Urban Trends

Patterns and trends for urban population growth were described in detail in AR5. This provided regional and global analysis of urban population projections for 2030 and 2050 based on UN data from 2012. The latest population projections from the same source (UNDESA, 2018a) reinforce the trends identified previously, with even higher estimates for global urban populations. The 2012 data used in AR5 projected a global urban population of 4,984 million in 2030 and 6,252 million in 2050; the 2018 revisions project 5,167 million and 6,680 million respectively. Particularly noteworthy is the higher projections provided for sub-Saharan Africa's urban population: increasing from 596 million to 666 million in 2030, and from 1,069 million to 1,258 million in 2050. These figures highlight the continued trend towards larger urban populations, and the particular significance of this in areas which currently have relatively small proportions of their populations living in towns and cities.

Globally, an additional 2.5 billion people are projected to be living in urban areas by 2050, with up to 90 percent of this increase concentrated in the regions of Asia and Africa, particularly in India, China and Nigeria where 35 percent of this urban growth is projected to occur (UNDESA, 2018a). Much of this growth continues to outstrip the ability of governments or the private sector to plan, fund and provide for sustainable urban infrastructure and this is most marked in low-income and informal settlements.

[PLACEHOLDER FOR SECOND ORDER DRAF: Table could be inserted here. There could be lots more on the demographic trends – happy to do this, although I'm not sure that it is necessary.]

One critical element of global urban trends, which was given prominence in both the Special Report on 1.5°C and the Research and Action Agenda, is informality. This refers both to the informal economy and to informal settlements, and is one of the key defining features of cities and settlements in the global south. In almost all nations in the Global South, more than half the urban workforce work in informal employment; the proportions are particularly high in South Asia (82 percent in informal employment) and sub-Saharan Africa (66 percent) (Chen, 2014; Chen et al., 2016). The term 'informal settlement' refers to urban settlements or neighbourhoods that developed outside the formal system that is meant to record land ownership and tenure and without meeting a range of regulations relating to planning and land use, built structures and health and safety. These are not the same as slums, the definitions for which are usually based around measures of housing quality, service provision and overcrowding. While most countries do not generate formal statistics on the number of people living in informal settlements, UN Habitat provides regional and global estimates of the number of urban households that are 'slum' households which are likely to include most residents of informal settlements. These estimates suggest that there were 880 million 'slum dwellers' in 2016, including some 56 per cent of the urban population in sub-Saharan Africa and more than 30 percent of the urban population of South Asia (UN-Habitat, 2016). Informality is particularly important in understanding climate risks and responses in cities and settlements, and also in relation to key infrastructure. As highlighted in AR5, occupants of informal settlements are typically more exposed to climate events with low-quality housing, limited capacity to cope, and limited or no risk-reducing infrastructure.

[START BOX 6.1 HERE]

Box 6.1: Understanding Climate Change Risks and Adaptation Actions in the Global Urban Hinterland

There has long been a realization of the complex relationships that sustain urban areas. These are not just relationships with the immediate region on which the urban area may depend for land and resources, but also broader networks of dependence that extend in space, through what is understood as 'urban teleconnections' (Seto et al., 2012). Teleconnections means that there is a continuous interaction between multiple forms of social and spatial organization that transcend space (Moser and Hart, 2015). For example, flood episodes in Africa, such as the Limpopo floods that have taken place regularly in Maputo, Mozambique in the last decade, relate to conditions of vulnerability that span long distance spatial relationships, such as the extent to which debris blocks streams, the management of green spaces and the challenges from overflowing sewers and therefore, urban flood management requires coordinated actions at local, regional and national level (Douglas, 2017). These perspectives relate with emerging accounts of the urban condition in urban theory that reject the singularity of Euclidean space as represented in a map, and highlight instead the urban as a relational space constituted through material and social interactions: a relational, rather than a territorial, urban space (Jayne et al., 2017).

This mode of thinking inspired a reimagination of the categories of human settlement, particularly challenging the differentiation of characteristic spaces that separate 'urban' from 'non-urban' spaces, and portray a mythical countryside (Brenner and Schmid, 2017). There has long been in the development literature an emphasis on the rural-urban continuum not only to characterise the complex processes of rural-urban migration but also to point out with different dimensions of access to natural (Ward and Shackleton, 2016). However, new theories of planetary urbanization (Brenner, 2014), that recognise the relational character of urban settlements, go beyond this by arguing that there is not a constitutive 'outside' to urbanisation, and that in today's world space is configured in diverse ways in relation to the urban. Brenner and Schmid (2017) suggest that this process of "planetary urbanization" is visible in four forms of socio-spatial transformation that are taking place at a planetary scale:

1. The creation of new scales of urbanization, involving not just urban regions, but rather, larger urbanization galaxies of a whole new size and order.
2. The blurring of boundary territories, with urban areas that reproduce characteristic once thought as rural and vice versa.
3. The fragmentation and disintegration of the 'hinterland' that are inserted in productive functions, without being urbanized completely.
4. The end of wilderness, with the enrolment of socio-ecological systems in urbanized territories which for some is a reflection of a wider epochal change, the Anthropocene.

The implications of growing evidence of the planetary scale of urbanization are far reaching for climate change adaptation because there is an implication that a planetary scale of urbanization fosters new, more radical intensities in the processes of resource exploitation (Arboleda, 2016b) and threatens the last safeguards to protect large tracts of non-productive land, such as the Amazon (Wilson, 2018). There have also been calls against the use of one single theoretical lens to examine urbanisation, which is, in summary, an heterogeneous and plural process (Oswin, 2018). Nevertheless, the recognition of urbanization as a planetary process has implications for the consideration of urban adaptation actions. For example, the expansion of cities leads to both encroachment of and dependence on agricultural hinterland. In 2010/2011, drought-exacerbated wildfires across Russia's agricultural hinterland not only led to extreme air pollution in Moscow and other large cities in the region, it also disrupted global supply chains of wheat and caused skyrocketing global food prices (Zscheischler et al., 2018). Floods in Bangkok, Thailand, in 2011 destroyed many foreign-owned factories, leading to a global shortfall in different types of IT equipment (Levermann, 2014).

Conceptualizing a planetary scale urbanization highlights the ambiguity of new urban spaces, with emerging connected systems of small- and medium-sized cities and growth of metropolitan areas that transcend rural and urban boundaries and traditional governance boundaries (Arboleda, 2016a; Davidson et al., 2019; Shaw, 2015). These key trends are highlighted in the UN World Urbanization Prospects (2018a). These trends have also long been recognised in development planning with the concept of the peri-urban interface or the rural-urban fringe. The peri-urban interface includes 'transitional territories' that are marked by the ambiguity of built environment organizations and governance institutions. Politically defined municipal jurisdictions are often superimposed upon ecological boundaries, while urban planning and policy mandates are divided across local, regional, national, or even hybrid institutions that may have conflicting interests, priorities, or mandates. As a result, adaptation actions are often difficult to implement (or even highlight contentious) in these transitional territories. Medellín, Colombia, for example, is building a 46-mile-long green belt to manage growth while also protecting urban forests, providing access to green spaces, and reducing urban heat island effects (Anguelovski et al., 2016). Such a large-scale 'green' infrastructure project requires coordination between regional transport authorities and the different municipalities in charge of housing and public services (Chu et al., 2017). In this case, local and regional authorities have competing mandates – such as a competition for taxpaying residents in peri-urban, 'commuting' zones – as well as different infrastructure investment logics, political drivers, and constituent needs. Similarly, in Surat, India, where flooding episodes of the Tapi River are being exacerbated by climate change, decisions about floodwater release are made by a watershed management authority in consultation with state level organs across the states of Gujarat, Maharashtra, and Madhya Pradesh (Bhat et al., 2013). The watershed authority, which is constituted primarily to manage water for upstream agricultural purposes, is required to release water to prevent overflow and inundation; however, there is no corresponding requirement to inform downstream communities of increased outflow.

These unique specificities of peri-urban vulnerabilities are emergent in the literature of policy-making and planning, which tends to focus on either rural or urban contexts (Sassen, 2015) Limited land ownership and tenure insecurity, often characterising peri-urban spaces, could also hinder people's incentives to invest in permanent infrastructure to buffer themselves from flood events, as witnessed in slums in peri-urban Nairobi (Thorn et al., 2015). Further, because of the transitory nature of peri-urban contexts, approaches to building resilience and adaptation that focus on community mobilization can be difficult. Social capital is constantly eroded in peri-urban contexts through incidences of voluntary economic migration or forced relocation and displacement.

Given the diversity in peri-urban settings, no blue-prints are possible in building adaptive capacity to the impacts of climate change. However, studies show that creating social capital by promoting civic engagement can be an important way of doing so (Narain et al., 2017). This requires building the capacity of the community to engage with service providers. The 'negotiated approach' has also been tried to engage the communities in dialogue with state agencies (Harris et al., 2018; Ziervogel et al., 2017), as demonstrated in parts of peri-urban Kolkata, India and Khulna, Bangladesh (Gomes and Hermans, 2018; Gomes et al., 2018). Given the diversity and social and economic heterogeneity in peri-urban settings, however, studies point to the limited relevance of the concept of 'community resilience', critiquing the notion of 'community' as a homogenous, monolithic whole (Shrestha, 2019). Enhancing adaptive capacity in a peri-urban context requires instead a vision that views the populations and communities as an integrated system, in which urban and rural livelihoods are interdependent and mutually vulnerable (Eakin et al., 2010). When environmental change is coupled with strong social and economic transition, the challenge of defining an appropriate unit of governance becomes more complex.

A study on eight cities in East and West Africa – namely Kampala, Addis Ababa, Dar es Salaam, Douala, Ibadan, Nairobi, Dakar and Accra – demonstrates the potential of urban and peri-urban agriculture and forestry in mitigating and adapting to climate change in urban and peri-urban areas of East and West Africa (Lwasa et al., 2014). The co-benefits of UPAF include storm protection, erosion control, flood regulation, and micro climate moderation. Windstorm reduction and maintenance of soil hydrology are other benefits of urban forestry.

Models of urban design and governance that emphasize pluralism of governance and public rather than private securitisation of urban space are more likely to support climate resilient pathways (medium evidence, high agreement).The challenges of new dimensions of planetary urbanization are not captured entirely in the literature of the peri urban interface. Instead, some commentators identify a trend towards 'global suburbanism' in which specific forms of 'suburban' development (neither urban nor rural) are transforming our ways to understand settlements (Keil, 2018). Suburban development has two spatial implications: first, there is a decentralisation of the urban, and as centres are taking away the governance logics of urban areas become unusable. Alternative modes of controlling and governing the suburb emerge, often related to the growth of enclaves and enclave urbanization that impacts directly on the appropriation of resources (Calvet and Broto, 2016; Gammage, 2016). This constitutes new ways of appropriating spaces and resources that constitute forms of climate change securitisation and provoke different forms of defensive urbanism that are exclusionary and which exacerbate inequalities (Haase et al., 2017; Hodson, 2010). Second, suburbanization is related to a move towards the privatization of public spaces and the decline of public infrastructures, collective spaces and green projects, again leading to what it is increasingly known as climate gentrification (Long and Rice, 2019; North et al., 2017).

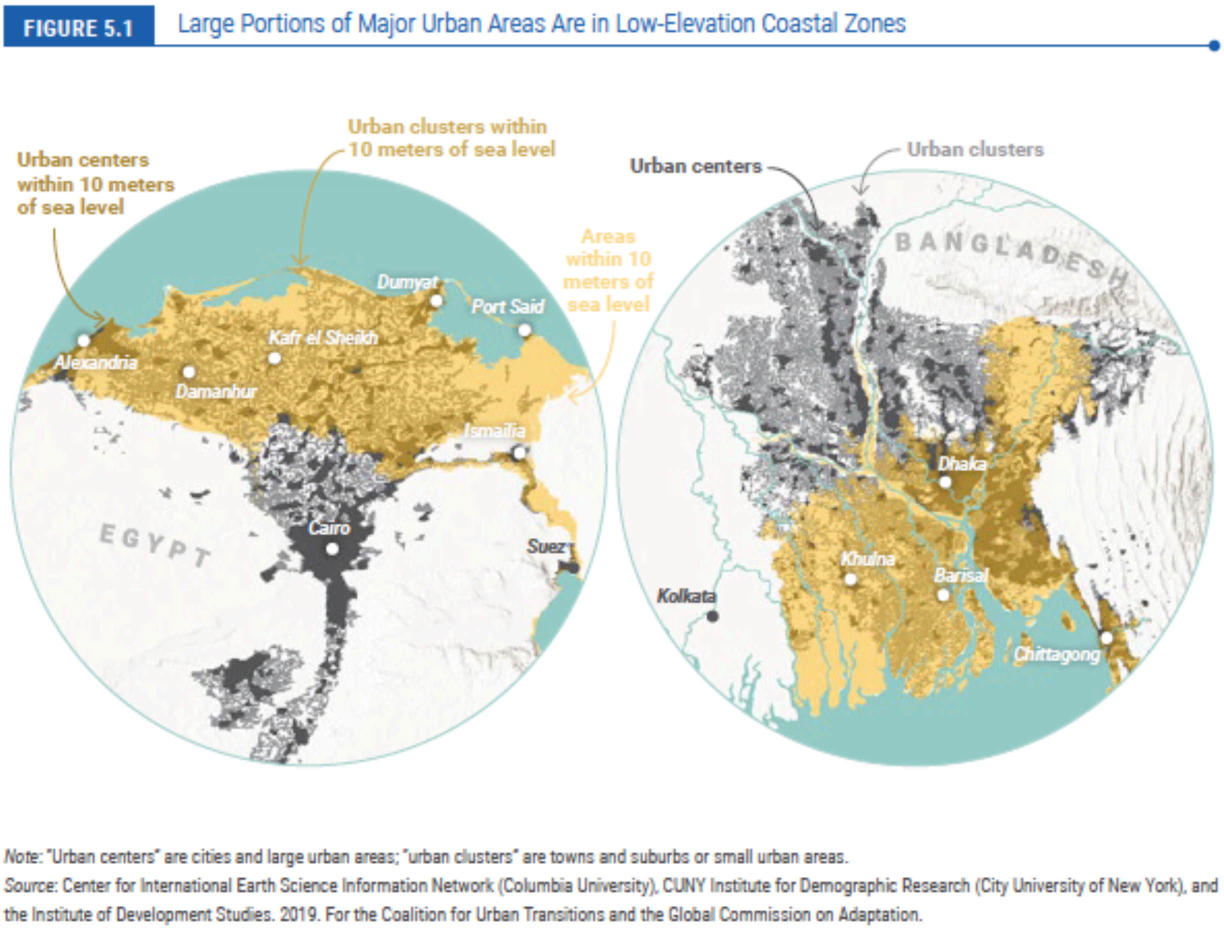


Figure Box 6.1.1: [PLACEHOLDER FOR SECOND ORDER DRAFT]

[END BOX 6.1 HERE]

6.1.5 International Policy Architecture: Points of Departure

Since AR5, cities and other settlements, and particularly unplanned and/or ‘informal’ settlements within these centres, have continued to grow at rapid rates. As a result, cities and settlements remain crucial both as sites of action on climate change and sites of increased exposure to risk (medium evidence, high agreement).

This section begins with a review of the changes in global policy architecture affecting urbanization and climate adaptation since the AR5 including first, new international policy agreements with global impact; second, international policy agreements with regional and sectoral implications and third; how international policies impact urban civil society and community-based initiatives. Discussion in the rest of this chapter will review the implications and interrelations of climate change and urban settlements, cities and infrastructure, considering risk management and integrated adaptation, mitigation and sustainable development risks and infrastructure planning and action within and between urban systems and challenges for governance, leadership, and policy-making.

Despite a rapid growth in literature about city level case studies, especially wealthy large cities (Lamb et al., 2019), there is limited evidence of long-term urban climate research and few cross city and cross regional comparative studies (Bai et al., 2018). However, emerging research has drawn attention to the consequences of three significant changes in international policy architecture, influencing urban adaptation.
First, climate justice is becoming an increasing focus of climate change and urban policy, encouraged by international frameworks (Agyeman et al., 2016; Bulkeley et al., 2014a; UN-Habitat, 2016). Second, emerging literature highlights that the rapid multiplication of actors in climate change policy at the urban level has not yet found voice in international policy and the effectiveness of new forms of poly-centric governance for climate is uncertain (Hale, 2016; Hsu et al., 2017; Jordan et al., 2015). Third, new research highlights the need to balance the overall emphasis on coordination of urban policy responses with the need to address structural vulnerabilities within the specific conditions in which they occur (Castán Broto, 2017b; Long and Ziervogel, 2020; Mason and Rigg, 2019).

One of the major challenges towards delivering international urban climate policy has been agreeing a definition of urban settlements and identifying ‘slums’ or informal settlements in particular (UN-Habitat, 2015), and a focus in the literature on the preparation of large wealthy cities at the expense of small and median sized cities in the global South (Lamb et al., 2019). A recent review suggest that fewer than half of European cities of any size that have been tracked have developed climate adaptation plans (Reckien et al., 2017), never the less the growth in city engagement in planning has ensured cities have become significant actors in international and multilateral-regional global climate agreements (Bäckstrand and Kuyper, 2017).

Since the AR5 was released six new international agreements and initiatives have been achieved, each of which has far-reaching implications for the management of rapid urbanisation and climate change; these include; the Paris Climate Agreement (United Nations, 2015b) the New Urban Agenda (United Nations, 2016); The 2030 Agenda for Sustainable Development including the Sustainable Development Goals (United Nations, 2015c); The Sendai Framework for Disaster Risk Reduction (UNISDR, 2015); and the IPCC 1.5 report (Masson-Delmotte et al., 2018).

Table 6.1: Summary of international agreements (source: (Satterthwaite et al., 2018). [PLACEHOLDER FOR SECOND ORDER DRAFT: to be modified to speak more explicitly to climate change]

Agenda (date of agreement)	**Scope of agreement**	**Key relevance for urban development and governance**
Sendai Framework for Disaster Risk Reduction (March 2015)	Global agreement for reducing disaster risks in all countries and at all levels	Identifies rapid urbanisation as a key underlying risk factor for disasters. Promotes shift from disaster response to disaster risk reduction among national and local governments.

		Is strong on importance of local governments for this, but weak on urban governance for disaster risk reduction, including civil society.
Addis Ababa Action Agenda (July 2015)	Global agreement arising from the International Conference on Financing for Development	Includes general comments on the importance of local actors and recognises the need for strengthening capacities of municipal and local governments. Commits to "support" local governments to "mobilise revenues as appropriate". Offers little on how to get finance to support local governments addressing these commitments.
Transforming our world: the 2030 Agenda for Sustainable Development (September 2015)	Global agreement adopted by 193 governments that includes the 17 Sustainable Development Goals (SDGs)	Includes SDG11, which speaks explicitly to making cities "inclusive, safe, resilient and sustainable". There is extensive reference to universal provision of basic services in other SDGs which will require substantial efforts in cities; equality and governance are also stressed. Focuses on national goals and national monitoring with insufficient recognition of key roles of local and regional governments and urban civil society in addressing most of the SDGs. This is despite the sustained engagement of both local government networks and associations and civil society representatives throughout the inter-governmental negotiation process.
The Paris Agreement (December 2015)	Global agreement under UN Framework Convention on Climate Change: signed by 195 and ratified by 170 member states	References "cities and subnational authorities" as one of many non-Party stakeholders with no reference to their specific roles, responsibilities, capacities and need for support. Encourages cities to develop specific agendas for action.
The World Humanitarian Summit (May 2016)	Not an agreement, but a summit attended by representatives of 180 member states with more than 3,500 commitments to action generated	Includes five agreed 'core responsibilities' with relevance for urban areas, and commitments were made by professional associations, non-governmental organizations and networks of local authorities to address these in towns and cities. Urban governments were not well represented, and their key roles were not discussed extensively.
The New Urban Agenda (October 2016)	Global agenda adopted at UN Conference on Housing and Sustainable Urban Development (Habitat III)	Intended as the global guideline for sustainable urban development for 20 years, but little coherence with the other agreements and little buy-in from the organisations seeking to implement them. Has limited recognition of urban governments or civil society as initiators and drivers of change. Includes extensive mention of sub-national and local governments, but mainly as implementers of national policies.

6.1.6 Changes in International Policy Architecture: Centrality of Climate Change and Urban Development in International Development Agendas

Since AR5 literature that has examined international agreements has documented three processes in international policy that have direct relevance to this chapter. First, there has been a growing focus on both climate change and urban development in international development agendas (Bulkeley, 2015b; Knieling, 2016; van der Heijden et al., 2018). On the one hand, some literature notes how urban and infrastructure policy has become more visible in international arenas, in a response that has been described as urban optimism in climate change policy (Barnett and Parnell, 2016).

On the other hand, as climate has become a prominent concern in urban international policy literature, caution has been expressed that many cities, particularly smaller cities and informal settlements in the global South where development is rapid, need greater support for local governance, more information, and more diverse sources of finance to meet the vision of global climate agreements (Cohen, 2019; Greenwalt et al., 2018). Moreover, the response of many cities to climate change is often constrained by wider political, social and economic structures, development path dependences and high carbon lock-in (Johnson, 2018; Jordan et al., 2015; Princeti, 2016).

The debate on urban vulnerability and climate change also received greater global attention with the adoption of the Sustainable Development Goals (SDGs) (United Nations, 2015c), which include goals on urban areas (SDG 11) and on climate action (SDG13). As a blueprint for human dignity, the Sustainable Development Goals emphasise the need to consider how to achieve a better and more sustainable future while 'leaving no one behind.' In doing so, they emphasise an agenda focused on wellbeing, inequality and justice. One of the questions inherent to the SDGs is the extent to which trade-offs and synergies between multiple development goals can be resolved by urban communities. For example, both SDG 11 and SDG 13 are closely interrelated (United Nations, 2015c). The objective for SDG11 is defined as: "Make cities and human settlements inclusive, safe, resilient and sustainable" and has ten associated targets including ensuring access for all to adequate, safe and affordable housing and basic services; participatory planning; safeguarding heritage features; reducing disasters particularly water related disasters and economic impacts on the poor; and promoting resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction". However, as the IPCC 1.5 special report emphasized, adaptation strategies there are positive and negative trade offs amongst SDGs and emphasis on just one such as health, can create unintended (and potentially negative) consequences for another such as energy consumption and growth (International Council for Science, 2017; Roy et al., 2018a). Through the Agenda 2030, national governments have been charged with overall responsibility for enabling and monitoring adequate policies to deliver on the SDGs, but the role of other institutions, including local government and the private sector, is also emphasised.

The Sendai Framework for Disaster Risk Reduction 2015–2030, signed in 2015, highlights urbanisation as one of the key drivers of risk, which is also applicable to addressing climate change risk. The Sendai Framework builds on the preceding Hyogo Framework which concluded in 2015. Where Hyogo placed explicit attention on the aim of reducing risk root causes in development vision, planning and management, the Sendai Framework has oriented more towards the integration of risk management into development planning, including for cities, settlements and infrastructure. The 'ten essentials' on disaster risk, developed by the UNISDR, and updated to incorporate the Sendai focus on risk reduction, highlight the need to consider responses to chronic stressors and sudden shocks through governance and financial capacity; planning and disaster preparation; disaster response and post-event recovery (UNISDR, 2017). These principles have become widely accepted guidelines for local authorities dealing with risk in urban areas. The Sendai Framework is explicit in supporting signatory governments working in collaboration with local governments and non-governmental actors in risk reduction. The opportunity for managing and reducing risk that come from non-state actors was highlighted also by the World Humanitarian Summit. The resulting Grand Bargain aims to transform the humanitarian sector, placing more control into the hands of survivors and building concrete mechanisms for building development gain into humanitarian action. Despite such calls for integrated development planning with clear relevance to cities, the contribution cities could make to international disaster recovery and sustainable development is hampered by, "meagre funding for collaboration, and poor data collection and sharing" (Acuto, 2016). As a result, opportunities for effective political commitments to reduce and respond to climate risk, while recognised, remains ill-defined in emerging literature (Speckhard, 2016).

In many cases, international agreements have helped draw attention to the enormous gaps in resources and capacities that local governments and other sub-national governments face (Satterthwaite et al., 2018). The Addis Ababa Action Agenda (United Nations, 2015a), for example, has emphasised the need to ensure adequate financing at all levels of government, especially sub-national and local governments to support sustainable development, including infrastructure and international cooperation for financing large scale projects for sustainable energy, transport, water and sanitation that contribute to climate change mitigation and adaptation. However, the variability of institutional arrangements in different countries, including variations of local governments financial and administrative independence, makes it difficult to develop a universal framework challenges the use of traditional forms of funding such as grants, taxes or transfers (UN-Habitat, 2016).

The Paris Agreement also highlights the role for subnational governance. The Intended Nationally Determined Contributions provide the basis for urban responses, while there has also been an emphasis on additional contributions made beyond these (Bäckstrand and Kuyper, 2017). Over two-thirds – 113 out of 164 – of the submitted Intended Nationally Determined Contributions referenced urban responses in the context of sustainable development, climate mitigation and adaptation (UN-Habitat, 2016). Analysis of these revealed 58 focused on urban climate adaptation, 17 focused on both adaptation and mitigation, and 4 focused on mitigation (UN-Habitat, 2017). Simultaneously, multiple efforts have emerge to align the actions of nation states with those of other actors, including the Non-State Actor Zone for Climate Action Platform for Sub-National Action (Hsu et al., 2017). While significant optimism has been gathered around the possibility to intervene at subnational level, the most difficult challenge has been to establish a coherent view of the overall contribution that cities and settlements are making (Chan et al., 2015b; Hale, 2016). Although meeting the Paris goals will require staying within a 'carbon budget', supporting rapidly developing urban areas in the global South to the same infrastructure level as developed cities may consume significant proportions of this (Bai et al., 2018).

The New Urban Agenda (adopted in Quito in October 2016) posits national urban policies as a central device to inform the role of cities and subnational governments in addressing sustainable development. However, it contains only a limited recognition of the multiple forms of social innovation that have emerged in the last two decades, including participatory budgeting, forms of social financing and crowdfunding, and forms of low-cost urban infrastructure that are increasingly shown as being necessary for transformative urban adaptation. The significance of the NUA for climate adaptation is largely in the way in which it frames the role for cities within national and international systems, including an ongoing assessment of their contribution to sustainability and resilience.

6.1.7 International Agreements with a Regional and Sectoral Focus

There is increasing international effort amongst non-Party stakeholders to the Paris Climate Agreement to collaborate to meet the Paris Climate goals, from regions, states, cities and business in global climate governance (Chan et al., 2015a; Data Driven Yale NewClimate Institute PBL, 2018). Recent reviews of contributions by non- state actors estimate that 8,419 subnational actors, including 8,237 cities and municipalities in 128 countries representing 16% (cities) and almost 15% (regions) together with 2,175 companies, headquartered in 54 countries, have pledged at least one climate commitment via a regional climate platform including for example the European Union (EU) Covenant of Mayors, the Global Covenant of Mayors for Climate and Energy and United Nations Framework Convention on Climate Change (UNFCCC) Non-State Actor Zone for Climate Action (Data Driven Yale NewClimate Institute PBL, 2018).

There is significant scope for greater international collaboration via cross-city and regionally coordinated urban system responses to climate change (medium evidence, high agreement). There is also a proliferation of new non-governmental and public-private actors that address both adaptation and mitigation in cities and settlements, including: the C40 Cities Climate Leadership Group, 100 Resilient Cities, We Mean Business, and We Are Still In (Ireland and Clausen, 2019). However, there is as yet limited research into the effectiveness of these initiatives in enhancing medium and small city adaptation and limited documentation of climate adaptation actions by non-traditional agents, particularly in the global South (Lamb et al., 2019).

Emerging literature has also documented the regionally coordinated ways that some cities are responding to infrastructure needs to identify cluster areas that are expected to experience similar warming trends locally, and the opportunity for modelling the effect for example of increasing green cover and reducing building density options (Emmanuel and Loconsole, 2015). There are also co-benefits in coordinating regional urban assessments of eco-system based adaption, but relatively few examples of this coordination at regional scale (Geneletti and Zardo, 2016).

6.1.8 International Policy Approaches with a Civil Society and Community-based Focus

Social movements and civil society play a key role in transforming cities and informal settlements to advance climate justice and help integrate international efforts for climate adaptation and mitigation with local action (medium evidence; high agreement). Analysis of patterns of participation since AR5 have demonstrated the "continued importance of 'traditional' actors in international climate politics, in particular national governments and international organizations" (Chan et al., 2015a) however new urban activists and stakeholders including youth, and indigenous and minority communities and Non Governmental Organizations alongside business groups have also been visible in global urban climate debate, pressing for faster, more far reaching change (Alves et al., 2019; Crnogorcevic and Leo, 2019; Frantzeskaki et al., 2016;

O'Brien et al., 2018; Smith and Patterson, 2018). Emergent urban social movements for climate justice often build on established international networks of local activists such as Shack and Slum Dwellers International and are focused on human rights, indigenous sovereignty and land claims, and access to water, intergenerational justice, and gender and have underscored calls for far-reaching transformative change in ways that contribute to :pre-figurative" politics in ways supporting community capability to shift to more socially and environmentally-just urban transformations (Akbulut et al., 2019; Foran, 2019; Smith and Patterson, 2019; Vandepitte et al., 2019).

Social movements have traditionally been the drivers of wide spread societal change and the coordination of global movements and protests together with support for local government leadership for change is significant and important for legitimating and mobilizing challenges to business as usual (Dunlap and Brulle, 2015). New urban social movements also have the ability to reframe and refocus policy discussion for example around mobility policy in cities in ways that bring inequality and climate justice to the fore in discussion of transportation, and urban energy transitions (Sheller and Urry, 2016). Opportunities for individual and community level engagement in climate adaptation and mitigation planning, for example in energy and home insulation at the neighbourhood or street level, can also encouraging greater individual engagement in urban climate policy discussion despite the challenges of individual lifestyle change due to energy infrastructure lock-in (Tosun and Schoenefeld, 2017).

6.2 Impacts and Risks

This section assesses the impacts of hazards associated with climate change that will affect cities, settlements and key infrastructure. In particular the ways in which climate systems and urban systems interact to produce particular patterns of loss and risk. The IPCC Special Report on 1.5 degrees drew several conclusions that are relevant to this, notably that "Global warming of 2°C is expected to pose greater risks to urban areas than global warming of 1.5°C (medium confidence)" The sections below focus on hazards associated with temperature extremes (and the urban heat island), flooding (including sea-level rise), landslides, drought and air quality before addressing the key impacts and risks associated with particular sectors.

6.2.1 Dynamic Interaction of Urban Systems with Climate

One over-arching feature that cuts across a range of systems is the changing pattern of global urban exposure to hazards (UNDESA, 2018b) (See Section 6.1 for a short summary of exposure to risk). Urban systems interact with climate systems in multiple, dynamic and complex ways. Climate change can have direct impacts on the functioning of urban systems, urban systems can substantially alter the local experiences of climate change. There is a substantial body of evidence on both these topics, however there is less research on the inter-relationships between multiple systems and climate change. This is despite the fact that many cities are exposed to multiple climate-related hazards: more than 100 cities analysed as part of a 571 city study in Europe were deemed vulnerable to two or more climate impacts (Guerreiro et al., 2018).

The local or regional scale impacts of the physical drivers of urbanisation can be considerable and enhances exposure of urban populations independent of global climate change. Specifically in relation to floods and droughts, Güneralp et al (2015) calculate that even without accounting for climate change, the extent of urban areas exposed to flood hazards will increase 2.7 times between 2000 and 2030, the extent exposed to drought hazards will increase about 2 times in this period, and urban land exposed to both floods and droughts will increase more than 2.5 times.

6.2.1.1 Temperatures and Urban Heat Island

The urban heat island (UHI) is the discernible increase of surface and air temperatures in urban areas relative to its surroundings; it is caused by physical changes to the surface energy balance of the pre-urban site upon which the city is built on (Oke et al., 2017), combined with waste heat emissions from anthropogenic sources e.g. heating/cooling in buildings, transportation, and biological metabolism (Chow et al., 2014; Sailor, 2011). The size and shape of urban areas directly affect intensities of city-wide UHI, although considerable intra-urban variations in urban temperatures exist depending on local-scale land use classification (Ching et al., 2018; Stewart and Oke, 2012). Successful methods of reducing urban temperatures and UHI involve increasing the proportion of urban greenery, increasing reflectivity by raising urban albedo, and reducing waste heat from transport and building heating/air conditioning (Akbari et al., 2016).

While the causes of UHI are predominantly local in origin, a considerable body of evidence exists on how multi-scale impacts and consequent risks arise from elevated temperatures within settlements enhanced by climate change (*very likely, high confidence*). The UHI itself is amplified during heat waves (Founda and Santamouris, 2017; Li and Bou-Zeid, 2013; Mishra et al., 2015), the extent to which varies regionally and by time of day (Ward et al., 2016; Zhao et al., 2018). Some evidence suggests that UHI intensities are more suppressed under high temperature events (Scott et al., 2018), but amplification of night time UHI during heat waves is expected to increase in all regions in future climates (Zhao et al., 2018). The interaction of heat waves and urban heat island effects in cities present risks for numerous aspects of urban systems, primarily for people and other living organisms and the supporting physical and energy infrastructure.

Human health and well-being are threatened by both independent and combined effects of heat waves and the urban heat island in cities, especially during the warm seasons (Heaviside et al., 2017; Hondula et al., 2017). The consequences of high temperatures on human mortality and morbidity are well-documented; multi-city meta-analyses indicate that high temperatures increase mortality risk in most countries and regions (*very likely, high confidence*); in one study of 384 cities across 13 countries, approximately 0.42% of total mortality was attributable to high temperatures, with considerable city-to-city variability in the total effect size (Gasparrini et al., 2015; Guo et al., 2014). Fewer studies exist for morbidity outcomes, but there is strong evidence of significant effects across a wide suite of health events resulting from high temperatures (Li et al., 2015; Phung et al., 2016). Not all health outcomes are consistently associated with heat events in all geographic locations. Temperature-mortality and temperature-morbidity research is lacking in several parts of the world including most of Africa, South America, southeast Asia, and the Middle East, but evidence from some low- and middle-income regions points to a significant and measurable effect (Campbell et al., 2018; Green et al., 2019; Odhiambo Sewe et al., 2018)(*medium confidence*).

While there are many studies that examine temperature-health effects with a focus on cities, few examine the manner in which the temperature-mortality or temperature-morbidity association is modified by the UHI (Schinasi et al., 2018). Very few studies formally attribute a fraction temperature-related health effects to the urban heat island itself; one estimate from London suggests that approximately 50% of heat wave mortality in 2003 resulted from the urban heat island (Heaviside et al., 2016). There is evidence from a limited set of locations that adverse temperature-health events occur at higher rates in hotter parts of cities or regions owing to urbanization effects (Burkart et al., 2016; Gran Castro and Ramos De Robles, 2019; Jenerette et al., 2016; Ma et al., 2015)(*medium confidence*). These patterns *likely* result from overlapping social vulnerabilities and historical development trends that place disadvantaged populations in part of cities with stronger UHI; these from demographic (e.g. cities with a larger proportion of elderly or young populations having greater exposure to heat events) and socio-economic (e.g. access to shelter) factors, as well as air pollution events that are exacerbated by heat e.g. photochemical smog or ozone (Fernandez Milan and Creutzig, 2015; Gronlund et al., 2015; Harlan et al., 2019; Sheffield et al., 2018; Voelkel et al., 2018; White-Newsome et al., 2014).

Increasing heat extremes from UHI and climate change in cities result in emergent health risks and costs to society, and can multiply existing urban health vulnerabilities across the lifespan, including heat stress and illness, while decreasing safe outdoor activity hours for recreation, sports, and labor (International Labor Organization 2019). Specifically, mass gatherings (e.g., cultural and sporting events), construction activities, youth activities, and active transportation are impacted by the combined effects of urban heat and climate change. These occupational or recreational activities require higher metabolic loads (e.g., athletes, warfighters, occupational labor), thus heightening the risk of exertional heat illness or death. Specific emerging risks for occupational and related heat illnesses are found in urban tropical or subtropical low-income and middle-income countries (Andrews et al., 2018; Green et al., 2019). As urban warmth increases, Recent research illustrates a direct decline in labour and thus economic output (Graff Zivin and Neidell, 2014; Yi and Chan, 2017) and lowered productivity (Houser et al., 2015; Stevens, 2017). In-situ monitoring of micro-climates felt by outdoor workers provide helpful information to reduce risk, yet also come with compliance costs (i.e., cancelling work/decreasing hours) to workers or the company, even for cities in more temperate climates (Vanos et al., 2019).

Globally, heat stress in urban areas are projected to reduce labour capacity by 20% in hot months by 2050 compared to a current 10% reduction (Dunne et al., 2013). Burke et al. (2015) demonstrate a non-linear relationship between temperature and global economic productivity, with potential global losses of 23% by 2100 due to climate change alone. Zander et al. (2015) estimate heat-related reductions in urban labour productivity to cost $5.2–7.3 billion Australian dollars per year, based on self-reported performance reduction and absenteeism across 1,726 workers in 2013–14. In China, high-temperature subsidies are given at outdoor air temperatures above 35°C, and is projected to increase to 250 billion yuan per year after 2030 (compared to 38.6 billion yuan per year for 1979–2005) (Zhao et al., 2016).

A key emerging risk for increased urban heat would be the detrimental impact on the biometeorology of athletes participating in international sporting events held in cities. Extreme heat negatively affects athletic performance, with serious concerns for heat stroke leading to death particularly given the highly competitive and motivated nature of elite athletes (Brocherie et al., 2015; Casa et al., 2015). Professional athletes across multiple sports have modulated their performance to account for the increased heat exposure (Nassis et al., 2015; Smith et al., 2018), or increased athlete attrition occurs during competition - especially in endurance events under heat extremes (Smith et al., 2016). The emergent risk also affects spectators to these events; Heat extremes occurring during the Summer 2020 Olympic/Paralympic Games in Tokyo, Japan are a concern for athletes, spectators, and workers/volunteers (Hosokawa et al., 2018; Kosaka et al., 2018; Matzarakis et al., 2018; Vanos et al., 2019). The risk of unpredictable disruptions to an event arising from climate concerns may cost billions of dollars based on years of planning, hundreds of thousands of people, and large global media attention, yet such precautions may help avoid serious risk to athletes (Smith et al., 2016).

Another emerging urban heat risk pertains to medical issues for urban residents. Chronic kidney disease, which is associated with prolonged exposure to high heat and dehydration, potentially is the first documented health epidemic associated with climate change and heat (Glaser et al., 2016). Research into the cause and origin of this disease is ongoing, with recent reviews indicate that occupational heat exposure with physical exertion and inadequate hydration may (Glaser et al., 2016; Wesseling et al., 2015) or may not (Herath et al., 2018) be a causal factor. Heat stress and dehydration are also related to behavioral and learning concerns, with dehydration impairing concentration and cognition for both adults and children (Merhej, 2019).

While emerging literature recognizes the agency or action that young citizens can take in responding to climate change (Cutter-Mackenzie and Rousell, 2019; Nche et al., 2019) young children in cities are also particularly sensitive to aspects of climate change for example heatwaves and may have little experience or capacity to cope with heat extremes (Norwegian Red Cross, 2019). The vulnerability of youth his is compounded with projected urbanisation rates and poor infrastructure particularly in Asian and African cities (Smith, 2019) The emerging risks effecting these vulnerable demographic segments can develop in conjunction with increased urban warmth. Literature on pediatric heat exposure is associated with increases in emergency department visits for heat-related illnesses, electrolyte imbalances, fever, renal disease, and respiratory disease in young children (Winquist et al., 2016) with less severe outcomes such as lethargy, headaches, rashes, cramps, and exhaustion negatively affecting children in school and play environments (Hyndman, 2017; Vanos, 2015); yet, comparatively less information regarding heat-health relationships and emerging urban risks exist for children (Ahdoot and Pacheco, 2015; Xu et al., 2014). This lack of information may be due to the nature of population-based data (grouped as 0–65 or >65 ages) or to a lack of heat-related pediatric mortalities (versus associated morbidities), apart from documented cases of pediatric vehicular heat stroke events in cities (Winquist et al., 2016).

Apart from increased risks related to physiological effects from urban warmth, there is also increased risk to quality of life of urban dwellers. Social surveys from temperate and tropical cities point to reductions in the quality of life during heat events, including increased incidence of personal discomfort in outdoor settings, elevated anxiety, depression, and other indicators of adverse psychological health, and reductions in physical activity, social interactions, work attendance, tourism, and recreation (*very likely, high confidence*) (Chow et al., 2016; Elnabawi et al., 2016; Lam et al., 2018; Obradovich and Fowler, 2017; Wang et al., 2017; Wong et al., 2017). These negative risks and impacts *very likely* apply to indoor thermal comfort due to climate change, evidenced by negatively affected thermal comfort indices and/or increased number of overheating hours is reported by many studies employing numerical simulations in which different climate scenarios were used to project future climate data (*high confidence*) (e.g. Dino and Meral Akgül, 2019; Dodoo and

Gustavsson, 2016; Hamdy et al., 2017; Invidiata and Ghisi, 2016; Liu and Coley, 2015; Makantasi and Mavrogianni, 2016; Mulville and Stravoravdis, 2016; Osman and Sevinc, 2019; Pérez-Andreu et al., 2018; Roshan et al., 2019; Salthammer et al., 2018; Taylor et al., 2016; van Hooff et al., 2014; Vardoulakis et al., 2015).

Enhanced urban warmth can place economic stresses on residents and households through higher demand for utilities in the warm season (particularly electricity in regions where air conditioning is or will become more prevalent), medical costs associated with care for heat illnesses and related health effects, missed work, and other causes (Jovanović et al., 2015; Liu et al., 2019; Schmeltz et al., 2016; Soebarto and Bennetts, 2014; Zander et al., 2015; Zander and Mathew, 2019). Such stresses are projected to increase in many regions associated with continuing global-scale climate change and urbanization (e.g. Ang et al., 2017; Véliz et al., 2017), although some of these effects are offset by reduced stresses in winter associated with UHI or rising temperatures more generally (Hirano and Fujita, 2012). There is evidence from some locations that socioeconomically disadvantaged populations are more likely to reside in hotter parts of cities, and they are also more likely to live in dwellings that are of poorer or older construction materials and have less effective insulation (Harlan Sharon et al., 2013; Inostroza et al., 2016; Tomlinson et al., 2011). Thus, the economic burden of the urban heat island effect, and heat waves, can be especially burdensome on residents who face more economic challenges overall.

Considerable impacts to the physical infrastructure of cities is also subject to adverse effects from the intersection of UHI effect and heat waves (*very likely, high confidence*). Utility systems are of particular concern because of their interconnected nature and the potential for cascading effects within and across systems with any disruptions (Rampurkar et al., 2016). Power systems are considered particularly vulnerable to heat events because of the myriad connections between environmental conditions and power production and transmission. Stresses on urban power systems during heat events include increased demand, especially for air conditioning, in parts of the world where it is widely used (Ang et al., 2017; Bartos et al., 2016; Santamouris et al., 2015). Furthermore, heat can decrease the efficiency of power transmission, increase risks for failure of electrical system components, and constrain the availability of water resources used in power production (Behrens et al., 2017; Clark et al., 2019; Panteli and Mancarella, 2015; Srinivasan et al., 2018; Van Vliet et al., 2016). Water resources and systems that support urban areas are also subject to disruption from heat events and UHI. Water consumption from multiple sectors increases with higher temperatures, and water evaporates more readily into a warmer atmosphere, which can deplete surface water supplies (Grouillet et al., 2015; Kifle Arsiso et al., 2017; McGloin et al., 2016; Nazif et al., 2017). A third critical urban system subject to adverse heat wave and UHI is transportation. Road and rail network performance can be compromised when paving materials and rail buckle or fail as a consequence of expansion during high temperature events (Binti Sa'adin et al., 2016; Chinowsky et al., 2013; Ferranti et al., 2016; Fletcher et al., 2015; Twerefou et al., 2015). Furthermore, airplane efficiency is reduced, or in some cases disallowed, at certain temperature thresholds (Coffel and Horton, 2014). Stresses and vulnerabilities to power, water, and transportation systems, combined with direct effects of high temperatures on agricultural productivity and transportation, can challenge urban food systems (Berardy and Chester, 2017). Lastly, UHI also increases the concentrations of atmospheric pollutants e.g. higher urban temperatures directly affects ozone chemistry and releases ozone precursors (Knight et al., 2016).

The risks from heat islands and heat waves are projected to worsen (very likely, medium confidence). Depending on the concentration pathway, between half (RCP2.6) to three-quarters (RCP8.5) of human population could be exposed to periods of life-threatening climatic conditions arising from coupled impacts of extreme heat and humidity by 2100 (Mora et al., 2017)[Figure 6.3 - overlaid population expansion of urban areas up until 2100 overlaid with changing temperature under RCP2.6, 4.5 and 8.5 scenarios per (Mora et al., 2017)]. Cities in mid-latitudes e.g. throughout Belgium by 2050 are potentially subject to twice the levels of heat stress compared to their rural surroundings under all RCP scenarios (Wouters et al., 2017), but a disproportionate level of exposure arises within tropical humid areas as cities in these climate regions (e.g. Nairobi) have year-round warm temperatures and higher humidity, requiring less warming to exceed "dangerous" thresholds (e.g. Scott et al., 2017). There is also evidence indicating that UHIs have a synergistic coupling, i.e. warmer urban temperatures enhance heat waves, with the strength of synergy dependent on time of day. This coupling is best observed at night for cities across the globe and will be strengthened under all future climate scenarios (Zhao et al., 2018).

Figure 6.3: [PLACEHOLDER FOR SECOND ORDER DRAFT: population and heat exposure. Up to six global maps of heat distribution and urban places (large cities and urban regions) under past, current and specific model scenarios to show exposure patterns and the relative influence of urban and climate dynamics in this over time. To developed in collaboration with WGI]

6.2.1.2 Urban Flooding

Many cities lie in high-risk areas related to flooding from pluvial, fluvial and coastal inundation. An estimated two-thirds of the world's largest coastal cities being directly vulnerable to rising sea levels, local and regional land subsidence, storm surges from severe storms, and changing intensities and frequencies of precipitation events (Hoegh-Guldberg et al., 2018; Koop and van Leeuwen, 2017). Extreme precipitation events - through either excessive amounts or prolonged deficits of rain and snowfall, are projected to increase in a warming climate. While clear evidence exists on urbanisation directly affecting local or regional temperatures, there is less confidence on the scale or influence of urbanisation on inducing or disrupting precipitation in cities. Han et al. (2014) note that observational studies from 19 cities indicate that urban areas affect spatial distribution and potentially increases precipitation amounts over and/or downwind of settlements; however, larger-scale synotic factors appear to be more important in affecting precipitation extremes. The occurrence of measured precipitation extremes within urban areas from 1973-2012 appear to occur far less when compared to heat events; Mishra et al. (2015) note that out of 241 urban areas, only 17% (10%) of sites experienced statistically significant increases in frequencies of extreme precipitation events (annual maximum precipitation). Changes in urban flood vulnerabilities impart considerable stress unto urban systems susceptible to impacts arising from flood events (Molenaar et al., 2015). The resultant water-associated risks observed in cities are also strongly influenced by topographical factors related to elevation, slope, and coastal location of cities that will heighten exposure to climate hazards [see Cross-Chapter Paper 2 for more information of observed risks from coastal cities]. The risks are also influenced by dynamic developments in both the built form and population growth of settlements; disproportionate risk may arise depending on the state of urban infrastructure e.g. transportation, drainage and water conveyance systems.

- Changes in risks of urban areas exposed to flooding through a combination of sea level rise, land subsidence, and/or extreme precipitation from severe storms (case studies from Hurricane Sandy and Harvey; see also literature from Section 4.3.3.2 in SROCC and from SR1.5 3.4.2 and 3.4.8)
- Projected risks from urban floods being driven by exposure from climate change per RCP scenarios, and risks to physical and social urban infrastructure - including current economic damage and increased risks to re-insurance.
- Long-term feedbacks between humans and floods may lead to complex phenomena such as coping strategies, levee effects, call effects, adaptation effects, and poverty traps. Such phenomena cannot be represented by traditional flood risk approaches that are based on scenarios. Instead, dynamic models of the coupled human-flood interactions are needed (Barendrecht et al., 2017).

6.2.1.3 Urban Drought

- Overview of how regional drought (and drought types - meteorological, agricultural, socio-economic) directly affects urban areas in terms of exposure through vulnerability framework historically and presently (update from AR5; (Buurman et al., 2017); Güneralp et al (2015)
- Examination of studies projecting risks to urban areas from modelling studies (Liu et al., 2018; Sun et al., 2017)
- Transboundary issues of drought exposure from surface and subsurface water access and storage and variations between cities along river catchments that enhance risks at finer spatial scales (e.g. SR15 Section 3.4.2 and 3.4.8, (Chuah et al., 2018));
- Demand- and supply-side water resource management in settlements affecting current impacts and vulnerability (particularly on sensitivity and adaptive capacity), and to future risks (Gober et al., 2016; Marengo et al., 2017);
- Reference to Chapter case study box on Cape Town.

6.2.1.4 Wind Storms

High wind speeds associated with cyclonic weather systems can cause significant structural damage to buildings and key infrastructure as well as causing human injury through flying debris. This section will assess the literature describing impacts and risks arising from urbanisation.

6.2.1.5 Landslides and Mass Movements

Landslides are secondary impacts of weather events when triggered by heavy rainfall. This section will describe the conditions and occurrence of rain driven landslides, mudflows and other mass movements in urban areas and affecting urban infrastructure networks. In addition to events occurring within urban areas, it is frequent for road and communications infrastructure to be damaged by these hazards with significant impacts on settlements and associated production processes or markets that are then cut off.

6.2.1.6 Cold Shocks, Ice Storms and Extreme Snow Fall

Frigid weather events are associated with climate change as a result of shifts in global atmospheric circulation that can being unusually cold air masses over urban areas and their connected infrastructures. This section will assess the literature on observed associations between these climatic phenomena and urban events and their impacts.

6.2.2 Key Risks Arising from Urbanization Processes

The literature on key climate risks for cities and settlements highlight the comprehensive, multi-scalar, and systemically inter-connected nature of such risks. Projected climatic changes – such as changing precipitation patterns, temperatures, and sea levels – contribute to pressures on human wellbeing and infrastructure systems. Furthermore, risks evolve due to macro-scale drivers of change such as urbanization, economic development, land use changes and other emergent factors (Adger et al., 2018). This section synthesises and assesses the emerging literature on key risks across several key domains: (1) risks to agricultural systems across urban-rural settings; (2) risks to water, health, and energy infrastructures; (3) risks to land use, housing, and community structures; and (4) risks to human security and mobility. For cities and settlements, such risks are of particular concern due to a lack of adaptive capacity across many economically important sectors, low levels of resource and capacity support to enhance adaptive capacity, as well as uncertainties over how risks in one sector lead to ‘cascading’, compounding, or knock-on effects across other sectors (Zscheischler and Seneviratne, 2017).

6.2.2.1 Risks to Agricultural Systems across Peri-Urban and Urban-Rural Settings and Subsequent Food Security

Peri-urban areas are widely growing in importance and spread. There is no uniformly accepted definition of the word peri-urban (Narain and Nischal, 2007; Narain and Singh, 2017), but broadly it refers to spaces in transition that combine features of both rural and urban areas. They are located usually at the periphery of cities, providing resources for urban expansion and receiving urban wastes, though scholars caution against purely place based definitions of peri-urban, highlighting instead the importance of underlying institutional contexts (Iaquinta and Drescher, 2000; Narain and Singh, 2017). They are socially and economically heterogeneous, accommodating a wide variety of occupational interests. Urbanization processes affect demand for natural resources, causing their reappropriation from rural to urban purposes; thus natural resources are constantly under stress (Allen, 2003; Gomes and Hermans, 2018; Narain and Singh, 2017; Shrestha et al., 2018). This may give rise to conflicts and contestations over natural resources, but may also be associated with new forms of cooperation in the face of scarcity (Roth et al., 2019; Shrestha et al., 2018; Vij et al., 2018).

Peri-urban spaces are relevant and important from the perspective of climate risks and vulnerability because these spaces suffer from double exposure (Leichenko and O'Brien, 2002). On the one hand, they experience stressors attributed to urbanization processes, such as loss of access to natural resources like land and water. On the other hand, they suffer from climate change and variability. For instance, climate change poses challenges to agricultural production and farmer livelihoods in both rural and urban settings. Recent research shows that climate change is projected to reduce production of the four major food crops – wheat, rice, maize, and soybean – by more than 10% by 2050 (Tai et al., 2014). Temperate and sub-tropical regions, in particular, may experience substantial crop yield losses due to extreme heat stress (Teixeira et al., 2013). In Europe, for example, areas with Continental and Mediterranean climates will experience decreased crop productivity due to increasing drought and water scarcity (Iglesias and Garrote, 2015; Iglesias et al., 2011). Regions abutting the Atlantic Ocean will experience increased flood risks and sea level rise, leading to coastal water intrusion and loss of soil quality. Boreal regions, however, may experience benefits attributed to gradual warming (Iglesias et al., 2011). Recent research from the United States also show large negative impacts of extreme heat on agricultural productivity (Burke and Emerick, 2016). Across the tropics, agricultural yields are constrained because of reducing water availability rather than heat. Comparative research from Southern Africa show a reduction in crop yields by as much as 20% by the 2080s due to decreasing precipitation (Conway et al., 2015; Leck et al., 2015). This therefore potentially exacerbates food insecurity across the Global South where many populations are already vulnerable to hunger and malnutrition (Wheeler and Von Braun, 2013).

Climate adaptation in the agricultural sector entails diversifying farming systems, local planning, building responsive governance systems, enhancing leadership skills, and building asset diversity (Campbell et al., 2014; Lipper et al., 2014). Globally, recent research estimates that a US$225 billion investment is required by 2050 to offset negative agricultural yields attributed to temperature and precipitation changes (Lobell et al., 2013). Such investments in agricultural adaptation could increase crop yields by an average of 7% to 15% (Challinor et al., 2014; Thornton et al., 2014), though this is constrained due to the need for substantial investments in irrigation infrastructure (Elliott et al., 2014). For example, in the Kumaon Hills of North West India, local residents lost access to springs to new settlers who acquired lands around them to build hotels, cottages, and luxury resorts (Narain and Singh, 2019). At the same time, changes in precipitation and decline in snowmelt caused a reduction in groundwater recharge. Farmers thus had to shift from irrigated to rainfed agriculture.

Furthermore, capital investments in more effective water use and management may improve adaptation potential – such as in the case of maize, wheat, barley and other food crops in Europe (Moore and Lobell, 2014). This therefore points to the reality that adaptive capacity in the agricultural sector is not solely determined by the presence of appropriate technology, but is also constrained by the lack of supporting institutions, human capacity, and decision-making structures (Feola et al., 2015; Niles et al., 2015). For example, a study of rural villages in Tanzania found a need to invest in rural infrastructure, particularly targeting education systems, women's empowerment, strengthening social capital, micro-credit, and agricultural extension as effective adaptation strategies (Below et al., 2012). Research from Nepal also shows important role played by local public, private, and civic institutions in co-producing climate sensitive agricultural technologies (Chhetri et al., 2012).

In urban and peri-urban contexts, sustainable agriculture can enhance food security, productive greening, ecosystem services, and promote overall resilience policy (de Zeeuw and Drechsel, 2015; Lwasa et al., 2014). Urban agriculture can enable functionally sustainable landscape systems that achieve adaptation and mitigation co-benefits, including in the context of food security, biodiversity conservation, and poverty alleviation (Duguma et al., 2014; Harvey et al., 2014). For example, a study from Munich, Germany, found that intensive urban agriculture could provide local fruit/vegetables, wastewater recycling and harvesting, and biogas generation (Gondhalekar and Ramsauer, 2017). Other approaches – such as agroforestry (Mbow et al., 2014), agro-ecology (Altieri and Nicholls, 2017), climate-smart agriculture (Lipper et al., 2014), and climate resilient agriculture (Lal, 2013) – can further achieve climate co-benefits through land restoration, diversification, and water conversation while providing local economic benefits. Despite these perceived adaptation benefits, urban and peri-urban agriculture continue to face decreasing land and water resources as well as ineffective policies and poor governance (Padgham et al., 2015).

Finally, peri-urban populations suffer challenges addressing which can be hampered by a conventional rural-urban dichotomy in planning and building adaptive capacity. A study of flood risk and vulnerability in evolving peri-urban spaces in the Upper Lerma River Valley, Mexico demonstrated how livelihood and land use change altered peri-urban residents' perceptions of risk and loss (Eakin et al., 2010). The approach of planning authorities to see flooding as a rural and agricultural problem failed to take into account the role of urbanization as a driver of flooding and water risk in the valley. Thus building resilience of peri urban communities to the impacts of climate change would require greater collaboration between rural and urban governments.

6.2.2.2 Risks to Key Infrastructures

Infrastructure provides services such as lighting, heating, sanitation, and mobility that are essential for modern society. The physical infrastructure that enables these services – roads, tracks, pipes, wires, stations, ports, amongst many others – is rapidly growing around the world emphasizing its importance. However, the quality and accessibility of infrastructure services are varied (Table 6.4).

Current variability is already causing impacts on infrastructure systems around the world. The Economist Intelligence Unit (2015) estimates present value losses to the US$143tn of current manageable assets of $4.2tn by 2100 under a 2°C scenario, which would rise to $13.8tn under a 6°C scenario. Extreme events are associated with disruption or complete loss of these infrastructure services, whilst gradual changes in mean conditions are altering infrastructure performance. Infrastructure is usually costly to repair and also have significant impacts on people's health and wellbeing.

Recent literature shows a number of climate-induced risks on infrastructure systems across different sectors. Climate change can, for example, influence energy consumption patterns by changing how household and industrial consumers respond to short-term weather shocks as well as how they adapt to long-term changes (Auffhammer and Mansur, 2014). Recent studies from Stockholm, Sweden, show that future heating demand will decrease while cooling demand will increase (Nik and Sasic Kalagasidis, 2013). At a building-scale, a study from the United States showed that climate change will affect peak and annual building energy consumption (Fri and Savitz, 2014). From an infrastructure standpoint, the vulnerability of current hydropower and thermo-electric power generation systems may change due to changes in climate and water systems and projected reduction of usable capacities (Byers et al., 2016; Van Vliet et al., 2016). These examples show how energy infrastructure planning under climate change must take into account a greater number of scenarios and investigate impacts on particular energy segments (Sharifi and Yamagata, 2016).

At a global scale, more than four billion people live under conditions of severe water scarcity, with nearly half living in India and China (Mekonnen and Hoekstra, 2016). Much of the literature on the climate risks to water explore the need to explore vulnerabilities in an integrated manner, across interlinked water, energy, and land use systems (Döll et al., 2015). This nexus approach articulates a need to more efficiently use land, water, energy, and other resources in a coordinated way to minimize trade-offs and maximize synergies (Howells et al., 2013; Rasul and Sharma, 2016). Water-related risks – including droughts, floods, and other water resource availability issues – lead to cascading risks for sectors reliant on water. A recent study from the United Kingdom, for example, shows that changes in rainfall and evapotranspiration over the next 50 years could lead to changed river flow regimes and associated impacts on water quality, aquatic ecosystems, and water freshwater availability (Watts et al., 2015). Conversely, emerging studies on extreme drought events in California, United States, highlight the role of elevated mean temperatures in altering water availability and overall drought intensity and impact (Diffenbaugh et al., 2015; Mann and Gleick, 2015), which lead to long-term implications for agricultural production in the region (Cheng et al., 2016).

A recent Lancet study highlighted that climate risks can lead to under-nutrition, mental health impacts, cardiovascular diseases, respiratory diseases, water-borne diseases, and vector-borne diseases (Watts et al., 2017). From a nutrition standpoint, climate risks can increase dietary and weight-related problems, including a 3.2% reduction in global food availability, 4.0% reduction in fruit and vegetable consumption, and 0.7% reduction in red meat consumption by 2050 (Springmann et al., 2016). Climate stressors are also linked to threats to mental health, with a recent study from the United States showing a 2% increase in the prevalence of mental health issues associated with a 1°C of five-year warming (Obradovich et al., 2018). Climate risks can further change the distribution of allergens, vector-borne, and infectious diseases, including typhus, cholera, malaria, dengue, and West Nile virus infection (Caminade et al., 2014; Franchini and Mannucci, 2015). Climate change is also linked to air pollution and air pollution-related health impacts, as ozone and fine particle-related mortalities are expected to increase (Orru et al., 2017). Although data on the climate change burden of disease and injury is not refined enough for proper detection and attribution (Ebi Kristie et al., 2017), evidence does suggests that climate-induced health risks can reinforce each other. For example, differential exposure to heat and cold, air pollution, pollen, food safety risks, emerging infections, and flood are key climate risks influence health outcomes in the United Kingdom (Paavola, 2017). In Pacific Island Countries, climate-related health risks include trauma from extreme events, heat-related illnesses, reduction in food and water safety, vector-borne diseases, respiratory illnesses, and others, which are all exacerbated by population pressures and health system deficiencies (McIver et al., 2016). However, more generally, additional research into non-communicable diseases, malnutrition, and mental health is needed (Verner et al., 2016).

Give the different risks to energy, water, and health infrastructure, recent literature suggests that adaptation should address these risks in an integrated and co-beneficial manner. For example, many studies show the opportunities associated with ecosystem- or nature-based approaches, as interventions targeting biodiversity and ecosystem services have the potential to improve food security, air/water quality, and reduce climate vulnerability climate resilience (Lin et al., 2015; Voskamp and Van de Ven, 2015). Improving ecosystem functions can offer climate mitigation benefits, such as carbon sequestration, energy conservation, and improving air quality (Kabisch et al., 2016; McPhearson et al., 2016a; Salmond et al., 2016a; van Hooff et al., 2014). Improved water and ecosystem management can also lead to positive health impacts (Demuzere et al., 2014), although this means strengthening current disease control efforts while managing short-term climate risks (Campbell-Lendrum et al., 2015). A recent study of Bulawayo (Zimbabwe), Cape Town (South Africa), Dar es Salaam (Tanzania), and Cairo (Egypt) showed that looking cities and settlements as nexus arenas maybe helpful to further risk management across energy, water, and health infrastructures (Chirisa and Bandauko, 2015).

6.2.2.2.1 Information and Communication Technology infrastructure

Information and Communication Technology (ICT) comprises the integrated networks, systems and components that enable the transmission, receipt, capture, storage and manipulation of information by users on and across electronic devices (Fu et al., 2016). Communication and services support many activities in a modern economy, from connecting small businesses in remote locations, to controlling traffic lights, and handling trillions of dollars of trade in global markets. At the same time data and computer processing is increasingly concentrated in data centres on fewer, larger, sites. This improves efficiency but can increase impacts should those sites be compromised.

ICT infrastructure faces a number of climate risks. Increased frequency of coastal, fluvial or pluvial flooding will damage key ICT assets such as cables, masts, pylons, data centres, telephone exchanges, base stations or switching centres (Fu et al., 2016). This leads to loss of voice communications, inability to process financial transactions and interruption to control and clock synchronization signals. Insufficient information about the location and nature of many ICT assets limits detailed quantitative assessment of climate change risks.

Fixed line ICT networks that sprawl over large areas are especially susceptible to increases in the frequency or intensity of storms would increase the risk of wind, ice and snow damage to overhead cables and damage from wind-blown debris. More intense or longer droughts and heatwaves can cause ground shrinkage and damage underground ICT infrastructure (Fu et al., 2016). High summer temperatures pose challenges particularly to data centres, which may require increased cooling. In mountain and northern permafrost regions, communications and other infrastructure networks are subject to subsidence as a result of warming permafrost (Li et al., 2016; Melvin et al., 2017; Shiklomanov et al., 2017).

Radio systems can experience disruption from weather conditions. Over the last 20 years in the UK, the incidence of rain disrupting radio frequencies above 5GHz has increased (Ofcom, 2012). Increased altitude of the boundary between liquid and solid hydrometeors (a water-based atmospheric phenomenon such as clouds, rain, snow, or sleet) leads to greater rain attenuation on links with satellites (Paulson and Al-Mreri, 2011). Higher temperatures may increase sea surface ducting which can lead to greater interference between signals (Naveed and Siddle, 2013).

6.2.2.2.2 Energy infrastructure

Energy infrastructure underpins modern economies and quality of life. Disruption to power or fuel supplies impacts upon all other infrastructure sectors, and affects businesses, industry, healthcare, and other critical services. The economic impacts of climate change risks are significant, for example in the EU the expected annual damages to energy infrastructure, currently €0.5 billion per year, are projected to increase 1612% by the 2080s (Forzieri et al., 2018). In China 33.9% of the population are vulnerable to electricity supply disruptions from a flood or drought (Hu et al., 2016), whilst in the USA, higher temperatures are projected to increase power system costs by about $50billion by the year 2050 (Jaglom et al., 2014). Climate change is expected to alter energy demand, for example heatwaves increase spot market prices (Pechan and Eisenack, 2014) with a disproportionate impact on the poorest and most vulnerable populations. This section focuses on the aspects of energy infrastructure are susceptible to a range of climate risks (Cronin et al., 2018), whilst issues pertaining to energy demand are considered in WG3.

6.2.2.2.3 Electricity generation

Generation infrastructure can be directly damaged by floods, storm and other severe weather events. Furthermore, the performance of renewables (solar, hydro-electric, wind) is affected by changes in climate. Most thermoelectric plants require water for cooling, many are therefore situated near rivers and coasts and therefore vulnerable to flooding. Increases in water temperature or restrictions on cooling water availability affect hydro-electric and thermoelectric plants. A 1°C increase in the temperature of water used as coolant yields a decrease of 0.12-0.7% in power output (Ibrahim et al., 2014; Mima and Criqui, 2015). Excess biological growth, accelerated by warmer water, increases risk of clogging water intakes (Cruz and Krausmann, 2013). While some regions are expected to experience increased capacity under climate change (India and Russia), global annual thermal power plant capacity is likely to be reduced by 7–12% in the mid-century (Van Vliet et al., 2016). Worldwide, hydro-electric capacity reductions are projected 0.4-6.1% (Van Vliet et al., 2016). Analysis of the UK's water for energy generation abstractions showed that an energy mix of high nuclear or carbon capture technologies could require as much as six times the current cooling water demands (Byers et al., 2014; Byers et al., 2016).

Increasing temperatures improve the efficiency of solar heating, but decrease the efficiency of photovoltaic panels, and deposition and abrasive effects of wind-blown sand and dust on solar energy plants can further reduce power output, and the need for cleaning (Patt et al., 2013). Projected changes in wind and solar potential are uncertain, the trends vary by region and season (Burnett et al., 2014; Cradden et al., 2015; Fant et al., 2016). In an RCP8.5 scenario, Wild et al. (2015) conservatively calculate a global reduction of 1% per decade between 2005-2049 for future solar power production changes due to changing solar resources as a result of global warming and decreasing all-sky radiation over the coming decades. However, positive trends are projected in large parts of Europe, South-East of North America and the South-East of China.

6.2.2.2.4 Electricity transmission and distribution

Electricity transmission and distribution networks span large distances, with overhead power lines often traversing exposed areas. Power lines and other assets, such as substations, are often located near population centres, including those in floodplains. Structural damage to overhead distribution lines will increase in areas projected to see more ice or freezing rain (e.g. most of Canada), or wildfires (e.g. California) (Bompard et al., 2013; Jeong et al., 2018; Mitchell, 2013; Sathaye et al., 2013). Increases in windstorm frequency and intensity increase the likelihood of direct damage to overhead lines and pylons, in many locations this is limited but Tyusov et al. (2017) calculate an increase as high as 30% in parts of Russia. Disruption is also often a result of treefalls and debris damage (Schaeffer et al., 2012). Where failures modes are recorded, transmission pylons are more susceptible to wind damage, whilst distribution pylons are more likely to be affected by treefall and debris (Karagiannis et al., 2019). Increased temperatures can lead to the de-rating (lower performance) of power lines whose resistance increases with temperature with efficiency reductions of 2-14% being projected by 2100 (Bartos et al., 2016; Cradden and Harrison, 2013).

6.2.2.2.5 Fuels extraction and distribution

Non-electric energy infrastructure is susceptible to many of the same impacts as the electric infrastructure. Extreme weather events impact extraction (onshore and offshore) and refining operations of petroleum, oil, coal, gas and biofuels. Disruption of road, rail and shipping routes (Section 6.3.4.4) interrupts fuel supply chains. However, there are a number of risks that are specific to these sectors. Heat can lead to expansion in oil and gas pipes, increasing the risk of rupture (Sieber, 2013). Whilst heatwaves and droughts can reduce the availability of biofuel (Moiseyev et al., 2011; Schaeffer et al., 2012). Subsidence and shrinkage of soils damages underground assets such as pipes intakes (Cruz and Krausmann, 2013), permafrost thaw in Alaska (USA) is estimated to lead to £33M damages (Melvin et al., 2017), but low lying coastal deltas are particularly vulnerable (Schmidt, 2015).

6.2.2.2.6 Transport

Transport infrastructure enables the movement of people, goods and services. It includes roads, railways, waterways (manmade and natural), stations, ports and airports. Climate risks to transport infrastructure (from heat- and cold waves, droughts, wildfires, river and coastal floods and windstorms) in Europe could rise from €0.5bn to over €10bn by 2080s (Forzieri et al., 2018), whilst nearly four million people and 70% of current infrastructure in the Arctic permafrost domain at risk by 2050 (Hjort et al., 2018). Globally, Koks et al. (2019) calculate ~7.5% of road and railway assets are exposed to a 1/100 year flood event, and global Expected Annual Damages (EAD) of US$2.9-20.2bn (mean $13.4bn) due to direct damage from cyclone winds, surface and river flooding, and coastal flooding. The majority of this is caused by surface water and fluvial flooding (mean $10.7bn). Although twice as much infrastructure is exposed to cyclone winds a mean EAD of $0.5bn is significantly less that for coastal flooding ($2.3nb), as cyclone damages are largely limited to bridge damage and the cost of removing trees fallen on road carriageways and railway tracks. This is small relative to global GDP (~0.02%), but in some countries EAD equates to 0.5-1% of GDP, this is same order of magnitude as typical national transport infrastructure budgets, but especially significant for countries like Fiji that already spend 30% of their government budget on their transport system (World Bank Group, 2017). Koks et al. (2019) did not assess future climate change impacts, but comparable studies calculating changes in EAD from flooding based upon land use show increases of 170% - 1370% depending on global greenhouse gas emissions (Alfieri et al., 2017; Winsemius et al., 2015). Moreover, Schweikert et al., (2014) report that climate risks to transport infrastructure could cost as much as 5% of annual road infrastructure budgets by 2100, with disproportionate impacts in some lower and lower middle-income countries.

Increased river flows in many catchments will increase failures from bridge scours (Forzieri et al., 2018). HR Wallingford (2014) calculate that the projected 8% increase in scouring from high river flows in the UK will lead to 1 in 20 bridges being at high risk of failure by the 2080s, whilst in the USA the 129000 bridges currently deficient could increase by 100,000 (Wright et al., 2012).

Analysis by Forzieri et al. (2018) concludes that heatwaves will be the most significant risk to EU transport infrastructure in the 2080s as a result of buckling of roads and railways due to thermal expansion, melting of road asphalt and softening of pavement material. In the USA, over 50% more roads will require rehabilitation (Mallick et al., 2018), whilst $596m will be required through 2050 to maintain and repair roads in Malawi, Mozambique, and Zambia (Chinowsky et al., 2013).

Changes in temperature and rainfall patterns are expected to increase geotechnical failures of embankments and earthworks (Briggs et al., 2017; Powrie and Smethurst, 2018; Tang et al., 2018) from landslides, subsidence, sinkholes, desiccation and freeze-thaw action. Pk et al. (2018) show this could lead to a 30% reduction in the engineering factor of safety of earth embankments in Southern Ontario (Canada). Knott et al. (2017) highlighted risks to coastal infrastructure where ~30cm sea level rise sea level rise would also push up groundwater and reduce design life by 5-17% in New Hampshire (USA).

In addition to direct damages from flooding and heatwaves, disruption caused by road blockages will be increased by more frequent flood events. For example in the city of Newcastle upon Tyne (UK), road travel disruption across the city from a 1-in-50 year surface water flood event could increase by 66% by the 2080s (Pregnolato et al., 2017) whilst heatwaves could treble railway speed restrictions in parts of the UK (Palin et al., 2013).

Many airports, and by their nature ports, are in the low elevation coastal zone making them vulnerable to flooding and sea level rise. Airport and port operations could be disrupted by icing of aircraft wings, vessels, decks, riggings, and docks (Chhetri et al., 2015; Doll et al., 2014). Warming will increase microbiological corrosion of steel marine structures (Chaves et al., 2016), and fog, higher winds and waves may increase in frequency in some locations but these are uncertain and with regional variation (Boorman et al., 2010; Coll et al., 2013).

Waterways are still important transport routes for goods in many parts of the world, although they are mostly expected to benefit from reduced closure from ice (Jonkeren et al., 2014; Schweighofer, 2014), low flows will likely lead to reduced navigability and increased closures, van Slobbe et al. (2016) estimate the Rhine may reach a turning point for waterway transportation between 2070-2095. Obstruction due to debris and fallen vegetation of roads and rails and to inland and marine shipping from high winds are expected to increase (Karagiannis et al., 2019; Kawai et al., 2018; Koks et al., 2019).

Within cities or nations the impacts of climate change on transport infrastructure are notable, but recent analysis has highlighted the implications for disruption to global supply chains (Becker et al., 2018; Pató, 2015; Shughrue and Seto, 2018).

6.2.2.2.7 Surface water management

This section will consider risks to, and adaptation options for, urban drainage, stormwater management, green infrastructure, sustainable urban drainage systems (see also sections 6.3.3.7 and 6.3.3.8). Key points will include:

- The risk is increasing from changing hazard intensity, and urban development choices. Kendon et al. (2014) and Ban et al. (2015) show that changes in high intensity, short duration (sub-daily), extreme rainfall is likely, with projected changes in intensity of up to 40%. This would lead to changes in surface water flood risk and combined sewer overflow frequencies and volumes (Arnbjerg-Nielsen et al., 2013).
- Global built up area is expected to increase three fold between 2010-2050 (Liu et al., 2016) increasing the global fraction of impermeable land.
- Over time urban change can alter the fraction of impermeable space within developed cities, for example this increased in cities in Great Britain from 37% to 44% between 2001-2016 (Foulkes et al., 2016).
- Studies in 4 cities suggested that urban development in 1984-2015 caused the flooded area to increase by 0-10% every time overall imperviousness increased by 1% (Skougaard Kaspersen et al., 2017).

Global exposure to surface water flooding is therefore increasing:

- Economic impacts are significant e.g. $79bn impacts through 2100 in 19 cities in the USA (Neumann et al., 2015) but proactive adaptation could reduce impacts by $51bn.
- There is substantial variability in flooded area for the 1in10 year event across European cities, though in general lower percentage of city flooded are in the north and west coastal areas of Europe, while the higher percentages are seen in continental and Mediterranean areas (Guerreiro et al., 2017).
- Analysis in Korea study suggests possible increases of nearly 70% above current design standards by 2100 (Kang et al., 2016).
- In UK, expected annual damages from surface water flooding may increase by £60M-200M for 2oC-4oC scenario; current adaptation insufficient to manage this, but enhanced adaptation could manage 2oC scenario (Sayers et al., 2015).

6.2.2.3 Risks to Land Use and Community Structures

Climate change will interact with on-going trends in urbanization and land use change across the world to create regionally specific risk profiles. As global urbanization projections continue to increase (Jiang and O'Neill, 2017), such trends will pose additional challenges to areas that already have high levels of poverty, unemployment, informality, and housing and service backlogs (Williams et al., 2019). There is some evidence to suggest that climate change is increasing urbanization rates, such as in Sub-Saharan Africa where manufacturing towns have experienced growth due to droughts in agricultural hinterlands (Henderson et al., 2017). However, much of the literature explores the new and emerging risks attributed to rapidly expanding urban settlements, demographic change, and encroachment into natural and agricultural lands. For example, between 2000 and 2030, rapid urbanization in Indonesia will elevate flood risks by 76-120% for river and coastal floods, while sea level rise will further increase the exposure by 19-37% (Muis et al., 2015). A similar study in Can Tho, Vietnam, showed that current urban development patterns put new assets and infrastructure at risk due to sea level rise and river flooding. Beyond water-related risks(Arnell and Gosling, 2016; Kundzewicz et al., 2014; Tessler et al., 2015), there is evidence to suggest that urbanization is exacerbating surface heat (Bounoua et al., 2015). For example, in the Beijing-Tianjin-Hebei metropolitan area in China, urbanization increases annual mean surface air temperature by more than 1°C (Wang et al., 2013). While in Sydney, Australia, research showed that rising temperatures is attributed to increased heat capacity of urban structures and reduced evaporation in the city environment (Argüeso et al., 2014).

Climate change also impact existing community and household structures across cities and settlements. Research shows that the physical forms, social structures, economic pathways, and governance systems of cities shape their risk profiles (Dodman et al., 2017b), while household vulnerabilities are mediated by wealth and capacity (Romero-Lankao et al., 2016). The experience of risk is also mediated via different social identities, such as through gender (Mersha and van Laerhoven, 2018), (Michael and Vakulabharanam, 2016), and other factors. As a result, poor, marginalized, and informal households are particularly at risk (Brown and McGranahan, 2016). For example, a study from Guadalajara, Mexico, showed that informal settlements are vulnerable due to scarce basic municipal services, inadequate government action, and residents' high acceptance of risk (Gran Castro and Ramos De Robles, 2019). Informal communities in Kampala, Uganda, are also rendered more vulnerable, particularly in terms of water and sanitation as a consequence of urbanization (Richmond et al., 2018). Finally, given its prevalence across many Global South contexts, a spatial assessment of informality showed the 91% of the city of Bengaluru in India continue to face a high degree of climate vulnerability (Kumar et al., 2016). In addition to facing emerging water- and heat-related risks, such areas are also more vulnerable to the health impacts of climate change (Scovronick et al., 2015).

6.2.2.4 Risks to Human Security and Mobility

Climate change-induced population movements include three potential outcomes: migration, displacement, and immobility (Black et al., 2013). Migration is often a household strategy to diversify risk, and it interacts with household composition, individual characteristics, social networks, and historical, political, and economic contexts (Carmin et al., 2015; Hayward et al., 2019, forthcoming; Hunter et al., 2015). Migration can however also be a strategy for urban settlements or tribal communities relocating in customary areas, for example as in the case of small Pacific developing island states like Vunidogoloa in Fiji where an entire settlement has already relocated within their own customary area (McMichael et al., 2019) (Hayward et al. 2019 forthcoming).

Climate change is often not a primary driver of decisions to migrate from rural to urban areas (Abu et al., 2014). For example, in Ghana's Volta River Delta, researchers have found different economic and political factors influence intentions and decisions around migration as opposed to increasing exposure to flooding (Codjoe et al., 2017). The literature notes that household socioeconomic vulnerability is often the most important decision criteria (Warner and Afifi, 2014). Numerous studies highlight how precarious rural livelihoods are a significant driver of out-migration, particularly in agriculture-dependent regions (Cai et al., 2016). For example, a multi-year study conducted in rural Pakistan showed that heat stress increases long-term migration of men, driven by a negative effect on farm income (Mueller et al., 2014). Another study from Mexico also showed that temperature, but not precipitation, influenced migration patterns due to unemployment in the agricultural sector (Nawrotzki et al., 2015). In Bangladesh, vulnerability of rural populations is increasing, so many of the poorest employ migration as a 'last resort' strategy (Paprocki, 2018; Penning-Rowsell et al., 2013).

Climate change can also be a driver of displacement, as recent studies estimate that more than 200 million people may be displaced by climate change by 2050 (Wyett, 2014). For example, sea level rise will lead to the displacement of communities along the coastal zones of the United States, likely leading to demographic shifts between the coast and interior of the country (Hauer, 2017). However, the literature also notes a need for more robust theories to explain causality and associations between the two phenomena (Gemenne et al., 2014). Initial research from Kenya and Sudan cite climate change as a 'threat multiplier', leading to the erosion of social order, state failure, and violent conflicts (Scheffran et al., 2014). This may also lead to adverse health and socioeconomic outcomes for individuals (McMichael et al., 2012). Other research notes a stronger role of climate change as a driver of conflict (Ide et al., 2014; Theisen et al., 2013), where conflict can further migratory patterns (Brzoska and Fröhlich, 2016). For example, a recent study highlighted how water and food insecurities, together with natural resource mismanagement, created conditions that contributed to insecurity and unrest in Syria and Egypt in 2011 (Werrell et al., 2015). In the cases of Israel, Jordan, and Syria, therefore, other studies have documented how the three countries have framed water, climate change, and migration as national security concerns (Weinthal et al., 2015).

Finally, migration can be an adaptation strategy (Bettini, 2014). Such forms of human mobility are particularly prevalent in Small Island Developing States and Atoll Island States (Betzold, 2015; Yamamoto and Esteban, 2017). For example, a study of the Cataret Islands in Papua New Guinea showed the importance of migration as a livelihood strategy (Connell, 2016). In other regions, such as in the Western Sahel (including Mali, Mauritania, and Senegal), migrant social networks can increase social resilience through the transfer of knowledge, technology, remittances, and other resources (Scheffran et al., 2012). However, the lack of resources and capacities to support mobility limits the effectiveness of migration as an adaptation strategy, therefore leading to both displacement and trapped populations in the future (Adger et al., 2015). For example, a study from the Peruvian Highlands showed that migration as an adaptation strategy can be constrained due to high-levels of place attachment, resource barriers, and low mobility potential (Adams, 2016). Given these differing accounts, the drivers of climate change-induced human mobility are thus country or regionally specific, so generalizing narratives around climate and migration are difficult (Gray and Wise, 2016).

6.2.3 Compounding and Cascading Risks

The presence of multiple forms of climate-induced risks leading to an impact is termed a concurrent or compound event (Leonard et al., 2014). The co-occurrence of multiple risk factors speak to the need to go beyond linear approaches to risk management to better address complex, multivariate, and interdependent risks (AghaKouchak et al., 2014; Cavallo and Ireland, 2014). For example, across many rural areas, the combination of droughts and heat waves can simultaneously lead to agricultural loss, forest mortality, and water scarcity (Miralles et al., 2019). Along coastlines, wind and precipitation extremes are likely to co-occur (Martius et al., 2016), while a recent study from Australia showed that extreme rainfall is likely to co-occur with extreme storm surge events (Zheng et al., 2013). Similar studies from Taiwan highlight the combination storm surge and freshwater discharge during flood events (Chen and Liu, 2014); while in the Netherlands, hydrological extremes are a result of storm surges preventing water discharge into the ocean, together local precipitation generating excessive water levels in the inland area (van den Hurk et al., 2015). The joint occurrence of storm surge, precipitation, and river discharge pose significant flood risks across other parts of Europe as well (Paprotny et al., 2018).

The co-occurrence of multiple climate-induced risks can also compound the impact of single or multiple hazard episodes (Hao et al., 2018; Zscheischler and Seneviratne, 2017). For example, during the 2014 California droughts in the United States, drought conditions were compounded by simultaneous low precipitation, extreme high temperatures, raging fires, record low water storage levels and snow pack conditions (AghaKouchak et al., 2014). A number of recent studies have particularly highlighted the compounding effect between sea level rise, rainfall, and storm surge, suggesting that the combined effect of these risks are greater than each of these variables on its own. In the Netherlands, research suggests that the probability of extreme storm surge conditions following extreme periods of rainfall is around three times greater than when modelling storm surge and discharge separately (Kew et al., 2013). Further research highlights the role of waves and tides, for example, as enforcing nonlinear interactions and feedbacks in the event of sea level rise and storm surge (Vitousek et al., 2017). Waves can amplify the risks associated with sea level rise by an average of 48-56% (Arns et al., 2017), and likely will more than double the frequency of water-related extreme events across the Tropics, in particular, by 2050 (Vitousek et al., 2017).

The prevalence of compounding risks therefore necessitates scientific models that account for nonstationarity attributed to multiple risk factors. For example, during the 2010/11 floods in Brisbane, Australia, sources of nonstationarity included rainfall, evapotranspiration, and general land use changes across the urban catchment area, which necessitated flood models that can address complexity over time (Leonard et al., 2014). Similar studies across the coastal United States show that although long-term sea level rise is the main driver of flooding, climate-induced storm surge and precipitate augment the flood potential across the region (Wahl et al., 2015). In particular, data shows that sea level rise amplifies the occurrence of 100-year floods along the coastal United States by approximately 40-fold by 2050 (Buchanan et al., 2017). Under such circumstances, the lack of consideration of compounding risks may lead to a significant underestimation of hazard potentials (Moftakhari et al., 2017b). Studies from Fuzhou City, China, for example, have already highlighted how existing flood defence infrastructure is incapable of addressing the simultaneous risks posed by increasing rainfall and tidal levels (Lian et al., 2013).

Cascading risks refer to the increasingly uncertain climate-induced stressors across time. At the global level, the cascading risks of rising temperatures can lead to changing water availability, ecosystem boundaries, and global feedbacks across time (Xu et al., 2009). Studies in Europe have shown that warmer temperatures have led to earlier spring snowmelt floods while delayed winter storms associated with polar warming have led to later winter floods (Blöschl et al., 2017). Cascading risks can also be influenced by direct human action. Research on the 'Millennium Drought' in Australia have showed that climate-driven changes in water availability over time were significantly reduced by increasing water demand and water storage augmentation (Mehran et al., 2017). Similar trends have been documented in Iran, where increasing population levels and development patterns have heightened water withdrawal levels and worsened water stress (Ashraf et al., 2018). Cascading risks can therefore significantly amplify the impact of single events across space, scale, and time (Zuccaro et al., 2018).

Higher temperatures can exacerbate impacts to health from poor air quality (and also humidity, rainfall and air movement in the city).

- Overview on current risks and impacts arising from urban respiration (Refer to (Baklanov et al., 2016), which refers to primary and secondary gaseous pollutants and airborne particulates/aerosols from settlements, especially megacities. Note also transboundary nature of air pollution from remote sources that impact on cities and settlements e.g. southeast Asian transboundary haze.
- Risks of indoor air pollution from cooking and heating from low-income, slum developments in cities in the Global South.
- Survey of how emitted urban air pollutants significantly impact on both regional viability (human health, agricultural/ecosystem productivity, visibility), and global change issues (climate, ozone depletion, oxidative capacity).
- Assessment of future risks related to urban residents from indoor and outdoor air pollution under RCP scenarios.

Compound and cascading climate risks require a different way of accounting for cumulative hazard impacts. Taken together, individual events can increase in frequency rapidly enough to impose significant social and economic costs (Moftakhari et al., 2017a). Emerging literature on how to address compound and cascading risks note the need for methodologies to assess multiple climate-induced hazards and risks, including dynamic exposure and vulnerability (Gallina et al., 2016). In term of policy, case studies from London's resilience planning process stressed the need for intermodal coordination, hazard risk and infrastructure mapping, clarifying tipping points and acceptable levels of risk, training citizens, strengthening emergency preparedness, identifying relevant data sources, and developing scenarios and contingency plans (Pescaroli, 2018). Others also note the utility of a systems approach to analyzing risks and benefits, including considerations of potential cascading ecological effects, full life cycle environmental impacts, and unintended consequences, as well as possible co-benefits of responses (Ingwersen et al., 2014).

- Literature on climate related "existential" risk in cities arising from compounding and cascading risks? (e.g. (Butler, 2018; Cohen, 2019)).

6.2.4 Impacts and Risks Arising from Adaptation

The emerging literature on assessing and evaluating risks associated with climate adaptation interventions shows that adaptation progress is often hampered by incomplete information/knowledge, a lack of awareness of cascading impacts, general mismanagement of actions, as well as opportunities for eroding long-term sustainable development priorities (Juhola et al., 2016). This section assesses three broad categories of risk associated with downstream adaptation impacts, including interventions that transfer vulnerability across space and time, plans that yield socioeconomically exclusionary outcomes, and actions that undermine sustainable and resilient development priorities in the long-term.

Emerging scholarship documenting strategies to cope with climate risks and hazards shows that adaptive capacity is often unequally distributed across sectors and communities (Matin et al., 2018; Thomas et al., 2018). As a result, particular adaptation interventions may lead to maladaptive outcomes at a different space and time. For example, a recent study from Central Gonja District in Ghana showed that coping measures, such as livelihoods diversification strategies like selling of firewood and charcoal production, together with adaptation responses, such as agricultural intensification, can lead to maladaptive outcomes and promote lock-ins that exacerbate future vulnerabilities (Antwi-Agyei et al., 2018). Similarly, in Muzarabani, Zimbabwe, adaptation strategies to flood risks such as stream bank cultivation and general infrastructure upgrading may promote disaster risk accumulation processes and destroy the overall ecological integrity of the area (Ncube-Phiri et al., 2014). Finally, in Muzaffapur District in India's Bihar state, the reliance on river embankments against flood risks is leading to an intensification of agricultural labor and household tasks, thereby exacerbating vulnerability of women, children, and poorer social segments (Pritchard and Thielemans, 2014). However, such incidences are not limited to developing countries. Recent assessments of the response to 2007-2009 droughts in California, United States, shows that actions often increased emissions of greenhouse gases, had high environmental opportunity costs, and led to a reduced incentive to adapt, which increased vulnerability of ecosystems and social groups that rely on those ecosystems for their health or employment (Christian-Smith et al., 2015). Many of these examples highlight the social amplification of climate risk, where responses to perceived climate hazards, whether in anticipation or in reaction, change the landscape of likelihood or consequence (Adger et al., 2018).

Some adaptation interventions can directly lead to exclusionary outcomes, particularly when adaptation plans and actions are primarily assessed through the prism of economic and/or financial viability (Shi et al., 2016). Numerous examples ranging from the 'Great Garuda' Plan in Jakarta Indonesia (Anguelovski et al., 2016; Salim et al., 2019), fragmentation of urban infrastructure intended to promote climate resilience in Manila, Philippines (Meerow, 2017), strategies to reduce risks in the event of mudslides in Sarno, Italy (D'Alisa and Kallis, 2016), and incidences of privileging wealth urban residents in urban greening projects in Medellin, Colombia (Anguelovski et al., 2019; Chu et al., 2017) all point to how a purely economic logic to adaptation can lead to exclusion and displacement of lower income or minority communities. The literature is increasingly referring to these processes as climate or green 'gentrification', where public officials and private investors are appropriating greening interventions, developing them, and repackaging them for sale to the middle class (Anguelovski et al., 2018a; Gould and Lewis, 2018). For example, in Miami-Dade County, Florida, United States, researchers found that adaptation functionality had a positive effect on property values (Keenan et al., 2018). In Gold Coast and Sunshine Coast, South East Queensland, Australia, where local communities have a strong preference for waterfront living, local governments are pressured by property developers to protect these coastal zones (Torabi et al., 2018). The exclusionary outcomes of some adaptation interventions can therefore further lead to the transfer of risk to communities that are socioeconomically more vulnerable.

Finally, some adaptation policies or actions can erode the preconditions for sustainable and resilient development by indirectly increasing society's vulnerability (Juhola et al., 2016; Neset et al., 2019). For example, recent research on Australia's adaptation policy has highlighted how a focus on financial strategies, preference for business-as-usual scenarios, and incremental change will not contribute to transformative change (Granberg and Glover, 2014). Case studies from Surat, India, further show how a focus on adapting industries and economically important assets in the city can divert policy attention away from general social equity and urban sustainability priorities (Chu, 2016a). While in Cambodia, recent research highlighted the conflict between adaptation practitioners and local communities, where the non-compliance with regulatory safeguards is leading to conflict and potential for maladaptation (Work et al., 2018). Finally, researchers of insurance-led adaptation actions have argued that since insurance regimes privilege normality, they tend to structurally embed risky behaviour and inhibit change (O'Hare et al., 2016). All of these examples illustrate how incremental strategies that rely on business-as-usual actions can further entrench unequal and unsustainable development patterns in the long-term.

6.3 Adaptation Pathways and Consequences for Equity, Mitigation and Economics

6.3.1 Introduction

Cities are complex entities where social, ecological and physical systems interact in planned and unplanned ways (Depietri and McPhearson, 2017; McPhearson et al., 2016a; McPhearson et al., 2016b). In adapting to climate change, infrastructure systems offer multiple pathways for adaptation. In this section, we take a broad view of the term infrastructure to include social systems, ecological systems and physical systems that underpin safe, satisfying and productive life in the city and beyond (Grimm et al., 2016). Figure 6.4 describes how adaptation choices for specific infrastructures from household to city-wide are influenced by their interaction with development processes, and how these can be evaluated through lived experience or expert knowledge. It is this diversity that leads to contested judgments on the appropriateness of infrastructural adaptation.

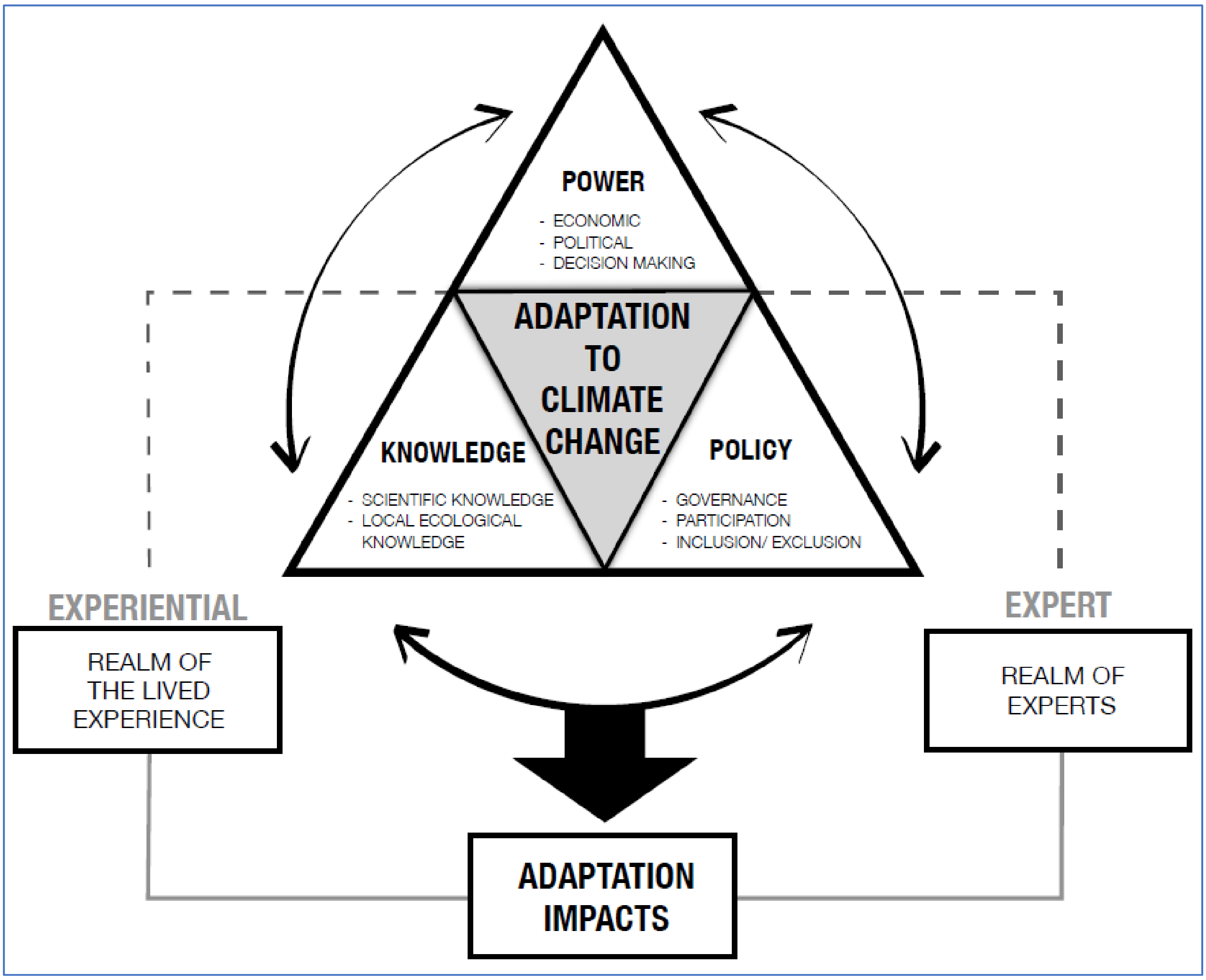


Figure 6.4: Adaptation choices are framed by and interact with development processes

Many of these infrastructure systems and the adaptations that they undertake can impact beyond the city. Indeed, seeing the city as a set of infrastructures broadly understood allows an assessment of adaptation that is not constrained to the administrative boundaries of urban settlements but also includes the flows of material, people and money between urban, peri-urban and more rural places.

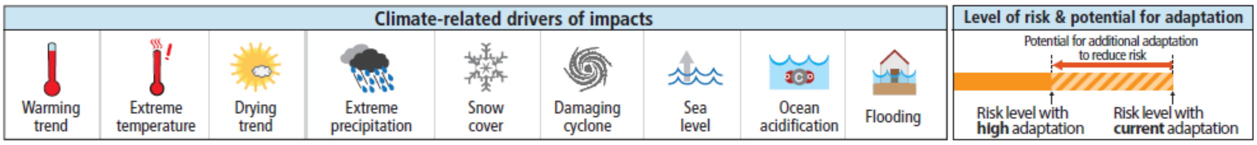
This section is divided into three broad categories of infrastructure: Social (housing, health, education, livelihoods and social safety nets, security, cultural heritage/institutions, disaster risk management and urban planning), Ecological (clean air, flood protection, urban agriculture, temperature, water and sanitation) and Physical (energy, transport, communications (digital), built form, solid waste management). For each infrastructure type, we assess observed adaptations and adaptive capacity using a common approach that draws out contributions to adaptation according to innovations in: technology and engineering, ecological/biophysical interventions, social-cultural, economic and institutional-legal.

Three cross-cutting assessments allow comment across the infrastructures according to their contributions to: Equity, Mitigation and Economics, and Finance.

Table 6.2 offers a summary of observed adaptation and future adaptive capacity by key risk type.

Table 6.2: Observed adaptation and future adaptive capacity by key risk type. [PLACEHOLDER FOR SECOND ORDER DRAFT: to be updated from AR5 version shown]

Table 8-3 | Urban areas: Current and indicative future climate risks. Key risks are identified based on an assessment of the literature and expert judgments by Chapter 8 authors, with the evaluation of evidence and agreement presented in supporting chapter sections. Each key risk is characterized as very low to very high. For the near-term era of committed climate change (2030–2040), projected levels of global mean temperature increase do not diverge substantially across emission scenarios. For the longer-term era of climate options (2080–2100), risk levels are presented for global mean temperature increases of 2°C and 4°C above pre-industrial levels. For each time frame, risk levels are estimated for a continuation of current adaptation and for a hypothetical highly adapted state.



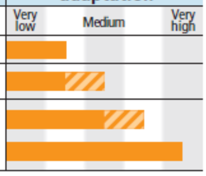
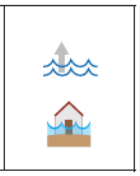
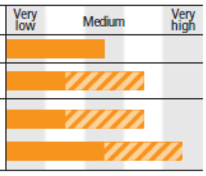
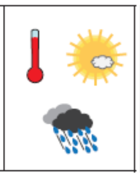
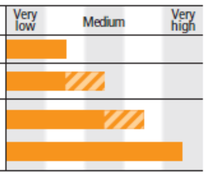
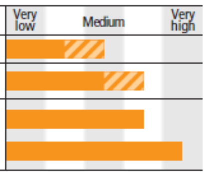
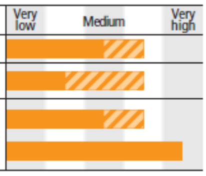
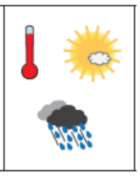
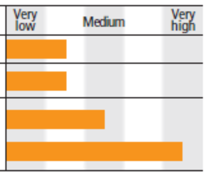
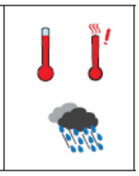
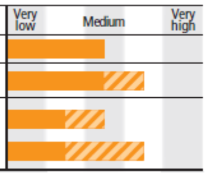
Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Modal urban (*medium confidence*) [8.2, 8.3, 8.4]	Climate change will have profound impacts on urban infrastructure systems and services, the built environment, and ecosystem services and hence on urban economies and populations. This could exacerbate existing social, economic, and environmental drivers of risk, especially for vulnerable groups who lack essential services. An appropriate urban governance frame and coordinated urban adaptation focused on the built environment, improved infrastructure, and services and risk reduction has significant potential for reducing key climate risks in the medium term and especially in the long term.		Present Near term (2030 – 2040) Long term (2080 – 2100) 2°C / 4°C	
Coastal zone systems (*medium confidence*) [8.2, 8.3]	Coastal cities with extensive port facilities and large-scale industries are vulnerable to increased flood exposure. High-growth cities located on low-lying coastal areas are also at greater risk. There is a possibility of nonlinear increase in coastal vulnerability over the next two decades.		Present Near term (2030 – 2040) Long term (2080 – 2100) 2°C / 4°C	
Terrestrial ecosystems and ecological infrastructure (*medium confidence*) [8.2, 8.3]	Ecosystem services will be impacted by altered ecosystem functions such as temperature and precipitation regimes, evaporation, humidity, and soil moisture levels, indicating close links with sustainable water management. Knowledge gaps exist with respect to thresholds to adaptation of various ecosystems.		Present Near term (2030 – 2040) Long term (2080 – 2100) 2°C / 4°C	
Water supply systems (*high confidence*) [8.2, 8.3]	Adaptation response requires changes to network infrastructure as well as demand side management, to ensure sufficient water supplies, increased capacities to manage reduced freshwater availability, flood risk reduction, and water quality.		Present Near term (2030 – 2040) Long term (2080 – 2100) 2°C / 4°C	
Waste water system (*high confidence*) [8.2, 8.3, 8.4]	Managing waste water flows improves water supply and ecosystem services. Reducing vulnerability of infrastructure may be easier in new areas, well-funded local bodies, or as part of scheduled interventions.		Present Near term (2030 – 2040) Long term (2080 – 2100) 2°C / 4°C	
Green built infrastructure (*medium confidence*) [8.3]	Green infrastructure not utilized sufficiently in most cities. Climate change impacts can bring attention to the dual benefits of green infrastructure for climate change mitigation and impact management.		Present Near term (2030 – 2040) Long term (2080 – 2100) 2°C / 4°C	
Energy systems (*high confidence*) [8.2, 8.4]	Most urban centers are energy intensive, with energy-related climate policies focused only on mitigation measures. A few cities have adaptation initiatives underway for critical energy systems. There is great potential for non-adapted, centralized energy systems to magnify and cascade impacts to national or transboundary consequences from localized extreme events.		Present Near term (2030 – 2040) Long term (2080 – 2100) 2°C / 4°C	

Table 8-3 (continued)

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Food systems and security (*high confidence*) [8.2, 8.3]	Urban food sources are dependent on local, regional, and often global 8.2, 8.3 supplies. Climatic drivers can exacerbate food insecurity, especially of the urban poor. Enhanced social safety nets can support adaptation measures. Urban and peri-urban agriculture, local markets, and green roofs hold good prospects as adaptive measures, but are under-utilised in rapidly growing cities.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low, Medium, Very high
Transportation systems (*medium confidence*) [8.2, 8.3]	A difficult sector to adapt due to large existing stock, especially in developed country cities, leading to potentially large secondary economic impacts with regional and potentially global consequences for trade and business. Emergency response requires well-functioning transport infrastructure.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low, Medium, Very high
Communication systems (*medium confidence*) [8.2, 8.3]	Resilient communication systems are a critical component of emergency response, and therefore adaptation. The rise of decentralized and networked mobile communications offers great potential for real-time and easily accessed information dissemination and communication systems. Information quality control is a key element in realizing the potential of communications systems for early warning and adaptation.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low, Medium, Very high
Urban risks associated with housing (*high confidence*) [8.3]	Poor quality, inappropriately located housing is often most vulnerable to extreme events. Adaptation options include enforcement of building regulations and upgrading. Some city studies show the potential to adapt housing and promote mitigation, adaptation, and development goals simultaneously. Rapidly growing cities, or those rebuilding after a disaster, especially have opportunities to increase resilience, but this is rarely realized. Without adaptation, risks of economic losses from extreme events are substantial in cities with high-value infrastructure and housing assets, with broader economic effects possible.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low, Medium, Very high
Human health (*high confidence*) [8.2, 8.3, 8.4]	Health is a higher order risk impacted by key developmental issues including water supply, water and air quality, waste management, housing quality, sanitation, food security, and provision of health care services and insurance. Certain groups of people are particularly vulnerable, such as the elderly, the chronically ill, the poor, and the very young, and require targeted social care interventions. Longer term developmental improvements need considerable financial resources and coherent intergovernmental action, limiting prospects for near-term adaptation.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low, Medium, Very high
Human security and emergency response (*medium confidence*) [8.3, 8.4]	Security is linked to key developmental issues such as income, housing, health care, education, and food security. Moderate prospects as city governments can enhance emergency response services, to significantly reduce vulnerability for those who are most at risk. Where security and emergency forces have limited public trust, and especially with regard to gender issues, scope for supporting adaptation and risk management is considerably constrained.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low, Medium, Very high
Key economic sectors and services (*medium confidence*) [8.2, 8.3]	Large diversity across cities in terms of key economic sectors and adaptive capacity to disruptions in city services. Cities reliant on climate-sensitive tourism or agriculture may require economic diversification. Good prospects for advancing co-benefits through "green" and "waste" economy.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low, Medium, Very high
Livelihoods (*medium confidence*) [8.3]	Informal economy is more vulnerable, and often less adaptive in the short term. Social protection measures, in the specific context of urban livelihoods, are required.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low, Medium, Very high
Poverty and access to basic services (*high confidence*) [8.3]	Reducing basic service deficit could reduce hazard exposure, especially of the poor and vulnerable, alongside upgrading of informal settlements, improved housing conditions and enabling the agency of low-income communities. Significant prospects where adaptation is already being implemented as part of human development or social protection.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low, Medium, Very high

6.3.2 *Social Infrastructure*

Social infrastructure describes social, cultural and financial activities and institutions as well as associated property, buildings and artefacts that can be deployed to reduce risk and recover from loss.

6.3.2.1 Housing

[PLACHOLDER FOR SECOND ORDER DRAFT: to assess the literature on housing as a tool in adaptive action and capacity. To include comment on strategies deployed in the formal and informal sectors. To draw out the key role played by housing as a focal point for wider provision of key infrastructure in urban development and in upgrading informal settlements. The opportunity that new building and upgrading provide for integrating risk reduction in the fabric of the city, and how far this has been observed.]

6.3.2.2 Health

[PLACHOLDER FOR SECOND ORDER DRAFT: to assess the literature on health sector investments as a tool in adaptive action and capacity. To include comment on strategies deployed in the formal and informal sectors and though public and private institutions. To comment on the added value of investing in health care as mechanisms to prevent cascading risks from direct impact to communicable disease.]

6.3.2.3 Education

Since AR5 there has been significant growth in research about climate education and activism (Simpson et al., 2019b). Youth, adult communities, the social media and commercial media can have a significant impact on advancing climate awareness and the legitimacy of adaptive action, particularly in large urban areas (*medium evidence; high agreement*). Climate change education has increasingly focused in urban settlements on enhancing children and young people's political agency in schools, universities, and in formal and informal media settings (Cutter-Mackenzie and Rousell, 2019). However, an ambiguous and cautious framing of climate impacts and adaptation for example around the science of urban heat islands by media can also exacerbate local community confusion and uncertainty (Iping et al., 2019). Communication strategies deployed in the formal education and social media can be highly influential in exchanging information and establishing narratives and viewpoints that frame what adaptive action is legitimate, especially in large cities (Simpson et al., 2019b). However, the effectiveness of communication strategies for change for example from Mayoral offices, can also be influenced by wider political and structural drivers including community literacy or political partisanship (Boussalis et al., 2019).

6.3.2.4 Security

[PLACEHOLDER FOR SECOND ORDER DRAFT: to assess the literature on policing and security as a tool in adaptive action and capacity. To include comment on strategies deployed in the state and community or private firms to provide reduce risk and los from extreme events associated with climate.]

6.3.2.5 Cultural heritage/institutions

To assess the literature on the specific concerns of adapting the management and protection of cultural heritage in the face of climate change risks in cities, including cascading risk, for example where temperature and air quality combine to erode stonework, or where flooding can cause loss of culturally irreplaceable buildings or artefacts.

There is consensus that built cultural heritage (BCH) is threated by the hazards of global climate change (Bertolin and Camuffo, 2015; Leissner et al., 2014; Leissner et al., 2015), including increased air temperature that hastens the deterioration rates due to salt deposits (Arnold and Zehnder, 1990; Camuffo et al., 2010a; Camuffo et al., 2010b; Smith and McAlister, 1986; Smith et al., 2008), mechanical instability and faster rates of fungal growth, pest damage and biological growth all of which contribute to decay (Sedlbauer, 2002; Sedlbauer et al., 2011) and material stress (Bonazza et al., 2009; Vegt, 2006). Flooding and sea-level rise leads to physical decay (Camuffo et al., 2017), or, in extreme cases to total loss, while water infiltration from post flood standing water exacerbates the decay (Camuffo, 2019). The freezing-thawing cycles of melting permafrost in the Scandinavian Peninsula and the Arctic lead to the decomposition of built materials (Grossi et al., 2007). Intersecting with all these impacts are the repercussions on the economic and social patterns of BCH such as, "last chance tourism" (Lemieux et al., 2018) that leads to increased touristic interest over a short time horizon.

The climate change adaptation options (AOs) for built cultural heritage fall into seven categories (Fatorić and Seekamp, 2017; Rockman et al., 2016). First, financial constraints constitute the primary barrier hindering adaptation solutions lead to no action at all or to merely monitoring and documentation, or to annual maintenance (Fatoric and Seekamp, 2017; Fatorić and Seekamp, 2017; Fatorić and Seekamp, 2018; Sesana et al., 2019; Xiao et al., 2019). Core and shell preservation are cost effective when they improve the condition of BCH (Bertolin and Loli, 2018; Loli and Bertolin, 2018a; Loli and Bertolin, 2018b), while elevation and/or relocation are extremely costly and might jeopardize the historic value (Xiao et al., 2019). To date, however, evidence indicates that adaptation actions prioritize archaeological sites (Carmichael et al., 2017; Dawson, 2013; Fatorić and Seekamp, 2018; Pollard et al., 2014). The efficacy of adaptation historic buildings can be increased through an increased and stable funding, incentives, stakeholder engagement, and legal and political frameworks (Dutra et al., 2017; Fatoric and Seekamp, 2017; Fatorić and Seekamp, 2017; Fatorić and Seekamp, 2018; Leijonhufvud, 2016; Phillips, 2015; Sesana et al., 2019; Sesana et al., 2018).

Other implementation barriers include, harnessing the expert and the local knowledge (of individuals and organizations) to identify quantitative methods and indicators that connect the cultural significance and local values vis-à-vis climatic change over time and that move beyond the prevalent high risk- or high vulnerability-centred approaches (Carmichael et al., 2017; Dawson, 2013; Fatorić and Seekamp, 2018; Filipe et al., 2017; Haugen et al., 2018; Kotova et al., 2019; Leijonhufvud, 2016; Pollard et al., 2014; Puente-Rodríguez et al., 2016; Richards et al., 2018), and also, accessing local resources (craftmanship and materials compatible with the originals) for improving built cultural heritage's adaptation capacity (Phillips, 2015).

6.3.2.6 Emergency Management (Risk Monitoring)

There is growing evidence of the benefits of early warning systems (EWS) for preparedness decision-making and action for climate and weather-related hazards such as cyclones and floods (Lumbroso et al., 2016; Marchezini et al., 2017; Zia and Wagner, 2015). Climate forecasting is constantly evolving and becoming increasingly accurate. Existing EWS remain insufficient and the complexity of urban landform makes accurate and detailed early warning difficult (Jones et al., 2015). This is particularly the case in LMICS where urban centers are often characterized by rapid expansion of interlinked formal and informal human settlements and land use zones. Often, forecast-based action tends to follow linear structures where forecast information is applied mainly for responding to negative impacts rather than anticipatory decision making and preparation to avoid such impacts (Marchezini et al., 2017). Early warning systems are effective for cyclonic activity but more limited for flooding. Probabilistic risk forecasting and forecast based early action are only beginning to be applied to urban contexts and often those that are most vulnerable do not receive warnings regarding hazardous events (Nissan et al., 2019). There is less capacity for EWS in LMICs with key challenges linked to a lack of well-established risk baseline information; accessibility, communication and understanding of forecast information, as well as political and institutional barriers and limited resources and capacities to act on such information (Jones et al., 2015; Marchezini et al., 2017; Mustafa et al., 2015; Zia and Wagner, 2015). Political and institutional barriers to the incorporation of climate information to decision making are not limited to LMICs (Harvey et al., 2019). Indeed, Bruno Soares and Dessai's (2016) comprehensive study revealed that in Europe, where climate services are increasingly accessible and well resourced, there is limited uptake of seasonal climate forecasts amongst most organizations across eight key sectors in informing their decision-making processes.

While climate forecasting is an increasingly central tool for risk management agencies, a focus on urban areas or key infrastructure is still considerably rare (Harvey et al., 2019; Lourenço et al., 2015; Nissan et al., 2019). The urbanization of risks poses significant challenges to humanitarian agencies. Humanitarian responses and local emergency management are vital for DRR yet are compromised in urban contexts where it is difficult to confirm property ownership and where renters and informal dwellers are often excluded from decision making and planning (Maynard et al., 2017; Parker and Maynard, 2015). Disaster survivors and growing urban refugee populations are often displaced across the city thereby complicating efforts to track and provide support (Maynard et al., 2017).

The inclusion of local knowledge and expertise in urban vulnerability and risk assessments can strongly enhance local resilience but its effectiveness is constrained by wider decision-making and policy contexts dominated by top-down approaches (Jones et al., 2015; Nissan et al., 2019; Sword-Daniels et al., 2018). Disaster impact and recovery time are strongly influenced by the behavior and actions of individuals, communities, businesses, and government organizations. Aaerts et al (2018) review shows how the limitations of existing risk assessment methods that tend to account for human behaviour in limited terms can be addressed through innovative flood-risk assessments that integrate behavioural adaptation dynamics. A growing literature highlights the need shows how multidisciplinary and inclusive approaches that include local knowledges can achieve greater accuracy in risk characterization and support lasting impact of investments into more robust climate services (Aerts et al., 2018; Harvey et al., 2019; Lourenço et al., 2015; Nissan et al., 2019; Singh et al., 2018; Sword-Daniels et al., 2018). This literature highlights the need for innovative approaches in urban contexts that transcend traditional approaches for local knowledge inclusion widely applied in rural contexts, such as participatory rural appraisal. Established non-state actors such as Shack and Slum Dwellers International are particularly effective at implementing inclusive approaches for local knowledge incorporation into urban decision making. Climate change and disaster risk exacerbate existing problems of economic development, yet macro-economic planning seldom incorporates adaptation. When urban economic crises overlap with increased climate pressure and disaster risks, the impacts are likely experienced in the city region and beyond (Pelling et al., 2018). The link between urban DRR, adaptation to climate change and macro-level trends of economic development requires further research and improved modes of communication to reach diverse city actors (Fankhauser and McDermott, 2016; World Bank, 2019a).

Insurance is a risk transfer mechanism for middle and high-income countries, yet is less widely available in LMICs (Surminski and Thieken, 2017). Additionally, where insurance options do exist in LMICs, these are not usually available to large populations living or operating in the informal sector. However, there are notable examples of low-income communities setting up their own disaster insurance mechanisms. For example, the Community Development Funds (CDFs) for the Baan Mankong upgrading programme in Thailand include disaster funds as insurance against housing damage (Archer, 2012). Flood insurance is widely available in many Organisation for Economic Co-operation and Development (OECD) countries but the demand and uptake differ significantly across countries (Hanger et al., 2018). This financial tool is subject to increasing pressure under the changing climate with growing concerns around affordability and availability. More holistic approaches are required where changes in the insurance industry are closely linked to improved building standards and land-use planning and their application, particularly in LMICs (Cremades et al., 2018). Such approaches also need to be closely linked to existing urban risk management planning approaches where urban livelihoods are seldom integrated (Beringer and Kaewsuk, 2018).

6.3.2.7 Livelihoods and Social Safety Nets

At the heart of building urban resilience are the people that inhabit settlements and cities and use the infrastructure (Bahadur & Tanner 2014). Understanding how livelihoods, particularly of the urban poor, are both impacted by climate risk and how they might be strengthened is therefore central to understanding urban climate adaptation (Dobson et al. 2015). Rapid urbanization and expanding infrastructure do not have a clear relationship with improved outcomes for urban livelihoods of low-income residents (Soltesova et al., 2014). Municipal and national efforts need to be closely aligned with building adaptive capacity of residents themselves, often through community-based adaptation (Dobson et al., 2015; Soltesova et al., 2014). Strengthening the financial and social infrastructure of poor households is a critical component of adaptive and transformative capacity (Haque et al., 2014; Ziervogel et al., 2016). Social safety nets are one mechanism for strengthening this capacity.

Social safety nets (social assistance) is the most influential of social protection systems, the other types include social insurance and labor market policies. World Bank (2015) and IPCC (2014) introduced "Adaptive Social Protection (ASP)" as a policy framework to address livelihood security and to increase the resilience of vulnerable populations to climatic shocks. ASP integrates the tools and techniques of social protection, climate change adaptation, and disaster risk reduction by providing predictable transfers and helping the poor and vulnerable households develop their human capital, diversifying their livelihoods (Hallegatte et al., 2016). The ASP was tested in Sahel countries and can be found similar mechanisms in Africa and Asia developing countries, which demonstrated that ASP covers a larger spectrum along the humanitarian-development continuum than most other shock-responsive social protection systems (Béné et al., 2018a).

Not all social protection is provided through formal institutions. In contexts of extreme poor or climatic extremes, national provisions and market charities are complementary of where family and kinship networks are weak and inadequate. The effective national interventions with a handful cases in urban areas (Table 6.3) show that ASP can be recognized as potentially effective and transformative interventions both at the system level (short-term and long-term coping strategies) and at the beneficiaries' level (vulnerable populations) (Béné et al., 2018a).

In the short term, social protection schemes can act as a crucial complement to risk management tools provided by communities and markets which tend to be insufficient in the face of large or systemic shocks, and too often exclude the most vulnerable (Hallegatte et al., 2016). Social protection can also facilitate long-term change and adaptation by improving education and health levels, as well as a proactive approach to managing climate-induced migration in both rural and urban areas (Adger et al., 2014; Schwan and Yu, 2018).

Table 6.3: Some urban cases for adaptive social protection. Adapted from (World Bank, 2015). [PLACEHOLDER FOR SECOND ORDER DRAFT: additional supporting literature]

Category	Example	Urban cases
Social safety nets (or social assistance)	Conditional and unconditional cash transfers, including non/contributory pensions and disability, birth and death allowances; Food stamps, rations, emergency food distribution, school feeding and subsidies; Cash or food for work programmes; Free or subsidized health services; Housing and utility subsidies; Scholarships and fee waivers, etc.	-A targeted asset transfer project for urban extreme poor in Dhaka city (Hossain and Rahman, 2018) - Emergency food stockpiling in Japan; safety net food stocks in India, Indonesia and Malaysia (Lassa et al., 2019) -Post-disaster relief in Beijing (Xie and Xin, 2014) -A child-focused cash transfer programme for displaced Syrian children in Lebanon (De Hoop et al.) -A targeted asset transfer project for urban extreme poor in Dhaka city (Hossain and Rahman, 2018)
Social insurance	Old age, survivor, and disability contributory pensions; Occupational injury benefit, sick or maternity leave; Health insurance, etc.	-Weather-index insurance in Guangzhou (Swiss-Re China case)
Labour market policies	Unemployment, severance, and early retirement compensation; Training, job sharing, and labor market services; Wage subsidizes and other employment incentives, including for disabled people, etc.	-Public works in Africa, Asia

An inclusive, targeted, responsive and equitable social protection can support long-term transformations toward more sustainable, adaptive and resilient societies (Adger et al., 2014; Béné et al., 2018a; Carter and Janzen, 2018; Hallegatte et al., 2016; Shi et al., 2018). The ASP is an important approach to transformational adaptation, and one which triggers a paradigm shift on the principles and mechanisms of social policy. The intersection of social policy, disaster risk reduction, and ACC, which relates to a discourse of poverty alleviation (in the WB, IPCC reports), may be shifted from a perspective with right-based or capability-based SP to a risk-based approach, with decoupling the climate vulnerable group with the poor. Countries at all income levels can set up ASP systems that increase resilience to natural hazards, but the systems need cost-benefit, scalable and flexible to adjust with future increasing climate risk. Bastagli (2014) suggested a new design for effective SP including: (i) increasing the amount or value of transfer; (ii) extending the coverage of beneficiaries; and (iii) introducing extraordinary payments or creating an entirely new program.

Targeting accuracy and timely risk sharing (disaster assistance) would benefit for both efficiency and equity of SP policy. Carter & Janzen (2018) find that the long-term level and depth of poverty can be improved by incorporating vulnerability-targeted social protection into a conventional social protection system. Ulriksen and Plagerson (2014) introduces citizens' duties to sustainable social protection which can build stronger solidarity and social inclusion without segregating "the poor" from "non-poor". Dulal & Shah (2014) argued that successful deployment of social protection instruments depend on how low, medium and highly adaptive households are targeted. In China, the national Targeted Poverty Alleviation strategy classified poverty family with several common driving factors and offered them with diverse SP policies and resources. Traditional disaster assistance is not a timely and cost-effective way as needed, especially for an providing effective response to slow-onset disasters or low-probability, high-impact extreme events. Index-based risk sharing (i.e., Weather insurance) is emerging to meet the gap and pre-finance the expected disasters. For example, introducing Public-Private Insurance Mechanism in Austria has a noticeable impact on the total monetary burden, causing it to fall by ~50% for regional governments with disaster risk reduction incentive (Unterberger et al., 2019).

6.3.2.8 Urban Morphology

The lack of long-term studies that assess the climate change impacts on urban form, including informal settlements (Bai et al., 2018; Ramyar et al., 2019), lead to impact assessments that often overlook urban form (Ramyar et al., 2019). Additionally, context-specific spatial tools and community-based approaches lack a precise connection to urban morphology. For example, there is a need for further studies that connect solar radiation, urban morphology (e.g., aspect and plot ratio), and the UHI (Giridharan and Emmanuel, 2018; Li et al., 2019).

Several tools and models that emerged in response to the recommendations of IPCC's 5th assessment report, including models that assess the impacts of urban heat island (UHI) (Ramyar et al., 2019), climatic uncertainty (Dhar and Khirfan, 2017a), flood vulnerability (Abebe et al., 2018), and inundation (Barau et al., 2015; Ford et al., 2019). For example, findings from Kano, Nigeria reveal that a lack of distribution of certain urban morphological features, including open spaces and streets (both pervious and impervious), roof and building materials (e.g., concrete and metallic), and urban ecological features (e.g., urban ponds and ecological basin) exacerbates inundations and their associated impacts (Barau et al., 2015). Also, findings on the urban forms of coastal settlements, particularly in small islands, reveal that they are experiencing severe beach erosion due to sea-level rise and storm surge that leads to landward retreat of coastline which threatens their social and economic activities (Dhar and Khirfan, 2016; Khirfan and El-Shayeb, 2019; Lane et al., 2015).

6.3.2.9 Urban Formal Planning

Formal planning mechanisms for climate adaptation include: 1) conventional (Euclidean) zoning regulations and land use planning (most prevalent); 2) conventional architectural and urban design regulations (to a lesser extent); and 3) innovative architectural and urban design standards (relatively recent). Although these conventional planning and design mechanisms are widely applied, often they are not implemented in climate adaptation planning where the emphasis remains centred on vulnerability assessments, governance, and social learning (Dhar and Khirfan, 2017b). Moreover, in LMICs mainstreaming resilience/adaptation will deliver limited results either because urban development occurs outside the parameters of formal planning mechanisms and/or due to the high degree of urban informality –both of which also diminish the effectiveness of early warning systems (EWS) for reducing the impacts of climate-related risks (Dodman et al., 2017b; Fraser et al., 2017).

Firstly, conventional (Euclidean) zoning regulations and land use planning range in scale from the regional to the local and are deployed to minimize or altogether eliminate slow and/or rapid onset risks through three primary measures, namely: protection, accommodation, or retreat. Protection entails, in addition to allocating zones for protective urban infrastructure (like seawalls, levees and dykes, and slope revetments), avoidance measures that restrict or prevent urban development (e.g., through growth containment and/or no-build zones). Accommodation involves land use modifications and/or conversions while retreat requires either compulsory or voluntary relocations and may entail buy outs (Butler et al., 2016; León and March, 2016; Lyles et al., 2018). The evidence indicates that risk eliminating retreat measures are less widely adopted than other risk reducing zoning and land use measures (Anguelovski et al., 2016; Butler et al., 2016; Lyles et al., 2018). This is attributed to the controversies of relocation and to the complexities of buyouts (Butler et al., 2016; King et al., 2016).

There is also high agreement that adaptation actions through zoning and land use are more effective when combined with other planning measures, for example: with Ecosystem-based Adaptations (EbA) (e.g., for flood management and curbing the urban heat island effect) (Anguelovski et al., 2016; Carter et al., 2015; Larsen, 2015; Nalau and Becken, 2018; Nolon, 2016; Perera and Emmanuel, 2018); with Community-based Adaptations (CbA) (trade-offs and valuations –i.e., which land uses are valued more) (Anguelovski et al., 2016; Carter et al., 2015; Larsen, 2015; McPhearson et al., 2018; Nalau and Becken, 2018; Nolon, 2016; Perera and Emmanuel, 2018); and with built form regulations and codes (Larsen, 2015; León and March, 2016; Nolon, 2016; Perera and Emmanuel, 2018; Straka and Sodoudi, 2019; Yiannakou and Salata, 2017); Limited evidence indicates that a narrow-scope, risk-reduction approach yields land use adaptation policies (accommodation and/or avoidance, specifically growth containment and no-build zones) that are better integrated within larger urban plans, hence, it is likely to perform better than a broad-scope approach that embeds adaptation planning within wider ranging community concerns (Lyles et al., 2018; Nalau and Becken, 2018).

Generally speaking, however, there is high agreement and robust evidence of the limited implementation of zoning and land use measures for climate adaptation from cities across diverse contexts. Studies from cities across the globe reveal that land-use planning systems remain predominantly orientated towards facilitating urban development without adequately considering disaster risk reduction (DRR) (see for example: such as Castán Broto's (2014) on Maputo, Dodman et al.'s (2017b) on cities across sub-Saharan Africa, and Jabareen's (2015) on Amman, Moscow, and Delhi). Another body of robust evidence with high agreement reveals that one or a combination of: lack clarity of implementation strategies for climate adaptation, lack of funding, competing priorities (especially, among professional planners and politicians), and institutional challenges face mainstreaming adaptation through land use planning whether through municipal or regional plans. This evidence spans cities in the Global South equally as in richer countries (see Jabareen's (2015) study of 20 cities globally). More specifically, evidence from Legazpi City and Camalig municipality in the Philippines points to the challenging of mainstreaming land use planning for climate adaptation (Cuevas, 2016; Cuevas et al., 2016) while evidence from Bangkok in Thailand points to competing priorities in land use decision-making processes (Marks, 2015). Moreover, evidence from 44 US local climate change adaptation plans (Woodruff and Stults, 2016) and from 31 coastal communities in Florida, USA (Butler et al., 2016) points to weak and/or failed implementation especially with regards to spatial land use policies for climate adaptation while evidence from 39 municipal plans in Canada's British Columbia reveals very little content surrounding land use for coastal protection combined with weak goals and policies relating to climate change (Stevens and Senbel, 2017). This parallels evidence from three Australian city-regions (South East Queensland, Melbourne, and Perth) that failed in deploying land use planning for water planning (management and adaptation to drought) (Serrao-Neumann et al., 2017). Yet, limited evidence from cities around the world such as: the urban Regions of Stuttgart and Berlin in Germany (Larsen, 2015), Greater Manchester in the UK (Carter et al., 2015), and Colombo in Sri Lanka (Perera and Emmanuel, 2018) reveals that risk reduction through zoning and land use effectively protected and expanded green infrastructure and soft land cover to alleviate pluvial flooding and decrease the UHI effect.

It is essential to underscore that evidence from richer countries and from the Global South reveals that Euclidean zoning and land use are more effective when governance systems facilitate the implementation of land use policies for climate adaptation based on sound decisions that preclude negative human-nature interactions and that curb spatial inequity –both of which trigger climate gentrification and render the, mostly economic, disadvantaged groups in society more vulnerable to climate-related risks (Keenan et al., 2018; Marks, 2015). Empirical evidence also points to the spill-over benefits of deploying zoning and land use planning for climate adaptation. Mostly, the increase in soft land cover and green infrastructure also contributes to mitigation through air quality enhancement, energy conservation, and carbon sequestration while its ecological benefits include the preservation and expansion of habitats. Moreover, zoning and land use that increase green (and blue) land cover consequently enhance the aesthetics of urban neighbourhoods and improve their liveability (such as through enhancing the conditions for walkability and cycling, hence, decreasing auto-dependency), which eventually attracts businesses and retail, stimulates economic prosperity, and increases property values (Carter et al., 2015; Larsen, 2015). Such increase in property values has also been observed in zones and areas protected from risks (such as flooding), where it triggers spatial inequity leading to climate gentrification risks (Keenan et al., 2018; Marks, 2015).

Secondly, conventional architectural and urban design regulations for urban form occur at different scales from the single building (building codes) to the urban scale (urban design regulations). To begin with, building codes and guidelines facilitate climate responsive buildings that adapt to a changing climate and that simultaneously change collective behaviour during extreme weather events (Osman and Sevinc, 2019). They include buildings that are adaptive to thermal comfort and to floods (e.g., building on stilts and amphibian architecture). A decrease in indoor thermal comfort due to climate change, evidenced by negatively affected thermal comfort indices and/or increased number of overheating hours is reported by many studies (e.g. Dino and Meral Akgül, 2019; Dodoo and Gustavsson, 2016; Hamdy et al., 2017; Invidiata and Ghisi, 2016; Liu and Coley, 2015; Makantasi and Mavrogianni, 2016; Mulville and Stravoravdis, 2016; Osman and Sevinc, 2019; Pérez-Andreu et al., 2018; Roshan et al., 2019; Salthammer et al., 2018; Taylor et al., 2016; van Hooff et al., 2014; Vardoulakis et al., 2015), most of which employed numerical simulations in which different climate scenarios were used to construct future climate data. The decrease in thermal comfort and increased overheating risks in buildings depends on the building characteristics, such as the thermal resistance, presence of solar shading, thermal mass, ventilation, orientation and geographical location (e.g. Dino and Meral Akgül, 2019; Dodoo and Gustavsson, 2016; Fisk, 2015; Hamdy et al., 2017; Invidiata and Ghisi, 2016; Liu and Coley, 2015; Makantasi and Mavrogianni, 2016; van Hooff et al., 2014; Vardoulakis et al., 2015). Research has shown that energy-efficient buildings with high insulation values and high airtightness, which do not have sufficient protection from solar heat gains, and/or have limited ventilation capabilities, are generally more vulnerable to overheating than older buildings (with low insulation levels) (e.g. Fisk, 2015; Fosas et al., 2018; Hamdy et al., 2017; Makantasi and Mavrogianni, 2016; Mulville and Stravoravdis, 2016; Ozarisoy and Elsharkawy, 2019; Salthammer et al., 2018; van Hooff et al., 2014; Vardoulakis et al., 2015).

Studies on the adaptation of urban areas through urban design measures since 2015 have mainly focused on the addition of green (e.g. Amani-Beni et al., 2018; Aminipouri et al., 2019; Andersson et al., 2019; de Munck et al., 2018; Gromke et al., 2015; Gunawardena et al., 2017; Klemm et al., 2015; Lai et al., 2019; Martins et al., 2016; Morille and Musy, 2017; Santamouris et al., 2017; Straka and Sodoudi, 2019; Taleghani et al., 2019; Toparlar et al., 2018; Xu et al., 2019) and blue infrastructures (e.g. Amani-Beni et al., 2018; Gunawardena et al., 2017; Lai et al., 2019; Martins et al., 2016; Montazeri et al., 2015; Montazeri et al., 2017; Santamouris et al., 2017; Tominaga et al., 2015; Ulpiani et al., 2019a; Ulpiani et al., 2019b; Xu et al., 2019), and the application of high albedo materials (increased short-wave reflectivity) (e.g. Kolokotsa et al., 2018; Kyriakodis and Santamouris, 2018; Lai et al., 2019; Macintyre and Heaviside, 2019; Santamouris et al., 2017; Straka and Sodoudi, 2019), to reduce urban air temperatures, increase outdoor thermal comfort, and decrease heat stress. Specifically, there is high agreement and robust evidence that ratio stipulations for green infrastructure, including (tree canopies, green roofs and walls, and pocket parks) introduce pervious/permeable surfaces for stormwater management, alleviate the UHI effect, increase biodiversity, and sequester CO2 (Eckart et al., 2017; Feitosa and Wilkinson, 2018; Geneletti and Zardo, 2016; Keeler et al., 2019; Nolon, 2016; Shooshtarian et al., 2018; Straka and Sodoudi, 2019). The impact of high-albedo materials on the canopy air temperature can be limited in particular cases and applying high-albedo materials can even – despite the positive effect on air temperature – result in a decrease of pedestrian thermal comfort due to higher mean radiant temperatures (Falasca et al., 2019; Lai et al., 2019; Morille and Musy, 2017; Nazarian et al., 2019; Straka and Sodoudi, 2019; Taleghani, 2018a; Taleghani, 2018b). There is also limited evidence that indicates ambivalence regarding other urban design measures depending on each context's specific conditions. For example, vertical compactness (increased canyon height or the proportion of building height to road width) in Berlin improved daytime cooling at the pedestrian level (due to shading, decreased radiation, and/or increased surface fraction) (Straka and Sodoudi, 2019), whereas in Thessaloniki, Greece and in Colombo, Sri Lanka this same measure increased the UHI effect (due to heat and gas pollutants trapping) (Perera and Emmanuel, 2018; Yiannakou and Salata, 2017). Conversely, horizontal compactness (low-rise compact urban form with decreased canyon width) decreased the UHI in Colombo (Perera and Emmanuel, 2018), but increased it in Berlin (Straka and Sodoudi, 2019). Lastly, there is limited but growing evidence (e.g., from Iquique, Chile and from Volusia County, Florida) on the effectiveness of the horizontal connectivity of the network of open spaces (streets, squares, parks …etc.) in providing redundant and unobstructed alternatives for evacuation and recovery during rapid onset events (see Helderop and Grubesic, 2019 on Volusia; León and March, 2016 on Iquique; Sharifi, 2019).

Buildings can be adapted to the negative consequences of climate change by altering their characteristics, for example increasing the insulation values (e.g. Barbosa et al., 2015; Fisk, 2015; Fosas et al., 2018; Invidiata and Ghisi, 2016; Makantasi and Mavrogianni, 2016; Pérez-Andreu et al., 2018; Taylor et al., 2018; Triana et al., 2018; van Hooff et al., 2014), adding solar shading (e.g. Barbosa et al., 2015; Dodoo and Gustavsson, 2016; Invidiata and Ghisi, 2016; Makantasi and Mavrogianni, 2016; Osman and Sevinc, 2019; Pérez-Andreu et al., 2018; Taylor et al., 2018; Triana et al., 2018; van Hooff et al., 2014), increasing natural ventilation, preferably during the night (e.g. Cellura et al., 2017; Dino and Meral Akgül, 2019; Dodoo and Gustavsson, 2016; Fosas et al., 2018; Makantasi and Mavrogianni, 2016; Mulville and Stravoravdis, 2016; Osman and Sevinc, 2019; Pérez-Andreu et al., 2018; Triana et al., 2018; van Hooff et al., 2014), applying high-albedo materials for the building envelope (Baniassadi et al., 2018; Invidiata and Ghisi, 2016; Triana et al., 2018; van Hooff et al., 2014), altering the thermal mass (Din and Brotas, 2017; Mulville and Stravoravdis, 2016; van Hooff et al., 2014), adding green roofs/facades to poorly insulated buildings (de Munck et al., 2018; Feitosa and Wilkinson, 2018; Geneletti and Zardo, 2016; Skelhorn et al., 2014; van Hooff et al., 2014).

In general, the most promising adaptation measures are a combination of solar shading with increased levels of insulation and ample possibilities to apply natural ventilation to cool down a building (e.g. Barbosa et al., 2015; Dodoo and Gustavsson, 2016; Fosas et al., 2018; Makantasi and Mavrogianni, 2016; Taylor et al., 2018; Triana et al., 2018; van Hooff et al., 2014); however, it must be noted that the cooling potential of natural ventilation will decrease in the future due to increasing outdoor air temperatures. Similarly, air conditioning performance also decreases with increasing outdoor temperatures, in addition to being maladaptive where use is associated with carbon emitting electricity production systems.

Several reasons for a limited implementation of climate change adaptation measures are mentioned in literature, such as the lack of regulations, the priority to a reduction of heating energy demand instead of thermal comfort/cooling demands in a lot of countries, the lack of knowledge of building owners, the focus on short term profits, and practical limitations such as the costs involved (Albers and Bosch, 2015; Boezeman and de Vries, 2019; Hurlimann et al., 2018; Keskitalo et al., 2016; Roders and Straub, 2015), but also practical constraints, for example, related to safety and privacy which limits the applicability of increased natural ventilation as an adaptation measure at the building scale (Barbosa et al., 2015; van Hooff et al., 2014).

The negative effects of climate change on indoor thermal comfort can lead to an increased use of active cooling systems in buildings, which will lead to even higher outdoor temperatures and an increased emission of CO2 (Dino and Meral Akgül, 2019; Huang and Hwang, 2016; Pérez-Andreu et al., 2018). Regardless of whether it is extreme heat or cold, context-specific building adaptation is either active (energy consuming) or passive (no- or low energy consumption). Empirical evidence, however, reveals that is not possible to achieve 100% thermal comfort without using mechanical cooling systems, but sustainable solar energy powered systems ensure avoiding maladaptation (Osman and Sevinc, 2019).

Thirdly, innovative architectural and urban design standards and tools include form-based codes, Leadership in Energy and Environmental Design-Neighbourhood Development (LEED-ND), low impact development (LIDs), and Local climate zones (LCZs). To begin with, form-based codes (FBCs, also known as Smart Code) and LEED Neighbourhood Development (LEED-ND) combine land use and urban design regulations for built form. Rather than separating uses as in conventional zoning and land use planning, FBCs regulate the three-dimensional form of buildings and spaces (massing, architectural character, and siting of streets, squares, and green corridors…etc.) while allowing compatible uses to be incrementally established within (Form-Based Codes, 2015). FBCs have been adopted to varying degrees and scales in North America, from single development projects to cities (e.g., Miami, USA), to state-wide endorsement (e.g., California, USA) (Garde, 2018; Garde et al., 2015). There is evidence on their adoption in some European cities (e.g., Stockholm and Malmo, Sweden) (Stojanovski, 2018), with more recent calls for their applications in Abu Dhabi, the UAE (Sabri and Ahmed, 2019) and in port cities in South Korea (Hwang and Kim, 2017). As for LEED-ND, it is an extension to the urban landscape of the globally applied LEED certification for buildings. LEED-ND combines land use, transportation, ecological and green infrastructure, energy, and smart materials criteria in the design, planning, and construction of neighbourhoods (Balsas, 2018). LEED-ND's rating system includes 41 design criteria distributed over five categories, three of which are strongly linked to climate adaptation[1]: 1) Smart Location and Linkage (SLL) (e.g., mixed-use development; transit; and

[1] FOOTNOTE: The two other categories are Regional Priority Credits (RPC) and Innovation and Design Process (IDP) (Garde 2017; Nolon 2016).

walkability and cycling), 2) Green Infrastructure and Buildings (GIB) (energy, water, and natural resources efficiency; decreased UHI and light pollution; historic preservation and adaptive reuse); and 3) Neighbourhood Pattern and Design (NPD) (e.g., compact, mixed-use development with diverse housing types; street design; and minimal surface parking) (Garde, 2018). Although LEED building designation is widespread globally, LEED-ND has yet to gain traction (Balsas, 2018).

While there is a dearth of empirical studies that assess FBCs and LEED-ND vis-à-vis climate adaptation, the limited empirical evidence highly agrees that these planning tools increased the ratios of impervious surfaces that absorb rainwater runoff and green infrastructure providing an array of ecosystem services that address various climatic hazards and risks (e.g., stormwater management, UHI, etc.) (Balsas, 2018; Garde, 2018; Garde and Hoff, 2017; Garde and Kim, 2017). For example, evidence from Denver and nearly 40 cities in California and, USA) reveals that their FBC plans that replaced conventional zoning and land use, integrate LEED-ND's 41 criteria for climate adaptation to a greater extent than their previous conventional zoning and land use measures (Garde, 2018; Garde and Hoff, 2017; Garde and Kim, 2017). FBCs and LEED-NDs's focus on connectivity (transit, walkability, and cycling), energy efficiency and green infrastructure, and on compact, mixed-use urban developments would ideally contribute to mitigation and equity (through the provision of transit and movement modalities combined with a diversity of housing types). There is also limited evidence that FBCs projects are more adaptive to the UHI effect than the conventional (Euclidean) zoning (Heris, 2018). Yet, there is evidence that the that that LEED-ND standards do not include provisions for low-income housing, combined with the costs associated with the certification lead to developments that exclude economic and social diversity, hence, generate spatial inequity with spill-over gentrification impacts for the surrounding neighbourhoods (Benson and Bereitschaft, 2019; Garde et al., 2015; Szibbo, 2016).

As for Low Impact Developments (LIDs), they were developed in Prince George's County in Maryland, USA at the turn of the millennium with a particular focus on stormwater management through the provision of green infrastructure (Coffman, 1999). LIDs entail amendments to local land use and built form regulations to include structural and non-structural techniques, such as: saving trees in situ, building restriction in ecologically sensitive areas, road orientation, in situ wastewater treatment systems (e.g., sand filters), and building codes (Eckart et al., 2017; Nolon, 2016). Globally, LID's are paralleled by New Zealand's low impact urban design and development (LIUDD), Australia's water sensitive urban design (WSUD), and Europe's sustainable urban drainage systems (SuDS) (Eckart et al., 2017). There is high agreement and high confidence that LIDs effective at managing stormwater runoff, especially in the warmer seasons and for shorter return period events (storm event of low intensity, duration, and antecedent moisture level) although the outcomes are dependent on the context-specific conditions (e.g., soil types and organic content) (Chang et al., 2018; Eckart et al., 2017; Gülbaz and Kazezyılmaz-Alhan, 2017; Larsen, 2015; Palla and Gnecco, 2015; Sohn et al., 2019). Simultaneously, there is limited evidence to indicate that LIDs' effectiveness for larger extreme events improves when combined/coordinated with conventional stormwater management approaches (Eckart et al., 2017). Although LIDs might be less costly, the implementation timespan is long; Maryland's LIDs retrofitted 15,000 acres of impervious surface with green infrastructure over 15 years while Philadelphia's "Green City, Clean Water" program aims to convert 10,000 acres into green cover over 25 years. The former's estimated cost was $1.2 billion secured through financing from long-term public–private partnerships, while the latter is estimated to cost $1 billion (as opposed to $8 billion for retrofitting the existing grey stormwater infrastructure system))(Larsen, 2015).

More recently, Local climate zones (LCZs) have been deployed to provide a mapping tool that combines the three-dimensional built form, land and building uses, and land cover while simultaneously accounting for urban ventilation at scales ranging from the micro context-specific scale to the larger district scale (Emmanuel and Loconsole, 2015; Lelovics et al., 2014; Perera and Emmanuel, 2018; Stewart and Oke, 2012; Wang and Ouyang, 2017). There is limited but increasing evidence on this nascent tool's potential for climate adaptation especially in hot and humid topical urban centres (Giridharan and Emmanuel, 2018; Perera and Emmanuel, 2018). The limited evidence thus far agrees that LCZs offer: (1) nuanced adaptation options that account for the complexity of the factors contributing to UHI; (2) together with Local Thermal Zones (LTZs) (classifications of the Land Surface Temperature (LST)), they offer monitoring and evaluation mechanisms for the adaptation interventions (Hamstead et al., 2016; Perera, 2016; Perera and Emmanuel, 2018; Wang and Ouyang, 2017); and (3) they incorporate social and economic considerations, hence, identify instances of inequitable climate (Hamstead et al., 2018; Perera and Emmanuel, 2018). For example, in Colombo, LCZs revealed that new high-rise developments for housing disadvantaged communities are in fact more heat stressed than the lightweight low-rise structures they replaced.

The barriers and future opportunities: The literature concurs that municipal plans, even when they discuss climate adaptation, lack clear implementation strategies that operationalize climate adaptation especially when compared to other aspects of urban planning (see for example Araos et al., 2017 on Dhaka; Carter et al., 2015 on Greater Manchester, UK; Jabareen, 2015 on cities across the globe; Nordgren et al., 2016 on 85 organizations in the USA; Woodruff and Stults, 2016 on 44 local climate change adaptation plans in the USA). Specifically, with regards to land use planning and built form regulations for climate adaptation, the literature identifies an array of barriers to implementation that explain its limited mainstreaming. Firstly, hazards, vulnerability, and risks and consequently, the ensuing adaptation options are localized. Yet, land use planning systems are inherently hierarchical while climate models are rarely localized (Juhola, 2016). Secondly, while there is improvement in fact-based plans (Stevens and Senbel, 2017; Woodruff and Stults, 2016), there is still a need for global and local data combinations for climate change and particularly for spatially articulating climate data at the local scale , and in ways accessible to planners and inclusive of the local ecological knowledge (LEK) (Carter et al., 2015; Cuevas, 2016; de Groot-Reichwein et al., 2018; Dhar and Khirfan, 2017a; Pearce et al., 2015; Vogt et al., 2016; Yiannakou and Salata, 2017). Thirdly, there is a need for more consistency in "uncertainty" levels to guide policy-making (Carter et al., 2015; Dhar and Khirfan, 2017a; Woodruff and Stults, 2016). There is high agreement that climate uncertainty hinders the translation of adaptation policies into action by rendering it difficult to set clear planning policies, to bring stakeholders on board, and to estimate and allocate funding especially for long term spatial planning (Araos et al., 2017; Butler et al., 2016; Carter et al., 2015; Juhola, 2016; Woodruff and Stults, 2016). Fourthly, complexity preclude the mainstreaming of climate adaptation plans warrant cross-sectoral and cross-disciplinary collaborations (researchers, planners, and policy-makers) across all governance levels (national, regional, municipal) (Carter et al., 2015; Dhar and Khirfan, 2017a; Juhola, 2016; McClure and Baker, 2018).

Moreover, there is a need to produce consistent and integrated national scale policies that lead to developed institutional capacities for adaptation planning at the local municipal scale. Also, important are the commitment of elected officials the level of prioritization of climate change adaptation, the institutional incentives, and clarity in the guidelines for mainstreaming climate adaptation plans into the local land use plans (Araos et al., 2017; Cuevas, 2016; McClure and Baker, 2018; Shi et al., 2015). Lastly, there is a need for developing clear indicators for measurable objectives for evaluating the climate adaptation components of the plans (whether land use, urban design or other) (Doherty et al., 2016; Stevens and Senbel, 2017).

6.3.3 Nature-Based Solutions

Well-functioning ecosystems can play a significant role in buffering communities and infrastructure from climate hazards at different scales. Widely recognized as "low-regret" measures for disaster risk reduction and climate change adaptation green and blue infrastructure in cities can provide nature-based solutions to mediate temperature shocks and provide natural flood defences, such as via mangrove stands in coastal areas and wetland and stream restoration (Andersson et al., 2019; Frantzeskaki et al., 2019; McPhearson et al., 2018). Grass and riparian buffers and forested watersheds can enhance flood and drought protection for cities and settlements. Despite increasing knowledge on nature-based solutions (here encompassing literature on ecosystem services for climate change adaptation and resilience, ecosystem-based adaptation, and benefits of green and blue infrastructure for adaptation), recent studies indicate that nature-based approaches to adaptation and resilience are still under-recognised in urban planning and development (Frantzeskaki et al., 2019; Geneletti and Zardo, 2016; Matthews et al., 2015). While the literature on nature-based solutions to climate change adaptation and disaster risk reduction in urban areas is growing extensively the potential of ecosystem services for actually meeting the high demand for urban hazard related services while also supporting health and well-being, particularly in low and middle-income countries, is uncertain. Grey infrastructure often damages or eliminates biophysical processes necessary to sustain people, ecosystems and habitats, and livelihoods, where green infrastructure can be more flexible and cost effective for providing flood risk reduction and other benefits (Palmer et al., 2015). Hybrid approaches integrate green, blue and grey (engineered) infrastructure in adaptation planning and hazard protection (Depietri and McPhearson, 2017; Grimm et al., 2016). Explicit policy uptake by city authorities is increasing (Hansen et al., 2015; Hölscher et al., 2019) such as in the case of New York where in 2010 the city committed to a hybrid infrastructure plan for storm water management, investing US$ 5.3 billion over 20 years, of which US$2.4

billion is targeted for green infrastructure investments (Depietri and McPhearson, 2017; McPhearson et al., 2014). A subsect of services from urban ecosystems are being increasingly invested in as "nature-based solutions" (NBS) for climate adaptation pathways (Frantzeskaki et al., 2019; Kabisch et al., 2016; Keeler et al., 2019). Co-benefits of NBS are an additional reason that NBS are being increasingly taken up by cities for adaptation including benefits for health and livelihoods, particularly for poor, marginalized groups (Cederlöf, 2016; Maughan et al., 2018; Poulsen et al., 2015; Poulsen et al., 2017; Simon-Rojo, 2019). At the same time concerns about unintended consequences of investing in green infrastructure for NBS such as how it may contribute to gentrification (Anguelovski et al., 2018b; Haase et al., 2017; Turkelboom et al., 2018) underline the challenges of investing in adaptation in complex urban systems.

6.3.3.1 Temperature Regulation

Nature-based strategies including street trees, green roofs, and other urban vegetation can reduce heat and extreme heat by cooling private and public spaces. Vegetation through shading, evapotranspiration, and change in surface albedo is the primary mechanism for urban cooling (Coutts et al., 2016). Shading reduces mean radiant temperature, which is the dominant influence on outdoor human thermal comfort under warm, sunny conditions (Thorsson et al., 2014). Apart from lowering temperature, nature-based solutions may also contribute to lower energy costs by reducing demand for conventional sources of cooling (e.g. air conditioning), especially during peak- demand periods. Homes with shade trees that are located in cities where air conditioning systems are common can save over 30% of residential peak cooling demand (Doick et al., 2014). Modelling has shown that green roofs, if employed widely throughout urban areas, have the potential to significantly lower the regional heat profile of cities (Santamouris, 2014). Community or allotment gardens, backyard greening, and other types of low vegetation, as well as lakes, ponds, rivers, and streams, can also provide local cooling benefits to nearby residents (Gunawardena et al., 2017; Larondelle et al., 2014).

Urban climate models show that increased vegetation cover results in reducing both mean air temperatures and extreme temperatures during heat waves (Heaviside et al., 2015). Greater density and more canopy coverage relative to other built and paved surfaces increases shade provision and evapotranspiration (Hamstead et al., 2016). However, local cooling by vegetation depend on regional climate context, geographic setting of the city, urban form, the density and placement of the trees, in addition to a variety of other ecological, technical, and social factors (Salmond et al., 2016b). For example, green spaces less than 0.5-2.0 ha may have negligible cooling effects, beyond the shaded area itself (Gunawardena et al., 2017; Zardo et al., 2017).

To maximize the adaptation benefits of NBS for regulating urban heat it is helpful to prioritize tree planting and other urban greening initiatives in areas where heat vulnerability and risk are the highest, especially communities that lack urban tree canopy, accessible parks to cool off during hot days or heat waves, and/or mechanized home cooling systems (Keeler et al., 2019). Planting trees closely together and choosing tree species with leaves that have the greatest leaf area index or the largest leaves, as those trees have the greatest shading and evapotranspiration benefits that, in turn, provide the greatest cooling effects. Drought resistant trees, often native trees, are ideal to avoid high watering costs. Native trees can provide additional benefits for local biodiversity or if fruit or nut trees can provide co-benefits for local food production.

6.3.3.2 Air Quality Regulation

Planting trees or vegetated barriers along streets or in urban forests or parks can reduce particulate matter, the ambient air pollutant with the largest global health burden (Janhäll, 2015; McDonald et al., 2016; Tiwary et al., 2008). However, findings show that trees can also positively or negatively affect ground-level ozone (Calfapietra et al., 2013; Kroeger et al., 2014), airborne pollen concentrations (Willis and Petrokofsky, 2017), and indirectly affect air quality through reduced emissions from energy production offset by shade provision (Keeler et al., 2019). Studies suggest that to minimize the potential of tree canopy to hold air pollutants near the ground and increase human exposure, a single line of roadside trees with high PM removal capacity should be planted along major roads, with enough spacing between tree canopies to allow wind flow between trees (Faber and Krieg, 2002). Tree planting near schools, nursing homes, and hospitals ensure that benefits provided by trees are delivered to the populations that stand to benefit the most from improved air quality.

Trees can also have negative effects by increasing pedestrian exposure to pollution if trees are introduced in heavily travelled street canyons where air pollutants can be trapped. To maximize the adaptation benefits of NBS for improving air quality planners and managers should target tree selection for species with low VOC emissions, low allergen emissions, and high pollutant deposition potential (Keeler et al., 2019). It is also important to consider the seasonality of trees since air quality impacts of deciduous varieties are minimal in dormant seasons (Beckett et al., 2000; Yang et al., 2015a), as well the potential aerodynamic effects of urban vegetation (Calfapietra et al., 2013). It may be useful to couple tree planting with point-source reductions that reduce pollutant concentrations in urban environments.

6.3.3.3 Stormwater Regulation

Urban parks and open spaces, wetlands, green roofs and engineered stormwater treatment devices help manage stormwater and wastewater by reducing the volume of stormwater runoff and/or reducing contamination of runoff by pollutants (Keeler et al., 2019; Moore et al., 2016). Engineered devices include bioswales, rain gardens, and detention and retention ponds, and are becoming common and standard approaches to mitigate the negative effects of impervious surfaces on stormwater quality in cities (Zhou, 2014). Allotment gardens and street trees may also help reduce runoff and provide a stormwater retention service. Modelling and empirical studies show that nature-based solutions at small spatial scales lead to improvements in water quality and reduction of peak flows. There is less evidence of the effectiveness of nature-based solutions at larger temporal and spatial scales. However, a modelling study in London estimated peak runoff reduction of up to 85% with widespread installation of green roofs (Pochee and Johnston, 2017).

Cities with combined sewer infrastructure are likely to see benefits from NBS due to reductions in stormwater quantity and reduced sewage overflows. Cities where a large proportion of residents lack access to piped infrastructure and drink surface water could be expected to see large benefits, especially to human health, from NBS investments (Keeler et al., 2019). Where future large-scale upgrades or installation of grey infrastructure will be necessary, growing cities may see large net benefits from investments in NBS. Older cities, and new, rapidly urbanizing areas that lack large scale water infrastructure may see the greatest benefits from enhanced NBS, relative to cities where heavy investments infrastructure upgrades have already been made. Cities facing climate changes that including more frequent or extreme precipitation may also see large water quality benefits from investment in NBS (Keeler et al., 2019).

During periods with intense precipitation, low-lying urban parks and open space, engineered devices, and wetlands can play an important role in reducing stormwater runoff volumes, by providing places for water to be stored and infiltrate during heavy storms (Moore et al., 2016). However, the magnitude of the runoff reduction service will depend on the total area in green infrastructure, and its position on the landscape. The performance of NBS depends on the degree to which their extent and spatial configuration in the city are optimized to capture runoff (Fry and Maxwell, 2017). Overall, nature- based solutions are attractive adaptation options compared to and in combination with grey infrastructure and cities where planners and stormwater engineers are increasingly incorporating NBS in stormwater management.

6.3.3.4 Food Production and Security

Urban agriculture can contribute to food provisioning as well as multiple non-provisioning ecosystem services such as cultural services including recreation, place-making, and mental health (Soga et al., 2017). Several studies have attempted to estimate the extent to which urban agriculture could theoretically meet urban total food or vegetable demand (Badami and Ramankutty, 2015; McClintock, 2014). Its role in urban food security and social cohesion is context-dependent (arising partly from the intention of urban farmers and communities) and is therefore difficult to generalize at the city, regional, or global scale.

To maximize the adaptation benefits of NBS for food production and security practitioners should embrace the multi-functionality of urban agriculture rather than viewing it as being solely about food production. Its food function (Pourias et al., 2016) or its contribution to food security are important across a range of contexts. Across cities at the global scale, potential for open air urban food production may be practically constrained by land availability (Badami and Ramankutty, 2015; Martellozzo et al., 2014). This is particularly true in some lower-income countries where rapid urbanization is occurring, which compounds existing food insecurity (Satterthwaite et al., 2010; Vermeiren et al., 2013). Land availability and suitability for gardens can be further constrained by land-use history, including past industrial uses that can contaminate soils (e.g., with pollutants such as lead). Other fundamental ecological moderators for urban agriculture provisioning include the availability of sunlight and freshwater. These moderators have the potential to interact with each other and with non-ecological moderators in such a way as to affect production and resource requirements. For example, a study conducted in Vancouver, Canada, demonstrated that light attenuation from buildings and trees can both reduce crop yield and reduce water demand for crop growth (Johnson et al., 2015).

Climate and climate change is an important potential moderator for food security. While urban agriculture may provide benefits in terms of stability of food access in low-income households in some regions of the Global South where the climate is warmer, the shorter growing seasons in colder climates will reduce the role of outdoor urban agriculture in year-round food supply and diets. Higher heating costs to produce vegetables indoors in cities during northern winters requires considerable amounts of energy and may result in fossil fuel emissions depending on the energy source (e.g., natural gas heaters)(Goldstein et al., 2016). Conversely, some regions (e.g., large tracts of South and Southeast Asia) can support multiple growing cycles per year for some crops, particularly in tropical areas where irrigation is available.

6.3.3.5 Coastal Flood Protection

This section supports Cross-Chapter Paper 2: Cities and Settlements by the Sea.

Coastal ecosystems including coral and oyster reefs, coastal forests including mangroves and other tree species, salt marshes and other types of wetland habitat, seagrass, dunes, and barrier islands can have strong impacts on reducing flood losses and damage from storms (Boutwell and Westra, 2016; Bridges et al., 2015; Narayan et al., 2017; World Bank, 2016; Yang et al., 2015b; Zhao et al., 2014). Recent literature highlights the value of nature-based approaches for coastal protection in terms of avoided damages and human well-being (Keeler et al., 2019; Narayan et al., 2017; Silva et al., 2016). For example, coastal and marine vegetation and reefs dissipate wave energy, attenuate wave heights and nearshore currents, decrease the extent of wave runup on beaches, and trap sediments (Bridges et al., 2015; Ferrario et al., 2014). These effects result in lower water levels and reduce shoreline erosion, which in turn has potential to save lives and prevent millions of dollars in property damages (Narayan et al., 2017).

Narayan et al. (2017) estimate that coastal wetlands alone reduced direct flood damages by US$625 million during Hurricane Sandy in the United States in 2012. Similarly, Das and Vincent found that villages with wider mangroves between them and the coast experienced significantly fewer deaths than villages with narrow or no mangroves during a 1999 cyclone in India (World Bank, 2016). Recently, Arkema et al. (2017) noted that the number of people, poor families, elderly and total value of residential property most exposed to hazards along the entire coast of the USA can be reduced by half if existing coastal habitats remain fully intact. Researchers, practitioners, and policy-makers are increasingly calling for the use of natural and nature- based approaches to protect urban shorelines from coastal hazards (Bilkovic et al., 2017; Cunniff and Schwartz, 2015). The expectation is that coastal ecosystems can help stabilize shorelines and protect communities from flooding while providing other co-benefits for people and ecosystems. Vegetation along protected coastlines, with higher frequency, lower intensity coastal hazards (National Research Council, 2014) may be more effective for stabilizing shorelines and reducing risk to coastal communities and properties.

Still, coastal habitats also have limitations in their ability to protect coasts from extreme events. Some studies suggest reduced effectiveness of vegetation and reefs for coastal protection from large storm waves and surge (Guannel et al., 2016; Möller et al., 2014) and there is active debate in the literature about the ability of ecosystems to mitigate the impact of tsunamis (Gillis et al., 2017). Further research is needed to understand and quantify coastal protection services provided by these hybrid green-grey solutions, especially in urban areas (Bilkovic et al., 2017).

To maximize the adaptation benefits of NBS for improving coastal flood protection research suggests that cities should seek to restore and conserve the vegetation and reef types that are appropriate for the exposure setting and in sufficient abundance to be effective. In particular, planners and managers are advised (Keeler et al., 2019) to use vegetation in protected bays as alternatives to hard infrastructure for shoreline stabilization. However, the influence of ecosystems on flooding and erosion is variable and depends on a suite of social, ecological, and infrastructural factors that vary within and among urban areas (Bridges et al., 2015; Narayan et al., 2017; Ruckelshaus et al., 2016).

6.3.3.6 Riverine Flood Impact Reduction

Nature-based solutions reduce both the volume of floodwater and the impact of floods. NBS reduce the volume of runoff by increasing infiltration and water storage (Salvadore et al., 2015; Shuster et al., 2005), and affect the production and impact of flood waters through reducing river energy and flow speed through physical blockage, stabilizing riverbanks during flood events, creating space for floodwaters to expand, and combating land subsidence (Ahilan et al., 2018; Palmer et al., 2014).

Source reduction strategies include permeable areas such as parks and open spaces as well as engineered devices like raingardens, bioswales, and retention ponds that help retain stormwater running off impervious areas. River restoration can reduce flood peaks and provide space for floodwaters to expand. Planting and maintaining vegetation along riverbanks, often in the form of parks or river restoration, maintains structural integrity during flood events. Wetland construction and improved connectivity to floodplains also reduces flood peaks.

To maximize the adaptation benefits of NBS for riverine flood protection studies suggest that planners and managers should use nature-based solutions to reduce the impacts of urban flooding, especially for small to medium-scale flood events (lower than 20% mean annual flood) by installing nature-based solutions to increase infiltration on low slopes and high-permeability soils (Keeler et al., 2019). Efforts to restore floodplains are important to create space for floodwaters and reduce exposure by moving people out of the hazard zone. Floodplain restoration also provides access to the river that has multiple benefits, e.g. recreation, access to water for domestic use, and other cultural ecosystem services. A key adaptation strategy is to reduce streambank erosion (a result of high peak flow) using riparian vegetation, which is at least as effective as engineered solutions (Keeler et al., 2019).

Cities manage flood risk using different types of adaptation and regulatory mechanisms (Naturally Resilient Communities, 2017). Built flood-control infrastructure, such as levees and stream channelization, reduces the demand for nature-based flood impact reduction. Cities facing flood risk that do not currently have extensive grey flood-mitigation infrastructure may find nature-based solutions to be an appealing, lower cost solution (Keeler et al., 2019). In cities where flood-control grey infrastructure already exists there is less demand for nature-based solutions of flood protection, but nature-based solutions may provide important back-up, especially in a changing climate that may increase flood hazards (City of Los Angeles, 2017; Elmqvist et al., 2019).

6.3.3.7 Water Provisioning and Management

The role of nature-based solutions has been increasingly recognized for improving urban water management, which emphasizes the central role of water management in building sustainable and liveable cities (Wong and Brown, 2009). Nature-based solutions that protect or restore the natural infiltration capacity of a watershed can increase the water supply service to various extents depending on whether they are through street trees, parks and open space, community gardens, and engineered devices such as rain gardens, bioswales or retention ponds that are designed to increase stormwater infiltration. Additional sources of water may be available to replace the water supplied by nature-based solutions, such as rainwater harvesting, inter-basin transfers, or desalination plants. Reliance on naturally sourced, locally available surface water and groundwater is more energy-efficient and economical than desalination or water reuse for potable use, while rainwater harvesting is even more economical. However, Bhaskar et al (2016) reviewed the effect of urbanization and nature-based solutions on baseflow and suggest that the confounded effects of infiltration and evapotranspiration losses, combined with the subsurface infrastructure (sewer systems) and geology, makes it difficult to predict the magnitude of baseflow enhancement resulting from the implementation of nature-based solutions in cities.

The characteristics of the urban water system, including its environment, regulation, and built infrastructure affect the demand on main surface and subsurface water sources (McDonald et al., 2014). Water demand management measures, either structural (e.g. rainwater harvesting measures, water saving devices) or non-structural (e.g. education) influence can modify the amount and seasonality of demand for water resources. Additionally, technological factors including urban infrastructure such as groundwater wells and pumping technologies increases the demand for water supply via groundwater recharge (Okotto et al., 2015).
To maximize the adaptation benefits of NBS for urban water supply research suggestions that managers and planners should continue to use nature-based solutions as alternatives to traditional stormwater management techniques, where possible, since these solutions can promote groundwater recharge. Green infrastructure is increasingly being used for stormwater absorption in cities. It will be important to prioritize the use of rain gardens, wetlands, or engineered infiltration ponds or bioswales over street trees as nature-based solutions most likely to promote recharge and reduce evapotranspiration.

6.3.3.8 Sanitation

[PLACHOLDER FOR SECOND ORDER DRAFT: this section will assess the literature on ecosystem services contribution to sanitation in places exposed to climate change associated risks and the scope for further adaptive capacity and action from deploying this method of risk reduction.]

6.3.4 Productive Infrastructure

Productive infrastructure describes physical infrastructure with direct contributions to supporting the functioning of urban and wider economies. Engineered measures for hazard mitigation such as seawalls, slope revetments, river levees, as well as air conditioning are increasingly implemented in urban centres but are less affordable and accessible in low and middle-income countries due to high construction and maintenance costs. These adaptive measures can also counter mitigation objectives due to reliance on climate polluting energy sources. Despite this, engineering measures such as seawalls for tsunami protection and cooling areas in cities provide critical hazard reduction functions in urban contexts (Depietri and McPhearson, 2017). Pelling et al (2018) highlight, sustainable risk reduction can be better achieved where these engineering measures include the at-risk poor majority and inclusive planning to support pro-poor risk reduction.

6.3.4.1 Physical Infrastructure

Substantial investment is planned and required to replace, upgrade and extend the world's infrastructure. Globally it is estimated that investment of $94tn between 2016 and 2040 is required (Oxford Economics, 2017). Infrastructure is a priority for adaptation because its performance is sensitive to climate (particularly extreme events) and decisions on design and renovation have long-lasting implications and are hard to reverse. To avoid longer-term impacts on society, the economy, and environment, it is crucial that future investment, and retrofit of existing infrastructure, is undertaken in the context of the risks of climate change.

Table 6.4: Indication of the proliferation of infrastructure networks and their usage. [PLACEHOLDER FOR SECOND ORDER DRAFT: consider usefulness of the context to reinforce the point about the importance of infrastructure to modern living and also its rapid growth and for other sectors]

Infrastructure	Scale	Usage	Coverage / Equity of access	References
Information and Communication Technology	Worldwide: 91M mobile phones in 1995; 8.2BN in 2018 worldwide	Worldwide: 43,000 PB in 2014 242,000 PB in 2018 (*1PB = 1million GB)	Europe: 85% population are unique mobile subscribers Asia Pacific: 66% SSA: 45%	(ITU, 2019) (Vodafone, 2019) (GSMA, 2019)
Electricity networks	>20M km power lines in Europe and USA.	25721 TWh (2017)	Global: 3130kWh/person Haiti: 39kWh/person Iceland: 53,832kWh/person	(IEA, 2019) (World Bank, 2019b) (ETSAP, 2014)

Railways	2.69M km		Switzerland: 0.7m/person; 141m/km^2 Canada: 2.2m/person; 8.6m/km^2 India: 0.06m/person; 23m/km^2	(Koks et al., 2019)
Roads	63.46M km		Belgium: 15m/person; 5km/km^2 Malawi: 1m/person; 164m/km^2 Canada: 31m/person; 115m/km^2	(Koks et al., 2019) (WorldByMap, 2017)
Water	3.3 million km^2 land equipped for irrigation The Global Reservoir and Dam Database (conservatively records) at least 7100 dams	This irrigated land accounts for about 70% of total water withdrawals These dams can retain over 7800km^3 water.	Sub-Saharan Africa: 24% coverage of safely managed drinking water services, 28% safely managed sanitation services Europe & N. America: 94%, 78%	(Grigg, 2019) (Lehner et al., 2011) (Lehner et al., 2019) (UN Water, 2018)

[START BOX 6.2 HERE]

Box 6.2: Infrastructure Interdependencies

Infrastructures are increasingly dependent on each other—for power, control (via ICT) and access for deliveries or servicing. Moreover, a range of other mechanisms can create interdependencies that impact upon climate risks (Dawson et al., 2018). In the UK, all infrastructures utilities identify failure of components in another utility as a risk to their systems (Dawson et al., 2018). Key interdependencies include:

i. The use of ICT for data transfer, remote control of other systems, and clock synchronization. Pant et al. (2016) show that ICT is crucial for the successful operation of the UK's rail infrastructure. The study shows that flooding of the ICT assets in the 1-in-200-year floodplain would disrupt 46% of passenger journeys across the whole network;
ii. Water to generate hydroelectricity and for cooling thermal power stations. Reductions in usable capacity for 61–74% of the hydropower plants and 81–86% of the thermoelectric power plants worldwide for 2040–2069 (Van Vliet et al., 2016), which are sensitive to energy infrastructure choices (Byers et al., 2016);
iii. Energy to power other infrastructure systems. Failure of urban energy supply disrupts other infrastructure services, with disproportionate impacts on the urban poor (Silver, 2015);
iv. Transport systems that ensure access for resources such as fuel, personnel and emergency response. Pregnolato et al. (2017) show disruption across the city from a 1-in-10 year storm event could increase by 43% by the 2080s.
v. Geographical proximity of assets leads to multiple infrastructures being simultaneously exposed to the same climate hazard. Disruption is disproportionately larger for interconnected networks (Fu et al., 2014)
vi. There is usually limited information on the risks between infrastructure sectors, and without frameworks for collaborative working which, when coupled with commercial and security sensitivities, remain barriers to routine sharing and cooperation between operators. Despite this methods to tackle interdependence in climate risk analysis are emerging (Dawson, 2015) for example Thacker et al. (2017) analysed the criticality of the UK's infrastructure networks by integrating data on infrastructure location, connectivity, interdependence, and usage. The analysis showed that criticality hotspots are typically located around the periphery of urban areas where there are large facilities upon which many users depend or where several critical infrastructures are concentrated in one location. As infrastructure systems become increasingly interconnected, associated risks from climate change will increase and require a cross-sectoral approach to adaptation (Dawson et al., 2018).

[END BOX 6.2 HERE]

6.3.4.2 Information and Communication Technology Infrastructure

Information and Communication Technologies (ICTs) are deeply intertwined with the functioning of urban and infrastructure systems, and are at the core of the 'smart city' concept (Angelidou, 2015). Key elements in urban, national and international communications systems will need to be strengthened. Whilst widely diffused, low-cost technology tools and software-based applications need to be considered in the design and implementation of smart-city solutions, in particular those related to climate change adaptation.

Although networked like many other infrastructure systems, ICT components have some distinctive properties. They are relatively cheap, and the advent of wireless communications has enabled ICT to have the widest reach of all infrastructures. Components can be rapidly deployed or repaired, and generally ICT networks are therefore built with inherent redundancy and flexibility (Sakano et al., 2016). Components have a wide range of expected lifetimes which leads to faster cycles of innovation and potentially therefore uptake of climate resilience in this infrastructure sector. For example, mobile phones and computers may last as little as a year, cables and switching units may be moved and upgraded to improve bandwidth every few years, poles and masts are typically designed to last several decades, whilst exchanges and other critical nodes can be in use for over half a century.

ICTs are playing an increasing role in resilience building and climate change adaptation by enabling access to critical knowledge and information needed for decision-making, by facilitating learning and coordination among stakeholders and building social capital, as well as by helping to monitor, visualize and disseminate current and future climate impacts (Eakin et al., 2015; Haworth et al., 2018; Heeks and Ospina, 2019; Imam et al., 2017). Advocacy and awareness raising through ICTs such social media applications can influence behaviours and attitudes in support of adaptive pathways (Laspidou, 2014).

ICTs play a role in adaptive responses to both short-term shocks and long-term trends associated with climate change. Timely access to information (e.g. early warning, temperature and rainfall, agricultural advice) through ICTs (e.g. mobile devices, SMS, radio, social media) can be crucial to respond and mitigate the impact of emergencies such as floods and drought, for identifying pest and disease prevalence, and for informing livelihood options, key in adaptation pathways of vulnerable (Devkota and Phuyal, 2018; Panda et al., 2019).

In addition to contributing to the robustness and stability of the critical infrastructure in the event of disasters, ICTs can strengthen other attributes of resilient urban systems by enabling learning and community self-organization, cross-scale networks and flexibility, helping vulnerable stakeholders, in particular, to adjust to change and uncertainty (Heeks and Ospina, 2015; Heeks and Ospina, 2019). Big data is being used to inform responses to humanitarian emergencies (Ali et al., 2016; Pham et al., 2014), as well as to generate new forms of citizen engagement and reporting (e.g. community-based maps of flood-prone areas) that can help to inform coping and adaptive responses.

ICT is inadequate on its own to make a significant difference (Toya and Skidmore, 2015). The availability of locally relevant information (e.g. weather-based advisory messages, local market prices), the accessibility of the information by all members of the community (e.g. using various text, audio and visual content, local languages, addressing gender-related exclusion, cost and digital competencies), and the applicability of the information at the appropriate scale (local, regional or national), including data quality and verification, influence the role of ICTs in adaptive pathways (Haworth et al., 2018; Namukombo, 2016).

Information privacy and security, as well as the unintended impacts of ICTs on inequality and on widening existing gaps (e.g. due to poverty, gender and power differentials), can also constrain the contribution of ICTs to adaptation (Haworth et.al. 2018), and are among the key challenges that need to be addressed in order to fully realize their potential.

The selection and use of ICTs for adaptation needs to be fairly grounded in the broader socio-cultural, economic, political and institutional context, to ensure that these tools effectively help address existing, emerging and future adaptive needs.

Increased pervasiveness of ICT, in smart cities, smart infrastructure and day to day living, will evidently have long term implications for climate change risks. For example, even if the ICT network is resilient heatwaves, it is dependent on the electricity network to power it. Conversely, other networks are dependent upon ICT for control systems, e.g., Smart Grids for energy. There is limited information on how these interdependencies, and associated risks, will evolve.

[PLACEHOLDER FOR SECOND ORDER DRAFT: possible cross-cutting box (joint with WGIII) on ICT at the nexus of adaptation and mitigation. ICT is a huge driver of change, offers many opportunities but creates new threats. It receives only limited coverage in previous IPCC reports and elsewhere.

- ICT has huge potential to support adaptation and manage risks.
- However, it is also a driver of greenhouse gas emissions through cloud servers and data centres, printing, personal computers and other hardware etc.
- It also provides opportunities for reducing travel needs (e.g. videoconferencing), and optimising/demand management on energy and transport infrastructure networks.
- Thus, if well designed and used ICT has potential to contribute positively to both adaptation and mitigation agenda; conversely, if not, it can aggravate both.]

6.3.4.3 Energy Infrastructure

[PLACEHOLDER FOR SECOND ORDER DRAFT: This section will assess adaptation and risk management in energy infrastructure and its wider implications for integrated systems e.g. on maintenance of light, health systems and water pumping. This will include adaptation in energy systems sources from out-of-city sights e.g. hydroelectric power, tidal and wave energy; advantages and disadvantages for adaptation of centralised and decentralised energy production systems, and trends in low and zero carbon production. Links will be made to Chapter 8, Working group III on the adaptiveness of low and zero carbon energy production systems compared to existing systems.]

A number of measures are available to adapt existing energy infrastructure to climate change. Cables can be upgraded in anticipation of reduced efficiency in a warmer climate, although in many locations this may be achieved autonomously to meet growth in demand. Assets such as pylons can be strengthened, relocated, or replaced with new equipment built to higher standards, an example of this is in the UK where a total of £172 million is being invested in between 2011-2023 to raise flood protection of substations to be resilient to the 1 in 1000 year flood (ENA, 2015).

Longer term strategies could include a combination of increased network redundancy and decentralization of generation locations (Fu et al., 2016), or the use of 'defensive islanding' which involves splitting the network into stable islands in order to isolate components susceptible to failure and subsequently trigger a cascading event (Panteli et al., 2016). Smart grids are being increasingly deployed within municipalities to provide more efficient management of supply and demand and mitigate greenhouse gas emissions, however, there is limited understanding of their performance and reliability during floods and other extreme weather events (Feldpausch-Parker et al., 2018; Vasenev et al., 2016).

Adaptation and preparedness at the household level can minimize impacts during power outages, but neighbourhood level assistance may be more appropriate to ensure support for vulnerable households, and coordination of action and information (Ghanem et al., 2016). More generally, it is important for responder organisations integrate energy needs in disaster preparedness and response plans. Whilst over the longer term, reducing household and industrial demand for energy supply will reduce the need for capital investments and upgrades (Fu et al., 2016).

As shown in Table 6.4 access to energy supply varies considerably, in particular many African countries require substantial energy infrastructure to support their economic development. The combination of smart technologies with solar and other renewable generation provides a huge opportunity (Anderson et al., 2017;

Kolokotsa, 2017). However, care must be taken in rapidly developing cities as failure to ensure energy access during urbanization can reduce resilience and lead to undesirable lock-in (Ürge-Vorsatz et al., 2018).

6.3.4.4 Transport

A wide range of adaptation options are available for transport infrastructure and most provide a good benefit cost ratio (Doll et al., 2014; Forzieri et al., 2018). Options include upgrading infrastructure (which can often be achieved autonomously as part of standard repair and replacement schedules), strengthening, or relocating (critical) assets. Wright et al. (2012) calculated that strengthening bridges in the USA would cost \$140-\$250bn by 2090 (or several billion dollars a year), but costs are reduced by 30% if interventions are made proactively. Koks et al. (2019) calculate a benefit cost ratio of greater than one for over 60% of the world's roads exposed to flooding. The greatest benefits are in low and middle income countries where reductions in flood risk are typically between 40-80%. Pregnolato et al. (2017) showed that in the city of Newcastle upon Tyne (UK) two carefully targeted interventions at key locations to manage surface water flooding reduced the impacts of the 1 in 50 year event in 2050 by 32%.

Another approach is to deploy smart technologies and new designs can improve the resilience of cars, trains, boats and other vehicles to cope with more extreme weather. Mobility transformations have the potential to improve mobility and accessibility, to influence urban form and to reduce vehicular use, vehicle miles travelled and vehicle-based emissions (Sperling et al., 2018). Carpooling operations in 8 countries across Europe and South America doubled the average number of passengers per vehicle from 1.9 to 3.9 people and cut carbon dioxide emissions by nearly 30 percent – the equivalent of 3 months' traffic in Berlin (BlaBlaCar, 2019). Ride-hailing - matching nonprofessional drivers of private vehicles with paying passengers - positively impacts low-income, low car ownership households in Los Angeles (Brown, 2018), and fills market gaps in cities where public transit infrastructure is inadequate, unreliable or unsafe (Suatmadi et al., 2019; Vanderschuren and Baufeldt, 2018). Whether the resulting impacts are positive or negative, largely depends on local, national and international policy and practices.

Full system re-design may enable the greatest resilience but it does not usually have a good benefit cost ratio (Doll et al., 2014). Moreover, Caparros -Midwood et al. (2019) show that transport infrastructure planners will not always be able to resolve trade-offs between managing climate risks and mitigating greenhouse gases without tackling other sectors. However, infrastructure planners should continually seek opportunities for positive infrastructure lock-in where available (Ürge-Vorsatz et al., 2018).

6.3.4.5 Built Form

In addition to nature-based solutions, interventions to reduce the UHI effect and deal with urban heat waves include installing air conditioning, establishing public cooling centers (i.e., for use during heat waves), and increasing surface albedo through "cool roofs" (i.e., with high-reflectance materials). The relative efficiency of cool roofs compared to green roofs is variable, because while white roofs have similar potential to reduce the UHI (Li et al., 2014), they can quickly turn grey due to dust and air pollution, losing their effectiveness (Gunawardena et al., 2017). Passive cooling is a design-based, widely used strategy to create naturally ventilated buildings, making it an important alternative to address the UHI for residential and commercial buildings (Al-Obaidi et al., 2014). Generally, passive cooling is achieved by controlling the interactions between the house envelope and the natural elements. Simple façade fixes such as overhangs, louvres, and insulated walls are effective at shading buildings from solar radiation while complex ones such as texture walls, diode roofs, and roof ponds are effective at minimizing heat gains from solar radiation and ambient heat (Oropeza-Perez and Østergaard, 2018).

In addition, wind towers, solar chimneys, and air vents are features that facilitate cool air circulation within buildings while dissipating heat. These features may be arranged to address hotspots or highly frequented spaces within buildings. Similar to nature-based solutions, the effectiveness of passive cooling to ameliorate the UHI varies widely depending on the location of the sun, wind direction, and the type of strategy used. For instance, natural ventilation strategies (e.g. wind towers, solar chimneys, etc.) can result in temperature reductions between 4°C and 15°C. Shading strategies alone can reduce indoor temperatures by 3°C, while heat sinks (in which heat is directed at a medium such as water) may result in indoor temperatures up to 6 °C lower than the outdoor temperature (Oropeza-Perez and Østergaard, 2018). Experience in Kano (Nigeria) has shown that incorporating indigenous knowledge into building design and urban planning can increase resilience to heat and flood risks (Barau et al., 2015).

6.3.4.6 Surface Water Management

[PLACEHOLDER FOR SECOND ORDER DRAFT:
- Hard engineering interventions can increase the capacity of the waste/stormwater treatment plants and drainage systems. However, this is expensive.
- Green infrastructure provides multi-functional adaptation with many benefits to health, wellbeing, biodiversity etc. as well as surface water management (Demuzere et al., 2014).
- Unused roof space can represent up to 50% of the impermeable surfaces of cities – providing opportunity (Mentens et al., 2006).
- However, challenges in uptake despite being more socially and environmentally equitable (Thorne et al., 2018).
- Capacity limits to using solely green infrastructure as they are ineffective at managing high return period floods so green infrastructure can only be part of the adaptation strategy in many areas (Pregnolato et al., 2016).
- Examples from 5 leader cities (Liu and Jensen, 2018).
- 45 Blue/Green Cities Index (Van Leeuwen et al., 2016).
- Challenges and opportunities in informal settlements (e.g. Birtchnell et al., 2019; Douglas, 2018; Herslund et al., 2018).]

6.3.5 Cross-Cutting Themes

6.3.5.1 Equity and Justice

It is clear that infrastructure, ranging from social to ecological to physical to digital, can help to reduce the impacts of climate change (Stewart and Deng, 2014). In many places, however, poor infrastructure standards and limited access to infrastructure can undermine the ability to adapt to climate risks. In African cities, for example, where growing numbers of people live in informal settlements, there is a lack of risk-reducing infrastructure such as piped water, sanitation and drains. Related to this exposure to health, flooding and drought risks of people living in slums is a growing concern (Lilford et al., 2016). Not only are there deficits but there are differences in who benefits from infrastructures, as they are inherently political (McFarlane and Silver, 2017). They are embedded in social contexts, politics and cultural norms. An example, given by Anand (2015), shows that fixing water leaks in Mumbai depends as much on the politics of who is involved and whose knowledge is prioritised, as on the technical aspects. Increasing attention is being paid in the literature to these issues of equity and injustice, recognising that it is inadequate to focus on the technical nature of infrastructure alone (Bulkeley et al., 2014b).

This section focuses explicitly on equity and justice concerns as they relate to infrastructure and adaptation pathways. Unfortunately, there is limited evidence of how infrastructures, implemented to reduce climate risk, have reduced inequality. Rather, there is more evidence to suggest that current infrastructure implementation pathways are increasing inequality (Anguelovski et al., 2016; Chu et al., 2016). For example, in Jakarta and Boston, sea walls and temporary flood barriers respectively have been erected in economically valuable areas, leading to precious resources protecting privileged groups rather than the poor (Anguelovski et al., 2016; Salim et al., 2019). Exploring this and other examples of adaptation through the lens of distributive and procedural justice, as established in previous climate justice work is important, whilst acknowledging spatial and recognition injustices as important too (Chu and Michael, 2018; Fisher, 2015).

Distributive justice calls attention to unequal access to services, land, capital and technology. When residents are unable to access adequate services and infrastructure their exposure to climate risks can be increased (Castán Broto, 2017b). Often infrastructure is not adequately implemented in low-income urban areas and not equally accessible to all. For example, low-income neighbourhoods often have less green space and therefore less associated cooling benefits. Understanding who has access to what infrastructure contributes to the growing emphasis on redressing the drivers of social vulnerability, that are central to just urban adaptation (Michael et al., 2018; Shi et al., 2016).

The quality and maintenance of infrastructure is often unequal across cities. Property that is highly exposed to risk is seen as dangerous and of lower value (Wamsley et al., 2015). Similarly, areas suffering from disinvestment in infrastructure, might have a high risk of flooding (Haddock and Edwards, 2013). Zoning and land use trade-offs have been seen to be unequally skewed in favour of prime real estate and economically valuable assets (e.g., protecting factories and refineries from flooding) (Anguelovski et al., 2016; Carter et al., 2015).

The location and type of housing, where urban residents reside, can determine the extent of vulnerability to climate risks. Significant investment is needed to make a home resilient, which may be beyond the means of many, especially residents of informal settlements. The lack of security of tenure results in a disincentive to invest in improving housing (Haque et al., 2014; Porio, 2011). Landlords of houses or rooms for rent in informal settlements also have little incentive to invest in improving their rental structures (Roy et al., 2013).

Changing land use and increasing green spaces to reduce climate risks and attract investments and job opportunities has increased real estate values, triggered climate gentrification in some areas (Keenan et al., 2018) and decreased access to affordable housing in some areas (Carter et al., 2015; Larsen, 2015). Displacement through evictions and relocations linked to land use conversion has also increased people's vulnerability (Anguelovski et al., 2016).

Post-disaster resettlement has worsened land tenure insecurity at times. In Tacloban, in the Philippines, following typhoon Haiyan, displaced persons are more likely to lack a claim to land or permanent housing which may push them back to unsafe land (Oxfam 2014 cited in (Sovacool et al., 2018)). In the case of post-disaster transition housing, the length of rental contracts may not suit the flexibility required of households seeking to rebuild their lives. Opdyke et al (2017) find that 6-12 month contracts were more effective in meeting the needs of households, compared to 2-year fixed contracts which meant households were more likely to abandon the units in less than 12 months.

Thermal inequity can be seen as a distributive justice concern too (Mitchell and Chakraborty, 2018). Social structure has been shown to disproportionately increase the exposure to urban heat, due to inadequate housing and less access to air-conditioning for individuals of lower socioeconomic status. This is exacerbated by a lack of public investment in landscape management of low-income neighborhoods, which limits the potential energy savings from trees in these areas.

Understanding elites and their investment in infrastructure has implications for distributive justice, particularly when there is secession from public infrastructure services that has financial implications for viability. In the case of the Cape Town drought, wealthy households secured their water needs through off-grid technologies such as rainwater tanks and boreholes. This resulted in less revenue being collected for municipal water and less ability to cross-subsidise water for poor households (Simpson, 2019; Ziervogel, 2019b). More attention needs to be paid to how urban responses to climate change are configured by these infrastructure networks (Bulkeley et al., 2014b) as well as how there might be a shift in infrastructure serving the interests of urban elites and failure to adequately consider the needs of the disadvantaged (Shi et al., 2016).

Procedural justice, which focuses on the institutional processes by which adaptation decisions are made, brings attention to the lack of representation of diverse voices in urban adaptation pathways. Understanding who is excluded and included is important. For example, in cities, increasing numbers of migrants are confronted with lack of access to citizenship rights and housing tenure. Migrants often are not allowed to formally claim public provisions in health, finance, and shelter in times of need, making them particularly vulnerable to climate and other risks (Chu and Michael, 2018). Further, migrants and their settlements are likely unrecognized in spatial or infrastructure development plans. In this context, social infrastructure, zoning and land use planning for climate adaptation has triggered inequity through omission, as migrants, the urban poor and their adaptation needs are often excluded from the planning process (Anguelovski et al., 2016).

Procedural justice does, however, have the potential to produce transformational outcomes that can address inequality (Holland, 2017). Transformative adaptation can be achieved if power shifts and people have the agency to influence decisions and exert change. To ensure that cities build and develop infrastructure that serves the needs of the disadvantaged people, a shift in urban climate governance is required towards more participation and inclusion (Anguelovski et al., 2016; Hölscher et al., 2019; Ziervogel, 2019a). This can stimulate innovation, surface power relations and address diverse needs (Chu et al., 2018; Martel and Sutherland, 2019). Experiments in including marginalized groups in adaptation planning are starting to emerge, such as in Quito (Ecuador) and Surat (India), where disadvantaged youth, informal settlers, and other vulnerable communities are included in discussions of short-/long-term adaptation needs and fair distribution of adaptation resources (Chu et al., 2016). These processes need to shift the focus to the rights of citizens and how infrastructure might change rather than supporting the persistence of existing infrastructure (Ziervogel et al., 2017).

A number of things need to be considered in order to respond to urban injustices. Understanding the nature of vulnerability of residents, particularly those living in areas of high exposure to climate risk, can help to identify who is most vulnerable and how best to adapt (Wilby and Keenan, 2012). Age and disability has a direct link to higher vulnerability to heat stress (Conry et al., 2015). Similarly, those people pursuing outdoor livelihoods are also more vulnerable to heat stress (Conry et al., 2015). In least developed countries, less than 60% of the urban population is estimated to have access to piped water. This has a direct impact on health and well-being, and emphasizes the importance of alternative resources for these households (World Health Organization et al., 2017).

Backlogs in infrastructure planning and delivery might lead to adaptation responses being undervalued (Castán Broto, 2017b). However, a range of infrastructure interventions can simultaneously address inequality and adaptation. To avoid creating exclusionary ecological enclaves, planning tools can be used including incentives, sponsorships, subsidies, or underwriting of costs by local governments (Larsen, 2015). Additionally, alternative or complementary regulation responses can be used that focus more on equitable spatial dimensions including form-based codes and LEED-ND. Hazard-specific approaches can also help with adaptation, like low impact developments for urban flooding and local climate zones and local temperature zones for UHI.

It is also important to understand differential adaptive capacity in order to assess who is less able to adapt to climate risks sufficiently (Thomas et al., 2019). Poor, young, and old members of the population may have few opportunities to relocate away from flooded areas in the long-term or to evacuate in the short term. It is also harder for many from low-income areas to rebuild after an extreme event (Defeo et al., 2009; Peterson and Lowe, 2009). Lack of housing tenure and sub-standard housing has been shown to limit the ability of residents to improve and manage their landscapes and therefore it is hard for them to enhance energy efficiency (Dempsey et al., 2011). Access to information is critical for adapting to climate risk and reducing vulnerability to hazards, yet access to this information is often not equally available (Ma et al., 2014). For example, low literacy can hamper ability to respond to early warning information (Dugan et al., 2011).

When looking at urban adaptation justice it is important to recognise that the adaptation of one individual or household may have a negative impact elsewhere (Holland, 2017; Limthongsakul et al., 2017). For example, the case of an area of peri-urban Bangkok experiencing localized flooding due to unregulated private sector development saw households take both individual action (building flood walls around homes, digging temporary drainage swales in the carriageway) and collective action (petitioning authorities, pumping water into vacant land). These actions to a certain extent merely displaced the flood water to other areas, or created new problems for example by damaging the carriageway, creating negative impacts on other households and the wider community. However, ultimately it was the actions of improperly-regulated private sector developers which was driving the need for this autonomous adaptation (Limthongsakul et al., 2017).

One of the tensions that emerge when addressing injustice is that the global provision of modern infrastructure is increasingly seen as unfeasible. It is unfeasible, both in terms of the current high emissions associated with infrastructure (World Bank, 2017) as well as the centralized, high standard ideal (Coutard and Rutherford, 2015; Lawhon et al., 2018). The urban poor meet their basic needs through both 'formal' and 'informal' infrastructure technologies given their limited access to infrastructure networks. So, questions emerge around alternative decentralized responses and the implications for justice and equity going forward.

6.3.5.2 Mitigation and Adaptation

As analytical concepts, mitigation and adaptation have helped, over the years, to structure thinking and action around climate change. However, during the period since the last AR5, there has been a growing debate about the adequacy of a neat separation between adaptation and mitigation (Castán Broto, 2017b). The delivery of climate change action has revealed numerous co-benefits between adaptation and mitigation, around diverse areas such as implementing nature-based solutions and delivering health and development benefits (Puppim de Oliveira and Doll, 2016; Spencer et al., 2017; Suckall et al., 2015; Ürge-Vorsatz et al., 2014). There has been a strong interest in delivering development benefits alongside climate mitigation, thus benefiting the overall infrastructure base (Suckall et al., 2015). Some of these co-benefits have also emerged in experiences of urban planning, pointing towards the dilemma of separating adaptation and mitigation in a context in which integration, rather than an analytical differentiation, was seen as a need to transcend work in silos (Aylett, 2015). As urban planning needs to consider carefully long timescales, the neat separation between mitigation and adaptation runs counter to integrated forms of planning that consider scales (time and space) carefully and that aimed to deliver the sustainable city as a whole (Bai, 2007; Davoudi et al., 2009).

For example, the idea of climate compatible development was raised an attempt to consider the simultaneous wins that emerge between adaptation, mitigation, and development, requiring institutional building and partnerships to deliver triple win solutions (Mitchell and Maxwell, 2010; Seo et al., 2017; Stringer et al., 2014). Clean cooking is an area where there are explicit interactions between the possibilities to deliver health outcomes alongside better air quality, reduced heat island effect and emission reductions (e.g., examples from Ulan Bator or Sudan; check urban-specific evidence). However, evidence for the actual possibility of achieving such triple wins is scarce (Tompkins et al., 2013). One commonly cited example has been the use of air conditioning units as a means to manage urban heat island impacts. In densely populated cities such as Hong Kong, the use of air conditioning may be integrated into a particular energy culture and, as an incumbent solution, it may displace alternative options for cooling the urban environment through the use of green infrastructure, public spaces and changes in cultural practices of thermal comfort (Castán Broto, 2019). Such focus also affects the most disadvantaged people who may not have access to appropriate technology and floor area, especially for the over 200,000 Hong Kong inhabitants who live in precarious sub-divided units (Castán Broto, 2019). In conclusion, in both urban environments and infrastructural sectors, triple wins are only realizable through broader perspectives that link climate compatible development to institutional change or the achievements of wider welfare objectives such as those enshrined in the United Nations 2030 Agenda of Development (Castán Broto et al., 2015b; England et al., 2018)(High agreement, medium evidence).

The aspiration to deliver climate change action within a broader agenda of transformative change received renewed attention after the publication of the 1.5 degrees report which argues for a focus on urban transformations and highlighted that informal settlements were vital to understand the delivery of these transformations. Deep decarbonization has emerged as a new idea that regards the development of low or zero carbon pathways as a condition for good adaptation in the long term, which becomes urgent in the face of growing impacts attributable to climate change (Bataille et al., 2016; Ribera et al., 2015; Wesseling et al., 2017). Urbanization opens opportunities for deep mitigation in low impact developments, and hence, it is imperative to understand the implications of those opportunities for climate action (Mulugetta and Broto, 2018). However, as with previous attempts to deliver integration between mitigation and adaptation policy, there is a limited understanding of the extent to which transformative gains exist, whether the focus to achieve integration distracts attention from most immediate needs to deliver adaptation programmes on the ground, and a need to explore the implications in terms of social justice, given that both adaptation and mitigation policies may have detrimental impacts on the lives of the most deprived urban populations.

6.3.5.3 Economics and Finance

[PLACHOLDER FOR SECOND ORDER DRAFT: this section will assess the literature on the relationships between adaptive actions on the macro-economy of urban areas and on individual livelihoods.]

6.4 Institutional, Financial and Governance Structures that Enhance the Resilience of and Enable Adaptation

Since IPCC AR5, a growing body of literature identifies a need to move from adaptive capacity to transformative capacity, and there is evidence that some new forms of urban governance are emerging which include civil society and prioritise the concerns of marginalized voices, and future generations- as indicated in the worldwide student mobilizations against climate change (Cloutier et al., 2018; Maor et al., 2017; Wood, 2019). However, despite new literature, local financial institutions and urban governance structures that can enhance urban resilience remain relatively undeveloped in practice (limited *evidence, high agreement*).

Attention is increasing in the peer-reviewed literature to integrating multi-scale urban governance approaches to climate change, but there is no "one size fits all" approach and new literature suggests many settlements continue to face significant governance, social, and financial barriers in building adaptive capacity for planning and implementation (Dilling et al., 2019; Tobón and Barton, 2019). Governance mechanisms must adjust to the physical state of urban areas, finance, and cultural capital and the socio-economic differentiation of cities and settlements.

6.4.1 Governance of Climate Change Adaptation and Mitigation

Since AR5, the speed and scope of urban change, particularly in informal settlements of Africa and Asia and cities of fewer than one million inhabitants increasingly highlight the need for a focus on inequity and opportunities for community participation and accountability in urban planning (UN-Habitat, 2016). There is also a need for local information and data management, and local access to adequate financing, and policy coordination for sustainable planning including, for example, air quality, infrastructure, risk assessment, health and wellbeing (Creutzig et al., 2019). Due to fast and often unplanned urbanization, especially West Africa, East Africa, South Asia, and Southeast Asia, unexpected climate events and risks are growing. They include urban flooding, heat stress, and droughts among others (Bai et al., 2018; Li et al., 2018). Many cities are beginning to plan and design adaptation plans focusing on resilience building. However, there are tensions between the conceptualization of resilience as a property of infrastructure systems or as a condition related to socio-ecological relations underpinning structural drivers of vulnerability and the political economy of disasters (Béné et al., 2018b). Resilient infrastructures, for example, may not respond to the needs of poor people living in slum locations which bear the brunt of changing climate. Thus, infrastructure interventions appropriate in some places may result in mal-adaptive outcomes in others, sometimes within the same city or urban area (Torabi et al., 2018).

This sub-section assesses literature on institutional and governance issues in urban settings (including social norms, regulations, and decision making processes) to understand policies and institutions for building climate resilient pathways. This literature draws attention to institutional arrangements that address the structural drivers of vulnerability and embed transformative institutions in societies, cultures, and economies (Baeza et al., 2019; McEvoy, 2019). The spatial configuration of cities has significant effects on climate change and has become essential to enacting adaptive responses within a resilience framework (Brunetta and Caldarice, 2019). New literature highlights how urban planning approaches and capacity-building strategies to deal with growing vulnerability to severe climate events and mounting demands for a shift to a low carbon economy are becoming inadequate (Carter et al., 2015; Dhar and Khirfan, 2017b; Juhola, 2016). Also, adaptation measures require an accompanying large-scale transformation of urban governance for a 1.5 °C-warmer world. Efforts to adapt to the newer challenges may have to take up to speed, especially in urban areas and settlements with lower levels of development where rapid urbanization, climate change vulnerability, and environmental justice collide (Solecki et al., 2018).

6.4.2 Cases of Urban Adaptation: pointers for Institutional Development and Governance

The literature on the governance of adaptation has grown since the AR5, turning attention to urban areas in all world regions, although there are still significant geographical gaps in the literature, with an absence of cases from cities and settlements in the Middle East, North Africa, Central Asia, and former USSR countries. Like in the Special Reports, empirical case studies show that successful adaptation to climate change is context-specific and responsive to the particular needs of urban locations (Robust evidence, high agreement). Emerging assessments of urban adaptation in cities and informal settlements in countries such as

Bangladesh, India, South Korea, South Africa, Ethiopia, show opportunities for greater collaboration for institutional governance to respond to the enormous challenges in the coming decades. Adaptation action has grown in urban areas and settlements around the world. However, for governance scholars, there is a fear that adaptation actions have not always been translated into clear outcomes on the ground and more recent work has focused on the evaluation of adaptation actions (Reckien et al., 2015; Uittenbroek, 2016; Woodruff and Stults, 2016) (high confidence, high agreement) (see also section 6.4.7). A common determinant of successful adaptation actions is the inclusion of indigenous or local knowledge. Approaches to integrate knowledge range from the extractive, where knowledge is included to enable planning outcomes, for example by providing higher resolution understanding of land-use cover in urban settlements as part of flood risk management; to participatory, where local stakeholders are included in identify key risks and proposing resilience strategies. Box 6.3 provides a closer assessment of indigenous and local knowledge in adaptation decision-making.

[START BOX 6.3 HERE]

Box 6.3: Mobilising Indigenous Knowledge and Local Knowledge in Cities and Settlements

The population of urban indigenous people is increasing in developed regions such as Canada (Statistics Canada, 2016), the US (Norris et al., 2010), Latin America and the Caribbean (The World Bank, 2015) and India (Government of India, 2011). Indigenous populations may be particularly vulnerable to climate risks in relation to other sectors of the urban population because they may be disjointed from their livelihoods and they may be exposed to structural drivers of vulnerability including poverty, segregation and unequal access to basic services. These conditions may also hinder their adaptive capacity in urban areas.

The Indigenous/local knowledge (IK/LK) held by indigenous communities in urban areas is a practical resource for informing climate resilient pathways for sustainable urban development. IK/LK helps in impact detection and evaluation in urban areas. For instance, IK/LK helps identifying climate variability (Codjoe et al., 2014). Recent studies document the rapidly expanding role and relevance of IK/LK in weather forecasting in urban areas (Ebhuoma and Simatele, 2019; Magee et al., 2016), climate change adaptation in urban agriculture (Solomon et al., 2016; Wahab and Popoola, 2018), urban food security (Simatele and Simatele, 2015), planning and managing urban solid waste (Kosoe et al., 2019), urban flood management (Hooli, 2016; Jameson and Baud, 2016; Thorn et al., 2015), drought perception and coping strategies (Saboohi et al., 2019), and ecological restoration and urban commons management (Nagendra, 2016; Nagendra and Mundoli, 2019). Thus, IK/LK is a useful source of information to build scientific understanding about climate change impacts, vulnerability and adaptation in urban areas.

IK/LK has an important role to play in urban planning and management. For example, IK/LK helps to define baselines of past changes both in climate and ecological terms, for example from indigenous place names in places where historical records are lacking and recording names and characteristics of natural phenomenon (see Businger et al., 2018 for a review of Hurricane history in Hawaiian newspapers; also Wickman, 2018). Through inter-generational cumulative experience and oral narratives, locational histories and cultural practices, IK/LK can provide a historical perspective on changes in urban commons such as lakes and trees (Nagendra, 2016) as well as past climatic changes or climate baselines (Ajayi and Mafongoya, 2017) and Shifting Baseline Syndrome (Fernández-Llamazares et al., 2015; Soga and Gaston, 2018).

Recent evidence confirms the role of IK/LK and practices in management of climate risks through early warning preparedness and response. These practices are particularly important where alternative early warning methods are absent. For instance, Kasei, Joshua and Benefor (2019) show that IK gathered through observations on changes in natural indicators (such as links between rainfall patterns, certain flora and fauna, and temperature changes) could be applied to develop early warning of climate hazards (floods and droughts) in informal urban settlements in African countries like Ghana. Similarly, Hiwaski, Luna and Marcal (2015) show that observations of changes in the environment and celestial bodies are used to predict climate-related hazards in Indonesia, the Philippines and Timor-Leste where communities in turn use local materials and methods, and customary practices to respond to the impacts of climate change.
Climate change-related loss and damage that are intangible require more caution in assessment processes (Andrei et al., 2015; Barnett et al., 2016; Roberts and Pelling, 2018; Thomas and Benjamin, 2018).

Incorporating IK/LK can help in generating more people-oriented and place-specific scenarios leading to developing adaptation policies that fosters identity, dignity, self-determination, and better collective decision-making/capacity to act (McShane, 2017; Preston, 2017).

Traditional ecological knowledge is found to shape indigenous perceptions about climate change (see Pyhälä et al., 2016 for a review). Local perceptions about climate change in turn shape adaptation behaviour of the community (Larcom et al., 2019; Lee et al., 2015). Therefore, addressing the loss of traditional/local environmental knowledge is important in order to devise community appropriate climate adaptation response (Fernández-Llamazares et al., 2015).

The contributions of IK/LK to resilience through sustainable development strategies and choices, especially where communities can apply their traditional knowledge to their new urban situation such as through modern mass media and technology, need more attention. IK/LK when combined with modern digital technology can be effectively used for mapping biodiversity as shown by the success of the tool called Leafsnap in the US (Kress et al., 2018). While utilising IK/LK alongside modern Artificial Intelligence techniques offer an effective tool to improve drought forecasting and prediction (Akanbi and Masinde, 2018), the incorporation of IK/LK into a drought prediction tool was found to improve the tool's resilience and relevance to the countries in sub-Saharan Africa (Masinde, 2015). Evidence also show relevance and successful incorporation of IK/LK into entrepreneurial projects. The aboriginal-owned and operated social enterprise called Indigital, based in the Kakadu World Heritage Area in Australia, uses digital technology to record sacred sites, knowledge and stories thus contributing both to heritage conservation and job creation in the digital economy (Cooper et al., 2019). IK/LK's potential for innovation and creative economies in urban and peri-urban areas should be further explored and encouraged (see Choy et al., 2016; Thorn et al., 2015).

Indigenous people are mobilising against the use of their land for extractive purposes (Jacqueline-Andersen, 2018). Including IK/LK can help to disrupt historical path-dependency and address indigenous dispossession, historical inequities and marginalisation of indigenous values in adaptation policy (see Maldonado et al., 2016; Orlove et al., 2014; Parsons et al., 2019; Pearce et al., 2015). Inclusion of IK/LK can enable energy justice by addressing the poor siting of power infrastructure, fuel poverty, and pollution and livelihood impacts on marginalised communities (see Jenkins et al., 2016 for a review). Mobilisation of IK/LK can help in taking decisions that better support ecosystems while also directly involving indigenous communities and local institutions in the decision-making as seen in case of the Sami people of Finnmark and wind farms (McCauley et al., 2015).

Given that indigenous and non-indigenous worlds are intertwined (Gombay and Palomino-Schalscha, 2018), incorporating IK/LK can help identifying the values and cultural practices that shape perceptions of nature and justice in indigenous communities (Necefer et al., 2015; Reid et al., 2014) thus challenging the dominant knowledges/ideas and strengthening environmental stewardship.

IK/LK can help in identifying actions that can ensure effective institutions, strategies and choices for risk management. IK/LK can be included in climate adaptations in urban areas through the process of facilitation. This includes mobilising community to participate both cognitively and physically in adaption activities such as through co-production of knowledge (Marfai et al., 2015); developing integrated observing systems such as community based observation networks (Alessa et al 2015), integrating ecosystem based adaptation strategies in institutional structures (Nalau et al., 2018), using Multiple Evidence Based Approach for integrating IK/LK and scientific knowledges into decision making (Tengö et al., 2014), and adopting forms of governance that centre stage indigenous people in decision making (Horn, 2018) while also providing socio-economic benefits. For instance, Indigenous land management approaches and governance can involve local people in ecological restoration, cultural heritage conservation, and income generation from sustainable enterprises as seen in case of peri-urban landscapes of Australia (Wilson et al., 2018). Incorporating IK/LK for integrated socio-ecological assessments to facilitate climate-induced community relocation and adaptive governance strategies is necessary to foster adaptation and resilience in context of both urban and peri-urban relocations (Bronen, 2015).

It is important to identify and address barriers to incorporation of IK/LK such as environmental injustice, dominance of scientific knowledge, oppression and/or racism and fragmentation of IK/LK including gender and generational divides (see Burke and Heynen, 2014; Kelly, 2019; Lövbrand et al., 2015; Victor, 2015;

Whyte, 2017). Although IK/LK is increasingly seen as a valuable resource for environmental assessment and sustainable development (see Reyes-García et al., 2016 for a review), most studies focus on rural areas. There is a need for context-based studies on the potential of IK/LK to shape climate resilient pathways in urban areas that are affordable, participatory and sustainable.

[END BOX 6.3 HERE]

Adaptation action remains focused on institutional change and reform, which limits attention to the more practical aspects of delivering adaptation on the ground (medium confidence, high agreement). For example, we have reviewed 140 published cases of urban adaptation published in recent years, and 68% of them focused on different processes of governance and institutional reform. There were two types of institutional reform proposed in this sample of cases. On the one hand, about half of the cases focused on institutional reform focus on a single actor that can provide leadership within the specific urban area. Analysis commonly focused on the reform of local governments (Di Giulio et al., 2018; Koch, 2018; Pasquini et al., 2015; Roberts and O'Donoghue, 2013). On the other hand, there is a set of studies that focuses on establishing linkages between multiple organizations that can deliver action, through processes of coordination. This idea is commonly linked to work inspired by theoretical analysis of multi-level governance (Barton, 2013; Jaglin, 2013; Reed et al., 2015; Restemeyer et al., 2017).

For example, in terms of examining the reform of a single actor, Pasquini et al (2015) document a case of two municipalities in Cape Town, South Africa, explaining the factors that enabled action at the local government level. The authors place high confidence and agreement on the fact that there were environmental champions at the political leadership level who drove the agenda of urban adaptation. Success was equivalent to mainstreaming adaptation, which in this case required access to a knowledge base, resources at hand, political stability and the presence of dense social networks.

Mainstreaming and aligning adaptation objectives with other potential benefits of sustainable development is a crucial aspect enabling action at the local level (High confidence, high agreement). For example, in Ethiopia, Ogato et al (2017) evaluated the needs for mainstreaming climate change adaptation into urban land use planning and management. They projected tactical activities in Ambo town that faces climate related disaster risks such as urban flooding, water stress, and water shortages, increased urban heat, wind and dust storms. There were, however, some limitations related to the extent to which the town administration had succeeded in mainstreaming climate change adaptation into urban planning and management.

Linking adaptation action aspirations with resources is another concern in this literature, that joins insights from political economy to understand how adaptation to climate change is budgeted and financed. For example, Lee and Kim (2018) examined adaptation in six metropolitan cities in South Korea. The authors compared the adaptation plans and budget expenditures of six metropolitan cities in South Korea between 2012–2016. The outcomes showed that the actual implementation of adaptation programs diverged substantially from the original plans, both in terms of total spending and sector-specific spending. Infrastructure development, water management, and health sector expenditures for disaster risk reduction topped the adaptation priorities. Overall the actual spending on climate change adaptation programs was less than the planned budget. The adaption options prioritized also differed by cities depending on city-specific issues and challenges. Chu (2016b) notes that climate change is progressively posing risks to infrastructure and public services in human settlements in South Asia. Studying six climate change adaptation experiments across the cities of Surat, Indore, and Bhubaneswar in India, the author exposes the politics behind how experiments are considered, implemented, and reinforced considering local development needs. He shows that policy experiments are often framed around achieving tangible urban economic benefits and maximizing specific project complementarities, which allow emerging adaptation priorities access to established policy directives and funding streams. The urban political-economic context shapes directly the results of actions (high confidence, high agreement).

Studies that emphasise institutional coordination across levels of governance often focus on how national governments can promote action at local level. The support of the national government is crucial for effective action at the local level (medium confidence, high agreement). For example, Araos et al (2017) document the case of Dhaka which faces the risks of extreme heat and flooding. The national level plan for Bangladesh projected several adaptation approaches. However, in the list of priorities, urban areas are secondary compared to coastal protection and protecting the agricultural production system that support the livelihoods of millions of impoverished Bangladeshis. The local government has minimal human and financial resources which hinders coordination amongst different stakeholders. Lack of transparency also constitutes a barrier in planning for adaptation at the municipal level. Adaptation policy is dictated from the top with little opportunity to engage multiple stakeholders. The authors provide medium agreement and confidence on the trickling effect of national urban adaptation directives to municipal governments if appropriated coordination mechanisms are in place, but examples from elsewhere suggest that national policy alone is not sufficient to deliver action on the ground without local support.

While there is a small subset of adaptation cases that focus explicitly on how to deliver interventions which are specific to urban environments, geographically located case studies of interventions with a particular objective to intervene in urban environments are still rare (high confidence, high agreement). In urban settings, three key objectives are the most common:

1. addressing urban poverty and inequality to address the structural drivers of vulnerability, through incremental infrastructure, slum upgrading and community-based adaptation (Ahmed et al., 2018; Anguelovski et al., 2016; Chu et al., 2017; Kumar, 2013; Rumbach, 2017);
2. redefining socio-ecological relations, with a particular emphasis on developing governance for ecosystem services (Cloutier et al., 2018; e Sousa and Ríos-Touma, 2018; Mabon and Shih, 2018);
3. matching adaptation with ongoing programmes for urban development tied to the business community or urban regeneration programmes (Heath et al., 2012; Huang-Lachmann et al., 2018; Huang-Lachmann and Lovett, 2016; Lund, 2018).

There are many examples of community-based responses to climate impacts, often discussed under the label of 'coping' strategies, which result predominantly in incremental improvements. Hambati and Yengoh (2018), for example, have documented coping responses of communities residing on the disaster-prone steep slopes of Mwanza, Tanzania. In response to multiple forms of disaster (floods, flash floods, landslides, and storms), residents have adopted a variety of strategies to reduce impacts. Strategies include construction of physical protection against flooding, through reforestation, construction of terraces, flood diversion measures, and interventions to protect houses (such as raised doorstep or use of sandbags and adoption of building techniques for making homes resilient to storms and landslides). Non-structural strategies include seasonal migration to the highlands. As argued by Hambati and Yengoh, this form of responses provides some protection against the impact of disasters but fail to address underlying structural causes of vulnerability. Other studies of community-based adaptation have pointed towards the need to link local responses to broader systems of governance, for example to address transboundary issues (Limthongsakul et al., 2017), to support the up-scaling of local solutions (Danière et al., 2016), to increase the uptake of adaptation measures (Liang et al., 2017), or to inform the design of more effective policies for resilience (Berquist et al., 2015; Odemerho, 2015).

Zölch et al (2018) present the case of Germany where the use of ecosystem services and biodiversity to help people adapt to climate change is increasingly considered as an alternative, compared to traditional, engineering-based approaches. The authors investigate the implementation of urban ecosystem-based adaptation in strategic adaptation planning in all German municipalities with population over 100,000. They investigated the integration of ecosystem-based adaptation into municipal adaptation strategies. Their study shows that there is no widespread uptake of ecosystem services principles in urban planning. While current strategies differ expressively in their type, structure, scope, maturity, and content, conservation objectives remain implicit. 76% of the assessed strategies include ecosystem-based adaptation measures, which focus on enhancing the conservation, restoration, creation or sustainable management of ecosystems, and 25% of all strategies highlight the multiple benefits of these measures. Better policy support and mainstreaming of ecosystem-based adaptation will improve sustainable urban development (high confidence, high agreement) (see also section 6.3).

Huang-Lachmann and Lovett (2016) provide examples of climate protection action that relies on urban development and entrepreneurship. Making a comparison between the climate strategies of Hamburg and Rotterdam, the authors find that local authorities in Hamburg emphasize climate proofing through regulatory mechanisms, whereas Rotterdam has provided an institutional environment that favors eco-innovation. In Rotterdam, the municipal government has worked directly with the private sector to enhance protection against flooding, for example by constructing a marketing strategy around the 'floating city' concept. This approach has, according to their evidence, contributed to the expansion of a 'floating housing' market in the urban area, which has produced benefits for the local real estate and construction industries and at the same time opened up for export opportunities for businesses providing consultation expertise, delta technologies, and architectural models. Rotterdam represents an example of an urban development strategy in which climate risk (in the form of flooding) is converted into a set of opportunities for economic growth and innovation. However, despite the enthusiasm for the green economy, such opportunities are rare and, although not adaptation actions require investment, substantial public investment is often required to deliver adaptation actions (high confidence, high agreement) (see also section 6.4.7 on finance and insurance).

These assessments do not give us a blueprint for institutional governance. Instead, they point out what could be done to improve governance for better adaptation. The urban adaptation literature has focused on institutional approaches. This work highlights the importance of bottom-up planning (high confidence, high agreement), mainstreaming adaptation in land use planning (high confidence, high agreement), the operation of environment champions as political workers (high confidence, high agreement), the need for explicit support for adaptation influencing fund expenditure, the potential of multi-institutional coordination, and the support that it is still needed for the development of policy and frameworks (high confidence, high agreement). Different models of governance emerge, as explained below.

6.4.3 What Does it Mean to Deliver Adaptation Action which is Transformative?

There is increasingly agreement that what constitutes 'urgent' and 'far-reaching' transformation depends both on the aspirations and opportunities for change within settlements and local community expectations and ideas (Choko et al., 2019). There is no one transformative solution or approach just as there is no consensus in the literature around a shared idea that settlements, cities and urban areas can be reduced to an administrative unit (Chu et al., 2018; Goh, 2019; Shi, 2019). There is also a consensus against representations of cities that reduce settlements to a homogeneous, single actors whose perspectives are exemplified in the figure of the city Mayor (Gordon and Acuto, 2015). Instead, there is an increasing trend towards the development of perspectives that acknowledge the inherent complexity of human settlements, and how they develop from the coevolution between socio-economic, political, technological and ecological systems.

Adaptation and related concepts of urban climate resilience emerge as specific concerns within a broader, ever-expanding agenda of sustainable development (Wachsmuth et al., 2016). Urban areas can play a positive role in advancing sustainability (Barnett and Parnell, 2016) (Medium evidence, high agreement). Urbanisation as a transformative force can contribute to both climate change adaptation and mitigation (Parnell, 2016) (median evidence, high agreement). The potential for urban communities to drive change is noted in the New Urban Agenda. New literature is emerging about how these adaptive changes at the urban level could be transformative, integrating both far reaching rapid emission reduction and community protection (Rosenzweig and Solecki, 2018; Wamsler and Raggers, 2018; Ziervogel, 2019a). What is transformative in an adaptation context is still under discussion.

Simultaneously, there is an increasing critique about the overall simplification of urban centres given the diversity of settlements but also, in light of the complexity of urbanization processes (Angelo and Wachsmuth, 2015). Moreover, there is an increasing consensus about the need to examine the governance of urban areas within broader regions, so that urban transformations happen hand in hand with more general processes of transition towards more sustainable societies and regions (Simon, 2016).

Table 6.5: Transformative change ideals depending on the view of the city. Own elaboration based on (Frantzeskaki et al., 2017).

Perspectives on settlements	Transition processes	Pathways	Strategies
As a system	Activation of specific elements enables the	Alignment of different components and coordination of outcomes	Foster coordination, orchestration

	complete reconfiguration of the system		
As a process	Competing ideas of change involved in a political struggle for the definition of outcomes	Multiple trajectories interact with uncertain outcomes	Open up pathways, disruptive innovations

6.4.3.1 *Systems Perspective on Urban Areas and Human Settlements*

The systems perspective on human settlements emphasize the interconnections across technological, social and ecological domains (McPhearson et al., 2016a). Generally, changes in urban systems are thought as happening alongside two separate domains: a socio-technical domain, and a socio-ecological domain.

6.4.3.1.1 Socio-technical vs. socio-ecological

The scholarship on socio-technical systems emphasise the coupling of certain forms of institutional and social organisation with the integration of specific technologies within that particular system (Bergek et al., 2015; Bulkeley et al., 2016; Bulkeley et al., 2014b; Frantzeskaki et al., 2017; Hansen and Coenen, 2015; Rutherford and Coutard, 2014). Socio-ecological perspectives on urban change examine the coupling of socio-economic systems and ecosystems, and the direct dependence of different forms of human organisation from natural resources (Grimm et al., 2013; Haberl et al., 2014; Jepsen et al., 2015; Singh et al., 2012).

There have been, however, increasing efforts to rethink across these two perspectives, integrating both aspects of socio-ecological and socio-technological change (Cousins and Newell, 2015; Guibrunet et al., 2017; Newell and Cousins, 2015). The interdependence between technological and ecological systems underpinning urban society comes to the fore, particularly, when discussing achieving urban resilience (Boyd and Juhola, 2015; Meerow et al., 2016).

6.4.3.1.2 The possibility of urban transformations

The change of focus in literature towards the interlocking of drivers of change and vulnerability has motivated an interest in fostering an urban transformation. However, while the idea of transformation has been adopted across the field, there is not consensus about what an urban transformation that addresses adaptation means (high confidence, high agreement).

For example, Restemeyer's et al (2017) study the Delta Programme in the Netherlands to argue that the major transformation requires changing an anthropocentric worldview, and let go of fantasies of control to learn to leave with socio-ecological risks. Those illusions of control are the ones that create lock-in. The focus here of the transformation is the change of management paradigm.

This kind of perspective resonates with other emerging approaches to transformation influenced by systems thinking and the work of environmental philosophers such as Donella Meadows, who saw higher order learning and innovation as the critical route towards resilience (a chief example of this is Fink (2019). Reed et al (2015), for example, advocate greater citizen engagement as a means to facilitate policy objectives such as the implementation of specific measures or the mainstreaming of environmental knowledge into adaptation practices. Similarly, Cloutier et al (2018) advocate a process of DIY planning in which stakeholders focus on creating and improving specific urban spaces they inhabit, such as it happens with urban greening experiments led by civic stakeholders. Daniere et al (2016), for example, examine the cases of Hanoi and Bangkok to explore the transformative potential of social learning through the activism and possibilities of collaboration of informal settlement dwellers. Chu (2018b) argues particularly for local governments to play an active role in bringing the citizen's knowledge into the adaptation process. The classic text by Dodman (2010) already argued that knowledge and most crucially learning at the level of the community and the citizen was central to deliver adaptation. In many ways, the recognition of the importance of local knowledge becomes supported by the evidence of material experiences of housing and urban infrastructure including improper waste disposal, inadequate drainage, and poor sanitation (Douglas et al., 2018; Roy et al., 2018b).

In contrast, other approaches in literature, for example, Duijn & van Buuren (2017) focus on transformation at the institutional level. This resonates with critiques of adaptation or risk reduction as an individual responsibility (Sou, 2018). Here, the focus of adaptive transformations is on the coordination of collective efforts ((Haque et al., 2014), see also section below). The coordination of multiple actors is a condition to enable transformative institutions (Torabi et al., 2018). Transformation is also linked to development efforts (Chu et al., 2017; Roberts and O'Donoghue, 2013). The role of communities and citizens in such approach is ambiguous. For example, Limthongsakul et al (2017) regard citizen-led experimentation as autonomous adaptation that substitutes for lack of action which causes additional risk, and hence, transformation requires recognising this adaptation and regulate it. Daniere et al (2016) in contrast argued that citizens and communities, such as those in informal settlements, form strong and durable networks that ultimately provide an institutional setting that can support resilience.

Rojas et al (2015) also focus on institutions and their role in urbanization to produce and regulate risks, but they take a historical approach to think how different institutional arrangements substitute each other to respond to the demands of the context. In this sense, transformation is often linked with the emergence of new paradigms of risk and resource management which link the theme of institutional development back to the production of knowledge. Part of this change of paradigm involves the reconfiguration of socio-ecological relations through new engagements with nature and green infrastructure (Roberts et al., 2012). Often, indigenous and traditional traditions of nature management provide entry points for the sustainable management of resources, such as seed banks, urban agriculture and the local management of watersheds and floods which is at odds with conventional structures of expert knowledge (Chandra and Gaganis, 2016; Cid-Aguayo, 2016). These traditions are vital both because of the solution space that they open in the local context but also because how they serve to create resilience through collective and intergenerational learning (Chandra and Gaganis, 2016). Using the case of a neglected neighbourhood in Mexico City, Chelleri (2015) shows that transformation is intimately linked with both institutional development for the integration of citizens in decision making and recognition of citizens' knowledge. Despite the political nature of transformative approaches and the evidence that transformative approaches rely on protest and political activism, few authors recognise this strategy (but see (Bahadur and Tanner, 2014; Chu et al., 2017; Dierwechter and Wessells, 2013; Merlinsky, 2016).

6.4.3.1.3 From adaptive to transformative capacity

In any case, the integration of systems perspectives poses significant governance challenges because of the focus on realigning interlinked environmental, social and economic relations (Simon and Leck, 2015). Thus, considerable effort has gone in recent years to deliver system-based paradigms to understand transformative change, which has been translated into specific recommendations for institutional and governance interventions.

The idea of transformative capacity has emerged like a new set of ideas responding directly to previous concerns about adaptive capacity. Adaptive capacity is narrowly understood as the system's capacity to change to fit the new conditions in a changing external environment. However, in the current situation, the adaptation challenge is not one of merely adapting, but rather, a transformation is needed to address current impacts (Matyas and Pelling, 2015; Pelling, 2010). Transformation is a form of adaptation, but one that challenges the principles in which a society is established (Pelling et al., 2015).

From a systems perspective, a transformation will mean a broader reconfiguration of multiple interconnected systems. Because of the need to accept complexity and uncertainty as inherent parts of that transformation, some of the literature has focused on how to make that transformation possible, rather than envisage ready-made linear avenues towards urban transformations. The response to the peer reviewed literature on adaptive capacity has been the term of 'transformative capacity' that aims to examine the capacity of a system to respond to external changing conditions in a manner that transforms the system towards a more sustainable state (Ziervogel et al., 2016).

6.4.3.1.4 Components of transformative capacity

Wolfram (2016) identifies a set of components of transformative capacity in urban areas that can be loosely grouped into three categories (see Table 6.6): (1) agency and forms of interaction, (2) development processes and (3) relational dimensions. Transformative capacity extends across multiple agency levels or geographical locations, as well as multiple domains. The idea of transformative capacity follows both the socio-ecological transitions and socio-technical transitions literature to argue that reflective and iterative learning is integral to fostering transformative capacity (c.f. Luederitz et al., 2017). The proposal is to consider the development and application of novel governance arrangements based on broad participation, a diversity of actor networks, socially embedded leadership, and empowerment of communities, alongside an understanding of the system dynamics, which refers to system awareness, collective visions, practical experimentation, reflexivity, capacity building, and institutional mainstreaming, and the multiple levels of agency or scales which enable processes of transformation.

Table 6.6: Criteria for transformative governance (Wolfram, 2016).

Components of transformative governance	Satisfied when evidence (i.e. explicit references to) found for…
Inclusive, multiform urban governance (C1) Participation / inclusiveness (C1.1)	Citizens and/or civil society organizations participating directly in planning and/or decision-making processes.
Diverse governance modes / Networks (C1.2)	Different and various stakeholders working together and building connections between sectors in different manners.
Sustained intermediaries and hybridization (C1.3)	An intermediary positioned between the stakeholders of a project.
Transformative leadership (C2)	Leadership acting as a driving collaborative force in an initiative.
Empowered communities (C3) **Social needs (C3.1)**	Either analysing or addressing social needs.
Autonomous communities (C3.2)	Integrating into the design of the project different aspects of community empowerment.
System awareness (C4) Baseline analysis and system(s) awareness (C4.1)	Agendas aiming to tackle sustainability challenges after deliberate analysis of urban systems.
Recognition of path dependencies (C4.2)	Explicitly tackling systemic barriers to change.
Foresight (C5) Co-production of knowledge (C5.1)	Involvement of various and multiple stakeholders in knowledge production processes.
Collective vision for change (C5.2)	An explicit future vision shared among stakeholders as a means for motivating partners and fostering commitments.
Alternative scenarios, future pathways (C5.3)	Comparative scenarios that evaluate the mutual shaping of social, ecological, economic and technological dimensions.
Experimentation with disruptive solutions (C6)	Deliberate use of experiments or ideas that seek to challenge the existing landscape of established policies, technologies or social practices.
Innovation embedding (C7) Resources for capacity development (C7.1)	Project stakeholders sharing resources for capacity development outside the project to disseminate and multiply results.
Mainstreaming transformative action (C7.2)	Attempts to generalise the project operation or results beyond the initial context of application.
Regulatory frameworks (C7.3)	New regulation was established as a result of the project or as part of the project activities.
Reflexivity and social learning (C8)	Stakeholders reflecting on learning and capacity building processes.
Working across human agency levels (C9)	Project activities contributing to capacity development across human agency levels.
Working across levels and scales (C10)	Project activities contributing to building capacity across geographical or political-administrative levels.

While multiple aspects of this framework are already part of adaptation assessments, there is a strong need to invest on governance mechanisms that facilitate the empowerment of communities, reflexivity and social learning (Castán Broto et al., 2018). Thus, the transformative capacity framework emphasizes that alongside different forms of technical expertise there is a need to broaden the interventions of disadvantaged populations (Wolfram et al., 2019) . For example, transformative capacity frameworks may foster forms of inclusive governance to deliver types of risks assessment that work for the poor in countries such as South

Africa (Ziervogel, 2019a). Another feature has been claiming the growing importance of including sectors of the population which have been traditionally excluded of climate change governance, such as children, but this requires adapting current planning institutions in most of the world (Nordström and Wales, 2019).

6.4.3.1.5 Summary of the systems perspective

Overall, transformations within a systems perspective respond to the perceived need to forge alignments between different systems. Both socio-ecological and socio-technical perspectives theorize the possibility of tipping points, leverage points or disruptive technologies able to challenge the stable regime to create a broader reconfiguration (O'Neill et al., 2018). Developing climate resilient pathways is about finding out those intervention points and create the openings for transformative capacities that can take advantage of those.

6.4.3.2 Socio-political Processes Obscured in Systems Perspectives

However, planners and urban theorists often find themselves uncomfortable with systems perspectives because they tend to emphasize bio-physical connections over the structural systems of social and political relations that shape urban systems (Westman et al., 2019).

Perspectives on the political economy of urban transformations, as well as in the field of urban political ecology conceive of the city as a process in which diverse elements are maintained in circulation to sustain hegemonic systems (Bulkeley et al., 2014b; Edwards and Bulkeley, 2017; Ernstson and Swyngedouw, 2018; Keil and Macdonald, 2016; Silver, 2017). The central question about urban transformation in those perspectives is urban transformation for whom, and at what price. However, the same literature regards urban transformation as an opportunity to address simultaneously the unfairness inherent to socio-ecological relations (which technologies and infrastructures mediate).

New literature in urban governance is increasingly concerned with a different understanding of pathways for transformation and adaptive planning. A trajectory can be thought of as a linear route for urban change, from state A to state B, accelerated with the application of a certain policy. However, numerous trajectories can interact and open up the opportunity of different urban futures (Castán Broto, 2017a). All these different trajectories can be aggregated in climate resilient pathways, in which different imaginations of the city, or the settlement, exist sometimes questioning each other and closing down alternative destinations (Hodson et al., 2015; Rydin et al., 2013). Pathways open up the possibility of having alternative courses of action within a given city, recognizing the incommensurable values that shape sustainability policy (e.g. Marletto, 2014; O'Neill et al., 2015; Rydin et al., 2012; Turnheim et al., 2015). As a result, the conceptualization of settlements and cities as processes, subject to ongoing negotiation and political struggle (Rutherford and Coutard, 2014) provides a very different perspective of change and one in which the competition between different narratives of change within a single pathway is central to shaping the transformation outcomes. Here, the emphasis is not on alignment but contrast, and the question is not where the points of intervention are, but rather, how to create disruptions of the hegemonic regime.

The systems and process perspectives are not incompatible, but their different emphasis results in different conceptualizations of change in urban areas, which has implications for the kind of actions that can take place to bring about climate resilience pathways.

6.4.4 What Does Political and Societal Will for Change Look Like?

6.4.4.1 Multiple Actors Deliver Effective Adaptation Actions

There is a wide range of actors, public and private, within civil society and community groups, who can deliver adaptation actions (high confidence, high agreement). Association between actors may enable impacts across different locations and scales. However, their interventions are uneven. In our review of 140 cases of adaptation, we found that the local government maintains a prominent role leading adaptation at the local scale. Like in previous assessments (e.g. Castan Broto and Bulkeley, 2013), more than half of cases reviewed were led by local governments (although local government is also a heterogeneous category and local governance arrangements vary across administrative and political context. This reflects an enduring focus on government authorities as a key source of responsibility in local adaptation action (see also section

6.4.3). The second largest category consists of articles that explicitly emphasize the need for multiple actors to engage in local adaptation strategies, through collaborative processes of planning, learning, experimentation, capacity building, construction of coalitions and channels for communication (see also section 6.4.3). Many of these studies directly focus on institutional arrangements that facilitate these forms of interaction between communities, experts, government representatives, firms and international organizations. The third category consists of research uses community-based action as a main frame of reference. Some of these neighbourhood-based level cases also include studies that address individual or household-driven action or measures led by civil society organizations with a strong community-connection (see also section 6.4.3).

Ostensibly missing from the peer-reviewed literature is research with a primary focus on the private sector, reflecting a wider shortcoming in urban adaptation, where the private sector appears to play a limited role (Biagini and Miller, 2013; Linnenluecke et al., 2013; Pauw and Pegels, 2013; Surminski, 2013). On the one hand, businesses have an essential role to play in adaptation actions, both through self-regulation or through the provision of critical adaptive interventions (High confidence, high agreement). For example, consultancy firms are identified as one form of business engaged in collaborative adaptation planning (Bahadur and Tanner, 2014), businesses can provide new or rehabilitate existing green infrastructure (Kithiia and Dowling, 2010), and utility companies can work in partnerships to provide flooding protection (Lund, 2018) or resilient services for the urban poor (Heath et al., 2012). There is an emerging interest in strategies to secure private sector inputs into urban adaptation programs (Hardoy and Ruete, 2013), the shifting boundaries between state and market in creating and implementing climate strategies (Hodson et al., 2013; Klein and Juhola, 2018; Mees, 2017), as well as obstacles associated with reconciling private sector interests in local climate programs (Anguelovski et al., 2016; Jaglin, 2013; Rumbach, 2017; Scoppetta, 2016). Frantzeskaki et al (2014) report a port relocation project in Netherlands where sustainability principles drove private sector participation. There are also public private partnership models for the development of infrastructure in adaptation, although the model is in decline (Harman et al., 2015). Klein et al (2017) cite examples from two cities - Helsinki and Copenhagen - where local authorities have shifted few adaptation responsibilities to private actors through regulations and public problem ownership. The case shows that local authorities decide where the private sector and citizens are required to take responsibilities and create policy and regulative environments which forces private sectors to participate.

On the other hand, there is an absence of research that addresses how businesses can play a leading role in urban adaptation. Overall, the private sector's participation in adaptation initiatives in urban areas are almost negligible (while the leading actor in more than 50 percent of the cases was local government) (see section 6.4.2). Another global assessment of role of private sector in urban adaptation using data from 402 cities conducted by Klein et al (2018) throws some light on this trend. The study reveals that for governing adaptation, regulation is not a very common approach. Most of the adaptation projects focus on the public sector and do not address private sector concerns or local people's participation. In the cases where they do, the private sector is more often governed through partnerships and participation. Also, the more advanced a city is, it is more likely that it would attract private sector investment. There are a few examples of private sector engagement in Europe, but even then, there is lack of evidence that private sector participation has been successful in other parts of the word (Pauw, 2015). This absence is particularly visible in developing countries that feature the fastest urban growth (Nagendra et al., 2018). Despite the calls for private sector participation there is weak evidence of involvement (Heurkens, 2016; Pauw, 2015). Further, the urban adaptation literature so far has not engaged with the heterogeneity of firm responses to climate impacts or the broader influence of business adaptation on the communities in which they operate (Linnenluecke and McKnight, 2017; McKnight and Linnenluecke, 2016). This oversight is especially problematic in light of the growing interest in sustainability-oriented business (Bocken et al., 2014; Schaltegger et al., 2016), which signals the ambition of embedding ecological principles in core business activities.

A range of transnational municipal networks (TMNs) also support and encourage cities and settlements in planning and implementing adaptation actions. Organisations such as 100 Resilient Cities have supported and ICLEI have developed protocols and implemented projects for member cities. These also encourage the sharing of information on appropriate practices between urban areas.

6.4.4.2 Conditions for Effective Urban Governance

Urban areas are new arenas for responding to climate change (Castán Broto, 2017b; Hölscher et al., 2019; Solecki et al., 2018) but governance options are constrained or enabled by access to adequate financing, the decision making of international insurers and support from national and international governance networks civil society and local and international business interests and employers. Emerging literature suggests that cities frequently face barriers of inadequate financing for climate adaptation and mitigation, but steering the finance raising process through strategic co-benefit schemes for mitigation and climate adaptation may offer new sources of revenue for urban planning (Cook and Chu, 2018).

What we have seen in the last years has been a growing range of actors intervening at multiple scales to deliver climate change adaptation and sustainable development actions (Chan et al., 2015b). However, as AR5 acknowledged, there is low confidence that these actions can result in an overall transformation, simply through their addition: what has been defined as the political action gap (Chan et al., 2015b). There has been an emphasis on coordination through the orchestration of multiple actions in climate change governance (Bäckstrand and Kuyper, 2017; Gordon and Johnson, 2017).

As explained above, few scholars would question that leadership is central to deliver governance systems able to bring cities into climate resilience pathways. Leadership is the one factor that repeatedly appears in empirical studies of climate change adaptation. However, there is less reflection on the multiple models of governance under which adaptation action emerges. Hence, under the buzzword of delivering, there is a wide range of institutional approaches for governance. The research in the AR5 showed that in a landscape of good intentions, effective systemic action was not visible. Thus, political and social will for transformation can take many forms (Figure 6.5). The following section discusses different styles of governance through which adaptation is delivered in terms of achieving outcomes, integrating and mainstreaming climate change action, facilitating orchestration, producing processes of coproduction, ensuring representation and justice, and the generation and visioning of resilient futures.

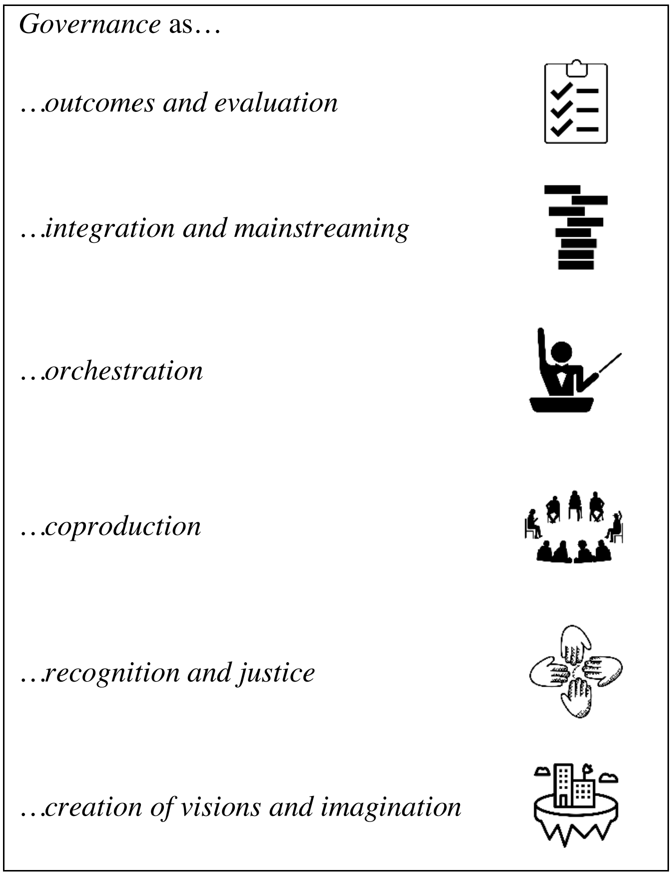


Figure 6.5: Multiple forms of urban governance for adaptation

6.4.4.2.1 Governance as outcomes and evaluation

There is an assumption that an adaptive response to climate change should be measurable. However, there have been extensive debates about the extent to which adaptation outcomes in cities are even measurable (Béné et al., 2018b). Visionary leadership should be one that achieves adaptation and resilience outcomes.

During the last years, there has been some debate about the problems of focusing on a set of measurable arenas. Environmental politics has long been shaped by a concern with the dominance of forms of eco-authoritarianism to the detriment of democratic and collaborative practices of environmental management. Technocratic perspectives on environmental policy are particularly relevant concerning the question of how local sustainability politics contribute to re-configurations of agency and power (Bulkeley, 2015a). In new policy areas, there is a need to create logics, or rationalities, for legitimate intervention, which may paradoxically lead to further reinforcing existing ones (Bulkeley et al., 2014b). The case of China, for example, has received praise in terms of delivering urban policies that put climate change at its core, thus suggesting its role providing leadership in climate change debates (Hilton et al., 2017). However, detailed analysis of case studies of sustainable development in China demonstrates that sustainability is achieved to the detriment of broader collaborative objectives, thus questioning the resilience of the whole enterprise (Westman and Broto, 2018).

The other challenge for outcomes-oriented forms of leadership is that it may tend to ignore areas of action in the city which may have an important role to play in improving resilience and enabling transformations. Urban development planning scholars argue that we cannot achieve such urban transformation without the incorporation of a highly gendered informal economy sector, from street vendors to waste collectors (Brown and McGranahan, 2016).

Informal settlements and informal economies that sector of the economy not monitored or taxed by formal institutions—are integral in managing urban resources for effective climate adaptation (Guibrunet and Castán Broto, 2016)(Limited evidence, High confidence).

6.4.4.2.2 Governance as integration and mainstreaming

Multiple forms of urban leadership are key to achieving transformative climate adaptation (medium evidence, high agreement). The majority of efforts have been directed towards aligning climate change outcomes with environmental and social co-benefits in urban areas (Aylett, 2014; Bain et al., 2016; Harlan and Ruddell, 2011). In the European Union, for example, there has been an effort to mainstream climate policy through 'climate policy integration' with measures take through the EU budget, but the beliefs that inform this are crucial to explaining this (Rietig, 2019). In this way, climate change policies have often followed experiences and prescriptions developed for sustainable cities which have not always been transformative (Hodson and Marvin, 2017).

Efforts to mainstreaming climate change in urban policy have often been seen as maintaining business-as-usual and not always aligned with transformative efforts to address climate change. For example, the focus on incremental actions is seen as an impediment for transformative innovation with critics arguing the approach is maintaining business-as-usual and not always aligned with transformative efforts to address climate change. (Aylett, 2014). Nevertheless, incremental actions for climate change mainstreaming constitute a first step towards a city-wide transformative strategy.

6.4.4.2.3 Governance as orchestration

It is now widely accepted that achieving the 1.5-degree objectives will require aligning sub-national and national-level action for a coordinated global response (Chan et al., 2015b). In this context, the UNFCCC has adopted a role as an orchestrator of a range of state and non-state actors to steer action in the right direction (Bäckstrand and Kuyper, 2017). Simultaneously, other actors have adopted a similar approach, whether this is at the local level of government or in other institutions such as disaster risks management institutes at the national or regional level, or network coordinators.

Multi-level governance remains an influential paradigm that recognizes the influence of government institutions operating at different scales, as well as diversification of actors from the private sector and civil society intervening in public issues. This paradigm has been integrated with the commitment to tackling fragmented and complex policy issues through collaboration between national governments and non-state actors, as explained in the 2030 Development Agenda, especially SDG17 ("Revitalize the global partnership for sustainable development"). A critique of the concept of multi-level governance in terms of its effectiveness across contexts and the transference of brunt of responsibility to less resourced local government is another element of debate.

6.4.4.2.4 Governance as coproduction

All forms of leadership outlined above focus on some form of communicative rationality, in line with the contemporary relevance of communicative approaches to decision-making in the environmental policy domain (McGranahan, 2015; Moretto and Ranzato, 2017). However, the last years have seen a trend towards considering coproduction as a center of the provision of urban services, particularly in terms of improving urban resilience. The concept of coproduction emerges from a concern with public management (Ostrom, 1996). Service coproduction follows the integration of multiple actors in the management and delivery of public services (Pestoff and Brandsen, 2013; Pestoff et al., 2013). In urban contexts, coproduction requires citizens and communities to actively participate in decisions that affect how their services are provided, working in partnership with the administrators, engineers, and managers who are traditionally responsible for those public services (Brandsen and Honingh, 2016).

There is high confidence that co-production is an effective tool to advance urban sustainability and social justice, which may be considered central to achieving the SDGs (Chowdhury et al., 2017; McGranahan, 2015; McGranahan and Mitlin, 2016; Moretto and Ranzato, 2017; Nastiti et al., 2017). These approaches have become increasingly central in responses to climate change alongside other bottom-up strategies (Vasconcelos et al., 2013). Note that in coproduction exercises there is a movement away from attempting to coordinate or orchestrate the actions of multiple actors, focusing instead on the possibility to produce, collaboratively, services that reduce the vulnerability of urban populations and increase their resilience.

Cooperative governance models provide insights for the design of forms of participatory and collaborative planning through which communities and state actors can identify concrete actions and available resources to improve services and mitigate structural vulnerabilities to disasters (Castán Broto et al., 2015b). Mitlin and McGranahan (2016) have studied paradigmatic examples of the co-production of sanitation services to show how co-production may improve outcomes while at the same time opening up avenues for grassroots organizations to claim political influence. Coproduction may provide the opportunity to change institutions in response to external interventions (Das, 2016). Although there are important risks in terms of the extent to which coproduction can be used to legitimize unfair interventions within a given context, coproduction may also be a tool for improving the accountability of dominant groups to vulnerable sectors of the population (Nastiti et al., 2017).

6.4.4.2.5 Governance as recognition and justice

Climate and energy justice theories draw on the experiences of the environmental justice movement (Bickerstaff, 2012; Bickerstaff et al., 2013; Hall et al., 2013; Perez et al., 2015). In this vein, they tend to reproduce the well-established 'three-legged' framework, which considers justice in terms of distribution, recognition and procedural justice (Fuller and McCauley, 2016; Jenkins et al., 2016; McCauley, 2018; McCauley et al., 2016). This framework highlights, straight away, the need for an explicit focus on who intervenes in the process of governance towards climate resilient pathways. However, there is less confidence in the direct application of justice-based frameworks to advance climate change adaptation policies (Fuller and McCauley, 2016).

Slogans such as 'leave no one behind' embedded in international urban policy recognize the connections between systems of oppression and exclusion that reproduce and perpetuate urban inequality and the delivery of urban services and security (Kabeer, 2016; Stuart and Woodroffe, 2016). Intersectionality theories examine the multiplicity and interconnected nature of such systems of oppression and exclusion (Grunenfelder and Schurr, 2015). In the context of climate change adaptation, intersectionality ties with the idea of how multiple deprivations shape access to services (from sanitation to health and education) and the exposition to environmental risks (Lau and Scales, 2016; Lievanos and Horne, 2017; Raza, 2017; Sicotte, 2014; Van Aelst and Holvoet, 2016; Yon and Nadimpalli, 2017).

For example, fisherwomen in the western coast of India rely on a complex arrangement of relationships around categories of class, caste, and gender that shapes their possibilities to draw political resources to maintain their livelihoods, and hence, influence the dynamics of transformation (Thara, 2016). Intersectionality is central to climate action (Khosla and Masaud, 2010; Reckien et al., 2017). It is a means to ensure that actions to build resilience provide an opportunity for broader social and political transformations. For example, including intersectionality deliberately in partnerships with communities can empower socially excluded groups and highlight issues of justice, while aligning agendas with local development priorities (Castán Broto et al., 2015a). Despite the high confidence on the growing importance of intersectionality concerns in the delivery of just environmental policies, there is limited evidence of its inclusion in adaptation policies.

6.4.4.2.6 Governance as the creation and imagination of alternative futures

The future of urban transformations does not lie on the possibility to deliver resilience outcomes, or the attempts at delivering resilience outcomes in fairer ways but rather, in the ability to imagine alternative urban futures (Glaas et al., 2018). For those scholars of climate change governance interested in experimental, voluntary approaches to climate change governance, the really attractive aspect of it is developing new and unexpected alternatives (Bulkeley et al., 2014b; Chan et al., 2015b). The diversity of collaborative arrangements for climate change experiments also suggests that climate policy diffusion is realized through a greater heterogeneity of channels than previously known (Mai and Francesch-Huidobro, 2015).

The experimentation paradigm has attracted widespread interest from scholars, policymakers and societal practitioners and it is driven by the awareness that current ways of organizing urban systems are unsustainable, and that novel and often radically different forms of social or technological innovation are required (Marvin et al., 2018). This focus on urban areas resonates with the sustainability transitions literature that seeks to understand and spur possibilities for achieving widespread change through various forms of experimentation and urban labs (Bulkeley et al., 2016; Nevens et al., 2013; Voytenko et al., 2016).

[START BOX 6.4 HERE]

Box 6.4: Resilience, Water Ecology, and Activism

In Bengaluru, India, communities have traditionally managed a network of water tanks of immense ecological importance. In the last half-century, however, urban development has increasingly threatened this blue network (Unnikrishnan and Nagendra, 2015). Bengaluru today depends on long-distance water transfers that create political conflict, and on a dense network of private boreholes that are depleting the city's water resources. Local scholars see the restoration of the existing community-managed network of water tanks as a more sustainable and socially just alternative for managing water resources. Citizens have turned towards different forms of activism to ensure the protection of water resources (Nagendra, 2016).

Unnikrishnan et al (2018) have documented how the colonial and postcolonial history of water management in Bangalore shapes the water infrastructure and systems of provision today. Water access inequalities can be traced to the patterns of spatial development developed by colonial policies. In Bangalore, records from the 6th century onwards show how city rulers invested in an interconnected, community-managed network of tanks and open wells, regularly recharged through harvested rainwater. The water system was changed at the end of the 18th century, as first the colonial state, then the post-independence government of Karnataka took responsibility for water management. Ideas of modernist planning influenced the development of new water infrastructure and piped networks, including the first piped infrastructure, bringing water from sources 30km away including the Hesarghatta and then the TG Halli reservoirs. The old network of tanks gradually deteriorated as tanks became disused, polluted or built over. Longer and more costly water transfers took place in the post-colonial period, delivering water from the Cauvery river in a massive engineering project with a high energetic cost and enmeshed in inter-state conflicts over the use of water. Scarcity is still a problem in Bangalore, whose inhabitants nevertheless see how the old tanks have not been transformed into inaccessible and polluted areas.

The citizen response has been an activist movement to reclaim the tanks for the city, accompanied with a plea to reconsider current water uses within the city. Unnikrishnan et al (2018) document different actions led by citizen- led collectives including projects for lake rejuvenation, filtering technologies to treat sewage, recovering the value of lakes through share of photos and art projects, and involvement of local knowledge in tank restoration. Those efforts suggest that there is an untapped potential to deliver adaptive green spaces through the recovery of Bangalore's tanks.

[END BOX 6.4 HERE].

6.4.5 What are the Institutions that Enable Far-reaching Change in Urban Areas?

As explained above, there is a strong focus on institutional development as a means to deliver governance through multi-level coordination, intermediaries, partnerships, stakeholder involvement, private sector roles, urban labs, community-based organizations and transnational networks of communities, other transnational networks. Section 4.4.1.1 of the 1.5 Special Report (Hoegh-Guldberg et al., 2018) noted that institutions can influence the viability of 1.5°C-consistent pathways. Specifically, institutions "would need to be strengthened… with the goal of ensuring that these embrace equity, justice, poverty alleviation and sustainable development…" (p.352). Recent scholarship reinforces the need to analyze interactions between institutional structures and relevant actors, particularly in the context of ensuring stability and flexibility in governance systems (Beunen et al., 2017). However, beyond a widespread acknowledgement that institutions 'matter', research into particular institutions and the drivers, processes, and outcomes of institutionalization at the local level remain broadly theoretical, although empirical investigations are emerging. Much of this research draws on seminal works on urban institutions and governance by Anguelovski and Carmin (2011), Aylett (2015), Carmin et al. (2015), and others.

Conceptually, Patterson, Voogt, and Sapiains (2019) note that there is no single model of the institutionalization of climate change into policy-making and planning at the local level, and ranges from dedicated (Uittenbroek et al., 2014), strategic (Chu et al., 2016; Storbjörk and Uggla, 2015), to comprehensive approaches. Institutionalization is often applied synonymously with 'mainstreaming,' which has long been explored in both theory and practice (Runhaar et al., 2018). For example, climate adaptation can potentially be mainstreamed into parallel agendas around community and economic development (Ayers et al., 2014), climate mitigation (Göpfert et al., 2019), spatial and infrastructure planning (Anguelovski et al., 2014), urban finance (Keenan et al., 2019; Musah-Surugu et al., 2018), public health (Araos et al., 2015), environmental management (Kabisch et al., 2016; Wamsler, 2015), multi-level decision-making (Ojea, 2015; Visseren-Hamakers, 2015), and others. Early assessments broadly categorized approaches to mainstreaming as integrating climate adaptation into long-range and sectoral plans (Anguelovski and Carmin, 2011; Aylett, 2015). A more recent assessment by Wamsler and Pauleit (2016) further disaggregated these substantive categories into programmatic, managerial, intra-/inter-organizational, regulatory, and directed forms of mainstreaming.

These various categories of mainstreaming adaptation in urban policy-making and planning rely on a nuanced understanding of how institutions change across and within the public sector, private actors, and civil society. Mainstreaming refers to the integration of climate adaptation into relevant institutional arrangements, actors, and agendas; therefore, as noted by Patterson, Voogt, and Sapiains (2019), such forms of institutional change should be understood as having input, procedural, and output components. A longitudinal view of institutional change and institutionalization allows for the assessment of actors and dynamics involved in integrating adaptation into the sectoral agendas or governance arrangements mentioned above. Further, this allows for a deeper analysis beyond 'visible' changes to policy-making and planning, to also consider whether or not rules-in-use have changed as well as the relationship to broader governance dilemmas that impose pressure on an urban governance system (Patterson and Huitema, 2019). However, institutional processes are complex, contested, and sporadic (Patterson et al., 2019) and are often inhibited by unclear planning mandates, conflicting development priorities, lack of leadership, and resource and capacity shortfalls (Anguelovski et al., 2014).

An input view of institutionalization focuses on the intrinsic capacities necessary to drive and incentivize change at the local level. Input indicators are often referred to political capacity/capital (Diederichs and Roberts, 2016; Rosenzweig and Solecki, 2018), existing or endogenous capacities (Moloney and Fünfgeld, 2015; Wamsler and Brink, 2014), or enablers and local drivers for adaptation (Dilling et al., 2017). A recent literature survey by Runhaar et al. (2018) showed that the most common drivers of institutionalizing adaptation include political commitment, cooperation with private actors, the presence of policy entrepreneurs, and availability of subsidies from higher levels of government which is on par with framing and linking to sectoral objectives. Research conducted across two municipalities in Western Cape, South Africa, showed the importance of a dedicated environmental champion, experience of historical climate impacts, as well as access to a knowledge base, the availability of resources, political stability, and the presence of dense social networks all positively affect adaptation mainstreaming (Pasquini et al., 2015). Research from In São Paulo, Brazil, showed how intrinsic political capacities and contextual factors – such as political ideology of elected officials – heavily shape the opportunities for embedding adaptation into ongoing urban agendas (Di Giulio et al., 2018).

A processual view of institutionalization describes and explains the production or constitution of adaptiveness in an urban governance setting (Patterson et al., 2019). This includes the production of networks, interactions, actor coalitions, and other underlying institutional procedures leading up to change. A study by Aylett (2015) noted the importance of internal networks between municipal departments, which meant informal channels of communication and cultivating personal contacts and trust between the person or team responsible for climate planning and staff within other local government agencies. Recent research from the United States highlight the importance of such internal networks (Hughes, 2015), where greater commitment by local elected officials, higher municipal expenditures per capita, and perceptions that the climate is already changing are statistically significantly associated with cities engaging in adaptation planning (Shi et al., 2015). Furthermore, decision-makers' ways of thinking together with the types of information and moral grounding provide keys rationales for institutional change (Carlson and McCormick, 2015). In urban areas in Africa, research on internal networks has been supplemented by investigations of informal arrangements and systems. For example, in Zimbabwe, informal, traditional, and civil society institutions are core arenas for issue discussion due to lower public sector capacities (Mubaya and Mafongoya, 2017). In Durban, South Africa, local governments rely considerably on shadow systems and informal spaces of information and knowledge exchange across their operations to introduce and sustain new ideas (Leck and Roberts, 2015).

An output view of institutional change focuses on the strategies, plans, and policies resulting from mainstreaming, as well as the evaluative metrics derived while reflecting back onto the process. Practically, this includes changes in policy and legal frameworks that structure decision-making, changes in policy instruments for implementation, changes in organizations to meet new objectives, and changes in coordination arrangements between different actors (Bellinson and Chu, 2019; Patterson and Huitema, 2019). Much research has focused on the production of actual adaptation plans and policies as an early indication of institutionalization. In a survey of 264 cities mainly in North America, Aylett (2015) found that 43% reported integrating adaptation into their long-range plans, 32% into broader sustainable development plans, and 32% into existing sectoral plans. Canadian cities were, in particular, more likely to have a plan specifically focused on adaptation and that it is being integrated into municipal long-range planning. In an analysis of 885 local climate plans across the European Union, Reckien et al. (2018) found that the presence of adaptation plans depended on the presence of a national climate legislation or, less common, an international climate network. Institutionally, this often means creating climate policies and programs that also help meet the existing priorities, goals, and core mandates of city agencies, creating interdepartmental working groups, and directly bridging city agencies by hiring or designating staff within local government agencies to coordinate that agency's engagement with adaptation (Runhaar et al., 2018).

Having these different perspectives of institutionalization at the local level allows for a more nuanced diagnosis of what is required to enable change. The input, processual, and output views of institutional change are not mutually exclusive and may, in fact, be iterative. As Beunen et al. (2017) suggest, institutional development for adapting to climate change will need to occur in situ to a large extent, by reworking existing setups and introducing new elements to address gaps or failures. This has been illustrated through various examples from around the world where cities are leveraging and enabling change through targeting input, processual, output, or a combination of institutionalization strategies. For example, in Manizales, Colombia, the city focused on incorporating climate adaptation into long-established environmental policy (Biomanizales) and local environmental action plan (Bioplan). Hardoy and Velásquez Barrero (2014) explains this strategy by highlighting the coherent, multi-level governance arrange in Manizales, including capacity to integrate disaster risk reduction, climate adaptation, and land use planning within a holistic view of development that includes the views of multiple stakeholders. Similarly, municipalities in Sweden can be 'pre-reactive' because adequate strategic guidelines are in place to frame the accessibility, aesthetics, and adaptability of waterfront developments (Storbjörk and Uggla, 2015). According to Aylett (2015), Asian cities also report high output effectiveness, where they are more likely to indicate the performance management contracts of senior local government officials, the budgeting procedures of local government agencies, and the procedures that local government agencies use for budgeting infrastructure spending.

Cities tend to leverage input and processual institutionalization strategies when there is lower public/political awareness of climate change or where governance systems are less conducive to change. The importance of targeting political leadership and capacity catalysts from the outset is important in the United States, for example, where climate action tends to be lower on the policy agenda (Carlson and McCormick, 2015; Hamin et al., 2014; Shi et al., 2015). In Mexico City, Mexico, the city government has invested in the institutionalization of climate policy through the creation of a formal boundary organization, the Mexico City Virtual Center for Climate Change, together with changes in the city's climate law and the development of inter-sectoral partnerships to implement climate goals (Hughes and Romero-Lankao, 2014). Other examples of institutionalization via formal boundary organizations that enable processual change include the Surat Climate Change Trust in Surat, India (Chu, 2016a), Initiative for Urban Climate Change and Environment in Semarang, Indonesia (Taylor and Lassa, 2015), and others. In Saint Louis, Senegal, Vedeld et al. (2016) further noted the importance of support from national and state level actors in enabling local institutional change. Such processual levers maybe important in situations of political instability (which disrupts patterns in champions and networks), clientelism (which can cause environmental projects to be discontinued) (Pasquini et al., 2015), or in contexts where there are high political and socioeconomic inequalities (Chu et al., 2016; Harris et al., 2018)(Chu, Anguelovski, and Carmin 2016).

In cities, although much of the rhetoric and drivers of institutional change are attributed to political agents working within public sector authorities, the literature is increasingly documenting important sources of change from non-state, civic, and private actors. Previous IPCC Assessment Reports noted how civil society actors were either in need of further awareness, sensitization, and capacitation around climate adaptation or how they were sources of locally based innovation (e.g., through community-based adaptation programs). However, since then, civil society and private actors have emerged as core knowledge holders and drivers of experimentation, even succeeding in changing public policy in the process.

From a procedural standpoint, locally driven forms of institutional change are distinct from locally based approaches. The former involves institutional bricolage and gradual multi-directional change, often redirected by interactive, co-productive, or even conflictual relationships between institutional actors (Chu et al., 2016). Public participation is the most basic form of institutional bricolage, where diverse sets of citizen interests, values, and ideals are brought together to inform change and solve public problems (Archer et al., 2014; Bisaro et al., 2018; Sarzynski, 2015). For example, in three cities across the Czech Republic, stakeholder participation exercises were used to prioritize climate change risks, provide impetus and opportunity for knowledge co-production, and support adaptation planning (Krkoška Lorencová et al., 2018). Similarly, in Quebec, Canada, citizens collaborated with the municipal authority to bring together climate science and 'ordinary' urban management and design solutions (Cloutier et al., 2015). According to Frantzeskaki et al. (2016), civil society-driven, co-productive approaches can pioneer new forms of institutional relations and practices due to retreating public sector powers across many countries.

Social movements can also enable different forms of institutional change, as exemplified by recent Youth Climate Strikes and Extinction Rebellion (limited evidence, medium agreement). Earlier social movements on climate mitigation, such as the Transition Movement (Feola and Nunes, 2014), (Feola and Nunes, 2014), may serve as an example for mobilizations more specifically about climate adaptation and the way new, net-worked, grassroots citizen activism and community organisation can encourage urban institutional change (Gunningham, 2019; Jordan et al., 2018; Wahlström et al., 2019). However emerging evidence also points to the need for careful consideration of any action and the need to support local urban planning efforts with national coordination (Inch, 2019). In the US, researchers are increasingly documenting the use of social media and digital narratives for galvanizing awareness and action. The pilot project #OurChangingClimate is one example of engaging youth with an understanding of their communities and their resilience or vulnerability to climate change (Napawan et al., 2017).

Locally driven institutional change can also be driven by private sector actors (Goldstein et al., 2019), who often have particular interests in the wellbeing of workers, continuity of supply chains, as well as land, property, and infrastructure asset protection.

Finally, locally driven institutional change can be driven by external actors, often transnational NGOs, philanthropic bodies, or city networks. Since the late 1990s, transnational municipal networks (TMNs) have increase awareness of climate change and served as a bridge for cities to access critical financial resources from private and philanthropic sources (Fünfgeld, 2015; Rashidi and Patt, 2018). Recently, transnational municipal networks have taken on more programmatic functions, working with cities to strategize, plan, and incrementally improve their organization functions in the face of climate change. For example, the Rockefeller Foundation's 100 Resilient Cities program (2014-2019) provided a two-year salary for a Chief Resilience Office (CRO) to be situated in a municipal authority to bridge silos, incentivize change, and develop climate-specific development strategies (Bellinson and Chu, 2019; Spaans and Waterhout, 2017). This has resulted in external actors taking on the role of enabling broad organization change, pathways of resource mobilization, and alternative forms of agenda-setting in cities (Chu, 2018a; Hakelberg, 2014).

Although the literature has documented a surge of civic and private actors support, co-producing, and creatively engineering change at the local level, the degree to which these urban/local level changes actually yield more effective climate adaptation strategies is unclear. For example, many studies document the ability of divergent interests to 'capture' the agenda based on the needs of elite groups (Anguelovski et al., 2016). Others critique the inability of local level adaptation actions to drive change at higher levels of governance, particular at national or global levels (Bansard et al., 2017; Fuhr et al., 2018; van der Heijden et al., 2018).

Institutionalization is often associated with a need to deliver an overview of the range of instruments available for mainstreaming adaptation concerns in local planning/policy. In many ways, these analyses adapt previous concerns with mainstreaming sustainability policies (e.g., Table 6.7). The question is whether we want to put forward a list of instruments, or it is better to focus on certain approaches such as transformative capacity?

Table 6.7: Instruments for mainstreaming adaptation.

Objectives	Type of instrument	Description	Examples
Policy	Information Instruments	A diverse range of activities such as training, research and development, awareness campaigns to produce and share information	Urban-LEDS II Capacity Building Workshop for cities in Lao, arranged for local government by ICLEI Southeast Asia Secretariat and UN-Habitat (UN-Habitat, 2019)
	Voluntary Instruments	Practices such as codes, labelling, management standards or audits, in a voluntary basis, that can provide incentives for adaptation	Singapore Environmental Council's Water Efficiency Labelling Scheme (WELS) (Tortajada and Joshi, 2013)
	Economic Instruments	Taxes or subsidies can be used to promote adaptive activities	US Office for Coastal Management NOAA Coastal Resilience Grants Program (NOOA, 2019)
	Regulatory Instruments	These include a range of mandatory requirements through controls, bans, quotas, licensing, standards often applied when a specific outcome is required	Building codes to enhance structural stability for storm resilience in Moore, Oklahoma (US) (Ramseyer et al., 2016)
Process	Visioning	Events that bring together different stakeholders to produce a city vision	Rotterdam Resilient City participatory processes to create resilience strategies (Resilient Rotterdam, 2016)
	Baseline studies	Focus on understanding the current conditions in a neighbourhood or city from an interdisciplinary perspective	*Flood Risks, Climate Change Impacts and Adaptation Benefits in Mumbai,* an OECD assessment study (Hallegatte et al., 2010)

	Development priorities	Specific methods to ensure an open definition of multiple priorities and contrasting values that will inform the planning process	Participatory housing upgrading through the Baan Mankong Program in Bangkok (Thailand) (Berquist et al., 2015)
Planning	Profiles	Develop a common understanding of how a city's sectors interact with adaptation and the governance capacity	New York City Panel on Climate Change 2019 Report (NYCPCC, 2019)
	Risk assessment	This includes a range of instruments to evaluate the impact of risk	Climate risk assessment for Buenos Aires, conducted by the World Bank (Mehrota et al., 2009)
	Impact assessment tools	Tools such as Strategic Impact Assessment or Sustainability Assessment provide a means to assess the impact of specific policies and programmes in relation to adaptive capacity	Economic Impact Assessment of Climate Change in Key Sectors in Nepal (Government of Nepal, 2014)
	Monitoring systems and indicators	Systems to take measurements at regular intervals to specify progress against objectives and revise the planning process	Climate Change Adaptation Indicators for London (London climate change partnership, 2018)
Management	Budgets and audits	Methods for the periodic revision of adaptation plans and policies	Helsinki Metropolitan area climate change adaptation monitoring strategy (HSY, 2018)

6.4.6 Finance and Insurance to Address Climate Change in Cities, Settlements, and Infrastructure in Cities in the Global North

Although many adaptation actions do not require significant resources, funding and financing are critical for others. Many early leaders in climate adaptation are, therefore, perhaps unsurprisingly, political capitals or financial centres in the global North with much larger resource envelopes and well-developed fiscal and financing capacities (Shi et al., 2015; Westerhoff et al., 2011)(medium confidence, low agreement).

6.4.6.1 Options for Financing Climate Change Adaptation in Cities, Settlements, and Infrastructure

It is difficult to quantify the amount of resources required to address climate change in cities in the global north. The funding required will depend on choices made about climate mitigation (the cost of adapting to a global temperature increase of 1.5oC will be a fraction of the cost of adapting to a global temperature increase exceeding 3oC); about climate adaptation (different adaptation options have different capital requirements, operating costs and returns on investment); and the financing sources and mechanisms that are selected (which incur different levels and kinds of costs). These options are further explained below.

Broadly, there are two options for adaptation investment: funding – direct expenditure in preparation for or response to climate change impacts – and financing – the deployment of market-based instruments to attract third-party resources to an adaptation action (Keenan et al., 2019). Finance must ultimately be paid for by funding. Using funding can be a lower cost strategy, as there is no third party expecting a return on investment. However, using financing can expand the total resource envelope available for adaptation (even if ultimately, the total volume of finance is constrained by the total level of funding available (White and Wahba, 2019)).

The choice of specific funding and financing mechanisms is often based on implicit economic world views (Keenan et al., 2019) or the technical support available to subnational governments in, for example, preparing municipal bonds or contracting for public-private partnerships. The urban finance literature has long called for critical interrogation of these choices, since they have profound implications for the total level and distribution of costs (Altshuler and Luberoff, 2004; Graham and Marvin, 2002); now that debate must urgently be extended to adaptation investments (Harman et al., 2015; Keenan et al., 2019).

To date, the climate imperative has not yet changing the landscape of urban infrastructure investment (White and Wahba, 2019). Mobilising adaptation investment in cities of the global North continues to depend on strengthening public finance capacities (particularly the ability to evaluate and integrate climate risk into economic decisions) and/or meeting the expectations of private investors and lenders. There is a large body of work on these relatively prosaic agendas. Climate change creates new investment risks as well as physical risks (Martimort and Straub, 2016), and highlights the limitations of current models to account for risk and uncertainty when pricing investments (Keenan, 2018). However, it does not yet seem that private investors and lenders are likely to provide adaptation finance on terms that are significantly easier or cheaper than conventional finance (White and Wahba, 2019).

6.4.6.2 Funding Availability

Cities in the global North typically have access to reasonably substantial volumes of funding that could be used to enhance resilience and build adaptive capacity. This includes both the private resources of individual households and firms (which varies significantly within and among cities) and the public budgets of different tiers of government.

Depending on levels of fiscal devolution within a country, public revenues may be collected and managed primarily at the national, state, metropolitan or local level. In federal countries, subnational governments collect an average of 49.4% of public revenues compared to only 20.7% in unitary countries. Subnational revenues represent over a quarter of total public revenues in Belgium, Canada, and Denmark, but less than 5% in Greece, Ireland and New Zealand (OECD/UCLG, 2019). The share of the national fiscus that is transferred to subnational governments also varies significantly among countries: grants and subsidies account for over three quarters of subnational government revenue in in Malta, but less than a quarter of subnational revenue in Iceland (OECD/UCLG, 2019). The capacity of a local government to collect revenues is further mediated by incomes within a city (which dictates the prospective tax base) and the capacity of civil servants to administer taxes, fees and charges. The result is that the budgets of metropolitan and local governments across the global North vary dramatically, even within countries. Löffler (2016) documents per capita municipal budgets of $1,114 in Saskatoon and $2,682 in Peterborough (Canada), $2,635 in Leipzig and $3,638 in Freiburg (Germany), to $4,907 in Bristol and $5,612 in Aberdeen (the United Kingdom). Understanding levels of fiscal devolution within a country is essential to determine where the capacity and responsibility for adaptation funding might plausibly sit within the government.

Although cities in the global North may have relatively substantial volumes of funding (even if not controlled by local governments), these revenue streams are often insufficient relative to the scale of adaptation requirements. Moreover, many local governments are unwilling to use their own funds for adaptation purposes, meaning that resources for resilience must be allocated by higher levels of government or other sources (Hughes, 2015; Wheeler, 2008)(Wheeler, 2008; Hughes, 2015) – which also perceive opportunity costs to adaptation investments. Funding from non-state actors is therefore proving important, particularly in U.S. cities where private foundations and non-profit organisations account for 17% and 16% of adaptation support (Carmin et al., 2012). Tapping into these sources of funding raises complex questions about accountability and ownership of urban adaptation (Chu, 2018a).

Climate risks and variability also threaten the fiscal models of many city governments and utilities. For example, a drought may disrupt water revenues both by reducing total water consumption and by incentivising households and firms to invest in independent water storage or supply infrastructure (Simpson et al., 2019a). Storm surges and sea-level rise may threaten sunk investments in revenue-generating infrastructures, such as toll roads or electricity generation and transmission systems. City governments, therefore, need to anticipate climate shocks and stresses and design their operating models and investment plans accordingly to ensure financial resilience (Clarvis et al., 2015).

6.4.6.3 Drivers of Finance

Adaptation financing entails attracting resources from a third party to cover the investment needs, which must ultimately be repaid with funding (usually from an end user). Common sources of this finance might include commercial banks, investment companies, pension funds, insurance companies and sovereign wealth funds (Floater et al., 2017). These capital sources have different risk-return expectations and investment horizons, so will suit different types and stages of projects. Many subnational governments in the global North have access to well-developed domestic, if not global, capital markets to raise and steer finance for urban investment.

However, investments in ex ante urban climate adaptation may prove less attractive to these financiers than other opportunities because of their long maturities, limited near-term returns and high levels of risk and uncertainty (Keenan et al., 2019). Many generate economic returns primarily through avoided losses from climate impacts, which are difficult to measure and are in any case more attractive to funders than financiers (Kaufman, 2014). Ex post, insurance already plays a critical role in protecting urban households, firms and other stakeholders from the full economic costs of high-severity, low-frequency events by sharing risk over time and space. Insurance can also be designed to incentivise risk-reducing behaviors and investments. However, the commercial feasibility of private-sector insurance depends on more robust estimates of current and future risks, and premiums commensurate with the ability and willingness of consumers to pay. Insurance schemes must, therefore, be complemented by ex-ante investments to improve climate modelling and reduce climate risk (Surminski et al., 2016).

National governments typically determine the fiscal transfers that subnational governments receive and the taxes, fees, and charges that they are permitted to collect. Local governments may be able to strengthen their own-source revenue collection and management capacities to better exploit these funding streams and improve their balance sheets, but their total budget will be limited to these funding sources (Ahmad et al., 2019). The amount of local public funding available for urban adaptation depends on the relationships across different levels of government.

Similarly, mobilising private finance for urban adaptation projects demands robust institutional, fiscal and regulatory frameworks, which are typically the responsibility of national authorities. For local governments to access private finance for adaptation may require national (or in federal countries, state) governments to reform policies and rules governing municipal borrowing, public-private partnerships, land value capture instruments, and other financing mechanisms. Such fiscal reforms tap into fundamental political and policy issues, such as the autonomy of local governments or the tariff-setting powers of national ministries (Gorelick, 2018; White and Wahba, 2019).

In sum, expanding the resource envelope available for adaptation investment is often beyond the authority or competency of city governments. Sovereign and state governments have critical roles to play in providing funding or securing finance for adaptation investments. This is particularly true where the impacts of climate change are distributed inequitably across a country, so that the costs borne by a city may exceed local budgets.

[START BOX 6.5 HERE]

Box 6.5: Finance and Insurance to Address Climate Change in Settlements, Infrastructure and Services in African Cities

In Africa, the effort to provide growing, and in parts increasingly affluent, urban populations with the shelter, infrastructure and services that will enable development in line with climate resilient pathways, requires an increase in investment in technologies and projects; new investment in institutions and other enabling conditions for climate resilient urban development; and investments that limit the impact on employees in industries and population groups that stand to lose their livelihood due to either climate change itself or the national commitment to towards low-carbon urban resilience (Robins, 2018).

Each of these three climate finance categories is subject to the same challenges that limit investment in African cities more generally (UCLG, 2017; UNCTAD, 2019). The world is expected to invest around US$6 trillion per year in infrastructure by 2030 (The Global Commission on the Economy and Climate, 2016). While a number of studies reveal the net economic benefit of climate resilient, low-carbon African cities (Global Commission on Economy and Climate, 2017), structural impediments remain to mobilising investment for the types of public good infrastructure that would unlock this benefit (Dodman et al., 2017a). Since the 1960s Gross Capital Formation (sometimes called Gross Domestic Investment) has been less than 22% in Africa, whilst in East Asian countries it has risen to 42% (OECD, 2016). Africa faces an estimated

40% infrastructure financing gap, but this gap is almost certainly higher in the continent's rapidly growing cities (Baker & McKenzie, 2015). Relative poverty, weak or absent local fiscal systems and contested tenure that prevents land being used as collateral, has historically restricted investment in African cities (Berrisford et al., 2018; Dodman et al., 2017b). Sub-Saharan African countries are reaching the 40%-urban threshold at national per capita incomes of around $1,000 per annum; significantly poorer than South East Asian and Latin American cities at the same level of urbanisation (Freire et al., 2014). Absolute poverty in conjunction with weak revenue collection and low levels of investment, render conventional infrastructure finance difficult, and limit the fiscal influence that can be applied to achieve urban density, ecosystem based adaptation or low-carbon energy (Berrisford et al., 2018; Cirolia and Mizes, 2019; Global Commission on Economy and Climate, 2017; Smolka, 2013). Sprawled urban development in Africa might make the provision of public services both more energy intensive and three times more expensive than high-density developments (Collier and Venables, 2016).

Data on private finance in African cities are inadequate (OECD, 2017) but all of Africa secured just 3.5% ($46 billion) of global FDI, in spite of a 10.9% increase in 2018 (UNCTAD, 2019). Mining and the extraction and processing of fossil fuels accounted for almost a third of greenfield FDI in Africa in 2018 (UNCTAD, 2019). The FDI secured by cities, has tended to serve and urban elite, and been used to build shopping malls, housing settlements and airlines (Watson, 2015). It is also unevenly distributed across the continent and within cities. Five countries, Egypt, South Africa, Congo, Morocco and Ethiopia accounted for more than half the total FDI in 2018 (UNCTAD, 2019), leaving large parts of Africa's growing cities described by financiers as "high risk" and their citizens deemed "unbankable" (UCLG, 2016).

Private financiers have begun entering public private partnerships with African cities, often supported by bilateral agreements between the respective countries, including the growing number of Asian and Middle-Eastern countries that have begun contributing to infrastructure in African cities (Cirolia and Rode, 2019). In the absence of enforceable spatial plans and strong urban governance, the risk remains that individual investment projects that are successfully completed will aggregate to create urban systems that are at risk from climate change through the locking-in of inequality, urban sprawl, flooding and greenhouse gas emissions (Dodman et al., 2017b; Wachsmuth et al., 2016). These risks will constitute a future burden for asset owners, financiers and insurers and cause a progressive haemorrhaging of economic opportunities in Africa's urban centres (UCLG, 2016).

All but two African countries (Libya and Western Sahara) have submitted Nationally Determined Contributions to the UNFCCC. Where it reaches sub-national governments, climate finance offers the opportunity to overcome structural impediments to urban finance in Africa (UCLG, 2016). Since 2015, renewable energy investment in developing and middle-income countries has exceeded that in developed countries, and while global investment in renewable energy fell in 2018, investment in renewable energy in Africa increased (Murdock et al., 2019). Ensuring that climate finance reaches the poorest communities in Africa's cities offers the prospect of sustainable development (Hallegatte and Mach, 2016). Examples include the roll-out of efficient public transport as the preferred means of commuting for city workers, the use of locally generated renewable energy, the introduction of waterless sanitation systems so as to reduce the cost of water treatment and the need for bulk infrastructure and the elimination of fuels such as charcoal, wood and paraffin.

Securing climate finance for urban development is contingent upon strong multi-level governance arrangements (OECD/UN-Habitat, 2018; Tait and Euston-Brown, 2017). National treasuries are required to align donor, DFI and private finance investments with domestic budgets allocations in supporting urban climate resilience (UCLG, 2016). This is particularly necessary in cities that do not yet have the balance sheets or rate-paying citizens necessary to enter financial markets on favourable terms. Similarly, Central Banks have a crucial role to play in managing the transition risks within cities and limiting the systemic impact of stranded urban assets due to technology shifts or sea-level rise for example (Safarzyńska and van den Bergh, 2017).

New energy, water and sanitation technologies are altering the public good nature of urban services and offer novel opportunities for private sector financiers and blended finance, but financial sector innovation remains necessary if technological innovation is to be scaled (Cities Climate Finance Leadership Alliance, 2015). UNEP has cited anecdotal evidence of a "quiet revolution" towards a more developmental and sustainable global finance sector, in part due to global Environmental, Social and Governance requirements, and industry initiatives within the financial and insurance sectors (UNEP, 2015). Six African countries have launched the Lomé Initiative, a platform to aggregate demand for financing for large-scale photovoltaic projects as part of the ISA's Affordable Finance at Scale programme. Similarly, ICLEI's Transformative Actions Program focuses on driving capital flows to towns, cities and regions to strengthen their capacity to attract climate investment. Scope remains to strengthen DFI programmes such as the World Bank's City Creditworthiness Programme and the activities of China's ExIm Bank with a bespoke urban climate dimension.

[END BOX 6.5 HERE]

6.4.7 Monitoring and Evaluation Frameworks

Monitoring and evaluation (M&E) frameworks for adaptation are far from being fully developed and operationalised both in theory and in practice at the local scale (high confidence, high agreement). Despite significant experience on the application of M&E in other sectors (e.g. health, water, industry or business) or with other climate change objectives (e.g. emissions reduction), the assessment of adaptation efforts has been to date under-theorised in current adaptation literature (Berrang-Ford et al., 2019). The challenges related to the evaluation of adaptation progress (lack of methods, agreed metrics, data, and definitions including the ambiguity of the concept of "adaptation") have been widely recognised after the Paris agreement (Ford et al., 2015; Magnan, 2016). However, the need to develop practical and efficient M&E frameworks to assess adaptation progress across all levels of public and private decision-making is still patent. This not only includes the assessment and consideration of public top-down adaptations but also, informal, bottom-up, community actions or corporate-led programs developed to reduce vulnerabilities and climatic risks and increase resilience and adaptive capacities of specific communities or territories (high confidence, high agreement).

Adaptation M&E objectives remain the same regardless of the scale and sector in which adaptation occurs. M&E processes are essential to ensure the sustainable consecution of adaptation goals and the validity of adaptation decisions taken in the past, as part of projects or strategic programs and across public and private policy scales. On the one hand, there is a need to guarantee that planned adaptation actions are implemented in an efficient, just and equitable way (Olazabal et al., 2019). On the other hand, and to guarantee the suitability of existing adaptation initiatives, there is a need to observe if and how environmental, social and economic vulnerability and climatic risk conditions evolve with time. In a framework of continued surveillance, M&E outputs facilitate adaptation decision-making by linking three aspects (Berrang-Ford et al., 2019): (1) changing vulnerabilities and risks, (2) established adaptation goals and targets and (3) adaptation efforts put in place. This way, M&E outputs help decide whether current adaptation efforts are sufficient or adequate, thus, enabling the learning process that adaptation action requires.

Different assessment frameworks at local scale use the existence of a monitoring system as an indicator of adaptation plan quality (Woodruff and Stults, 2016), adaptation policy credibility (Olazabal et al., 2019) or climate preparedness (Heidrich et al., 2013). However, M&E systems are still far from being established and operational in practise. Recent large-scale studies that have tracked urban adaptation documented public initiatives in major cities around the globe (Araos et al., 2016) have found that M&E frameworks are largely missing. The gap reveals: (1) a lack of awareness by local adaptation managers about the importance of M&E systems in adaptation decision-making, (2) inadequacy, irrelevancy or underuse of available M&E resources, or (3) the lack of knowledge, capacity, and resources to make M&E work in practice at city scale.

Olazabal et al (2019) argue that 6 components are at least required to make M&E operational at urban adaptation planning scale: (1) the definition of a context-specific tailored M&E system adapted to local existing institutions, (2) the definition of a responsible party (public authority, department, group or organisation) that will be in charge of M&E system management, (3) the definition and assignation of appropriate budget over time, (4) the identification of monitoring objectives and indicators, (5) the definition of a method and/or process to evaluate outcomes of the monitoring process and eventually, (6) the reporting process (how and who the outputs will be reported to). Klostermann et al. (2018) also emphasise the importance of the learning process and the establishment of cyclic iterative approaches where monitoring objectives are selected, procedures are put in place, data is collected and evaluated, and information from the evaluation process and from experience is used to manage adaptation policy and planning processes. Yet, practical M&E exemplary approaches to operationalise these components across different urban contexts (considering decision-making cultural differences, capacities, resources or data availability) are still missing.

In contrast, much has been discussed on the benefits and limits of adaptation metrics, and on types and uses of such indicators (Christiansen et al., 2018). The IPCC's Fifth Assessment Report provided accountability of different frameworks used to develop adaptation metrics, highlighting the role of vulnerability-based indicators. In relation to these, Ford and colleagues (2018) call for a re-evaluation of vulnerability approaches as these often neglect contextual needs of the adaptation process which means that are typically not conducted at the appropriate scale of decision making that adaptation action requires neither accompanied by adequate context-specific assessment of institutions and organisations. Risk-based approaches are seen as an alternative in a context where the monitoring of decision-relevant variables in urban climate adaptation planning is essential to link climatic risk assessment and action (Hallegatte and Engle, 2019; Kingsborough et al., 2016; McDermott and Surminski, 2018). McDermott and Surmisnki (2018) moreover argue that because of the need to define normative frameworks for risk evaluation - what is acceptable and what is not (Galarraga et al., 2018) - these approaches may offer an opportunity for the generation of a shared understanding on goals and limitations of adaptation. However, risk-based indicators may also create a bias towards quantifiable variables that tend to be based on climatic modelling outputs, engineering or financial assessments. Based on this and various examples of urban development projects, Hallegatte and Engle (2019) claim it is not only important to consider output-based indicators but also process-based indicators that talk about government, voice and empowerment (see Box 6.6).

In spite of these debates, that are often science-oriented or project-focused, little has been studied on how to make M&E approaches practical at the local scale. Cities across the globe face important social, environmental, and economic conflicts related to resource scarcity, poverty, environmental pollution, population growth, and that coexist with climatic risks. In this challenging context, cities and towns are currently working towards wider global urban sustainability objectives (e.g. SDG 11 – The Urban SDG) that should include climate change adaptation and disaster risk reduction (e.g. SDG 13). SDG and the New Urban Agenda are ambitious and comprehensive plans and have the capacity to mobilise actors and resources (Valencia et al., 2019). For this reason, it makes sense to integrate climate change adaptation assessment goals and needs into existing frameworks for the sake of efficiency in the process of measuring, evaluating and reporting. This will benefit more clearly to small urban areas and cities in developing regions that often face data scarcity and may also find available indicators irrelevant for their realities and thus, be required to adjust them (Simon et al., 2016).

M&E frameworks to assess adaptation at local scale need to be compatible with existing formal and informal institutions (rules, norms, and procedures) already in place for the assessment of sustainability (e.g. Local Agenda, sustainability appraisals), resilience (e.g. 100 Resilient Cities, new standards for urban resilience), GHG emissions reporting (e.g. Global Covenant of Mayors for Energy & Climate). In a context where adaptation efforts need to be aggregated and evaluated across nations (Magnan, 2016) and their implications on wider objectives such as sustainable development and social justice need to be assessed (Long and Rice, 2019), urban adaptation M&E systems should also be able to inform upper policy levels, with special emphasis in the national and international processes that enable a global stocktake of adaptation.

[START BOX 6.6 HERE]

Box 6.6: Learning from Environmental Performance Evaluation Urban Planning Frameworks to Deliver Resilience Outcomes in Urban Adaptation

Delivering effective adaptation measures depends on the availability of adaptation frameworks that enable ongoing evaluation. Adaptation governance is not a one-off but a long-term commitment, that requires an active process of re-evaluation. Many of the problems of evaluation have already been faced in the delivery of environmental outcomes. For that reason, adaptation evaluation can learn from other evaluation frameworks, such as water resilience evaluation frameworks. These frameworks vary across a continuum from those who focus on narrow quantitative indicators on the one hand, and those which expand the vision of evaluation to incorporate multiple social, technological and ecological dimensions of resilience and vulnerability.

Temperature and rainfall extremes, severe storms, landslides and other disasters associated with a changing climate have a negative effect on the quality of life of urban communities, particularly for women, children and marginalized communities (Reese, 2018; Salmond et al., 2018; Santamouris and Kolokotsa, 2015). The literature on the negative impact of climate change on combined indices of quality of life indicates that this impact is most significant in cities of the global south compared with the global north. Further, there are apparent regional differences and disparities between Africa, Latin America, and Asia. This is more in their level of provisioning of urban infrastructure. Nagendra et al (2018) use a combination of indexes to compare regional variations between cities of the global north and the global south. They use the city prosperity index (includes six sub-dimensions - productivity index, infrastructure development index, qualify of life index, environmental sustainability index, and urban governance and legislation index), infrastructure development index (four sub-dimensions - housing infrastructure index that includes improved shelter with cement floor and access to improved water, social infrastructure index including physicians density, information and communication technology index that includes internet access and urban mobility index that includes the use of public transport, average daily travel time and traffic fatalities) quality of life index (includes three sub-dimensions: health index meaning life expectancy at birth, under-five mortality rate etc., education index meaning literacy rate, mean years of schooling etc., and safety and security index including homicide rate and environmental sustainability index (two sub-dimensions including air quality index and water and energy index).

For example, to quantify water security, the Asian Development Bank (2016) developed a water security framework that has five interdependent key dimensions. It defines water security when system manages their resources and services to meet household's water and sanitation needs, supports productive economies, develop liveable cities and towns, restores healthy rivers and ecosystems and builds resilient communities that can adapt to changes (Adb, 2016). The five key dimensions are – household water security (access to piped water supply, improved sanitation and hygiene), economic water security (agricultural, Industrial and energy water security), urban water security (water supply, wastewater treatment, Drainage/floods and river's health), environment water security (river health, hydrological alteration, governance of the environment), resilience to water-related disasters (floods and windstorms, drought, storm surges and coastal floods). Based on these five dimensions, water security is observed from the household level to water-related disasters. It uses indicators and a scaling system to rank the progress of each of the 49 countries in the Asia Pacific Region. Its first outlook in 2013 ranked the countries based on this assessment followed by a second assessment in 2016 at the interval of five years. It showed that overall, the region had a positive trend in strengthening water security since 2013 when 38 out of 49 countries were assessed as water insecure. In 2016, the number fell to 29 countries. Index based framework provides an overall understanding of where the country is moving and could be used for larger level strategic change in policy directions at the country level. It has been critiqued on the use of aggregation which does not cover the nuances at the local level. Climate change issues are also not tackled in this framework.

Recognizing that the information about global water resources lacks a common framework that gives rise to fragmented knowledge, Srinivasan et al (2012) analyse 22 human–water system case studies across the glove to identify water resource system outcomes and the factors that drive them. Using the qualitative comparative analysis, the cases are grouped into six "syndromes": groundwater depletion, ecological destruction, drought-driven conflicts, unmet subsistence needs, resource capture by the elite, and water reallocation to nature (Srinivasan et al., 2012). Each of these groups were related to a set of factors such as demand and supply changes, governance systems, and infrastructure. The study recommends that each syndrome is generated by a limited set of causal pathways and highlight the importance of both immediate and fundamental causes of forms of water resource utilization. This index gives a policy outlook on making informed choices on harnessing water resources, leaving for nature, distributing water across sectors and agents in ways that reflect inherent resource limitations, cultural values, historical context, and political realities. Apart from global water-related indexes, there are sectoral indices that focus on assessment of an area. For example, two indexes have been applied in flood risk governance integrating societal resilience, resource efficiency, and legitimacy. Alexander, Priest, and Mees (2016) present a coherent evaluation framework to evaluate flood defence and mitigation governance in England. It provides an essential step in assessing, monitoring and strengthening flood risk governance. Radhakrishnan et al (2017) developed a framework for structuring the local adaptation responses using the inputs from numerous viewpoints in an urban adaptation environment. Since the adaptation measures are derived from multiple viewpoints, it carries increased flexibility in having a more important adaptation measures and amplified pathways. The enhanced flexibility is considered in identifying the link between adaptation measures; determining the compatibility of the actions with one another; and creating a knowledge base encompassing all plausible sequences and time epochs at which the measure could be positioned based on external factors.

As an alternative, Eizenberg and Jabareen (2017) present the framework that relates water sustainability to social sustainability. They theorise risk is a constitutive concept of sustainability. The risk evolving from changing the climate and related uncertainties pose serious social, spatial, structural, and physical threats to people and the place they live in. The social sustainability framework endeavours to confront risk while also addressing social concerns. is the framework includes four interrelated concepts of socially oriented practices, where each concept has a distinguishing function in the framework and includes major social features. They consist of urban forms (physical dimensions of socially desired urban and community physical forms), equity (Social, economic, and environmental injustices that pose risk to society), eco-prosumption (responsibility of society to reduce future risk and help mitigate local and global efforts) and safety (Safety and security for humans and non-humans is the fundamental requirement for social sustainability).

Steele et al (2015) present the framework from urban climate justice perspective. They conceptualise urbanisation and climate change that causes negative impacts on poor and marginalized people. Their framework identifies how the most vulnerable have less power and capacity to respond to a changing climate and its impacts. Vulnerabilities are intimately intertwined at the urban scale and according to the authors, dealing with them requires an interdisciplinary urban climate justice agenda. Shi et al (2016) present a roadmap to reorient research on the social dimensions of urban climate adaptation around four broad areas related to equity and justice. First, expansion in the participation of the poor in adaptation planning. Second, expanding adaptation to rapidly growing cities that has less financial or institutional capabilities. Third, adopting a multilevel and multi-scalar approach to adaptation planning; and fourth, integrating justice into infrastructure and urban design processes. They call for pathways to more transformative adaptation policies in urban spaces.

These evaluation experiences have potential to inform climate change evaluation (high confidence, high agreement).

[END BOX 6.6 HERE]

6.4.8 Conclusion

OVERALL: "Intersectional, gender-responsive and inclusive leadership is key for climate change adaptation governance in formal and informal settlements" Key message (*limited evidence*, *high agreement*)

- Importance of situating adaptation governance (and finance, insurance) in a specific context, and primarily focusing on informality/sub-serviced/poorly serviced areas (high confidence, high agreement)
- From a systems perspective, there is a need to recognize the multiple aspects of transformative capacity frameworks, but these are not always actionable in practice (low confidence, high agreement)
- Remaining interest on local leadership as the dominant factor to deliver action on the ground, but with an overall agreement on what leadership is and a growing emphasis on forms of leadership that emphasize orchestration, enabling and co-production (low confidence)
- Growing interest in inclusive urbanization and inclusive climate adaptation needs to reflect upon intersectionality theory as a means to understand the structural drivers of risk and exclusion and relate adaptation to broader goals in the 2030 Sustainable Development Agenda (high confidence, high agreement)
- Transformative and justice concerns are integrated into monitoring frameworks, helping move away from static, indicator-based ones (medium confidence, high agreement)

[START CASE STUDY 6.1 HERE]

Case Study 6.1: Himalaya: Urbanisation and Climate Change in Himalayas – Increased Water Insecurity for the Poor

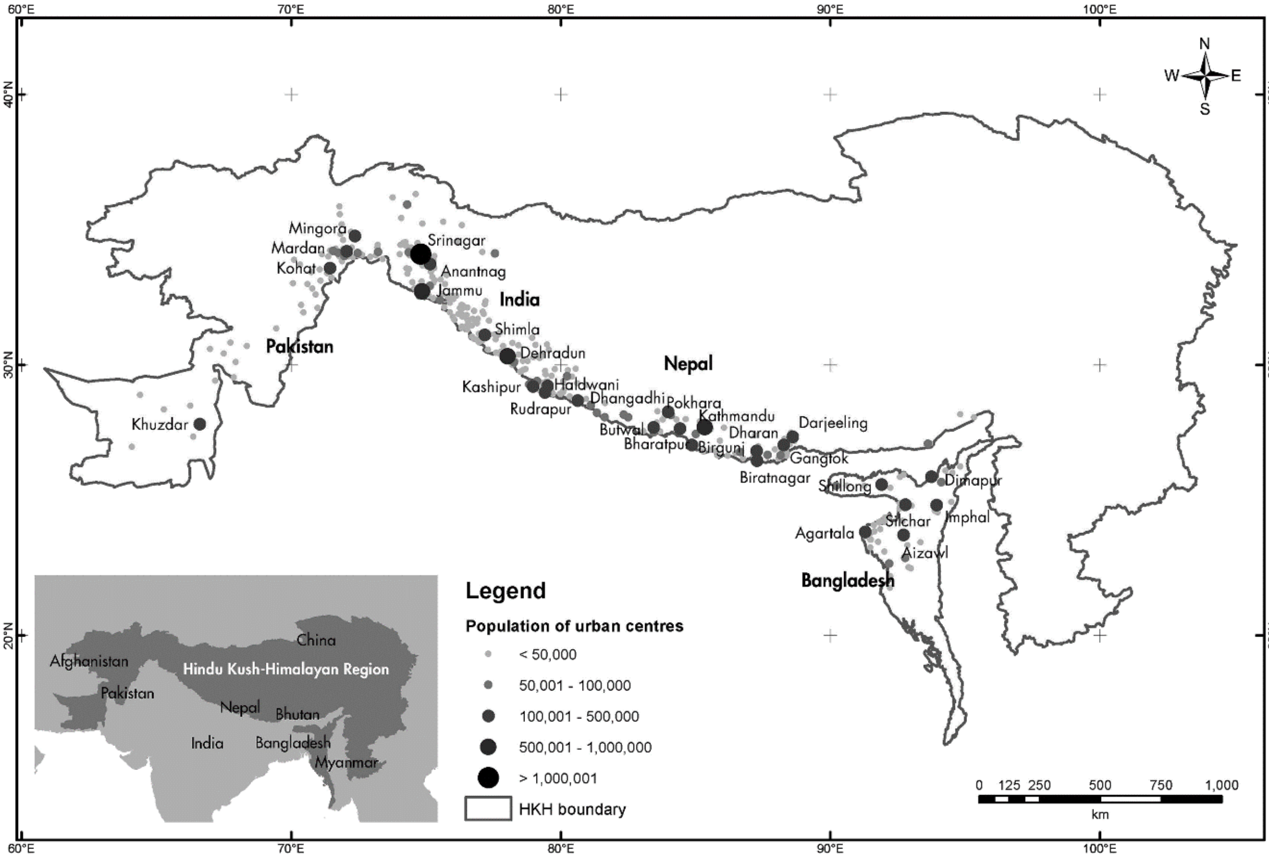


Figure 6.6: Figure based on (Singh et al., 2019)).

The Hindu Kush Himalayan region extends 3,500 km over all or part of eight countries from Afghanistan in the west to Myanmar in the east including major economies such as China and India. The region is home to 10 major river basins that feeds south and south-east Asia. As per 2017, the total population in the ten major river basins with their headwaters in the region is around 1.9 billion, including the 240 million in the mountain and hills of the Hindu Kush (Wester et al., 2019). The region is characterized by a unique mountain topography, climate, hydrology and hydrogeology. Each one of these factors plays an important role in determining the availability of water for people living in Himalayas. The total land mass that can support physical infrastructure for towns to develop is much less in the Hindu Kush Himalayan region as compared to the plains. Due to this physical constraint, the process of urbanization is slow in the region. Only 3 per cent of the total population in the region live in larger cities and 8 per cent in smaller towns. However, off late, there has been an increase in urbanization largely due to regional imbalances in providing economic opportunities for the poor. People from rural areas are flocking to the nearest urban centres in search of employment and other economic opportunities. As a result, the share of urban population is increasing in the region, while that of rural population is declining. Projections show that by 2050, more than 50% of the population in Hindu Kush countries will live in cities (UNDESA, 2014).

One of the major challenges of urbanisation in Himalayas is sprawling small towns under the population of 100,000 (see Figure 6.6). These towns would become major urban centers with a decade due to high growth rate. A recent study by Maharjan et al. (2018)(2018) on migration documented that 39% of rural communities have at least one migrant, of whom 80% are internal and the remaining 20% are international. Around 10 percent of the migration is reported as environmental displacement. The ever-expanding urban population in Himalayas throw many challenges especially in the context of climate change adaption. First, the unplanned urbanization is causing significant changes in land use and land cover with recharge areas of springs getting reduced. Most of the towns in Hindu Kush Himlayan region meet their water needs using supplies from springs, ponds and lakes which largely interlinked systems. Second, climate induced changes in the physical environment comprise of increase in rainfall variability. Due to this, heavy rains are becoming frequent and are leading to more landslides. Third, global warming has increased the average temperature in the Himalayas which has caused glacier melt and subsequent change in hydrological regimes of the region. These critical stressors – climatic and non-climatic, are adversely affecting the socio-ecology of urban conglomerations in region. Encroachment or degradation of natural water bodies and the disappearance of traditional water systems such as springs are evident. While water availability in these towns has been adversely affected by the climatic and socio-economic changes, demand for water has increased many folds. Some of the towns are major tourist attractions that creates floating population in peak tourist seasons challenging the carrying capacities of the towns. The residents have to cope with water scarcity as demand of water increases in peak seasons and water distribution through the public water supply systems becomes highly inequitable. The usual challenges of utilities being inefficient applies in these areas too though it becomes much more critical as the sources of water are limited and the local geology hardly supports accessing groundwater unlike in the plains. All these processes are resulting in increased water insecurity for the poor and marginalised in urban towns of Hindu Kush.

[END CASE STUDY 6.1 HERE]

[START CASE STUDY 6.2 HERE]

Case Study 6.2: Semarang, Indonesia

The City of Semarang, on the northern coast of Central Java in Indonesia, has a population of nearly two million and is vulnerable to sea level rise, urban flood and inundation, as well as associated public health and sanitation risks (Suhelmi and Triwibowo, 2018; Yuniartanti et al., 2016). Together with the City of Bandar Lampung in southern Sumatra, Semarang was a pilot city for the Asian Cities Climate Change Resilience Network from 2009 to 2016, which was a Rockefeller Foundation-funded initiative to develop resilience capacity across secondary and rapidly growing cities in South and Southeast Asia (Reed et al., 2015). Through a participatory 'Shared Learning Dialogue' process based on the Institute for Social and Environmental Transition-International's 'Climate Resilience Framework' (Kernaghan and Da Silva, 2014; Moench, 2014; Orleans Reed et al., 2013), Semarang's adaptation planning process began with identifying key vulnerabilities in the city – which included flooding and sea level rise – and designed a number of pilot projects to address these, which included a community-based flood early warning system (Archer and Dodman, 2015; Sari and Prayoga, 2018; Yuniartanti et al., 2016) . The planning process was led by a City Team that included key municipal decision-makers from the Disaster Management Agency of Semarang City, Water Resources Management Agency, as well as technical support from the non-governmental organization (NGO) Mercy Corps Indonesia (Nugraha and Lassa, 2018).

The planning process focused on mainstreaming climate adaptation into flood management policies, regulations, and budget allocations (Handayani et al., 2019). The process also allowed for policy experimentation through different pilot projects as well as built networks with on-going national and regional development frameworks, including the Mid-term Regional Development Plan of 2010-2015 (Lassa and Nugraha, 2015). Building on Semarang's ACCCRN experience, the city then became a member of the Rockefeller Foundation's 100 Resilient Cities program (2016-2018), and synthesised its experience in climate adaptation planning by publishing the Resilient Semarang strategy in May 2016 (Semarang City Government, 2016). The document has since catalysed further collaborative relationships between the city and the National Disaster Management Agency and the National Ministry of Development Planning. Recent assessments of Semarang's experience have noted progress in integrating and institutionalising adaptation and resilience building within existing local development frameworks but have simultaneously pointed out constraints to wider participation and inclusion.

[END CASE STUDY 6.2 HERE]

[START CASE STUDY 6.3 HERE]

Case Study 6.3: Beijing, China: Improving Urban Resilience to Rainstorms

Beijing is a mega city with more than 22 million population and per capita gross domestic product of USD 19100 in 2017. Although Beijing is at a lower risk to heavy rain than most of coastal Chinese cities, the heat island effect and global climate change increase the frequency and intensity of extreme weathers in Beijing It was hit by a 70-year-reccurence flood on 21 July 2012. Based on data from National Climate Centre, this extreme event is generated due to a tropical cyclone over the South China Sea which providing plenty of water vapor to Beijing basin area, which is characterized by its total precipitation (ranked at the 6th biggest rainstorm since 1951), raining intensity (daily rainfall of 190.3mm), and affected areas (80% area in Beijing above a major rainfall level of 100mm). The torrential rain affected 1.6 million people across the city (12.8% of the total population in 2012), resulting in 79 deaths and direct economic losses (in Chinese currency Renminbi) of RMB11.8 billion (about 0.07% of annual gross domestic product in Beijing). This catastrophe provoked criticises and reflections to the government's crisis management capacity and credibility from academia to the public.

After the 7-21 rainstorm, Beijing has taken engineering and non-engineering measures, such as a higher building code for drainage system and flood-proof infrastructure, enlarged coverage of early warning systems, an intelligent traffic monitoring and service system, and so on. Shortly after the disaster, "Regulations on the Protection of Beijing Rivers and Lakes" was revised to remove the illegal buildings on the riverbank. The accountability of emergency management was improved by more efficient coordination and timely information sharing between agencies. The weather forecast accuracy in 24 hours has also been effectively improved in recent years. On the July 20th, 2016, Beijing encountered another severe rainstorm exceeding the total precipitation of that in 2012. Owing to these effective actions, Beijing had no one death from flood in this extreme weather. Besides, Beijing municipal government gave a priority investment to disaster proofing and ecological restoration in the flood-prone zone, which contributes a higher resilience performance at district level than before.

[END CASE STUDY 6.3 HERE]

[START CASE STUDY 6.4 HERE]

Case Study 6.4: San Juan: Climate Change Adaptation in San Juan, Puerto Rico

San Juan is the capital of Puerto Rico and where most urban residents are concentrated. San Juan is the economic and main government hub of Puerto Rico, with most of its state and financial institutions located therein. The city occupies 200 km2 and has a total population of 395,326. It is part of the San Juan Metropolitan statistical area that contains more than 2.3 million people in 40 municipios (equivalent to mainland counties) and covers an area of 3,730 km2. Mean annual rainfall in the basin increases from the coast (1,500 mm) to the uplands (1,760 mm). The average annual high temperature in San Juan is 27.2°C, and the average annual low is 23.9°C. San Juan residents are exposed to multiple climate risks, including floods and storm surges from hurricanes and tropical storms, but also extreme precipitation events that lead to pluvial floods (e.g., 80 urban floods were documented between 2004–2014). Most recently, the city has suffered increasingly severe droughts, extremes and prolonged heat episodes during summers (Gould et al., 2018).

In September 2017 Puerto Rico experienced one of the most catastrophic hurricane seasons in recent history (Park and Hanna, 2017; Torres Gotay, 2017). Over a two-week period, the island was impacted by two powerful hurricanes, Irma (category 5) and María (category 4). The compounding effects of these extreme events decimated the island's power, water, communications, and transportation infrastructure, and an estimated 2975 people lost their lives (Milken Institute of Public Health, 2018). Hurricane Maria in particular also exposed existing social and economic vulnerabilities, such as high inequality and poverty rates, and a shrinking population as residents migrated away from the recent economic depression and fiscal crises affecting Puerto Ricans (Miller et al., 2017).

Hurricane Maria however spurred a surge in governmental and non-governmental initiatives to develop and build adaptation pathways to impacts of climate change at city and island scales (Eakin et al., 2018). The non-profit civic sector and well-organized community-based organizations took a protagonist role post-Maria in local and regional adaptation planning (Lugo, 2019). The San Juan Bay Estuary Program, a local NGO, recently launched alongside the Clinton Global Initiative a Commitment to Action to lead and help develop the first Watershed-Based Mitigation Plan for the metro region. The Puerto Rico Community Preparedness and Resiliency Initiative by the Fundación Comunitaria de Puerto Ricois working with a number of communities to design and implement risk reduction action plans, including nature-based solutions to protect communities from climate hazards, floods and sea level rise. Together they have brought together community development and climate change experts from the University of Puerto Rico (UPR), the Education Development Center, and the Regional Education Laboratory Northeast & Islands to co-produce the plans and strategies with community residents and support their implementation. The Rockefeller Foundation's 100 Resilient Cities, the Ford Foundation, and the Center for the New Economy joined forces in the ReImagina Puerto Rico initiative to develop short and long-term resilient strategies for Puerto Rico, many of which apply to San Juan but link the urban center with and other settled areas across the island. The ReImagina Puerto Rico report was generated through with the participation of public, private, NGO sectors, and the Puerto Rican diaspora, resulting in 97 concrete actions and recommendations to inform the rebuild and resiliency efforts. In the energy sector, numerous communities and NGOs have also develop new action plans to promote transitions to renewable energy and community-based micro grids, such as the Queremos Sol initiative (https://www.queremossolpr.com/), and the establishment of solar panels in community centers and residences by the Fundación Comunitaria and Resilient Power Puerto Rico.

Adaptation in governance strategies include major new policy developments at the state level that support climate adaptation in San Juan and island-wide. For example, the Puerto Rico Legislature approved in summer 2018 Senate Bill PS 773 "Ley de Mitigación, Adaptación y Resiliencia para el Cambio Climático de Puerto Rico" (Mitigation, Adaptation and Resilience Law for Climate Change in Puerto Rico) and more recently approved the Puerto Rico Energy Public Policy Act (Senate Bill PS 1121) which sets the island on a path to 100% renewable energy by 2050. In response to the Hurricane Maria, for the first time in Puerto Rico's history, the Puerto Rico Department of Natural Resources and Environment opened in 2019 a Call for Proposals requesting projects to implement nature-based solutions and green infrastructure as a strategy to adapt to climate change, including flood and heat.

[END CASE STUDY 6.4 HERE]

[START CASE STUDY 6.5 HERE]

Case Study 6.5: Cape Town

[PLACHOLDER FOR SECOND ORDER DRAFT: points to include:
- state of water resources in 2015 and how they worsened over 3 years
- role of climate change
- framing of drought
- crisis
- climate
- city-wide
- city level governance
- household response
- impact of drought

Can link to Working Group I case study on the analysis of the climate variability associated with the Cape Town drought and related attribution.

Cape Town's response to drought as an example of:
- how a city with high levels of inequality but substantial capacity responded
- how a technical managerial response had strengths and weaknesses

- were able to roll out technical solutions that helped in some ways
- recognized the limit of infrastructure and the need to change behavior/water consumption
- a shift in how water is thought of and managed
- implications of households and business going off-grid and impacting on financial viability of the water system and challenges for addressing inequality (as high water users used to subsidise poor households)
- climate-dependent water system that has shifted in some ways but not others
- importance of ecosystem
- hydrosocial nature of water]

[END CASE STUDY 6.5 HERE]

Frequently Asked Questions

FAQ 6.1: Why are cities, settlements, and different types of infrastructure vulnerable to the impacts of climate change?

[PLACEHOLDER FOR SECOND ORDER DRAFT]

FAQ 6.2: What actions are needed in cities and settlements to help reduce risks emerging from a changing climate?

[PLACEHOLDER FOR SECOND ORDER DRAFT]

FAQ 6.3: How can citizens, scientists, and policymakers work together to identify and reduce risks to infrastructure, cities and settlements?

[PLACEHOLDER FOR SECOND ORDER DRAFT]

FAQ 6.4: What decision-making and governance arrangements best enable cities and settlements to prepare for climate change impacts?

[PLACEHOLDER FOR SECOND ORDER DRAFT]

References

Abebe, Y., Kabir, G. and Tesfamariam, S., 2018. Assessing Urban Areas Vulnerability to Pluvial Flooding Using GIS Applications and Bayesian Belief Network model. Journal of cleaner production, 174: 1629-1641.

Abu, M., Codjoe, S.N.A. and Sward, J., 2014. Climate change and internal migration intentions in the forest-savannah transition zone of Ghana. Population and Environment, 35(4): 341-364.

Abudu Kasei, R., Dalitso Kalanda-Joshua, M. and Tutu Benefor, D., 2019. Rapid urbanisation and implications for indigenous knowledge in early warning on flood risk in African cities.

Acuto, M., 2016. Give cities a seat at the top table. Nature News, 537(7622): 611.

Adams, H., 2016. Why populations persist: mobility, place attachment and climate change. Population and Environment, 37(4): 429-448.

Adb, 2016. Asian water development outlook: Description of methodology and data, Mandaluyong City.

Adger, W.N., Arnell, N.W., Black, R., Dercon, S., Geddes, A. and Thomas, D.S.G., 2015. Focus on environmental risks and migration: causes and consequences. Environmental Research Letters, 10(6): 060201.

Adger, W.N., Brown, I. and Surminski, S., 2018. Advances in risk assessment for climate change adaptation policy. The Royal Society Publishing.

Adger, W.N., Pulhin, J.M., Barnett, J., Dabelko, G.D., Hovelsrud, G.K., Levy, M., Oswald, S. and Vogel, C.H., 2014. Human Security, IPCC, Cambridge.

Aerts, J.C.J.H., Botzen, W.J., Clarke, K.C., Cutter, S.L., Hall, J.W., Merz, B., Michel-Kerjan, E., Mysiak, J., Surminski, S. and Kunreuther, H., 2018. Integrating human behaviour dynamics into flood disaster risk assessment. Nature Climate Change, 8(3): 193-199.

AghaKouchak, A., Cheng, L., Mazdiyasni, O. and Farahmand, A., 2014. Global warming and changes in risk of concurrent climate extremes: Insights from the 2014 California drought. Geophysical Research Letters, 41(24): 8847-8852.

Agyeman, J., Schlosberg, D., Craven, L. and Matthews, C., 2016. Trends and Directions in Environmental Justice: From Inequity to Everyday Life, Community, and Just Sustainabilities. Annual Review of Environment and Resources, 41(1): 321-340.

Ahdoot, S. and Pacheco, S.E., 2015. Global climate change and children's health. *Pediatrics*, 136(5): e1468-e1484.

Ahilan, S., Guan, M., Sleigh, A., Wright, N. and Chang, H., 2018. The influence of floodplain restoration on flow and sediment dynamics in an urban river. Journal of Flood Risk Management, 11: S986-S1001.

Ahmad, E., Dowling, D., Chan, D., Colenbrander, S. and Godfrey, N., 2019. Scaling up investment for sustainable urban infrastructure: A guide to national and subnational reform. Coalition for Urbank Transition. London and Washington DC.

Ahmed, S., Nahiduzzaman, K.M. and Hasan, M.M.U., 2018. Dhaka, Bangladesh: unpacking challenges and reflecting on unjust transitions. Cities, 77: 142-157.

Ajayi, O.C. and Mafongoya, P.L., 2017. Indigenous knowledge systems and climate change management in Africa. CTA, Wagenigen.

Akanbi, A.K. and Masinde, M., 2018. Towards the Development of a Rule-Based Drought Early Warning Expert Systems Using Indigenous Knowledge. IEEE, Durban, pp. 1-8.

Akbari, H., Cartalis, C., Kolokotsa, D., Muscio, A., Pisello, A.L., Rossi, F., Santamouris, M., Synnefa, A., Wong, N.H. and Zinzi, M., 2016. Local climate change and urban heat island mitigation techniques–the state of the art. Journal of Civil Engineering and Management, 22(1): 1-16.

Akbulut, B., Demaria, F., Gerber, J.-F. and Martínez-Alier, J., 2019. Who promotes sustainability? Five theses on the relationships between the degrowth and the environmental justice movements. Ecological Economics, 165: 106418.

Al-Obaidi, K.M., Ismail, M. and Rahman, A.M.A., 2014. Passive cooling techniques through reflective and radiative roofs in tropical houses in Southeast Asia: A literature review. Frontiers of Architectural Research, 3(3): 283-297.

Albers, R.A.W. and Bosch, P.R., 2015. Overview of challenges and achievements in the climate adaptation of cities and in the Climate Proof Cities program. Building and Environment, 83: 1-10.

Alexander, M., Priest, S. and Mees, H., 2016. A framework for evaluating flood risk governance. Environmental Science & Policy, 64: 38-47.

Alfieri, L., Bisselink, B., Dottori, F., Naumann, G., de Roo, A., Salamon, P., Wyser, K. and Feyen, L., 2017. Global projections of river flood risk in a warmer world. Earth's Future, 5(2): 171-182.

Ali, A., Qadir, J., ur Rasool, R., Sathiaseelan, A., Zwitter, A. and Crowcroft, J., 2016. Big data for development: applications and techniques. Big Data Analytics, 1(1): 2.

Allen, A., 2003. Environmental planning and management of the peri-urban interface: perspectives on an emerging field. Environment and urbanization, 15(1): 135-148.

Altieri, M.A. and Nicholls, C.I., 2017. The adaptation and mitigation potential of traditional agriculture in a changing climate. Climatic Change, 140(1): 33-45.

Altshuler, A.A. and Luberoff, D.E., 2004. Mega-projects: The changing politics of urban public investment. Brookings Institution Press.

Alves, F.M., Campos, I. and Penha-Lopes, G., 2019. Multi-actor perspectives for climate resilient cities: a pilot case, Center for Ecology, Evolution and Environmental changes Faculty of Sciences of the University of Lisbon, Lisbon.
Amani-Beni, M., Zhang, B., Xie, G.-D. and Xu, J., 2018. Impact of urban park's tree, grass and waterbody on microclimate in hot summer days: A case study of Olympic Park in Beijing, China. Urban Forestry and Urban Greening, 32: 1-6.
Aminipouri, M., Rayner, D., Lindberg, F., Thorsson, S., Knudby, A.J., Zickfeld, K., Middel, A. and Krayenhoff, E.S., 2019. Urban tree planting to maintain outdoor thermal comfort under climate change: The case of Vancouver's local climate zones. Building and Environment, 158: 226-236.
Anand, N., 2015. Leaky States: Water Audits, Ignorance, and the Politics of Infrastructure. Public Culture, 27(2 (76)): 305-330.
Anderson, A., Loomba, P., Orajaka, I., Numfor, J., Saha, S., Janko, S., Johnson, N., Podmore, R. and Larsen, R., 2017. Empowering smart communities: electrification, education, and sustainable entrepreneurship in IEEE Smart Village Initiatives. IEEE Electrification Magazine, 5(2): 6-16.
Andersson, E., Langemeyer, J., Borgström, S., McPhearson, T., Haase, D., Kronenberg, J., Barton, D.N., Davis, M., Naumann, S., Röschel, L. and Baró, F., 2019. Enabling Green and Blue Infrastructure to Improve Contributions to Human Well-Being and Equity in Urban Systems. BioScience, 69(7): 566-574.
Andrei, S., Rabbani, G., Khan, H.I., Haque, M. and Ali, D.E., 2015. Non-economic loss and damage caused by climatic stressors in selected coastal districts of Bangladesh, Asian Development Bank, Dhaka.
Andrews, O., Le Quéré, C., Kjellstrom, T., Lemke, B. and Haines, A., 2018. Implications for workability and survivability in populations exposed to extreme heat under climate change: a modelling study. The Lancet Planetary Health, 2(12): e540-e547.
Ang, B.W., Wang, H. and Ma, X., 2017. Climatic influence on electricity consumption: The case of Singapore and Hong Kong. Energy, 127: 534-543.
Angelidou, M., 2015. Smart cities: A conjuncture of four forces. Cities, 47: 95-106.
Angelo, H. and Wachsmuth, D., 2015. Urbanizing urban political ecology: A critique of methodological cityism. International Journal of Urban and Regional Research, 39(1): 16-27.
Anguelovski, I. and Carmin, J., 2011. Something borrowed, everything new: innovation and institutionalization in urban climate governance. Current opinion in environmental sustainability, 3(3): 169-175.
Anguelovski, I., Chu, E. and Carmin, J., 2014. Variations in approaches to urban climate adaptation: Experiences and experimentation from the global South. Global Environmental Change, 27: 156-167.
Anguelovski, I., Connolly, J.J.T., Garcia-Lamarca, M., Cole, H. and Pearsall, H., 2018a. New scholarly pathways on green gentrification: What does the urban 'green turn'mean and where is it going? Progress in Human Geography: 0309132518803799.
Anguelovski, I., Connolly, J.J.T., Masip, L. and Pearsall, H., 2018b. Assessing green gentrification in historically disenfranchised neighborhoods: a longitudinal and spatial analysis of Barcelona. Urban Geography, 39(3): 458-491.
Anguelovski, I., Irazábal-Zurita, C. and Connolly, J.J.T., 2019. Grabbed Urban Landscapes: Socio-spatial Tensions in Green Infrastructure Planning in Medellín. International journal of urban and regional research, 43(1): 133-156.
Anguelovski, I., Shi, L., Chu, E., Gallagher, D., Goh, K., Lamb, Z., Reeve, K. and Teicher, H., 2016. Equity Impacts of Urban Land Use Planning for Climate Adaptation: Critical Perspectives from the Global North and South. Journal of Planning Education and Research, 36(3): 333-348.
Antwi-Agyei, P., Dougill, A.J., Stringer, L.C. and Codjoe, S.N.A., 2018. Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana. Climate Risk Management, 19: 83-93.
Araos, M., Austin, S.E., Berrang-Ford, L. and Ford, J.D., 2015. Public Health Adaptation to Climate Change in Large Cities: A Global Baseline. International Journal of Health Services, 46(1): 53-78.
Araos, M., Berrang-Ford, L., Ford, J.D., Austin, S.E., Biesbroek, R. and Lesnikowski, A., 2016. Climate change adaptation planning in large cities: A systematic global assessment. Environmental Science & Policy, 66: 375-382.
Araos, M., Ford, J., Berrang-Ford, L., Biesbroek, R. and Moser, S., 2017. Climate change adaptation planning for Global South megacities: the case of Dhaka. Journal of Environmental Policy & Planning, 19(6): 682-696.
Arboleda, M., 2016a. In the Nature of the Non-City: Expanded Infrastructural Networks and the Political Ecology of Planetary Urbanisation. Antipode, 48(2): 233-251.
Arboleda, M., 2016b. Spaces of extraction, metropolitan explosions: planetary urbanization and the commodity boom in Latin America. International Journal of Urban and Regional Research, 40(1): 96-112.
Archer, D., 2012. Finance as the key to unlocking community potential: savings, funds and the ACCA programme. Environment and Urbanization, 24(2): 423-440.
Archer, D., Almansi, F., DiGregorio, M., Roberts, D., Sharma, D. and Syam, D., 2014. Moving towards inclusive urban adaptation: approaches to integrating community-based adaptation to climate change at city and national scale. Climate and Development, 6(4): 345-356.
Archer, D. and Dodman, D., 2015. Making capacity building critical: Power and justice in building urban climate resilience in Indonesia and Thailand. Urban Climate, 14: 68-78.

Argüeso, D., Evans, J.P., Fita, L. and Bormann, K.J., 2014. Temperature response to future urbanization and climate change. Climate Dynamics, 42(7-8): 2183-2199.
Arkema, K. and Ruckelshaus, M., 2017. Transdisciplinary research for conservation and sustainable development planning in the Caribbean. In: P.S. Levin and M.R. Poe (Editors), In Conservation in the Anthropocene Ocean: Interdisciplinary Science in Support of Nature and People Elsevier, pp. 333–357
Arnbjerg-Nielsen, K., Willems, P., Olsson, J., Beecham, S., Pathirana, A., Bülow Gregersen, I., Madsen, H. and Nguyen, V.T.V., 2013. Impacts of climate change on rainfall extremes and urban drainage systems: a review. Water Science and Technology, 68(1): 16-28.
Arnell, N.W. and Gosling, S.N., 2016. The impacts of climate change on river flood risk at the global scale. Climatic Change, 134(3): 387-401.
Arnold, A. and Zehnder, K., 1990. Salt weathering on monuments. The conservation of monuments in the Mediterranean Basin, 31-58 pp.
Arns, A., Dangendorf, S., Jensen, J., Talke, S., Bender, J. and Pattiaratchi, C., 2017. Sea-level rise induced amplification of coastal protection design heights. Scientific reports, 7: 40171.
Ashraf, S., AghaKouchak, A., Nazemi, A., Mirchi, A., Sadegh, M., Moftakhari, H.R., Hassanzadeh, E., Miao, C.-Y., Madani, K. and Baygi, M.M., 2018. Compounding effects of human activities and climatic changes on surface water availability in Iran. Climatic Change: 1-13.
Auffhammer, M. and Mansur, E.T., 2014. Measuring climatic impacts on energy consumption: A review of the empirical literature. Energy Economics, 46: 522-530.
Ayers, J.M., Huq, S., Faisal, A.M. and Hussain, S.T., 2014. Mainstreaming climate change adaptation into development: a case study of Bangladesh. Wiley Interdisciplinary Reviews: Climate Change, 5(1): 37-51.
Aylett, A., 2014. Progress and challenges in the urban governance of climate change: results of a global survey. MIT.
Aylett, A., 2015. Institutionalizing the urban governance of climate change adaptation: Results of an international survey. Urban Climate, 14: 4-16.
Badami, M.G. and Ramankutty, N., 2015. Urban agriculture and food security: A critique based on an assessment of urban land constraints. Global Food Security, 4: 8-15.
Baeza, A., Bojorquez-Tapia, L.A., Janssen, M.A. and Eakin, H., 2019. Operationalizing the feedback between institutional decision-making, socio-political infrastructure, and environmental risk in urban vulnerability analysis. Journal of environmental management, 241: 407-417.
Bahadur, A. and Tanner, T., 2014. Transformational resilience thinking: putting people, power and politics at the heart of urban climate resilience. Environment and Urbanization, 26(1): 200-214.
Bai, X., 2007. Integrating global environmental concerns into urban management: the scale and readiness arguments. Journal of Industrial Ecology, 11(2): 15-29.
Bai, X., Dawson, R.J., Ürge-Vorsatz, D., Delgado, G.C., Salisu Barau, A., Dhakal, S., Dodman, D., Leonardsen, L., Masson-Delmotte, V., Roberts, D.C. and Schultz, S., 2018. Six research priorities for cities and climate change. Nature, 555: 23-25.
Bain, P.G., Milfont, T.L., Kashima, Y., Bilewicz, M., Doron, G., Garðarsdóttir, R.B., Gouveia, V.V., Guan, Y., Johansson, L.-O. and Pasquali, C., 2016. Co-benefits of addressing climate change can motivate action around the world. Nature Climate Change, 6(2): 154-157.
Baker & McKenzie, 2015. Spanning Africa's Infrastructure Gap: How development capital is transforming Africa's project build-out, The Economist.
Baklanov, A., Molina, L.T. and Gauss, M., 2016. Megacities, air quality and climate. Atmospheric Environment, 126: 235-249.
Balsas, C.J.L., 2018. Sustainable urbanism in temperate-arid climates: Models, challenges and opportunities for the Anthropocene. Journal of Public Affairs, 18(4): n/a-n/a.
Ban, N., Schmidli, J. and Schär, C., 2015. Heavy precipitation in a changing climate: Does short-term summer precipitation increase faster? Geophysical Research Letters, 42(4): 1165-1172.
Baniassadi, A., Sailor, D.J., Crank, P.J. and Ban-Weiss, G.A., 2018. Direct and indirect effects of high-albedo roofs on energy consumption and thermal comfort of residential buildings. Energy and Buildings, 178: 71-83.
Bansard, J.S., Pattberg, P.H. and Widerberg, O., 2017. Cities to the rescue? Assessing the performance of transnational municipal networks in global climate governance. International Environmental Agreements: Politics, Law and Economics, 17(2): 229-246.
Barau, A.S., Maconachie, R., Ludin, A.N.M. and Abdulhamid, A., 2015. Urban Morphology Dynamics and Environmental Change in Kano, Nigeria. Land Use Policy, 42: 307-317.
Barbosa, R., Vicente, R. and Santos, R., 2015. Climate change and thermal comfort in Southern Europe housing: A case study from Lisbon. Building and Environment, 92: 440-451.
Barendrecht, M.H., Viglione, A. and Blöschl, G., 2017. A dynamic framework for flood risk. Water Security, 1: 3-11.
Barnett, C. and Parnell, S., 2016. Ideas, implementation and indicators: epistemologies of the post-2015 urban agenda. Environment and Urbanization, 28(1): 87-98.
Barnett, J., Tschakert, P., Head, L. and Adger, W.N., 2016. A science of loss. Nature Climate Change, 6(11): 976.
Barton, J.R., 2013. Climate Change Adaptive Capacity in Santiago de Chile: Creating a Governance Regime for Sustainability Planning. International Journal of Urban and Regional Research, 37(6): 1916-1933.

Bartos, M., Chester, M., Johnson, N., Gorman, B., Eisenberg, D., Linkov, I. and Bates, M., 2016. Impacts of rising air temperatures on electric transmission ampacity and peak electricity load in the United States. Environmental Research Letters, 11(11): 114008.
Bastagli, F., 2014. Responding to a Crisis: The Design and Delivery of Social Protection, Overseas Development Institute, London.
Bataille, C., Waisman, H., Colombier, M., Segafredo, L. and Williams, J., 2016. The Deep Decarbonization Pathways Project (DDPP): insights and emerging issues. Climate Policy, 16(sup1): S1-S6.
Becker, A., Ng, A.K.Y., McEvoy, D. and Mullett, J., 2018. Implications of climate change for shipping: Ports and supply chains. Wiley Interdisciplinary Reviews: Climate Change, 9(2): e508.
Beckett, K.P., Freer Smith, P.H. and Taylor, G., 2000. Effective tree species for local air quality management. Arboricultural Journal, 26(1): 12-19.
Behrens, P., van Vliet, M.T.H., Nanninga, T., Walsh, B. and Rodrigues, J.F.D., 2017. Climate change and the vulnerability of electricity generation to water stress in the European Union. Nature Energy, 2(8): 17114.
Bellinson, R. and Chu, E., 2019. Learning pathways and the governance of innovations in urban climate change resilience and adaptation. Journal of Environmental Policy & Planning, 21(1): 76-89.
Below, T.B., Mutabazi, K.D., Kirschke, D., Franke, C., Sieber, S., Siebert, R. and Tscherning, K., 2012. Can farmers' adaptation to climate change be explained by socio-economic household-level variables? Global Environmental Change, 22(1): 223-235.
Benson, E.M. and Bereitschaft, B., 2019. Are LEED-ND developments catalysts of neighborhood gentrification? International Journal of Urban Sustainable Development.
Berardy, A. and Chester, M.V., 2017. Climate change vulnerability in the food, energy, and water nexus: concerns for agricultural production in Arizona and its urban export supply. Environmental Research Letters, 12(3): 035004.
Bergek, A., Hekkert, M., Jacobsson, S., Markard, J., Sandén, B. and Truffer, B., 2015. Technological innovation systems in contexts: Conceptualizing contextual structures and interaction dynamics. Environmental Innovation and Societal Transitions, 16: 51-64.
Beringer, A. and Kaewsuk, J., 2018. Emerging Livelihood Vulnerabilities in an Urbanizing and Climate Uncertain Environment for the Case of a Secondary City in Thailand. Sustainability, 10(5): 1452.
Berquist, M., Daniere, A. and Drummond, L., 2015. Planning for global environmental change in Bangkok's informal settlements. Journal of Environmental Planning and Management, 58(10): 1711-1730.
Berrang-Ford, L., Biesbroek, R., Ford, J.D., Lesnikowski, A., Tanabe, A., Wang, F.M., Chen, C., Hsu, A., Hellmann, J.J. and Pringle, P., 2019. Tracking global climate change adaptation among governments. Nature Climate Change, 9(6): 440.
Berrisford, S., Cirolia, L.R. and Palmer, I., 2018. Land-based financing in sub-Saharan African cities. Environment and Urbanization, 30(1): 35-52.
Bertolin, C. and Camuffo, D., 2015. Risk Assessment, Climate for Culture – Built Cultural Heritage in times of Climate Change, pp. 28-30.
Bertolin, C. and Loli, A., 2018. Sustainable interventions in historic buildings: A developing decision making tool. Journal of Cultural Heritage, 34: 291-302.
Bettini, G., 2014. Climate migration as an adaption strategy: de-securitizing climate-induced migration or making the unruly governable? Critical Studies on Security, 2(2): 180-195.
Betzold, C., 2015. Adapting to climate change in small island developing states. Climatic Change, 133(3): 481-489.
Beunen, R., Patterson, J. and Van Assche, K., 2017. Governing for resilience: the role of institutional work. Current Opinion in Environmental Sustainability, 28: 10-16.
Bhaskar, A.S., Beesley, L., Burns, M.J., Fletcher, T.D., Hamel, P., Oldham, C.E. and Roy, A.H., 2016. Will it rise or will it fall? Managing the complex effects of urbanization on base flow. Freshwater Science, 35(1): 293-310.
Bhat, G.K., Karanth, A., Dashora, L. and Rajasekar, U., 2013. Addressing flooding in the city of Surat beyond its boundaries. Environment and Urbanization, 25(2): 429-441.
Biagini, B. and Miller, A., 2013. Engaging the private sector in adaptation to climate change in developing countries: importance, status, and challenges. Climate and Development, 5(3): 242-252.
Bickerstaff, K., 2012. "Because We've Got History Here": Nuclear Waste, Cooperative Siting, and the Relational Geography of a Complex Issue. Environment and Planning A, 44(11): 2611-2628.
Bickerstaff, K., Walker, G. and Bulkeley, H., 2013. Energy Justice in a Changing Climate: Social equity and low-carbon energy. ZED Books, New York.
Bilkovic, D.M., Mitchell, M.M., La Peyre, M., K. and Toft, J.D., 2017. Living shorelines: The science and management of nature- based coastal protection. CRC Marine Science. CRS Press.
Binti Sa'adin, L.S., Kaewunruen, S. and Jaroszweski, D., 2016. Risks of Climate Change with Respect to the Singapore-Malaysia High Speed Rail System. Climate, 4(4).
Birtchnell, T., Gill, N. and Sultana, R., 2019. Sleeper cells for urban green infrastructure: Harnessing latent competence in greening Dhaka's slums. Urban Forestry & Urban Greening, 40: 93-104.
Bisaro, A., Roggero, M. and Villamayor-Tomas, S., 2018. Institutional Analysis in Climate Change Adaptation Research: A Systematic Literature Review. Ecological Economics, 151: 34-43.
BlaBlaCar, 2019. Zero Empty Seats BlaBlaCar.

Black, R., Arnell, N.W., Adger, W.N., Thomas, D. and Geddes, A., 2013. Migration, immobility and displacement outcomes following extreme events. Environmental Science & Policy, 27: S32-S43.
Blöschl, G., Hall, J., Parajka, J., Perdigão, R.A.P., Merz, B., Arheimer, B., Aronica, G.T., Bilibashi, A., Bonacci, O. and Borga, M., 2017. Changing climate shifts timing of European floods. Science, 357(6351): 588-590.
Bocken, N.M.P., Short, S.W., Rana, P. and Evans, S., 2014. A literature and practice review to develop sustainable business model archetypes. Journal of cleaner production, 65: 42-56.
Boezeman, D. and de Vries, T., 2019. Climate proofing social housing in the Netherlands: toward mainstreaming? Journal of Environmental Planning and Management, 62(8): 1-19.
Bompard, E., Huang, T., Wu, Y. and Cremenescu, M., 2013. Classification and trend analysis of threats origins to the security of power systems. International Journal of Electrical Power & Energy Systems, 50: 50-64.
Bonazza, A., Sabbioni, C., Messina, P., Guaraldi, C. and De Nuntiis, P., 2009. Climate change impact: mapping thermal stress on Carrara marble in Europe. Science of the Total Environment, 407(5): 4506-4512.
Boorman, P., Jenkins, G., Murphy, J. and Burgess, K., 2010. Future changes in fog frequency from the UKCP09 ensemble of regional climate model projections.
Bounoua, L., Zhang, P., Mostovoy, G., Thome, K., Masek, J., Imhoff, M., Shepherd, M., Quattrochi, D., Santanello, J. and Silva, J., 2015. Impact of urbanization on US surface climate. Environmental Research Letters, 10(8): 084010.
Boussalis, C., Coan, T.G. and Holman, M.R., 2019. Communicating Climate Mitigation and Adaptation Efforts in American Cities. Climate, 7(3): 45.
Boutwell, J.L. and Westra, J.V., 2016. The Role of Wetlands for Mitigating Economic Damage from Hurricanes. JAWRA Journal of the American Water Resources Association, 52(6): 1472-1481.
Boyd, E. and Juhola, S., 2015. Adaptive climate change governance for urban resilience. Urban studies, 52(7): 1234-1264.
Brandsen, T. and Honingh, M., 2016. Distinguishing different types of coproduction: A conceptual analysis based on the classical definitions. Public Administration Review, 76(3): 427-435.
Brenner, N., 2014. Implosions/explosions. Jovis, Berlin.
Brenner, N. and Schmid, C., 2017. Planetary urbanization, The Globalizing Cities Reader. Routledge, pp. 479-482.
Bridges, T.S., Wagner, P.W., Burks-Copes, K.A., Bates, M.E., Collier, Z.A., Fischenich, C.J., Gailani, J.Z., Leuck, L.D., Piercy, C.D., Rosati, J.D., Russo, E.J., Shafer, D.J., Suedel, B.C., Vuxton, E.A. and Wamsley, T.V., 2015. Use of Natural and Nature-Based Features (NNBF) for coastal resilience . US Army Corps of Engineers - Engineer Research and Development Center, US Army Corps of Engineers.
Briggs, K.M., Loveridge, F.A. and Glendinning, S., 2017. Failures in transport infrastructure embankments. Engineering Geology, 219: 107-117.
Brocherie, F., Girard, O. and Millet, P.G., 2015. Emerging Environmental and Weather Challenges in Outdoor Sports. Climate, 3(3).
Bronen, R., 2015. Climate-induced community relocations: using integrated social-ecological assessments to foster adaptation and resilience. Ecology and Society, 20(3).
Brown, A.E., 2018. Ridehail revolution: Ridehail travel and equity in Los Angeles, UCLA, Los Angeles.
Brown, D. and McGranahan, G., 2016. The urban informal economy, local inclusion and achieving a global green transformation. Habitat International, 53: 97-105.
Brunetta, G. and Caldarice, O., 2019. Putting Resilience into Practice. The Spatial Planning Response to Urban Risks. In: G. Brunetta, O. Caldarice, N. Tollin, M. Rosas-Casals and J. Morató (Editors), Urban Resilience for Risk and Adaptation Governance. Resilient Cities (Re-thinking Urban Transformation). Springer, Cham, pp. 27-41.
Brzoska, M. and Fröhlich, C., 2016. Climate change, migration and violent conflict: vulnerabilities, pathways and adaptation strategies. Migration and Development, 5(2): 190-210.
Buchanan, M.K., Oppenheimer, M. and Kopp, R.E., 2017. Amplification of flood frequencies with local sea level rise and emerging flood regimes. Environmental Research Letters, 12(6): 064009.
Bulkeley, H., 2015a. Accomplishing climate governance. Cambridge University Press, Cambridge.
Bulkeley, H., 2015b. Can cities realise their climate potential? Reflections on COP21 Paris and beyond. Local Environment, 20(11): 1405-1409.
Bulkeley, H., Coenen, L., Frantzeskaki, N., Hartmann, C., Kronsell, A., Mai, L., Marvin, S., McCormick, K., van Steenbergen, F. and Palgan, Y.V., 2016. Urban living labs: governing urban sustainability transitions. Current Opinion in Environmental Sustainability, 22: 13-17.
Bulkeley, H., Edwards, G.A.S. and Fuller, S., 2014a. Contesting climate justice in the city: Examining politics and practice in urban climate change experiments. Global Environmental Change, 25: 31-40.
Bulkeley, H.A., Castán Broto, V. and Edwards, G.A., 2014b. An urban politics of climate change: experimentation and the governing of socio-technical transitions. Routledge.
Burkart, K., Meier, F., Schneider, A., Breitner, S., Canário, P., Alcoforado Maria, J., Scherer, D. and Endlicher, W., 2016. Modification of Heat-Related Mortality in an Elderly Urban Population by Vegetation (Urban Green) and Proximity to Water (Urban Blue): Evidence from Lisbon, Portugal. Environmental Health Perspectives, 124(7): 927-934.

Burke, B.J. and Heynen, N., 2014. Transforming participatory science into socioecological praxis: valuing marginalized environmental knowledges in the face of the neoliberalization of nature and science. Environment and Society, 5(1): 7-27.
Burke, M. and Emerick, K., 2016. Adaptation to climate change: Evidence from US agriculture. American Economic Journal: Economic Policy, 8(3): 106-40.
Burke, M., Hsiang, S.M. and Miguel, E., 2015. Global non-linear effect of temperature on economic production. Nature, 527: 235.
Burnett, D., Barbour, E. and Harrison, G.P., 2014. The UK solar energy resource and the impact of climate change. Renewable Energy, 71: 333-343.
Businger, S., Nogelmeier, M.P., Chinn, P.W.U. and Schroeder, T., 2018. Hurricane with a history: Hawaiian newspapers illuminate an 1871 storm. Bulletin of the American Meteorological Society, 99(1): 137-147.
Butler, D.C., 2018. Climate Change, Health and Existential Risks to Civilization: A Comprehensive Review (1989–2013). International Journal of Environmental Research and Public Health, 15(10).
Butler, W.H., Deyle, R.E. and Mutnansky, C., 2016. Low-regrets incrementalism: Land use planning adaptation to accelerating sea level rise in Florida's Coastal Communities. Journal of Planning Education and Research, 36(3): 319-332.
Buurman, J., Mens, M.J.P. and Dahm, R.J., 2017. Strategies for urban drought risk management: a comparison of 10 large cities. International Journal of Water Resources Development, 33(1): 31-50.
Byers, E.A., Hall, J.W. and Amezaga, J.M., 2014. Electricity generation and cooling water use: UK pathways to 2050. Global Environmental Change, 25: 16-30.
Byers, E.A., Hall, J.W., Amezaga, J.M., O'Donnell, G.M. and Leathard, A., 2016. Water and climate risks to power generation with carbon capture and storage. Environmental Research Letters, 11(2): 024011.
Bäckstrand, K. and Kuyper, J.W., 2017. The democratic legitimacy of orchestration: the UNFCCC, non-state actors, and transnational climate governance. Environmental Politics: 1-25.
Béné, C., Cornelius, A. and Howland, F., 2018a. Bridging Humanitarian Responses and Long-Term Development through Transformative Changes—Some Initial Reflections from the World Bank's Adaptive Social Protection Program in the Sahel. Sustainability, 10(6): 1697.
Béné, C., Mehta, L., McGranahan, G., Cannon, T., Gupte, J. and Tanner, T., 2018b. Resilience as a policy narrative: potentials and limits in the context of urban planning. Climate and Development, 10(2): 116-133.
Cai, R., Feng, S., Oppenheimer, M. and Pytlikova, M., 2016. Climate variability and international migration: The importance of the agricultural linkage. Journal of Environmental Economics and Management, 79: 135-151.
Calfapietra, C., Fares, S., Manes, F., Morani, A., Sgrigna, G. and Loreto, F., 2013. Role of Biogenic Volatile Organic Compounds (BVOC) emitted by urban trees on ozone concentration in cities: A review. Environmental pollution, 183: 71-80.
Calvet, M.S. and Broto, V.C., 2016. Green enclaves, neoliberalism and the constitution of the experimental city in Santiago de Chile, The Experimental City. Routledge, pp. 107-121.
Caminade, C., Kovats, S., Rocklov, J., Tompkins, A.M., Morse, A.P., Colón-González, F.J., Stenlund, H., Martens, P. and Lloyd, S.J., 2014. Impact of climate change on global malaria distribution. Proceedings of the National Academy of Sciences, 111(9): 3286.
Campbell, B.M., Thornton, P., Zougmoré, R., van Asten, P. and Lipper, L., 2014. Sustainable intensification: What is its role in climate smart agriculture? Current Opinion in Environmental Sustainability, 8: 39-43.
Campbell, S., Remenyi, T.A., White, C.J. and Johnston, F.H., 2018. Heatwave and health impact research: A global review. Health & place, 53: 210-218.
Campbell-Lendrum, D., Manga, L., Bagayoko, M. and Sommerfeld, J., 2015. Climate change and vector-borne diseases: what are the implications for public health research and policy? Philosophical Transactions of the Royal Society B: Biological Sciences, 370(1665): 20130552.
Camuffo, D., 2019. Microclimate for Cultural Heritage: Measurement, Risk Assessment, Conservation, Restoration, and Maintenance of Indoor and Outdoor Monuments. Elsevier.
Camuffo, D., Bertolin, C. and Schenal, P., 2017. A novel Proxy and the Sea Level Rise in Venice, Italy, from 1350 to 2014. Climatic Change, 143(1): 73-86.
Camuffo, D., Fassina, V. and Havermans, J., 2010a. Basic environmental mechanisms affecting cultural heritage—understanding deterioration mechanisms for conservation purposes.
Camuffo, D., Pagan, E., Rissanen, S., Bratasz, Ł., Kozłowski, R., Camuffo, M. and Della Valle, A., 2010b. An advanced church heating system favourable to artworks: a contribution to European standardisation. Journal of Cultural Heritage, 11(2): 205-219.
Caparros-Midwood, D., Dawson, R. and Barr, S., 2019. Low Carbon, Low Risk, Low Density: Resolving choices about sustainable development in cities. Cities, 89: 252-267.
Carlson, K. and McCormick, S., 2015. American adaptation: Social factors affecting new developments to address climate change. Global Environmental Change, 35: 360-367.
Carmichael, B., Wilson, G., Namarnyilk, I., Nadji, S., Brockwell, S., Webb, B., Hunter, F. and Bird, D., 2017. Local and indigenous management of climate change risks to archaeological sites. Mitigation and Adaptation Strategies for Global Change, 23: 231-255.

Carmin, J., Nadkarni, N. and Rhie, C., 2012. Progress and Challenges in Urban Climate Adaptation Planning: Results of a Global, Progress and Challenges in Urban Climate Adaptation Planning: Results of a Global. Massachusetts Institute of Technology (MIT).
Carmin, J., Tierney, K., Chu, E., Hunter, L.M., Roberts, J.T. and Shi, L., 2015. Adaptation to Climate Change. In: R.E. Dunlap and R.J. Brulle (Editors). Oxford University Press, Oxford and New York, pp. 164-198.
Carter, J.G., Cavan, G., Connelly, A., Guy, S., Handley, J. and Kazmierczak, A., 2015. Climate change and the city: Building capacity for urban adaptation. Progress in Planning, 95(Complete): 1-66.
Carter, M.R. and Janzen, S.A., 2018. Social protection in the face of climate change: targeting principles and financing mechanisms. Environment and Development Economics, 23(3): 369-389.
Casa, D.J., DeMartini, J.K., Bergeron, M.F., Csillan, D., Eichner, E.R., Lopez, R.M., Ferrara, M.S., Miller, K.C., O'Connor, F., Sawka, M.N. and Yeargin, S.W., 2015. National Athletic Trainers' Association Position Statement: Exertional Heat Illnesses. Journal of Athletic Training, 50(9): 986-1000.
Castan Broto, V. and Bulkeley, H., 2013. A survey of urban climate change experiments in 100 cities. Global environmental change, 23(1): 92-102.
Castán Broto, V., 2014. Planning for climate change in the African city. International Development Planning Review, 36(3): 257-264.
Castán Broto, V., 2017a. Energy landscapes and urban trajectories towards sustainability. Energy Policy, 108: 755-764.
Castán Broto, V., 2017b. Urban governance and the politics of climate change. World development, 93: 1-15.
Castán Broto, V., 2019. Urban Energy Landscapes. Cambridge University Press, Cambridge.
Castán Broto, V., Ensor, J., Boyd, E., Allen, C., Seventine, C. and Macucule, D., 2015a. Participatory planning for climate compatible development in Maputo, Mozambique. Ucl Press.
Castán Broto, V., Macucule, D.A., Boyd, E., Ensor, J. and Allen, C., 2015b. Building collaborative partnerships for climate change action in Maputo, Mozambique. Environment and Planning A, 47(3): 571-587.
Castán Broto, V., Trencher, G., Iwaszuk, E. and Westman, L., 2018. Transformative capacity and local action for urban sustainability. Ambio.
Cavallo, A. and Ireland, V., 2014. Preparing for complex interdependent risks: a system of systems approach to building disaster resilience. International journal of disaster risk reduction, 9: 181-193.
Cederlöf, G., 2016. Low-carbon food supply: the ecological geography of Cuban urban agriculture and agroecological theory. Agriculture and Human Values, 33(4): 771-784.
Cellura, M., Guarino, F., Longo, S., Mistretta, M. and Tumminia, G., 2017. Effect of Climate Change on Building Performance: the Role of Ventilative Cooling, International Building Performance Simulation Association, San Francisco, CA, USA.
Challinor, A.J., Watson, J., Lobell, D.B., Howden, S.M., Smith, D.R. and Chhetri, N., 2014. A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change, 4: 287.
Chan, S., Falkner, R., van Asselt, H. and Goldberg, M., 2015a. Strengthening non-state climate action: a progress assessment of commitments launched at the 2014 UN Climate Summit, Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment working papers (242, 216), London, UK.
Chan, S., van Asselt, H., Hale, T., Abbott, K.W., Beisheim, M., Hoffmann, M., Guy, B., Höhne, N., Hsu, A. and Pattberg, P., 2015b. Reinvigorating international climate policy: a comprehensive framework for effective nonstate action. Global Policy, 6(4): 466-473.
Chandra, A. and Gaganis, P., 2016. Deconstructing vulnerability and adaptation in a coastal river basin ecosystem: a participatory analysis of flood risk in Nadi, Fiji Islands. Climate and Development, 8(3): 256-269.
Chang, N.-B., Lu, J.-W., Chui, T.F.M. and Hartshorn, N., 2018. Global policy analysis of low impact development for stormwater management in urban regions. Land Use Policy, 70(Complete): 368-383.
Chaves, I.A., Melchers, R.E., Peng, L. and Stewart, M.G., 2016. Probabilistic remaining life estimation for deteriorating steel marine infrastructure under global warming and nutrient pollution. Ocean Engineering, 126: 129-137.
Chelleri, L., Schuetze, T. and Salvati, L., 2015. Integrating resilience with urban sustainability in neglected neighborhoods: Challenges and opportunities of transitioning to decentralized water management in Mexico City. Habitat International, 48: 122-130.
Chen, M., 2014. Informal employment and development: Patterns of inclusion and exclusion. The European Journal of Development Research, 26(4): 397-418.
Chen, M., Roever, S. and Skinner, C., 2016. Urban livelihoods: Reframing theory and policy. Sage Publications Sage UK: London, England.
Chen, W.-B. and Liu, W.-C., 2014. Modelling flood inundation induced by river flow and storm surges over a river basin. Water, 6(10): 3182-3199.
Cheng, L., Hoerling, M., AghaKouchak, A., Livneh, B., Quan, X.-W. and Eischeid, J., 2016. How has human-induced climate change affected California drought risk? Journal of Climate, 29(1): 111-120.
Chhetri, N., Chaudhary, P., Tiwari, P.R. and Yadaw, R.B., 2012. Institutional and technological innovation: Understanding agricultural adaptation to climate change in Nepal. Applied Geography, 33: 142-150.
Chhetri, P., Corcoran, J., Gekara, V., Maddox, C. and McEvoy, D., 2015. Seaport resilience to climate change: mapping vulnerability to sea-level rise. Journal of Spatial Science, 60(1): 65-78.

Ching, J., Mills, G., Bechtel, B., See, L., Feddema, J., Wang, X., Ren, C., Brousse, O., Martilli, A., Neophytou, M., Mouzourides, P., Stewart, I., Hanna, A., Ng, E., Foley, M., Alexander, P., Aliaga, D., Niyogi, D., Shreevastava, A., Bhalachandran, P., Masson, V., Hidalgo, J., Fung, J., Andrade, M., Baklanov, A., Dai, W., Milcinski, G., Demuzere, M., Brunsell, N., Pesaresi, M., Miao, S., Mu, Q., Chen, F. and Theeuwes, N., 2018. WUDAPT: An Urban Weather, Climate, and Environmental Modelling Infrastructure for the Anthropocene. Bulletin of the American Meteorological Society, 99(9): 1907-1924.
Chinowsky, P.S., Price, J.C. and Neumann, J.E., 2013. Assessment of climate change adaptation costs for the US road network. Global Environmental Change, 23(4): 764-773.
Chirisa, I. and Bandauko, E., 2015. African Cities and the Water-Food-Climate-Energy Nexus: an Agenda for Sustainability and Resilience at a Local Level. Urban Forum, 26(4): 391-404.
Choko, O.P., Schmitt Olabisi, L., Onyeneke, R.U., Chiemela, S.N., Liverpool-Tasie, L.S.O. and Rivers, L., 2019. A Resilience Approach to Community-Scale Climate Adaptation. Sustainability, 11(11): 3100.
Chow, W.T.L., Akbar, S.N.A.B.A., Heng, S.L. and Roth, M., 2016. Assessment of measured and perceived microclimates within a tropical urban forest. Urban Forestry & Urban Greening, 16: 62-75.
Chow, W.T.L., Salamanca, F., Georgescu, M., Mahalov, A., Milne, J.M. and Ruddell, B.L., 2014. A multi-method and multi-scale approach for estimating city-wide anthropogenic heat fluxes. Atmospheric Environment, 99: 64-76.
Chowdhury, M.R., Jahan, F. and Rahman, R., 2017. Developing urban space: the changing role of NGOs in Bangladesh. Development in Practice, 27(2): 260-271.
Choy, D.L., Clarke, P., Serrao-Neumann, S., Hales, R., Koschade, O. and Jones, D., 2016. Coastal Urban and Peri-Urban Indigenous People's Adaptive Capacity to Climate Change. In: B. Maheshwari, Singh, V.P. and B. Thoradeniya (Editors), Balanced Urban Development: Options and Strategies for Liveable Cities. Springer, Cham, pp. 441-461.
Christian-Smith, J., Levy, M.C. and Gleick, P.H., 2015. Maladaptation to drought: a case report from California, USA. Sustainability Science, 10(3): 491-501.
Christiansen, L., Martinez, G.S. and Naswa, P., 2018. Adaptation metrics: Perspectives on measuring, aggregating and comparing adaptation results.
Chu, E., 2016a. The political economy of urban climate adaptation and development planning in Surat, India. Environment and Planning C: Government and Policy, 34(2): 281-298.
Chu, E., Anguelovski, I. and Carmin, J., 2016. Inclusive approaches to urban climate adaptation planning and implementation in the Global South. Climate Policy, 16(3): 372-392.
Chu, E., Anguelovski, I. and Roberts, D., 2017. Climate adaptation as strategic urbanism: assessing opportunities and uncertainties for equity and inclusive development in cities. Cities, 60: 378-387.
Chu, E. and Michael, K., 2018. Recognition in urban climate justice : marginality and exclusion of migrants in Indian cities. Environment and Urbanization(4).
Chu, E., Schenk, T. and Patterson, J., 2018. The dilemmas of citizen inclusion in urban planning and governance to enable a 1.5 C climate change scenario. Urban Planning, 3(2): 128–140.
Chu, E.K., 2016b. The governance of climate change adaptation through urban policy experiments. Environmental Policy and Governance, 26(6): 439-451.
Chu, E.K., 2018a. Transnational support for urban climate adaptation: Emerging forms of agency and dependency. Global Environmental Politics, 18(3): 25-46.
Chu, E.K., 2018b. Urban climate adaptation and the reshaping of state–society relations: The politics of community knowledge and mobilisation in Indore, India. Urban Studies, 55(8): 1766-1782.
Chuah, C.J., Ho, B.H. and Chow, W.T.L., 2018. Trans-boundary variations of urban drought vulnerability and its impact on water resource management in Singapore and Johor, Malaysia. Environmental Research Letters, 13(7): 074011.
Cid-Aguayo, B.E., 2016. People, Nature, and Climate: Heterogeneous Networks in Narratives and Practices about Climate Change. Latin American Perspectives, 43(4): 12-28.
Cirolia, L. and Rode, P., 2019. Urban infrastructure and development.
Cirolia, L.R. and Mizes, J.C., 2019. Property Tax in African Secondary Cities: Insights from the Cases of Kisumu (Kenya) and M'Bour (Senegal).
Cities Climate Finance Leadership Alliance, 2015. The Bangkok-Johannesburg Blueprint. CCFLA.
City of Los Angeles, 2017. Los Angeles River Revitalization.
Clark, S.S., Chester, M.V., Seager, T.P. and Eisenberg, D.A., 2019. The vulnerability of interdependent urban infrastructure systems to climate change: could Phoenix experience a Katrina of extreme heat? Sustainable and Resilient Infrastructure, 4(1): 21-35.
Clarvis, M., Bohensky, E. and Yarime, M., 2015. Can resilience thinking inform resilience investments? Learning from resilience principles for disaster risk reduction. Sustainability, 7(7): 9048-9066.
Cloutier, G., Joerin, F., Dubois, C., Labarthe, M., Legay, C. and Viens, D., 2015. Planning adaptation based on local actors' knowledge and participation: a climate governance experiment. Climate Policy, 15(4): 458-474.
Cloutier, G., Papin, M. and Bizier, C., 2018. Do-it-yourself (DIY) adaptation: Civic initiatives as drivers to address climate change at the urban scale. Cities, 74: 284-291.
Codjoe, S.N.A., Nyamedor, F.H., Sward, J. and Dovie, D.B., 2017. Environmental hazard and migration intentions in a coastal area in Ghana: a case of sea flooding. Population and Environment, 39(2): 128-146.

Codjoe, S.N.A., Owusu, G. and Burkett, V., 2014. Perception, experience, and indigenous knowledge of climate change and variability: the case of Accra, a sub-Saharan African city. Regional Environmental Change, 14(1): 369-383.
Coffel, E. and Horton, R., 2014. Climate Change and the Impact of Extreme Temperatures on Aviation. Weather, Climate, and Society, 7(1): 94-102.
Coffman, L., 1999. Low Impact Development Design Strategies; An Integrated Design Approach, Department of Environmental Resources; Programs and Planning Division, Prince George's county, Maryland.
Cohen, J.E., 2019. Cities and Climate Change: A Review Essay. Population and Development Review, 45(2): 425-435.
Coll, J., Woolf, D.K., Gibb, S.W. and Challenor, P.G., 2013. Sensitivity of ferry services to the Western Isles of Scotland to changes in wave and wind climate. Journal of Applied Meteorology and Climatology, 52(5): 1069-1084.
Collier, P. and Venables, A.J., 2016. Urban infrastructure for development. Oxford Review of Economic Policy, 32(3): 391-409.
Connell, J., 2016. Last days in the Carteret Islands? Climate change, livelihoods and migration on coral atolls. Asia Pacific Viewpoint, 57(1): 3-15.
Conry, P., Sharma, A., Potosnak, M.J., Leo, L.S., Bensman, E., Hellmann, J.J. and Fernando, H.J.S., 2015. Chicago's heat island and climate change: Bridging the scales via dynamical downscaling. Journal of Applied Meteorology and Climatology, 54(7): 1430-1448.
Conway, D., van Garderen, E.A., Deryng, D., Dorling, S., Krueger, T., Landman, W., Lankford, B., Lebek, K., Osborn, T., Ringler, C., Thurlow, J., Zhu, T. and Dalin, C., 2015. Climate and southern Africa's water–energy–food nexus. Nature Climate Change, 5(9): 837-846.
Cook, M.J. and Chu, E.K., 2018. Between Policies, Programs, and Projects: How Local Actors Steer Domestic Urban Climate Adaptation Finance in India. In: S. Hughes, E.K. Chu and S.G. Mason (Editors), Climate Change in Cities. The Urban Book Series. Springer, Cham.
Cooper, D., Kruglikova and N., 2019. Augmented Realities: The Digital Economy of Indigenous Knowledge, International Labor Organisation, Geneva.
Cousins, J.J. and Newell, J.P., 2015. A political–industrial ecology of water supply infrastructure for Los Angeles. Geoforum, 58: 38-50.
Coutard, O. and Rutherford, J., 2015. Beyond the Networked City: Infrastructure Reconfigurations and Urban Change in the North and South. Routledge, London.
Coutts, A.M., White, E.C., Tapper, N.J., Beringer, J. and Livesley, S.J., 2016. Temperature and human thermal comfort effects of street trees across three contrasting street canyon environments. Theoretical and applied climatology, 124(1-2): 55-68.
Cradden, L., Burnett, D., Agarwal, A. and Harrison, G., 2015. Climate change impacts on renewable electricity generation. Infrastructure Asset Management, 2(3): 131-142.
Cradden, L.C. and Harrison, G.P., 2013. Adapting overhead lines to climate change: Are dynamic ratings the answer? Energy Policy, 63: 197-206.
Cremades, R., Surminski, S., Costa, M.M., Hudson, P., Shrivastava, P. and Gascoigne, J., 2018. Using the adaptive cycle in climate-risk insurance to design resilient futures. Nature Climate Change, 8(1): 4.
Creutzig, F., Lohrey, S., Bai, X., Baklanov, A., Dawson, R., Dhakal, S., Lamb, W.F., McPhearson, T., Minx, J. and Munoz, E., 2019. Upscaling urban data science for global climate solutions. Global Sustainability, 2.
Crnogorcevic and Leo, 2019. School strike 4 climate: History, challenges and what's next, Green Left Weekly, pp. 10.
Cronin, J., Anandarajah, G. and Dessens, O., 2018. Climate change impacts on the energy system: a review of trends and gaps. Climatic change, 151(2): 79-93.
Cruz, A.M. and Krausmann, E., 2013. Vulnerability of the oil and gas sector to climate change and extreme weather events. Climatic change, 121(1): 41-53.
Cuevas, S., 2016. The interconnected nature of the challenges in mainstreaming climate change adaptation: evidence from local land use planning. Climatic Change, 136(3-4): 661-676.
Cuevas, S., Peterson, A., Robinson, C. and Morrison, T., 2016. Institutional capacity for long-term climate change adaptation: evidence from land use planning in Albay, Philippines. Regional Environmental Change, 16(7): 2045-2058.
Cunniff, S. and Schwartz, A., 2015. Performance of natural infrastructure and nature-based measures as coastal risk reduction features, Environmental Defense Fund, New York.
Cutter-Mackenzie, A. and Rousell, D., 2019. Education for what? Shaping the field of climate change education with children and young people as co-researchers. Children's Geographies, 17(1): 90-104.
Danière, A., Drummond, L., NaRanong, A. and Tran, V.A.T., 2016. Sustainable flows: water management and municipal flexibility in Bangkok and Hanoi. The Journal of Environment & Development, 25(1): 47-72.
Das, P., 2016. Uncharted waters: Navigating new configurations for urban service delivery in India. Environment and Planning A, 48(7): 1354-1373.
Data Driven Yale NewClimate Institute PBL, 2018. Global climate action of regions, states and businesses.
Davidson, K., Coenen, L., Acuto, M. and Gleeson, B., 2019. Reconfiguring urban governance in an age of rising city networks: A research agenda. Urban Studies: 0042098018816010.
Davoudi, S., Crawford, J. and Mehmood, A., 2009. Planning for climate change: strategies for mitigation and adaptation for spatial planners. Earthscan.

Dawson, R., 2015. Handling interdependencies in climate change risk assessment. Climate, 3(4): 1079-1096.
Dawson, R.J., Thompson, D., Johns, D., Wood, R., Darch, G., Chapman, L., Hughes, P.N., Watson, G.V.R., Paulson, K. and Bell, S., 2018. A systems framework for national assessment of climate risks to infrastructure. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 376(2121): 20170298.
Dawson, T., 2013. Erosion and Coastal Archaeology: Evaluating the Treat and Prioritising Action, HOMER Conference Proceedings. Oxford University Archeopress.
de Groot-Reichwein, M.A.M., Van Lammeren, R.J.A., Goosen, H., Koekoek, A., Bregt, A.K. and Vellinga, P., 2018. Urban heat indicator map for climate adaptation planning. Mitigation and adaptation strategies for global change, 23(2): 169-185.
De Hoop, J., Morey, M., Ring, H., Rothbard, V. and Seidenfeld, D., "Min Ila" Cash Transfer Programme for Displaced Syrian Children in Lebanon UNICEF and WFP.
de Munck, C., Lemonsu, A., Masson, V., Le Bras, J. and Bonhomme, M., 2018. Evaluating the impacts of greening scenarios on thermal comfort and energy and water consumptions for adapting Paris city to climate change. Urban Climate, 23: 260-286.
de Zeeuw, H. and Drechsel, P., 2015. Cities and agriculture: Developing resilient urban food systems. Routledge, London.
Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., Lastra, M. and Scapini, F., 2009. Threats to sandy beach ecosystems: a review. Estuarine, coastal and shelf science, 81(1): 1-12.
Dempsey, N., Bramley, G., Power, S. and Brown, C., 2011. The social dimension of sustainable development: Defining urban social sustainability. Sustainable development, 19(5): 289-300.
Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Bhave, A.G., Mittal, N., Feliu, E. and Faehnle, M., 2014. Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. Journal of Environmental Management, 146: 107-115.
Depietri, Y. and McPhearson, T., 2017. Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction. In: N. Kabisch, H. Korn, J. Stadler, Bonn and A. (Editors), Nature-Based Solutions to Climate Change Adaptation in Urban Areas: Linkages between Science, Policy and Practice. Springer International Publishing, Cham, pp. 91–109
Devkota, N. and Phuyal, R.K., 2018. Adoption Practice of Climate Change Adaptation Options among Nepalese Rice Farmers: Role of Information and Communication Technologies (ICTs). American Journal of Climate Change, 7(02): 135.
Dhar, T. and Khirfan, L., 2016. Community-based Adaptation through Ecological Design: Lessons from Negril, Jamaica. Journal of Urban Design, 21(2): 234-255.
Dhar, T. and Khirfan, L., 2017a. A Multi-scale and Multi-dimensional Framework for Enhancing the Resilience of Urban Form to Climate Change. Urban Climate, 17: 72-91.
Dhar, T.K. and Khirfan, L., 2017b. Climate change adaptation in the urban planning and design research: missing links and research agenda. Journal of Environmental Planning and Management, 60(4): 602-627.
Di Giulio, G.M., Bedran-Martins, A.M.B., Vasconcellos, M.d.P., Ribeiro, W.C. and Lemos, M.C., 2018. Mainstreaming climate adaptation in the megacity of São Paulo, Brazil. Cities, 72: 237-244.
Diederichs, N. and Roberts, D., 2016. Climate protection in mega-event greening: the 2010 FIFA™ World Cup and COP17/CMP7 experiences in Durban, South Africa. Climate and Development, 8(4): 376-384.
Dierwechter, Y. and Wessells, A.T., 2013. The uneven localisation of climate action in metropolitan Seattle. Urban Studies, 50(7): 1368-1385.
Diffenbaugh, N.S., Swain, D.L. and Touma, D., 2015. Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Sciences, 112(13): 3931-3936.
Dilling, L., Daly, M.E., Kenney, D.A., Klein, R., Miller, K., Ray, A.J., Travis, W.R. and Wilhelmi, O., 2019. Drought in urban water systems: Learning lessons for climate adaptive capacity. Climate Risk Management, 23: 32-42.
Dilling, L., Pizzi, E., Berggren, J., Ravikumar, A. and Andersson, K., 2017. Drivers of adaptation: Responses to weather- and climate-related hazards in 60 local governments in the Intermountain Western U.S. Environment and Planning A: Economy and Space, 49(11): 2628-2648.
Din, A. and Brotas, L., 2017. Assessment of climate change on UK dwelling indoor comfort. Energy Procedia, 122: 21-26.
Dino, I.G. and Meral Akgül, C., 2019. Impact of climate change on the existing residential building stock in Turkey: An analysis on energy use, greenhouse gas emissions and occupant comfort. Renewable Energy, 141: 828-846.
Dobson, S., Nyamweru, H. and Dodman, D., 2015. Local and participatory approaches to building resilience in informal settlements in Uganda. Environment and Urbanization, 27(2): 605-620.
Dodman, D., Colenbrander, S. and Archer, D., 2017a. Conclusion. In: D. Archer, S. Colenbrander and D. Dodman (Editors), Responding to climate change in Asian cities: Governance for a more resilient urban future. Routledge Earthscan, Abingdon.
Dodman, D., Leck, H., Rusca, M. and Colenbrander, S., 2017b. African Urbanisation and Urbanism: Implications for risk accumulation and reduction. International journal of disaster risk reduction, 26: 7-15.
Dodman, D., Mitlin, D. and Co, J.R., 2010. Victims to victors, disasters to opportunities: Community-driven responses to climate change in the Philippines. International Development Planning Review, 32(1): 1-26.

Dodoo, A. and Gustavsson, L., 2016. Energy use and overheating risk of Swedish multi-storey residential buildings under different climate scenarios. Energy, 97: 534-548.
Doherty, M., Klima, K. and Hellmann, J.J., 2016. Climate change in the urban environment: Advancing, measuring and achieving resiliency. Environmental Science & Policy, 66(Complete): 310-313.
Doick, K.J., Peace, A. and Hutchings, T.R., 2014. The role of one large greenspace in mitigating London's nocturnal urban heat island. Science of the total environment, 493: 662-671.
Doll, C., Klug, S. and Enei, R., 2014. Large and small numbers: options for quantifying the costs of extremes on transport now and in 40 years. Natural hazards, 72(1): 211-239.
Douglas, E.M., Reardon, K.M. and Täger, M.C., 2018. Participatory action research as a means of achieving ecological wisdom within climate change resiliency planning. Journal of Urban Management, 7(3): 152-160.
Douglas, I., 2017. Flooding in African cities, scales of causes, teleconnections, risks, vulnerability and impacts. International journal of disaster risk reduction, 26: 34-42.
Douglas, I., 2018. The challenge of urban poverty for the use of green infrastructure on floodplains and wetlands to reduce flood impacts in intertropical Africa. Landscape and Urban Planning, 180: 262-272.
Dugan, J.E., Airoldi, L., Chapman, M.G., Walker, S.J., Schlacher, T., Wolanski, E. and McLusky, D., 2011. 8.02-Estuarine and coastal structures: environmental effects, a focus on shore and nearshore structures. Treatise on estuarine and coastal science, 8: 17-41.
Duguma, L.A., Minang, P.A. and van Noordwijk, M., 2014. Climate change mitigation and adaptation in the land use sector: from complementarity to synergy. Environmental management, 54(3): 420-432.
Duijn, M. and van Buuren, A., 2017. The absence of institutional entrepreneurship in climate adaptation policy – in search of local adaptation strategies for Rotterdam's unembanked areas. Policy and Society, 36(4): 575-594.
Dulal, H.B. and Shah, K.U., 2014. 'Climate-smart' social protection: Can it be achieved without a targeted household approach? Environmental Development, 10: 16-35.
Dunlap, R. and Brulle, R., 2015. Climate Change and Society: Sociological Perspectives. Oxford Scholarship Online, New York.
Dunne, J.P., Stouffer, R.J. and John, J.G., 2013. Reductions in labour capacity from heat stress under climate warming. Nature Climate Change, 3: 563.
Dutra, L.X.C., Bayliss, P., McGregor, S., Christophersen, P., Scheepers, K., Woodward, E., Ligtermoet, E. and Melo, L.i.F.C., 2017. Understanding climate-change adaptation on Kakadu National Park, using a combined diagnostic and modelling framework: a case study at Yellow Water wetland. Marine and Freshwater Research, 69(7): 1146-1158.
Döll, P., Jiménez-Cisneros, B., Oki, T., Arnell, N.W., Benito, G., Cogley, J.G., Jiang, T., Kundzewicz, Z.W., Mwakalila, S. and Nishijima, A., 2015. Integrating risks of climate change into water management. Hydrological Sciences Journal, 60(1): 4-13.
D'Alisa, G. and Kallis, G., 2016. A political ecology of maladaptation: Insights from a Gramscian theory of the State. Global environmental change, 38: 230-242.
e Sousa, R.d.C. and Ríos-Touma, B., 2018. Stream restoration in Andean cities: learning from contrasting restoration approaches. Urban ecosystems, 21(2): 281-290.
Eakin, H., Lerner, A.M. and Murtinho, F., 2010. Adaptive capacity in evolving peri-urban spaces: Responses to flood risk in the Upper Lerma River Valley, Mexico. Global Environmental Change, 20(1): 14-22.
Eakin, H., Muñoz-Erickson, T.A. and Lemos, M.C., 2018. Critical Lines of Action for Vulnerability and Resilience Research and Practice: Lessons from the 2017 Hurricane Season. Journal of Extreme Events, 5(02n03): 1850015.
Eakin, H., Wightman, P.M., Hsu, D., Gil Ramón, V.R., Fuentes-Contreras, E., Cox, M.P., Hyman, T.-A.N., Pacas, C., Borraz, F. and González-Brambila, C., 2015. Information and communication technologies and climate change adaptation in Latin America and the Caribbean: a framework for action. Climate and Development, 7(3): 208-222.
Ebhuoma, E.E. and Simatele, D.M., 2019. 'We know our Terrain': indigenous knowledge preferred to scientific systems of weather forecasting in the Delta State of Nigeria. Climate and Development, 11(2): 112-123.
Ebi Kristie, L., Ogden Nicholas, H., Semenza Jan, C. and Woodward, A., 2017. Detecting and Attributing Health Burdens to Climate Change. Environmental Health Perspectives, 125(8): 085004.
Eckart, K., McPhee, Z. and Bolisetti, T., 2017. Performance and implementation of low impact development–a review. Science of the Total Environment, 607: 413-432.
Economist Intelligence Unit, 2015. The cost of inaction: Recognising the value at risk from climate change, The Economist.
Edwards, G.A. and Bulkeley, H., 2017. Urban political ecologies of housing and climate change: The 'Coolest Block'Contest in Philadelphia. Urban Studies, 54(5): 1126-1141.
Eizenberg, E. and Jabareen, Y., 2017. Social sustainability: A new conceptual framework. Sustainability, 9(1): 68.
Elliott, J., Deryng, D., Müller, C., Frieler, K., Konzmann, M., Gerten, D., Glotter, M., Flörke, M., Wada, Y., Best, N., Eisner, S., Fekete, B.M., Folberth, C., Foster, I., Gosling, S.N., Haddeland, I., Khabarov, N., Ludwig, F., Masaki, Y., Olin, S., Rosenzweig, C., Ruane, A.C., Satoh, Y., Schmid, E., Stacke, T., Tang, Q. and Wisser, D., 2014. Constraints and potentials of future irrigation water availability on agricultural production under climate change. Proceedings of the National Academy of Sciences, 111(9): 3239.
Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., Takeuchi, K. and Folke, C., 2019. Sustainability and resilience for transformation in the urban century. Nature Sustainability, 2(4): 267-273.

Elnabawi, M.H., Hamza, N. and Dudek, S., 2016. Thermal perception of outdoor urban spaces in the hot arid region of Cairo, Egypt. Sustainable Cities and Society, 22: 136-145.
Emmanuel, R. and Loconsole, A., 2015. Green infrastructure as an adaptation approach to tackling urban overheating in the Glasgow Clyde Valley Region, UK. Landscape and Urban Planning, 138(Complete): 71-86.
ENA, 2015. Climate Change Adaptation Reporting Power Second Round, Energy Networks Association, London.
England, M.I., Stringer, L.C., Dougill, A.J. and Afionis, S., 2018. How do sectoral policies support climate compatible development? An empirical analysis focusing on southern Africa. Environmental Science & Policy, 79: 9-15.
Ernstson, H. and Swyngedouw, E., 2018. Urban Political Ecology in the Anthropo-obscene: Interruptions and Possibilities. Routledge.
ETSAP, 2014. IEA Energy Technology Systems Analysis Programme - Technology Brief E12, IEA-ETSAP.
Faber, D.R. and Krieg, E.J., 2002. Unequal exposure to ecological hazards: environmental injustices in the Commonwealth of Massachusetts. Environmental Health Perspectives, 110(suppl 2): 277-288.
Falasca, S., Ciancio, V., Salata, F., Golasi, I., Rosso, F. and Curci, G., 2019. High albedo materials to counteract heat waves in cities: An assessment of meteorology, buildings energy needs and pedestrian thermal comfort. Building and Environment, 163.
Fankhauser, S. and McDermott, T.K.J., 2016. The Economics of Climate Resilient Development. Edward Elgar, Cheltenham.
Fant, C., Schlosser, C.A. and Strzepek, K., 2016. The impact of climate change on wind and solar resources in southern Africa. Applied Energy, 161: 556-564.
Fatoric, S. and Seekamp, E., 2017. Evaluating a decision analytic approach to climate change adaptation of cultural resources along the Atlantic Coast of the United States. Land Use Policy, 68: 254-263.
Fatorić, S. and Seekamp, E., 2017. Are cultural heritage and resources threatened by climate change? A systematic literature review. Climate Change, 142(1-2): 227–254.
Fatorić, S. and Seekamp, E., 2018. A measurement framework to increase transparency in historic preservation decision-making under changing climate conditions. Journal of Cultural Heritage, 30(3): 168-179.
Feitosa, R.C. and Wilkinson, S.J., 2018. Attenuating heat stress through green roof and green wall retrofit. Building and Environment, 140: 11-22.
Feldpausch-Parker, A.M., Peterson, T.R., Stephens, J.C. and Wilson, E.J., 2018. Smart grid electricity system planning and climate disruptions: A review of climate and energy discourse post-Superstorm Sandy. Renewable and Sustainable Energy Reviews, 82: 1961-1968.
Feola, G., Lerner, A.M., Jain, M., Montefrio, M.J.F. and Nicholas, K.A., 2015. Researching farmer behaviour in climate change adaptation and sustainable agriculture: Lessons learned from five case studies. Journal of Rural Studies, 39: 74-84.
Feola, G. and Nunes, R., 2014. Success and failure of grassroots innovations for addressing climate change: The case of the Transition Movement. Global Environmental Change, 24: 232-250.
Fernandez Milan, B. and Creutzig, F., 2015. Reducing urban heat wave risk in the 21st century. Current Opinion in Environmental Sustainability, 14: 221-231.
Fernández-Llamazares, Á., Díaz-Reviriego, I., Luz, A.C., Cabeza, M., Pyhälä, A. and Reyes-García, V., 2015. Rapid ecosystem change challenges the adaptive capacity of local environmental knowledge. Global Environmental Change, 31: 272-284.
Ferranti, E., Chapman, L., Lowe, C., McCulloch, S., Jaroszweski, D. and Quinn, A., 2016. Heat-Related Failures on Southeast England's Railway Network: Insights and Implications for Heat Risk Management. Weather, Climate, and Society, 8(2): 177-191.
Ferrario, F., Beck, M.W., Storlazzi, C.D., Micheli, F., Shepard, C.C. and Airoldi, L., 2014. The effectiveness of coral reefs for coastal hazard risk reduction and adaptation. Nature communications, 5: 3794.
Filipe, A., Renedo, A. and Marston, C., 2017. The co-production of what? Knowledge, values, and social relations in health care, PLoS Biology.
Fink, J.H., 2019. Contrasting governance learning processes of climate-leading and -lagging cities: Portland, Oregon, and Phoenix, Arizona, USA. Journal of Environmental Policy & Planning, 21(1): 16-29.
Fisher, S., 2015. The emerging geographies of climate justice. The Geographical Journal, 181(1): 73-82.
Fisk, W.J., 2015. Review of some effects of climate change on indoor environmental quality and health and associated no-regrets mitigation measures. Building and Environment, 86: 70-80.
Fletcher, C.G., Matthews, L., Andrey, J. and Saunders, A., 2015. Projected Changes in Mid-Twenty-First-Century Extreme Maximum Pavement Temperature in Canada. Journal of Applied Meteorology and Climatology, 55(4): 961-974.
Floater, G., Dowling, D., Chan, D., Ulterino, M., Braunstein, J., McMinn, T. and Ahmad, E., 2017. Global review of Finance for sustainable Urban Infrastructure. Coalition for Urban Transitions, http://newclimateeconomy. net/content/cities-working-papers.
Foran, J., 2019. System Change, Not Climate Change: Radical Social Transformation in the Twenty-First Century. In: Berberoglu and B. (Editors), The Palgrave Handbook of Social Movements, Revolution, and Social Transformation. Palgrave McMillan, Cham, pp. 399-425.

Ford, A., Barr, S., Dawson, R., Virgo, J., Batty, M. and Hall, J., 2019. A Multi-Scale Urban Integrated Assessment Framework for Climate Change Studies: A Flooding application. Computers, Environment and Urban Systems, 75: 229-243.
Ford, J.D., Berrang-Ford, L., Biesbroek, R., Araos, M., Austin, S.E. and Lesnikowski, A., 2015. Adaptation tracking for a post-2015 climate agreement. Nature Climate Change, 5(11): 967.
Ford, J.D., Pearce, T., McDowell, G., Berrang-Ford, L., Sayles, J.S. and Belfer, E., 2018. Vulnerability and its discontents: the past, present, and future of climate change vulnerability research. Climatic change, 151(2): 189-203.
Form-Based Codes, I., 2015. Form-based codes defined.
Forzieri, G., Bianchi, A., e Silva, F.B., Herrera, M.A.M., Leblois, A., Lavalle, C., Aerts, J.C.J.H. and Feyen, L., 2018. Escalating impacts of climate extremes on critical infrastructures in Europe. Global environmental change, 48: 97-107.
Fosas, D., Coley, D., Natarajan, S., Herrera, M., de Pando, M. and Ramallo-Gonzalez, A., 2018. Mitigation versus adaptation: Does insulating dwellings increase overheating risk? Building and Environment, 143: 740- 759.
Foulkes, C., Wilson, L., McMahon, C., Ecclestone, E., Wheeler, K. and Wynne, S., 2016. Updated indicators of climate change risk and adaptation action in England, ADAS Ltd f or the UK Committee on Climate Change.
Founda, D. and Santamouris, M., 2017. Synergies between Urban Heat Island and Heat Waves in Athens (Greece), during an extremely hot summer (2012). Scientific reports, 7(1): 10973.
Franchini, M. and Mannucci, P.M., 2015. Impact on human health of climate changes. European Journal of Internal Medicine, 26(1): 1-5.
Frantzeskaki, N., Castán Broto, V., Coenen, L. and Loorbach, D., 2017. Urban Sustainability Transitions. Routledge, London.
Frantzeskaki, N., Dumitru, A., Anguelovski, I., Avelino, F., Bach, M., Best, B., Binder, C., Barnes, J., Carrus, G., Egermann, M., Haxeltine, A., Moore, M.-L., Mira, R.G., Loorbach, D., Uzzell, D., Omann, I., Olsson, P., Silvestri, G., Stedman, R., Wittmayer, J., Durrant, R. and Rauschmayer, F., 2016. Elucidating the changing roles of civil society in urban sustainability transitions. Current Opinion in Environmental Sustainability, 22: 41-50.
Frantzeskaki, N., McPhearson, T., Collier, M.J., Kendal, D., Bulkeley, H., Dumitru, A., Walsh, C., Noble, K., van Wyk, E., Ordóñez, C., Oke, C. and Pintér, L., 2019. Nature-Based Solutions for Urban Climate Change Adaptation: Linking Science, Policy, and Practice Communities for Evidence-Based Decision-Making. BioScience, 69(6): 455-466.
Frantzeskaki, N., Wittmayer, J. and Loorbach, D., 2014. The role of partnerships in 'realising'urban sustainability in Rotterdam's City Ports Area, The Netherlands. Journal of Cleaner Production, 65: 406-417.
Fraser, A., Leck, H., Parnell, S., Pelling, M., Brown, D. and Lwasa, S., 2017. Meeting the challenge of risk-sensitive and resilient urban development in sub-Saharan Africa: Directions for future research and practice. International journal of disaster risk reduction, 26: 106-109.
Freire, M.E., Lall, S. and Leipziger, D., 2014. Africa's urbanization: challenges and opportunities. The growth dialogue, 7: 1-30.
Fri, R.W. and Savitz, M.L., 2014. Rethinking energy innovation and social science. Energy Research & Social Science, 1: 183-187.
Fry, T.J. and Maxwell, R.M., 2017. Evaluation of distributed BMP s in an urban watershed—High resolution modelling for stormwater management. Hydrological processes, 31(15): 2700-2712.
Fu, G., Dawson, R., Khoury, M. and Bullock, S., 2014. Interdependent networks: vulnerability analysis and strategies to limit cascading failure. The European Physical Journal B, 87(7): 148.
Fu, G., Horrocks, L. and Winne, S., 2016. Exploring impacts of climate change on UK's ICT infrastructure. Infrastructure Asset Management, 3(1): 42-52.
Fuhr, H., Hickmann, T. and Kern, K., 2018. The role of cities in multi-level climate governance: local climate policies and the 1.5°C target. Current Opinion in Environmental Sustainability, 30: 1-6.
Fuller, S. and McCauley, D., 2016. Framing energy justice: perspectives from activism and advocacy. Energy Research & Social Science, 11: 1-8.
Fünfgeld, H., 2015. Facilitating local climate change adaptation through transnational municipal networks. Current Opinion in Environmental Sustainability, 12: 67-73.
Galarraga, I., de Murieta, E.S., Markandya, A. and Abadie, L.M., 2018. Addendum to 'Understanding risks in the light of uncertainty: low-probability, high-impact coastal events in cities'. Environmental Research Letters, 13(2): 029401.
Gallina, V., Torresan, S., Critto, A., Sperotto, A., Glade, T. and Marcomini, A., 2016. A review of multi-risk methodologies for natural hazards: Consequences and challenges for a climate change impact assessment. Journal of environmental management, 168: 123-132.
Gammage, G., 2016. Future of the Suburban City. Island Press, Washington.
Garde, A., 2018. Form-Based Codes for Downtown Redevelopment: Insights from Southern California. Journal of Planning Education and Research, 38(2): 198-210.
Garde, A. and Hoff, A., 2017. Zoning reform for advancing sustainability: insights from Denver's form-based code. Journal of urban Design, 22(6): 845-865.

Garde, A. and Kim, C., 2017. Form-Based Codes for Zoning Reform to Promote Sustainable Development: Insights From Cities in Southern California. Journal of the American Planning Association, 83(4): 346-364.
Garde, A., Kim, C. and Tsai, O., 2015. Differences Between Miami's Form-Based Code and Traditional Zoning Code in Integrating Planning Principles. Journal of the American Planning Association, 81(1): 46-66.
Gasparrini, A., Guo, Y., Hashizume, M., Lavigne, E., Zanobetti, A., Schwartz, J., Tobias, A., Tong, S., Rocklöv, J. and Forsberg, B., 2015. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. The Lancet, 386(9991): 369-375.
Gemenne, F., Barnett, J., Adger, W.N. and Dabelko, G.D., 2014. Climate and security: evidence, emerging risks, and a new agenda. Climatic Change, 123(1): 1-9.
Geneletti, D. and Zardo, L., 2016. Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans. Land use policy, 50: 38-47.
Ghanem, D.A., Mander, S. and Gough, C., 2016. "I think we need to get a better generator": Household resilience to disruption to power supply during storm events. Energy Policy, 92: 171-180.
Gillis, L.G., Jones, C.G., Ziegler, A.D., van der Wal, D., Breckwoldt, A. and Bouma, T.J., 2017. Opportunities for protecting and restoring tropical coastal ecosystems by utilizing a physical connectivity approach. Frontiers in Marine Science, 4: 374.
Giridharan, R. and Emmanuel, R., 2018. The impact of urban compactness, comfort strategies and energy consumption on tropical urban heat island intensity: A review. Sustainable Cities and Society, 40(Complete): 677-687.
Glaas, E., Hjerpe, M., Storbjörk, S., Neset, T.-S., Bohman, A., Muthumanickam, P. and Johansson, J., 2018. Developing transformative capacity through systematic assessments and visualization of urban climate transitions. Ambio: 1-14.
Glaser, J., Lemery, J., Rajagopalan, B., Diaz, H.F., García-Trabanino, R., Taduri, G., Madero, M., Amarasinghe, M., Abraham, G., Anutrakulchai, S., Jha, V., Stenvinkel, P., Roncal-Jimenez, C., Lanaspa, M.A., Correa-Rotter, R., Sheikh-Hamad, D., Burdmann, E.A., Andres-Hernando, A., Milagres, T., Weiss, I., Kanbay, M., Wesseling, C., Sánchez-Lozada, L.G. and Johnson, R.J., 2016. Climate Change and the Emergent Epidemic of CKD from Heat Stress in Rural Communities: The Case for Heat Stress Nephropathy. Clinical Journal of the American Society of Nephrology, 11(8): 1472.
Global Commission on Economy and Climate, 2017. Unlocking the inclusive growth story of the 21st century: accelerating climate action in urgent times. Global Commission on Economy and Climate.
Gober, P., Sampson, D.A., Quay, R., White, D.D. and Chow, W.T.L., 2016. Urban adaptation to mega-drought: Anticipatory water modelling, policy, and planning for the urban Southwest. Sustainable Cities and Society, 27: 497-504.
Goh, K., 2019. Flows in formation: The global-urban networks of climate change adaptation. Urban Studies: 0042098018807306.
Goldstein, A., Turner, W.R., Gladstone, J. and Hole, D.G., 2019. The private sector's climate change risk and adaptation blind spots. Nature Climate Change, 9(1): 18-25.
Goldstein, B., Hauschild, M., Fernandez, J. and Birkved, M., 2016. Testing the environmental performance of urban agriculture as a food supply in northern climates. Journal of Cleaner Production, 135: 984-994.
Gombay, N. and Palomino-Schalscha, M., 2018. Indigenous Places and Colonial Spaces: The Politics of Intertwined Relations. Routledge, London and New York.
Gomes, S.L. and Hermans, L.M., 2018. Institutional function and urbanization in Bangladesh: How peri-urban communities respond to changing environments. Land Use Policy, 79: 932-941.
Gomes, S.L., Hermans, L.M. and Thissen, W.A.H., 2018. Extending community operational research to address institutional aspects of societal problems: Experiences from peri-urban Bangladesh. European Journal of Operational Research, 268(3): 904-917.
Gondhalekar, D. and Ramsauer, T., 2017. Nexus City: operationalizing the urban water-energy-food nexus for climate change adaptation in Munich, Germany. Urban Climate, 19: 28-40.
Gordon, D. and Acuto, M., 2015. If cities are the solution, what are the problems? The promise and perils of urban climate leadership, The urban climate challenge. Routledge, pp. 73-91.
Gordon, D.J. and Johnson, C.A., 2017. The orchestration of global urban climate governance: conducting power in the post-Paris climate regime. Environmental Politics, 26(4): 694-714.
Gorelick, J., 2018. Supporting the future of municipal bonds in sub-Saharan Africa: the centrality of enabling environments and regulatory frameworks. Environment and Urbanization, 30(1): 103-122.
Gould, K.A. and Lewis, T.L., 2018. From Green Gentrification to Resilience Gentrification: An Example from Brooklyn. City & Community, 17(1): 12-15.
Gould, W.A., Díaz, E.L., Álvarez-Berríos, N.L., Aponte-González, F., Archibald, W., Bowden, J.H., Carrubba, L., Crespo, W., Fain, S.J., González, G., Goulbourne, A., Harmsen, E., Holupchinski, E., Khalyani, A.H., Kossin, J., Leinberger, A.J., Marrero-Santiago, V.I., Martínez- Sánchez, O., McGinley, K., Méndez-Lázaro, P., Morell, J., Oyola, M.M., Parés-Ramos, I.K., Pulwarty, R., Sweet, W.V., Terando, A. and Torres-González, S., 2018. U.S. Caribbean, US Climate Change Research Program.
Government of India, 2011. ST in India as Revealed in Census 2011. Ministry of Tribal Affairs Government of India.
Government of Nepal, 2014. Economic Impact Assessment of Climate Change in Key Sectors in Nepal, Government of Nepal Ministry of Science, Technology and Environment (MoSTE), Kathmandu.

Graff Zivin, J. and Neidell, M., 2014. Temperature and the Allocation of Time: Implications for Climate Change. Journal of Labor Economics, 32(1): 1-26.
Graham, S. and Marvin, S., 2002. Splintering urbanism: networked infrastructures, technological mobilities and the urban condition. Routledge.
Gran Castro, J.A. and Ramos De Robles, S.L., 2019. Climate change and flood risk: vulnerability assessment in an urban poor community in Mexico. Environment and Urbanization(4): 095624781982785-095624781982785.
Granberg, M. and Glover, L., 2014. Adaptation and Maladaptation in Australian National Climate Change Policy. Journal of Environmental Policy & Planning, 16(2): 147-159.
Gray, C. and Wise, E., 2016. Country-specific effects of climate variability on human migration. Climatic Change, 135(3-4): 555-568.
Green, H., Bailey, J., Schwarz, L., Vanos, J., Ebi, K. and Benmarhnia, T., 2019. Impact of heat on mortality and morbidity in low and middle income countries: A review of the epidemiological evidence and considerations for future research. Environmental research.
Greenwalt, J., Raasakka, N. and Alverson, K., 2018. Building Urban Resilience to Address Urbanization and Climate Change. In: Z. Zommers, Z. and Z.a.M. Corps (Editors), Resilience: The Science of Adaptation to Climate Change, Amsterdam, pp. 151-164.
Grigg, N.S., 2019. Global water infrastructure: state of the art review. International journal of water resources development, 35(2): 181-205.
Grimm, N.B., Cook, E.M., Hale, R.L. and Iwaniec, D.M., 2016. A broader framing of ecosystem services in cities: benefits and challenges of built, natural or hybrid system function. In: K.C. Seto, W. Solecki and C.A. Griffith (Editors), Routledge Handbook of Urbanization and Global Environmental Change pp. 202–212
Grimm, N.B., Redman, C.L., Boone, C.G., Childers, D.L., Harlan, S.L. and Turner, B., 2013. Viewing the urban socio-ecological system through a sustainability lens: Lessons and prospects from the central Arizona–Phoenix LTER programme, Long term socio-ecological research. Springer, pp. 217-246.
Gromke, C., Blocken, B., Janssen, W., Merema, B., van Hooff, T. and Timmermans, H., 2015. CFD analysis of transpirational cooling by vegetation: Case study for specific meteorological conditions during a heat wave in Arnhem, Netherlands. Building and Environment, 83: 11-26.
Gronlund, C.J., Berrocal, V.J., White-Newsome, J.L., Conlon, K.C. and O'Neill, M.S., 2015. Vulnerability to extreme heat by socio-demographic characteristics and area green space among the elderly in Michigan, 1990–2007. Environmental Research, 136: 449-461.
Grossi, C.M., Brimblecombe, P. and Harris, I., 2007. Predicting long term freeze-thaw risks on Europe built heritage and archaeological sites in a changing climate. Science of the Total Environment, 377(2): 273-281.
Grouillet, B., Fabre, J., Ruelland, D. and Dezetter, A., 2015. Historical reconstruction and 2050 projections of water demand under anthropogenic and climate changes in two contrasted Mediterranean catchments. Journal of Hydrology, 522: 684-696.
Grunenfelder, J. and Schurr, C., 2015. Intersectionality - A challenge for development research and practice? Development in Practice, 25(6): 771-784.
GSMA, 2019. *Unique mobile subscribers penetration rate as share of population worldwide from 2016 to 2025, by region*. Statista.
Guannel, G., Arkema, K., Ruggiero, P. and Verutes, G., 2016. The power of three: coral reefs, seagrasses and mangroves protect coastal regions and increase their resilience. PloS one, 11(7): e0158094.
Guerreiro, S., Glenis, V., Dawson, R. and Kilsby, C., 2017. Pluvial flooding in European cities—A continental approach to urban flood modelling. Water, 9(4): 296.
Guerreiro, S.B., Dawson, R.J., Kilsby, C., Lewis, E. and Ford, A., 2018. Future heat-waves, droughts and floods in 571 European cities. Environmental Research Letters, 13(3): 034009.
Guibrunet, L., Calvet, M.S. and Broto, V.C., 2017. Flows, system boundaries and the politics of urban metabolism: Waste management in Mexico City and Santiago de Chile. Geoforum, 85: 353-367.
Guibrunet, L. and Castán Broto, V., 2016. 7. Towards an urban metabolic analysis of the informal city. Handbook of Cities and the Environment: 160.
Gunawardena, K.R., Wells, M.J. and Kershaw, T., 2017. Utilising green and bluespace to mitigate urban heat island intensity. Science of the Total Environment, 584: 1040-1055.
Gunningham, N., 2019. Averting Climate Catastrophe: Environmental Activism, Extinction Rebellion and Coalitions of Influence. King's Law Journal: 1-9.
Guo, Y., Gasparrini, A., Armstrong, B., Li, S., Tawatsupa, B., Tobias, A., Lavigne, E., Coelho, M.d.S.Z.S., Leone, M. and Pan, X., 2014. Global variation in the effects of ambient temperature on mortality: a systematic evaluation. Epidemiology (Cambridge, Mass.), 25(6): 781.
Göpfert, C., Wamsler, C. and Lang, W., 2019. A framework for the joint institutionalization of climate change mitigation and adaptation in city administrations. Mitigation and Adaptation Strategies for Global Change, 24(1): 1-21.
Gülbaz, S. and Kazezyılmaz-Alhan, C.M., 2017. Experimental Investigation on Hydrologic Performance of LID with Rainfall-Watershed-Bioretention System. Journal of Hydrologic Engineering, 22(1): D4016003.
Güneralp, B., Güneralp, n. and Liu, Y., 2015. Changing global patterns of urban exposure to flood and drought hazards. Global environmental change, 31: 217-225.

Haase, D., Kabisch, S., Haase, A., Andersson, E., Banzhaf, E., Baró, F., Brenck, M., Fischer, L.K., Frantzeskaki, N., Kabisch, N., Krellenberg, K., Kremer, P., Kronenberg, J., Larondelle, N., Mathey, J., Pauleit, S., Ring, I., Rink, D., Schwarz, N. and Wolff, M., 2017. Greening cities – To be socially inclusive? About the alleged paradox of society and ecology in cities. Habitat International, 64: 41-48.
Haberl, H., Erb, K.-H. and Krausmann, F., 2014. Human appropriation of net primary production: patterns, trends, and planetary boundaries. Annual Review of Environment and Resources, 39: 363-391.
Haddock, D. and Edwards, C., 2013. Urban Waters Federal Partnership: Proctor Creek Watershed, Atlanta, GA - Overall assessment of partnership since beginning.
Hakelberg, L., 2014. Governance by Diffusion: Transnational Municipal Networks and the Spread of Local Climate Strategies in Europe. Global Environmental Politics, 14(1): 107-129.
Hale, T., 2016. "All Hands on Deck": The Paris Agreement and Nonstate Climate Action. Global Environmental Politics, 16(3): 12-22.
Hall, S.M., Hards, S. and Bulkeley, H., 2013. New approaches to energy: equity, justice and vulnerability. Introduction to the special issue. Taylor & Francis.
Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D. and Vogt-Schilb, A., 2016. Shock Waves: Managing the Impacts of Climate Change on Poverty. Climate Change and Development, World Bank, Washington DC.
Hallegatte, S. and Engle, N.L., 2019. The search for the perfect indicator: Reflections on monitoring and evaluation of resilience for improved climate risk management. Climate Risk Management, 23: 1-6.
Hallegatte, S. and Mach, K.J., 2016. Make climate-change assessments more relevant. Nature News, 534(7609): 613.
Hallegatte, S., Ranger, N. and Bhattacharya, S.e.a., 2010. Flood Risks, Climate Change Impacts and Adaptation Benefits in Mumbai: An Initial Assessment of SocioEconomic Consequences of Present and Climate Change Induced Flood Risks and of Possible Adaptation Options, OECD.
Hambati, H. and Yengoh, G.T., 2018. Community resilience to natural disasters in the informal settlements in Mwanza City, Tanzania. Journal of Environmental Planning and Management, 61(10): 1758-1788.
Hamdy, M., Carlucci, S., Hoes, P.-J. and Hensen, J.L.M., 2017. The impact of climate change on the overheating risk in dwellings—A Dutch case study. Building and Environment, 122: 307-323.
Hamin, E.M., Gurran, N. and Emlinger, A.M., 2014. Barriers to Municipal Climate Adaptation: Examples From Coastal Massachusetts' Smaller Cities and Towns. Journal of the American Planning Association, 80(2): 110-122.
Hamstead, Z.A., Farmer, C. and McPhearson, T., 2018. Landscape-Based Extreme Heat Vulnerability Assessment. Journal of Extreme Events, 5(04): 1850018.
Hamstead, Z.A., Kremer, P., Larondelle, N., McPhearson, T. and Haase, D., 2016. Classification of the heterogeneous structure of urban landscapes (STURLA) as an indicator of landscape function applied to surface temperature in New York City. Ecological indicators, 70: 574-585.
Han, J.-Y., Baik, J.-J. and Lee, H., 2014. Urban impacts on precipitation. Asia-Pacific Journal of Atmospheric Sciences, 50(1): 17-30.
Handayani, W., Fisher, M.R., Rudiarto, I., Setyono, J.S. and Foley, D., 2019. Operationalizing resilience: A content analysis of flood disaster planning in two coastal cities in Central Java, Indonesia. International Journal of Disaster Risk Reduction: 101073.
Hanger, S., Linnerooth-Bayer, J., Surminski, S., Nenciu-Posner, C., Lorant, A., Ionescu, R. and Patt, A., 2018. Insurance, public assistance, and household flood risk reduction: A comparative study of Austria, England, and Romania. Risk Analysis, 38(4): 680-693.
Hansen, R., Frantzeskaki, N., McPhearson, T., Rall, E., Kabisch, N., Kaczorowska, A., Kain, J.-H., Artmann, M. and Pauleit, S., 2015. The uptake of the ecosystem services concept in planning discourses of European and American cities. Ecosystem Services, 12: 228-246.
Hansen, T. and Coenen, L., 2015. The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field. Environmental innovation and societal transitions, 17: 92-109.
Hao, Z., Singh, P.V. and Hao, F., 2018. Compound Extremes in Hydroclimatology: A Review. Water, 10(6).
Haque, A.N., Dodman, D. and Hossain, M.M., 2014. Individual, communal and institutional responses to climate change by low-income households in Khulna, Bangladesh. Environment and Urbanization, 26(1): 112-129.
Hardoy, J. and Ruete, R., 2013. Incorporating climate change adaptation into planning for a liveable city in Rosario, Argentina. Environment and Urbanization, 25(2): 339-360.
Hardoy, J. and Velásquez Barrero, L.S., 2014. Re-thinking "Biomanizales": addressing climate change adaptation in Manizales, Colombia. Environment and Urbanization, 26(1): 53-68.
Harlan Sharon, L., Declet-Barreto Juan, H., Stefanov William, L. and Petitti Diana, B., 2013. Neighborhood Effects on Heat Deaths: Social and Environmental Predictors of Vulnerability in Maricopa County, Arizona. Environmental Health Perspectives, 121(2): 197-204.
Harlan, S.L., Chakalian, P., Declet-Barreto, J., Hondula, D.M. and DarrelJenerette, G., 2019. Pathways to Climate Justice in a Desert Metropolis. In: L.R. Mason and J. Rigg (Editors), People and Climate Change: Vulnerability, Adaptation, and Social Justice. Oxford University Press, Oxford, pp. 23.
Harlan, S.L. and Ruddell, D.M., 2011. Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation. Current Opinion in Environmental Sustainability, 3(3): 126-134.

Harman, B.P., Taylor, B.M. and Lane, M.B., 2015. Urban partnerships and climate adaptation: challenges and opportunities. Current Opinion in Environmental Sustainability, 12: 74-79.
Harris, L.M., Chu, E.K. and Ziervogel, G., 2018. Negotiated resilience. Resilience, 6(3): 196-214.
Harvey, B., Jones, L., Cochrane, L. and Singh, R., 2019. The evolving landscape of climate services in sub-Saharan Africa: What roles have NGOs played. Climatic Change.
Harvey, C.A., Chacón, M., Donatti, C.I., Garen, E., Hannah, L., Andrade, A., Bede, L., Brown, D., Calle, A., Chará, J., Clement, C., Gray, E., Hoang, M.H., Minang, P., Rodríguez, A.M., Seeberg-Elverfeldt, C., Semroc, B., Shames, S., Smukler, S., Somarriba, E., Torquebiau, E., van Etten, J. and Wollenberg, E., 2014. Climate-Smart Landscapes: Opportunities and Challenges for Integrating Adaptation and Mitigation in Tropical Agriculture. Conservation Letters, 7(2): 77-90.
Hauer, M.E., 2017. Migration induced by sea-level rise could reshape the US population landscape. Nature Climate Change, 7(5): 321.
Haugen, A., Bertolin, C., Leijonhufvud, G., Olstad, T. and Broström, T., 2018. A methodology for long-term monitoring of climate change impacts on historic buildings. Geosciences, 8(10): 370-387.
Haworth, B., Biggs, E., Duncan, J., Wales, N., Boruff, B. and Bruce, E., 2018. Geographic information and communication technologies for supporting smallholder agriculture and climate resilience. Climate, 6(4): 97.
Hayward, B., Hinge, S.D., Tupuana', L. and Tualamali'i', L., 2019, forthcoming. Is it "too late"? Rethinking the political agency of Small Pacific Island Developing States in a warming world. Wires Climate Change.
Heath, T.T., Parker, A.H. and Weatherhead, E.K., 2012. Testing a rapid climate change adaptation assessment for water and sanitation providers in informal settlements in three cities in sub-Saharan Africa. Environment and Urbanization, 24(2): 619-637.
Heaviside, C., Cai, X.M. and Vardoulakis, S., 2015. The effects of horizontal advection on the urban heat island in Birmingham and the West Midlands, United Kingdom during a heatwave. Quarterly Journal of the Royal Meteorological Society, 141(689): 1429-1441.
Heaviside, C., Macintyre, H. and Vardoulakis, S., 2017. The urban heat island: implications for health in a changing environment. Current environmental health reports, 4(3): 296-305.
Heaviside, C., Vardoulakis, S. and Cai, X.-M., 2016. Attribution of mortality to the urban heat island during heatwaves in the West Midlands, UK. Environmental Health, 15(1): S27.
Heeks, R. and Ospina, A.V., 2015. Analysing urban community informatics from a resilience perspective. The Journal of Community Informatics, 11(1).
Heeks, R. and Ospina, A.V., 2019. Conceptualising the link between information systems and resilience: A developing country field study. Information Systems Journal, 29(1): 70-96.
Heidrich, O., Dawson, R.J., Reckien, D. and Walsh, C.L., 2013. Assessment of the climate preparedness of 30 urban areas in the UK. Climatic Change, 120(4): 771-784.
Helderop, E. and Grubesic, T.H., 2019. Streets, storm surge, and the frailty of urban transport systems: A grid-based approach for identifying informal street network connections to facilitate mobility. Transportation Research Part D: Transport and Environment.
Henderson, J.V., Storeygard, A. and Deichmann, U., 2017. Has climate change driven urbanization in Africa? Journal of Development Economics, 124(WPS6925): 60-82.
Herath, C., Jayasumana, C., De Silva, P.M.C.S., De Silva, P.H.C., Siribaddana, S. and De Broe, M.E., 2018. Kidney Diseases in Agricultural Communities: A Case Against Heat-Stress Nephropathy. Kidney International Reports, 3(2): 271-280.
Heris, M.P., 2018. Do Planning and Design Policies and Procedures Matter In Microclimate Management and Urban Heat Mitigation?, University of Colorado at Denver.
Herslund, L., Backhaus, A., Fryd, O., Jørgensen, G., Jensen, M.B., Limbumba, T.M., Liu, L., Mguni, P., Mkupasi, M., Workalemahu, L. and Yeshitela, K., 2018. Conditions and opportunities for green infrastructure – Aiming for green, water-resilient cities in Addis Ababa and Dar es Salaam. Landscape and Urban Planning, 180: 319-327.
Heurkens, E., 2016. Institutional conditions for sustainable private sector-led urban development projects: A conceptual model, *Proceedings of the International Conference on Sustainable Built Environment: Strategies-Stakeholders-Success factors (SBE16)*, Hamburg, pp. 726-735.
Hilton, I. and Kerr, O., 2017. The Paris Agreement: China's 'New Normal'role in international climate negotiations. Climate Policy, 17(1): The Paris Agreement: China's 'New Normal'role in international climate negotiations.
Hirano, Y. and Fujita, T., 2012. Evaluation of the impact of the urban heat island on residential and commercial energy consumption in Tokyo. Energy, 37(1): 371-383.
Hiwasaki, L., Luna, E. and Marçal, J.A., 2015. Local and indigenous knowledge on climate-related hazards of coastal and small island communities in Southeast Asia. Climatic Change, 128(1-2): 35-56.
Hjort, J., Karjalainen, O., Aalto, J., Westermann, S., Romanovsky, V.E., Nelson, F.E., Etzelmüller, B. and Luoto, M., 2018. Degrading permafrost puts Arctic infrastructure at risk by mid-century. Nature communications, 9(1): 5147.
Hodson, M., 2010. World cities and climate change: Producing urban ecological security. McGraw-Hill Education (UK).
Hodson, M., Burrai, E. and Barlow, C., 2015. Remaking the material fabric of the city: 'Alternative' low carbon spaces of transformation or continuity? Environmental Innovation and Societal Transitions.

Hodson, M. and Marvin, S., 2017. Intensifying or transforming sustainable cities? Fragmented logics of urban environmentalism. Local Environment: 1-15.
Hodson, M., Marvin, S. and Bulkeley, H., 2013. The intermediary organisation of low carbon cities: a comparative analysis of transitions in Greater London and Greater Manchester. Urban Studies, 50(7): 1403-1422.
Hoegh-Guldberg, O., Jacob, D., Taylor, M., Bindi, M., Brown, S., Camilloni, I., Diedhiou, A., Djalante, R., Ebi, K.L., Engelbrecht, F., Guiot, J., Hijioka, Y., Mehrotra, S., Payne, A., Seneviratne, S.I., Thomas, A., Warren, R. and Zhou, G., 2018. Impacts of 1.5ºC Global Warming on Natural and Human Systems, IPCC.
Holland, B., 2017. Procedural justice in local climate adaptation: political capabilities and transformational change. Environmental Politics, 26(3): 391-412.
Hondula, D.M., Balling, R.C., Andrade, R., Krayenhoff, E.S., Middel, A., Urban, A., Georgescu, M. and Sailor, D.J., 2017. Biometeorology for cities. International journal of biometeorology, 61(1): 59-69.
Hooli, L.J., 2016. Resilience of the poorest: coping strategies and indigenous knowledge of living with the floods in Northern Namibia. Regional environmental change, 16(3): 695-707.
Horn, P., 2018. Indigenous peoples, the city and inclusive urban development policies in Latin America: Lessons from Bolivia and Ecuador. Development Policy Review, 36(4): 483-501.
Hosokawa, Y., Grundstein, A.J. and Casa, D.J., 2018. Extreme Heat Considerations in International Football Venues: The Utility of Climatologic Data in Decision Making. Journal of Athletic Training, 53(9): 860-865.
Hossain, M.Z. and Rahman, M.A.U., 2018. Adaptation to climate change as resilience for urban extreme poor: lessons learned from targeted asset transfers programmes in Dhaka city of Bangladesh. Environment, development and sustainability, 20(1): 407-432.
Houser, T., Hsiang, S., Kopp, R., Larsen, K., Delgado, M., Jina, A., Mastrandrea, M., Mohan, S., Muir-Wood, R., Rasmussen, D.J. and Rising, J., 2015. *Economic risks of climate change: an American prospectus* . Columbia University Press, New York.
Howells, M., Hermann, S., Welsch, M., Bazilian, M., Segerström, R., Alfstad, T., Gielen, D., Rogner, H., Fischer, G., van Velthuizen, H., Wiberg, D., Young, C., Roehrl, R.A., Mueller, A., Steduto, P. and Ramma, I., 2013. Integrated analysis of climate change, land-use, energy and water strategies. Nature Climate Change, 3(7): 621-626.
HR Wallingford, 2014. Indicators to Assess the Exposure of Critical Infrastructure in England to Current and Projected Climate Hazards. Final report for the Adaptation Sub-Committee.
Hsu, A., Weinfurter, A.J. and Xu, K., 2017. Aligning subnational climate actions for the new post-Paris climate regime. Climatic Change, 142(3): 419-432.
HSY, 2018. Monitoring. Helsinki Region Environmental Services Authority HSY, Helsinki.
Hu, X., Hall, J.W., Shi, P. and Lim, W.H., 2016. The spatial exposure of the Chinese infrastructure system to flooding and drought hazards. Natural Hazards, 80(2): 1083-1118.
Huang, K.-T. and Hwang, R.-L., 2016. Future trends of residential building cooling energy and passive adaptation measures to counteract climate change: The case of Taiwan. Applied Energy, 184: 1230-1240.
Huang-Lachmann, J.-T., Hannemann, M. and Guenther, E., 2018. Identifying links between economic opportunities and climate change adaptation: empirical evidence of 63 cities. Ecological economics, 145: 231-243.
Huang-Lachmann, J.-T. and Lovett, J.C., 2016. How cities prepare for climate change: Comparing Hamburg and Rotterdam. Cities, 54: 36-44.
Hughes, S., 2015. A meta-analysis of urban climate change adaptation planning in the U.S. Urban Climate, 14: 17-29.
Hughes, S. and Romero-Lankao, P., 2014. Science and institution building in urban climate-change policymaking. Environmental Politics, 23(6): 1023-1042.
Hunter, L.M., Luna, J.K. and Norton, R.M., 2015. Environmental Dimensions of Migration. Annual Review of Sociology, 41(1): 377-397.
Hurlimann, A.C., Browne, G.R., Warren-Myers, G. and Francis, V., 2018. Barriers to climate change adaptation in the Australian construction industry – Impetus for regulatory reform. Building and Environment, 137: 235-245.
Hwang, S.-A. and Kim, J.-G., 2017. A Study on the Improvement of the Connection between Port Space and Hinterland Using FBCs. Journal of Navigation and Port Research, 41(4): 215-228.
Hyndman, B., 2017. Heat-Smart'schools during physical education (PE) activities: Developing a policy to protect students from extreme heat. *Learning Communities Journal*, 21: 56-72.
Hölscher, K., Frantzeskaki, N., McPhearson, T. and Loorbach, D., 2019. Tales of transforming cities: Transformative climate governance capacities in New York City, US and Rotterdam, Netherlands. Journal of environmental management, 231: 843-857.
Iaquinta, D.L. and Drescher, A.W., 2000. Defining the peri-urban: rural-urban linkages and institutional connections. Land reform, 2: 8-27.
Ibrahim, S., Ibrahim, M. and Attia, S., 2014. The impact of climate changes on the thermal performance of a proposed pressurized water reactor: nuclear-power plant. International Journal of Nuclear Energy, 2014.
Ide, T., Schilling, J., Link, J.S.A., Scheffran, J., Ngaruiya, G. and Weinzierl, T., 2014. On exposure, vulnerability and violence: spatial distribution of risk factors for climate change and violent conflict across Kenya and Uganda. Political Geography, 43: 68-81.
IEA, 2019. Electricity Information 2019, IEA.

Iglesias, A. and Garrote, L., 2015. Adaptation strategies for agricultural water management under climate change in Europe. Agricultural water management, 155: 113-124.
Iglesias, A., Quiroga, S., Moneo, M. and Garrote, L., 2011. From climate change impacts to the development of adaptation strategies: Challenges for agriculture in Europe. Climatic Change, 112(1): 143-168.
Imam, N., Hossain, M.K. and Saha, T.R., 2017. Potentials and challenges of using ICT for climate change adaptation: a study of vulnerable community in riverine islands of bangladesh, Catalyzing Development through ICT Adoption. Springer, pp. 89-110.
Inch, A., 2019. Signs of Hope in the Dark? Planning Theory & Practice, 20(3): 317-319.
Ingwersen, W.W., Garmestani, A.S., Gonzalez, M.A. and Templeton, J.J., 2014. A systems perspective on responses to climate change. Clean Technologies and Environmental Policy, 16(4): 719-730.
Inostroza, L., Palme, M. and de la Barrera, F., 2016. A Heat Vulnerability Index: Spatial Patterns of Exposure, Sensitivity and Adaptive Capacity for Santiago de Chile. PLOS ONE, 11(9): e0162464.
International Council for Science, 2017. A Guide to SDG Interactions: from Science to Implementation, Paris.
Invidiata, A. and Ghisi, E., 2016. Impact of climate change on heating and cooling energy demand in houses in Brazil. Energy and Buildings, 130: 20-32.
Iping, A., Kidston-Lattari, J., Simpson-Young, A., Duncan, E. and McManus, P., 2019. (Re) presenting urban heat islands in Australian cities: A study of media reporting and implications for urban heat and climate change debates. Urban Climate, 27: 420-429.
Ireland, P. and Clausen, D., 2019. Local action that changes the world: Fresh perspectives on climate change mitigation and adaptation from Australia. In: T. Letcher (Editor), Managing Global Warming. Elsevier, London, pp. 769-782.
ITU, 2019. *Number of mobile (cellular) subscriptions worldwide from 1993 to 2018 (in millions)*. In: Statista (Editor).
Jabareen, Y., 2015. City planning deficiencies & climate change – The situation in developed and developing cities. Geoforum, 63: 40-43.
Jacqueline-Andersen, P., 2018. *The Indigenous World 2018*. International Work Group for Indigenous Affairs, Copenhagen.
Jaglin, S., 2013. Urban Energy Policies and the Governance of Multilevel Issues in Cape Town. Urban Studies, 51(7): 1394-1414.
Jaglom, W.S., McFarland, J.R., Colley, M.F., Mack, C.B., Venkatesh, B., Miller, R.L., Haydel, J., Schultz, P.A., Perkins, B. and Casola, J.H., 2014. Assessment of projected temperature impacts from climate change on the US electric power sector using the Integrated Planning Model®. Energy Policy, 73: 524-539.
Jameson, S. and Baud, I.S.A., 2016. Varieties of knowledge for assembling an urban flood management governance configuration in Chennai, India. Habitat International, 54: 112-123.
Janhäll, S., 2015. Review on urban vegetation and particle air pollution – Deposition and dispersion. Atmospheric Environment, 105: 130-137.
Jayne, M., Hubbard, P. and Bell, D., 2017. Twin Cities: Territorial and Relational Urbanism. The SAGE Handbook of New Urban Studies: 63.
Jenerette, G.D., Harlan, S.L., Buyantuev, A., Stefanov, W.L., Declet-Barreto, J., Ruddell, B.L., Myint, S.W., Kaplan, S. and Li, X., 2016. Micro-scale urban surface temperatures are related to land-cover features and residential heat related health impacts in Phoenix, AZ USA. Landscape Ecology, 31(4): 745-760.
Jenkins, K., McCauley, D., Heffron, R., Stephan, H. and Rehner, R., 2016. Energy justice: A conceptual review. Energy Research & Social Science, 11: 174-182.
Jeong, D.I., Sushama, L., Vieira, M.J.F. and Koenig, K.A., 2018. Projected changes to extreme ice loads for overhead transmission lines across Canada. Sustainable Cities and Society, 39: 639-649.
Jepsen, M.R., Kuemmerle, T., Müller, D., Erb, K., Verburg, P.H., Haberl, H., Vesterager, J.P., Andrič, M., Antrop, M. and Austrheim, G., 2015. Transitions in European land-management regimes between 1800 and 2010. Land Use Policy, 49: 53-64.
Jiang, L. and O'Neill, B.C., 2017. Global urbanization projections for the Shared Socioeconomic Pathways. Global Environmental Change, 42: 193-199.
Johnson, C., 2018. The Power of Cities in Global Climate Politics: Saviours, Supplicants or Agents of Change? Palgrave Macmillan, London.
Johnson, M.S., Lathuillière, M.J., Tooke, T.R. and Coops, N.C., 2015. Attenuation of urban agricultural production potential and crop water footprint due to shading from buildings and trees. Environmental Research Letters, 10(6): 064007.
Jones, L., Dougill, A., Jones, R.G., Steynor, A., Watkiss, P., Kane, C., Koelle, B., Moufouma-Okia, W., Padgham, J., Ranger, N., Roux, J.-P., Suarez, P., Tanner, T. and Vincent, K., 2015. Ensuring climate information guides long-term development. Nature Climate Change, 5: 812.
Jonkeren, O., Rietveld, P., van Ommeren, J. and Te Linde, A., 2014. Climate change and economic consequences for inland waterway transport in Europe. Regional environmental change, 14(3): 953-965.
Jordan, A., Huitema, D., van Asselt, H. and Forster, J., 2018. Governing climate change: polycentricity in action? Cambridge University Press, Cambridge.
Jordan, A.J., Huitema, D., Hildén, M., van Asselt, H., Rayner, T.J., Schoenefeld, J.J., Tosun, J., Forster, J. and Boasson, E.L., 2015. Emergence of polycentric climate governance and its future prospects. Nature Climate Change, 5: 977.

Jovanović, S., Savić, S., Bojić, M., Djordjević, Z. and Nikolić, D., 2015. The impact of the mean daily air temperature change on electricity consumption. Energy, 88: 604-609.
Juhola, S., 2016. Barriers to the implementation of climate change adaptation in land use planning: A multi-level governance problem? International Journal of Climate Change Strategies and Management, 8(3): 338-355.
Juhola, S., Glaas, E., Linnér, B.-O. and Neset, T.-S., 2016. Redefining maladaptation. Environmental Science & Policy, 55: 135-140.
Kabeer, N., 2016. “Leaving no one behind”: the challenge of intersecting inequalities. ISSC, IDS and UNESCO, Challenging Inequalities: Pathways to a Just World, World Social Science Report: 55-8.
Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J., Zaunberger, K. and Bonn, A., 2016. Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecology and Society, 21(2).
Kang, N., Kim, S., Kim, Y., Noh, H., Hong, S. and Kim, H., 2016. Urban drainage system improvement for climate change adaptation. Water, 8(7): 268.
Karagiannis, G.M., Cardarilli, M., Turksezer, Z.I., Spinoni, J., Mentaschi, L., Feyen, L. and Krausmann, E., 2019. *Climate change and critical infrastructure – storms*, Publications Office of the European Union, Luxembourg.
Kaufman, N., 2014. Why is risk aversion unaccounted for in environmental policy evaluations? Climatic change, 125(2): 127-135.
Kawai, H., Koshiro, T., Endo, H. and Arakawa, O., 2018. Changes in Marine Fog Over the North Pacific Under Different Climates in CMIP5 Multimodel Simulations. Journal of Geophysical Research: Atmospheres, 123(19): 10,911-10,924.
Keeler, B.L., Hamel, P., McPhearson, T., Hamann, M.H., Donahue, M.L., Meza Prado, K.A., Arkema, K.K., Bratman, G.N., Brauman, K.A., Finlay, J.C., Guerry, A.D., Hobbie, S.E., Johnson, J.A., MacDonald, G.K., McDonald, R.I., Neverisky, N. and Wood, S.A., 2019. Social-ecological and technological factors moderate the value of urban nature. Nature Sustainability, 2(1): 29-38.
Keenan, J.M., 2018. Regional resilience trust funds: an exploratory analysis for leveraging insurance surcharges. Environment Systems and Decisions, 38(1): 118-139.
Keenan, J.M., Chu, E. and Peterson, J., 2019. From funding to financing: perspectives shaping a research agenda for investment in urban climate adaptation. International Journal of Urban Sustainable Development: 1-12.
Keenan, J.M., Hill, T. and Gumber, A., 2018. Climate gentrification: from theory to empiricism in Miami-Dade County, Florida. Environmental Research Letters, 13(5): 054001-054001.
Keil, R., 2018. Extended urbanization,“disjunct fragments” and global suburbanisms. Environment and Planning D: Society and Space, 36(3): 494-511.
Keil, R. and Macdonald, S., 2016. Rethinking urban political ecology from the outside in: greenbelts and boundaries in the post-suburban city. Local environment, 21(12): 1516-1533.
Kelly, S., 2019. Megawatts mask impacts: Small hydropower and knowledge politics in the Puelwillimapu, Southern Chile. Energy Research & Social Science, 54: 224-235.
Kendon, E.J., Roberts, N.M., Fowler, H.J., Roberts, M.J., Chan, S.C. and Senior, C.A., 2014. Heavier summer downpours with climate change revealed by weather forecast resolution model. Nature Climate Change, 4(7): 570.
Kernaghan, S. and Da Silva, J., 2014. Initiating and sustaining action: Experiences building resilience to climate change in Asian cities. Urban Climate, 7: 47-63.
Keskitalo, E.C.H., Juhola, S., Baron, N., Fyhn, H. and Klein, J., 2016. Implementing Local Climate Change Adaptation and Mitigation Actions: The Role of Various Policy Instruments in a Multi-Level Governance Context. Climate, 4(1): 7.
Kew, S.F., Selten, F.M., Lenderink, G. and Hazeleger, W., 2013. The simultaneous occurrence of surge and discharge extremes for the Rhine delta. Natural hazards and earth system sciences, 13(8): 2017-2029.
Khirfan, L. and El-Shayeb, H., 2019. Urban climate resilience through socio-ecological planning: a case study in Charlottetown, Prince Edward Island. Journal of Urbanism: International Research on Placemaking and Urban Sustainability.
Khosla, P. and Masaud, A., 2010. Cities, climate change and gender: a brief overview. In: I. Dankeman (Editor), Gender and Climate Change: An Introduction. Earthscan, New York, pp. 78-96.
Kifle Arsiso, B., Mengistu Tsidu, G., Stoffberg, G.H. and Tadesse, T., 2017. Climate change and population growth impacts on surface water supply and demand of Addis Ababa, Ethiopia. Climate Risk Management, 18: 21-33.
King, D., Gurtner, Y., Firdaus, A., Harwood, S. and Cottrell, A., 2016. Land use planning for disaster risk reduction and climate change adaptation: Operationalizing policy and legislation at local levels. International Journal of Disaster Resilience in the Built Environment, 7(2): 158-172.
Kingsborough, A., Borgomeo, E. and Hall, J.W., 2016. Adaptation pathways in practice: mapping options and trade-offs for London’s water resources. Sustainable cities and society, 27: 386-397.
Kithiia, J. and Dowling, R., 2010. An integrated city-level planning process to address the impacts of climate change in Kenya: The case of Mombasa. Cities, 27(6): 466-475.
Klein, J., Araos, M., Karimo, A., Heikkinen, M., Ylä-Anttila, T. and Juhola, S., 2018. The role of the private sector and citizens in urban climate change adaptation: Evidence from a global assessment of large cities. Global environmental change, 53: 127-136.

Klein, J. and Juhola, S., 2018. The influence of administrative traditions and governance on private involvement in urban climate change adaptation. Review of Policy Research, 35(6): 930-952.
Klein, J., Juhola, S. and Landauer, M., 2017. Local authorities and the engagement of private actors in climate change adaptation. Environment and Planning C: Politics and Space, 35(6): 1055-1074.
Klemm, W., Heusinkveld, B.G., Lenzholzer, S., Jacobs, M.H. and Van Hove, B., 2015. Psychological and physical impact of urban green spaces on outdoor thermal comfort during summertime in The Netherlands. Building and Environment, 83: 120-128.
Klostermann, J., van de Sandt, K., Harley, M., Hildén, M., Leiter, T., van Minnen, J., Pieterse, N. and van Bree, L., 2018. Towards a framework to assess, compare and develop monitoring and evaluation of climate change adaptation in Europe. Mitigation and adaptation strategies for global change, 23(2): 187-209.
Knieling, J., 2016. *Climate Adaptation Governance in Cities and Regions: Theoretical Fundamentals and Practical Evidence*. Wiley Blackwell, Chichester.
Knight, T., Price, S., Bowler, D. and King, S., 2016. How effective is 'greening' of urban areas in reducing human exposure to ground-level ozone concentrations, UV exposure and the 'urban heat island effect'? A protocol to update a systematic review. Environmental Evidence, 5(1): 3.
Knott, J.F., Elshaer, M., Daniel, J.S., Jacobs, J.M. and Kirshen, P., 2017. Assessing the effects of rising groundwater from sea level rise on the service life of pavements in coastal road infrastructure. Transportation Research Record, 2639(1): 1-10.
Koch, F., 2018. Mainstreaming adaptation: a content analysis of political agendas in Colombian cities. Climate and Development, 10(2): 179-192.
Koks, E.E., Rozenberg, J., Zorn, C., Tariverdi, M., Vousdoukas, M., Fraser, S.A., Hall, J.W. and Hallegatte, S., 2019. A global multi-hazard risk analysis of road and railway infrastructure assets. Nature communications, 10(1): 2677.
Kolokotsa, D., 2017. Smart cooling systems for the urban environment. Using renewable technologies to face the urban climate change. Solar Energy, 154: 101-111.
Kolokotsa, D.D., Giannariakis, G., Gobakis, K., Giannarakis, G., Synnefa, A. and Santamouris, M., 2018. Cool roofs and cool pavements application in Acharnes, Greece. Sustainable Cities and Society, 37: 466-474.
Koop, S.H.A. and van Leeuwen, C.J., 2017. The challenges of water, waste and climate change in cities. Environment, development and sustainability, 19(2): 385-418.
Kosaka, E., Iida, A., Vanos, J., Middel, A., Yokohari, M. and Brown, R., 2018. Microclimate Variation and Estimated Heat Stress of Runners in the 2020 Tokyo Olympic Marathon. Atmosphere, 9(5).
Kosoe, E.A., Diawuo, F. and Osumanu, I.K., 2019. Looking into the Past: Rethinking Traditional Ways of Solid Waste Management in the Jaman South Municipality, Ghana. Ghana Journal of Geography, 11(1): 228-244.
Kotova, L., Jacob, D., Leissner, J., Mathis, M. and Mikolajewicz, U., 2019. Climate Information for the Preservation of Cultural Heritage: Needs and Challenges, TMM_CH 2018: Transdisciplinary Multispectral Modelling and Cooperation for the Preservation of Cultual Heritage. Springer, Cham, pp. 353-359.
Kress, W.J., Garcia-Robledo, C., Soares, J.V.B., Jacobs, D., Wilson, K., Lopez, I.C. and Belhumeur, P.N., 2018. Citizen science and climate change: Mapping the range expansions of native and exotic plants with the mobile app Leafsnap. BioScience, 68(5): 348-358.
Krkoška Lorencová, E., Whitham, E.L.C., Bašta, P., Harmáčková, V.Z., Štěpánek, P., Zahradníček, P., Farda, A. and Vačkář, D., 2018. Participatory Climate Change Impact Assessment in Three Czech Cities: The Case of Heatwaves. Sustainability, 10(6).
Kroeger, T., Escobedo, F.J., Hernandez, J.L., Varela, S., Delphin, S., Fisher, J.R.B. and Waldron, J., 2014. Reforestation as a novel abatement and compliance measure for ground-level ozone. Proceedings of the National Academy of Sciences, 111(40): E4204-E4213.
Kumar, C.B., 2013. Climate change and Asian cities: So near yet so far. Urban Studies, 50(7): 1456-1468.
Kumar, P., Geneletti, D. and Nagendra, H., 2016. Spatial assessment of climate change vulnerability at city scale: A study in Bangalore, India. Land Use Policy, 58: 514-532.
Kundzewicz, Z.W., Kanae, S., Seneviratne, S.I., Handmer, J., Nicholls, N., Peduzzi, P., Mechler, R., Bouwer, L.M., Arnell, N., Mach, K., Muir-Wood, R., Brakenridge, G.R., Kron, W., Benito, G., Honda, Y., Takahashi, K. and Sherstyukov, B., 2014. Flood risk and climate change: global and regional perspectives. Hydrological Sciences Journal, 59(1): 1-28.
Kyriakodis, G.E. and Santamouris, M., 2018. Using reflective pavements to mitigate urban heat island in warm climates - Results from a large scale urban mitigation project. Urban Climate, 24: 326-339.
Lai, D., Liu, W., Gan, T., Liu, K. and Chen, Q., 2019. A review of mitigating strategies to improve the thermal environment and thermal comfort in urban outdoor spaces. Science of the Total Environment, 661: 337-353.
Lal, R., 2013. Food security in a changing climate. Ecohydrology & Hydrobiology, 13(1): 8-21.
Lam, C.K.C., Loughnan, M. and Tapper, N., 2018. Visitors' perception of thermal comfort during extreme heat events at the Royal Botanic Garden Melbourne. International Journal of Biometeorology, 62(1): 97-112.
Lamb, W.F., Creutzig, F., Callaghan, M.W. and Minx, J.C., 2019. Learning about urban climate solutions from case studies. Nature Climate Change, 9(4): 279-287.
Lane, D.E., Clarke, C.M., Clarke, J.D., Mycoo, M. and Gobin, J., 2015. Managing Adaptation to Changing Climate in Coastal Zones, Coastal Zones: Solutions for the 21st Century. Elsevier, pp. 141-160.

Larcom, S., She, P.-W. and van Gevelt, T., 2019. The UK summer heatwave of 2018 and public concern over energy security. Nature Climate Change, 9(5): 370.
Larondelle, N., Hamstead, Z.A., Kremer, P., Haase, D. and McPhearson, T., 2014. Applying a novel urban structure classification to compare the relationships of urban structure and surface temperature in Berlin and New York City. Applied Geography, 53: 427-437.
Larsen, L., 2015. Urban climate and adaptation strategies. Frontiers in Ecology and the Environment, 13(9): 486-492.
Laspidou, C., 2014. ICT and stakeholder participation for improved urban water management in the cities of the future. Water Util. J, 8: 79-85.
Lassa, J.A. and Nugraha, E., 2015. From shared learning to shared action in building resilience in the city of Bandar Lampung, Indonesia. Environment and Urbanization, 27(1): 161-180.
Lassa, J.A., Teng, P., Caballero-Anthony, M. and Shrestha, M., 2019. Revisiting Emergency Food Reserve Policy and Practice under Disaster and Extreme Climate Events. International Journal of Disaster Risk Science, 10(1): 1-13.
Lau, J.D. and Scales, I.R., 2016. Identity, subjectivity and natural resource use: How ethnicity, gender and class intersect to influence mangrove oyster harvesting in The Gambia. Geoforum, 69: 136-146.
Lawhon, M., Nilsson, D. and Silver, J., 2018. Thinking through heterogeneous infrastructure configurations. Urban Studies, 55(February 2017): 720-732.
Leck, H., Conway, D., Bradshaw, M. and Rees, J., 2015. Tracing the Water-Energy-Food Nexus: Description, Theory and Practice. Geography Compass, 9(8): 445-460.
Leck, H. and Roberts, D., 2015. What lies beneath: understanding the invisible aspects of municipal climate change governance. Current Opinion in Environmental Sustainability, 13: 61-67.
Lee, J.-S. and Kim, J., 2018. Assessing strategies for urban climate change adaptation: The case of six metropolitan cities in South Korea. Sustainability, 10(6): 2065.
Lee, T.M., Markowitz, E.M., Howe, P.D., Ko, C.-Y. and Leiserowitz, A.A., 2015. Predictors of public climate change awareness and risk perception around the world. Nature climate change, 5(11): 1014.
Lehner, B., Liermann, C.R., Revenga, C., Vörösmarty, C., Fekete, B., Crouzet, P., Döll, P., Endejan, M., Frenken, K. and Magome, J., 2011. High-resolution mapping of the world's reservoirs and dams for sustainable river-flow management. Frontiers in Ecology and the Environment, 9(9): 494-502.
Lehner, B.C., Reidy Liermann, C., Revenga, C., Vorosmarty, C., Fekete, B., Crouzet, P., Doll, P., Endejan, M., Frenken, K., Magome, J., Nilsson, C., Robertson, J.C., Rodel, R., Sindorf, N. and Wisse, D., 2019. Global Reservoir and Dam Database, Version 1 (GRanDv1): Dams, Revision 01. Palisades. In: NASA and S.D.a.A.C. (SEDAC) (Editors), New York.
Leichenko, R.M. and O'Brien, K.L., 2002. The dynamics of rural vulnerability to global change: the case of southern Africa. Mitigation and adaptation strategies for global change, 7(1): 1-18.
Leijonhufvud, G., 2016. Making sense of climate risk information: The case of future indoor climate risks in Swedish churches. Climate Risk Management, 13(C): 76-87.
Leissner, J., Kaiser, U. and Kilian, R., 2014. Climate for Culture: Built Cultural Heritage in Times of Climate Change. Weltbuch Verlag.
Leissner, J., Kilian, R., Kotova, L., Jacob, D., Mikolajewicz, U., Broström, T., Ashley-Smith, J., Schellen, H.L., Martens, M., van Schijndel, J., Antretter, F., Winkler, M., Bertolin, C., Camuffo, D., Simeunovic, G. and Vyhlídal, T., 2015. Climate for Culture: assessing the impact of climate change on the future indoor climate in historic buildings using simulations. Heritage Science, 3(1): 1-15.
Lelovics, E., Unger, J., Gál, T. and Gál, C.V., 2014. Design of an urban monitoring network based on Local Climate Zone mapping and temperature pattern modelling. Climate research, 60(1): 51-62.
Lemieux, C.J., Groulx, M., Halpenny, E., Stager, H., Dawson, J., Stewart, E.J. and Hvenegaard, G.T., 2018. "The End of the Ice Age?": Disappearing World Heritage and the Climate Change Communication Imperative. Environmental Communication, 12(5): 653-671.
Leonard, M., Westra, S., Phatak, A., Lambert, M., van den Hurk, B., McInnes, K., Risbey, J., Schuster, S., Jakob, D. and Stafford-Smith, M., 2014. A compound event framework for understanding extreme impacts. Wiley Interdisciplinary Reviews: Climate Change, 5(1): 113-128.
Levermann, A., 2014. Climate economics: Make supply chains climate-smart. Nature News, 506(7486): 27.
León, J. and March, A., 2016. An urban form response to disaster vulnerability: Improving tsunami evacuation in Iquique, Chile. Environment and Planning B: Planning and Design, 43(5): 826-847.
Li, D. and Bou-Zeid, E., 2013. Synergistic interactions between urban heat islands and heat waves: The impact in cities is larger than the sum of its parts. Journal of Applied Meteorology and Climatology, 52(9): 2051-2064.
Li, D., Bou-Zeid, E. and Oppenheimer, M., 2014. The effectiveness of cool and green roofs as urban heat island mitigation strategies. Environmental Research Letters, 9(5): 055002.
Li, G., Yu, Q., Ma, W., Chen, Z., Mu, Y., Guo, L. and Wang, F., 2016. Freeze–thaw properties and long-term thermal stability of the unprotected tower foundation soils in permafrost regions along the Qinghai–Tibet Power Transmission Line. Cold Regions Science and Technology, 121: 258-274.
Li, M., Gu, S., Bi, P., Yang, J. and Liu, Q., 2015. Heat waves and morbidity: current knowledge and further direction-a comprehensive literature review. International journal of environmental research and public health, 12(5): 5256-5283.

Li, X., Zhou, Y., Yu, S., Jia, G., Li, H. and Li, W., 2019. Urban Heat Island Impacts on Building Energy Consumption: A Review of Approaches and Findings. Energy, 174: 407-419.
Li, Y., Ren, T., Kinney, P.L., Joyner, A. and Zhang, W., 2018. Projecting future climate change impacts on heat-related mortality in large urban areas in China. Environmental Research, 163: 171-185.
Lian, J.J., Xu, K. and Ma, C., 2013. Joint impact of rainfall and tidal level on flood risk in a coastal city with a complex river network: a case study of Fuzhou City, China. Hydrology and Earth System Sciences, 17(2): 679.
Liang, Y., Jiang, C., Ma, L., Liu, L., Chen, W. and Liu, L., 2017. Government support, social capital and adaptation to urban flooding by residents in the Pearl River Delta area, China. Habitat International, 59: 21-31.
Lievanos, R.S. and Horne, C., 2017. Unequal resilience: The duration of electricity outages. Energy Policy, 108: 201-211.
Lilford, R.J., Oyebode, O., Satterthwaite, D., Chen, Y.-f., Mberu, B., Watson, S.I. and Sartori, J., 2016. The health of people who live in slums 2 Improving the health and welfare of people who live in slums. The Lancet, 6736(16): 1-11.
Limthongsakul, S., Nitivattananon, V. and Arifwidodo, S.D., 2017. Localized flooding and autonomous adaptation in peri-urban Bangkok. Environment and Urbanization, 29(1): 51-68.
Lin, B.B., Philpott, S.M. and Jha, S., 2015. The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps. Basic and Applied Ecology, 16(3): 189-201.
Linnenluecke, M.K., Griffiths, A. and Winn, M.I., 2013. Firm and industry adaptation to climate change: a review of climate adaptation studies in the business and management field. Wiley Interdisciplinary Reviews: Climate Change, 4(5): 397-416.
Linnenluecke, M.K. and McKnight, B., 2017. Community resilience to natural disasters: the role of disaster entrepreneurship. Journal of Enterprising Communities: People and Places in the Global Economy, 11(1): 166-185.
Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., Sen, P.T., Sessa, R., Shula, R., Tibu, A. and Torquebiau, E.F., 2014. Climate-smart agriculture for food security. Nature Climate Change, 4(12): 1068-1072.
Liu, C. and Coley, D., 2015. Overheating Risk of UK Dwellings Under a Changing Climate. Energy Procedia, 78: 2796-2801.
Liu, L. and Jensen, M.B., 2018. Green infrastructure for sustainable urban water management: Practices of five forerunner cities. Cities, 74: 126-133.
Liu, W., Sun, F., Lim, W.H., Zhang, J., Wang, H., Shiogama, H. and Zhang, Y., 2018. Global drought and severe drought-affected populations in 1.5 and 2° C warmer worlds. Earth System Dynamics, 9(1): 267-283.
Liu, Y., Saha, S., Hoppe, B.O. and Convertino, M., 2019. Degrees and dollars – Health costs associated with suboptimal ambient temperature exposure. Science of The Total Environment, 678: 702-711.
Liu, Z., He, C. and Wu, J., 2016. General Spatiotemporal Patterns of Urbanization: An Examination of 16 World Cities. Sustainability, 8(1).
Lobell, D.B., Baldos, U.L.C. and Hertel, T.W., 2013. Climate adaptation as mitigation: the case of agricultural investments. Environmental Research Letters, 8(1): 015012.
Loli, A. and Bertolin, C., 2018a. Indoor multi-risk scenarios of climate change effects on building materials in Scandinavian countries. Geosciences, 8(9).
Loli, A. and Bertolin, C., 2018b. Towards zero-emission refurbishment of historic buildings: a literature review. Buildings, 8(2): 22-38.
London climate change partnership, 2018. Climate Change Adaptation Indicators for London. London climate change partnership, London.
Long, D. and Ziervogel, G., 2020. Vulnerability and Adaptation to Climate Change in Urban South Africa, Urban Geography in South Africa. Springer, Cham, pp. 139-153.
Long, J. and Rice, J.L., 2019. From sustainable urbanism to climate urbanism. Urban Studies, 56(5): 992-1008.
Lourenço, T.C., Swart, R., Goosen, H. and Street, R., 2015. The rise of demand-driven climate services. Nature Climate Change, 6: 13.
Luederitz, C., Schäpke, N., Wiek, A., Lang, D.J., Bergmann, M., Bos, J.J., Burch, S., Davies, A., Evans, J. and König, A., 2017. Learning through evaluation–A tentative evaluative scheme for sustainability transition experiments. Journal of Cleaner Production, 169: 61-76.
Lugo, A., 2019. Social-Ecological-Technological Effects of Hurricane María on Puerto Rico: Planning for Resilience under Extreme Events. . Springer, San Juan.
Lumbroso, D., Brown, E. and Ranger, N., 2016. Stakeholders' perceptions of the overall effectiveness of early warning systems and risk assessments for weather-related hazards in Africa, the Caribbean and South Asia. Natural Hazards, 84(3): 2121-2144.
Lund, D.H., 2018. Governance innovations for climate change adaptation in urban Denmark. Journal of Environmental Policy & Planning, 20(5): 632-644.
Lwasa, S., Mugagga, F., Wahab, B., Simon, D., Connors, J. and Griffith, C., 2014. Urban and peri-urban agriculture and forestry: Transcending poverty alleviation to climate change mitigation and adaptation. Urban Climate, 7: 92-106.

Lyles, W., Berke, P. and Overstreet, K.H., 2018. Where to begin municipal climate adaptation planning? Evaluating two local choices. Journal of Environmental Planning and Management, 61(11): 1994-2014.
Löffler, G., 2016. Analysis of the State of Local Finance in Intermediary Cities, United Cities and Local Governments, Barcelona, Spain.
Lövbrand, E., Beck, S., Chilvers, J., Forsyth, T., Hedrén, J., Hulme, M., Lidskog, R. and Vasileiadou, E., 2015. Who speaks for the future of Earth? How critical social science can extend the conversation on the Anthropocene. Global Environmental Change, 32: 211-218.
Ma, W., Zeng, W., Zhou, M., Wang, L., Rutherford, S., Lin, H., Liu, T., Zhang, Y., Xiao, J., Zhang, Y., Wang, X., Gu, X. and Chu, C., 2015. The short-term effect of heat waves on mortality and its modifiers in China: An analysis from 66 communities. Environment International, 75: 103-109.
Ma, Z., Melville, D.S., Liu, J., Chen, Y., Yang, H., Ren, W., Zhang, Z., Piersma, T. and Li, B., 2014. Rethinking China's new great wall. Science, 346(6212): 912-914.
Mabon, L. and Shih, W.-Y., 2018. What might 'just green enough'urban development mean in the context of climate change adaptation? The case of urban greenspace planning in Taipei Metropolis, Taiwan. World Development, 107: 224-238.
Macintyre, H.L. and Heaviside, C., 2019. Potential benefits of cool roofs in reducing heat-related mortality during heatwaves in a European city. Environment International, 127: 430-441.
Magee, A.D., Verdon-Kidd, D.C., Kiem, A.S. and Royle, S.A., 2016. Tropical cyclone perceptions, impacts and adaptation in the Southwest Pacific: an urban perspective from Fiji, Vanuatu and Tonga. Natural Hazards and Earth System Sciences, 16(5): 1091-1105.
Magnan, A.K., 2016. Climate change: Metrics needed to track adaptation. Nature, 530(7589): 160.
Maharjan, A., Hussain, A., Bhadwal, S., Ishaq, S., Saeed, B.A., Sachdeva, I., Ahmad, B., Hassan, S.M.T., Tuladhar, S. and Ferdous, J., 2018. Migration in the lives of environmentally vulnerable populations in four river basins of the HinduKush Himalayan Region., HI-AWARE, Kathmandu.
Mai, Q. and Francesch-Huidobro, M., 2015. Climate Change Governance in Chinese Cities. Routledge, London.
Makantasi, A.-M. and Mavrogianni, A., 2016. Adaptation of London's social housing to climate change through retrofit: a holistic evaluation approach. Advances in Building Energy Research (ABER), 10(1): 99-124.
Maldonado, J., Bennett, T.M.B., Chief, K., Cochran, P., Cozzetto, K., Gough, B., Redsteer, M.H., Lynn, K., Maynard, N. and Voggesser, G., 2016. Engagement with indigenous peoples and honoring traditional knowledge systems, The US National Climate Assessment. Springer, pp. 111-126.
Mallick, R.B., Jacobs, J.M., Miller, B.J., Daniel, J.S. and Kirshen, P., 2018. Understanding the impact of climate change on pavements with CMIP5, system dynamics and simulation. International Journal of Pavement Engineering, 19(8): 697-705.
Mann, M.E. and Gleick, P.H., 2015. Climate change and California drought in the 21st century. Proceedings of the National Academy of Sciences, 112(13): 3858-3859.
Maor, M., Tosun, J. and Jordan, A., 2017. Proportionate and disproportionate policy responses to climate change: Core concepts and empirical applications. Journal of Environmental Policy & Planning, 19(6): 599-611.
Marchezini, V., Trajber, R., Olivato, D., Muñoz, V.A., de Oliveira Pereira, F. and Oliveira Luz, A.E., 2017. Participatory Early Warning Systems: Youth, Citizen Science, and Intergenerational Dialogues on Disaster Risk Reduction in Brazil. International Journal of Disaster Risk Science, 8(4): 390-401.
Marengo, J.A., Torres, R.R. and Alves, L.M., 2017. Drought in Northeast Brazil—past, present, and future. Theoretical and Applied Climatology, 129(3): 1189-1200.
Marfai, M.A., Sekaranom, A.B. and Ward, P., 2015. Community responses and adaptation strategies toward flood hazard in Jakarta, Indonesia. Natural hazards, 75(2): 1127-1144.
Marks, D., 2015. The urban political ecology of the 2011 floods in Bangkok: the creation of uneven vulnerabilities. Pacific Affairs, 88: 623.
Marletto, G., 2014. Car and the city: Socio-technical transition pathways to 2030. Technological Forecasting and Social Change, 87: 164-178.
Martel, P. and Sutherland, C., 2019. Governing River Rehabilitation for Climate Adaptation and Water Security in Durban, South Africa. In: P.B. Cobbinah and M. Addaney (Editors). Springer International Publishing, pp. 355-387.
Martellozzo, F., Landry, J.S., Plouffe, D., Seufert, V., Rowhani, P. and Ramankutty, N., 2014. Urban agriculture: a global analysis of the space constraint to meet urban vegetable demand. Environmental Research Letters, 9(6): 064025.
Martimort, D. and Straub, S., 2016. How to Design Infrastructure Contracts in a Warming World: A Critical Appraisal of Public–Private Partnerships. International Economic Review, 57(1): 61-88.
Martins, T.A.L., Adolphe, L., Bonhomme, M., Bonneaud, F., Faraut, S., Ginestet, S., Michel, C. and Guyard, W., 2016. Impact of Urban Cool Island measures on outdoor climate and pedestrian comfort: Simulations for a new district of Toulouse, France. Sustainable Cities and Society, 26: 9-26.
Martius, O., Pfahl, S. and Chevalier, C., 2016. A global quantification of compound precipitation and wind extremes. Geophysical Research Letters, 43(14): 7709-7717.
Marvin, S., Bulkeley, H., Mai, L., McCormick, K. and Palgan, Y.V., 2018. Urban living labs: Experimenting with city futures. Routledge, Oxon.

Masinde, M., 2015. An innovative drought early warning system for sub-Saharan Africa: Integrating modern and indigenous approaches. African Journal of Science, Technology, Innovation and Development, 7(1): 8-25.
Mason, L.R. and Rigg, J., 2019. People and Climate Change: Vulnerability, Adaptation, and Social Justice. Oxford University Press, Oxford.
Masson-Delmotte, V., Zhai, P., Pörtner, H.O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T., 2018. Summary for Policymakers, IPCC.
Matin, N., Forrester, J. and Ensor, J., 2018. What is equitable resilience? World Development, 109: 197-205.
Matthews, T., Lo, A.Y. and Byrne, J.A., 2015. Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. Landscape and Urban Planning, 138: 155-163.
Matyas, D. and Pelling, M., 2015. Positioning resilience for 2015: the role of resistance, incremental adjustment and transformation in disaster risk management policy. Disasters, 39(s1): s1-s18.
Matzarakis, A., Fröhlich, D., Bermon, S. and Adami, E.P., 2018. Quantifying Thermal Stress for Sport Events—The Case of the Olympic Games 2020 in Tokyo. Atmosphere, 9(12).
Maughan, C., Laycock Pedersen, R. and Pitt, H., 2018. The problems, promise and pragmatism of community food growing. Renewable Agriculture and Food Systems, 33(6): 497-502.
Maynard, V., Parker, E., Yoseph-Paulus, R. and Garcia, D., 2017. Urban planning following humanitarian crises: supporting urban communities and local governments to take the lead. Environment and Urbanization, 30(1): 265-282.
Mbow, C., Smith, P., Skole, D., Duguma, L. and Bustamante, M., 2014. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. Current Opinion in Environmental Sustainability, 6(September 2013): 8-14.
McCauley, D., 2018. Fossil Fuels and Energy Justice, Energy Justice: Re-Balancing the Trilemma of Security, Poverty and Climate Change. Springer International Publishing, Cham, pp. 27-50.
McCauley, D., Heffron, R., Pavlenko, M., Rehner, R. and Holmes, R., 2016. Energy justice in the Arctic: Implications for energy infrastructural development in the Arctic. Energy Research & Social Science, 16: 141-146.
McCauley, D., Rehner, R. and Pavlenko, M., 2015. Assessing the Justice Implications of Energy Infrastructural Development in the Arctic. In: R.J. Heffron, Little and G. (Editors), Delivering Energy Law and Policy in the EU and US. Edinburgh University Press, Edinburgh.
McClintock, N., 2014. Radical, reformist, and garden-variety neoliberal: coming to terms with urban agriculture's contradictions. Local Environment, 19(2): 147-171.
McClure, L. and Baker, D., 2018. How do planners deal with barriers to climate change adaptation? A case study in Queensland, Australia. Landscape and Urban Planning, 173(Complete): 81-88.
McDermott, T.K.J. and Surminski, S., 2018. How normative interpretations of climate risk assessment affect local decision-making: an exploratory study at the city scale in Cork, Ireland. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 376(2121): 20170300.
McDonald, R., Kroeger, T., Boucher, T., Wang, L. and Salem, R., 2016. Planting healthy air: A global analysis of the role of urban tress in addressing particulate matter pollution and extreme heat.
McDonald, R.I., Weber, K., Padowski, J., Flörke, M., Schneider, C., Green, P.A., Gleeson, T., Eckman, S., Lehner, B. and Balk, D., 2014. Water on an urban planet: Urbanization and the reach of urban water infrastructure. Global Environmental Change, 27: 96-105.
McEvoy, D., 2019. Climate Resilient Urban Development. Multidisciplinary Digital Publishing Institute.
McFarlane, C. and Silver, J., 2017. The Poolitical City : " Seeing Sanitation " and Making the Urban Political in Cape Town. Antipode, 49(1): 125-148.
McGloin, R., McGowan, H. and McJannet, D., 2016. The potential effects of anthropogenic climate change on evaporation from water storage reservoirs within the Lockyer Catchment, south-east Queensland, Australia. Marine and Freshwater Research, 67(10): 1512-1521.
McGranahan, G., 2015. Realizing the right to sanitation in deprived urban communities: meeting the challenges of collective action, coproduction, affordability, and housing tenure. World Development, 68: 242-253.
McGranahan, G. and Mitlin, D., 2016. Learning from Sustained Success: How Community-Driven Initiatives to Improve Urban Sanitation Can Meet the Challenges. World Development, 87: 307-317.
McIver, L., Kim, R., Woodward, A., Hales, S., Spickett, J., Katscherian, D., Hashizume, M., Honda, Y., Kim, H., Iddings, S., Naicker, J., Bambrick, H., McMichael Anthony, J. and Ebi Kristie, L., 2016. Health Impacts of Climate Change in Pacific Island Countries: A Regional Assessment of Vulnerabilities and Adaptation Priorities. Environmental Health Perspectives, 124(11): 1707-1714.
McKnight, B. and Linnenluecke, M.K., 2016. How firm responses to natural disasters strengthen community resilience: A stakeholder-based perspective. Organization & Environment, 29(3): 290-307.
McMichael, C., Barnett, J. and McMichael, A.J., 2012. An ill wind? Climate change, migration, and health. Environmental health perspectives, 120(5): 646-654.
McPhearson, T., Haase, D., Kabisch, N. and Gren, Å., 2016a. Advancing understanding of the complex nature of urban systems. Ecological Indicators, 70: 566-573.
McPhearson, T., Hamstead, Z.A. and Kremer, P., 2014. Urban ecosystem services for resilience planning and management in New York City. Ambio, 43(4): 502-515.

McPhearson, T., Karki, M., Herzog, C., Fink, H.S., Abbadie, L., Kremer, P., Clark, C.M., Palmer, M.I. and Perini, K., 2018. Urban Ecosystems and Biodiversity. In: C. Rosenzweig, W. Solecki, P. Romero-Lankao, S. Mehrotra, S. Dhakal and A.S. Ibrahim (Editors), Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network. Cambridge University Press, Cambridge, pp. 257-318.
McPhearson, T., Pickett, S.T.A., Grimm, N.B., Niemelä, J., Alberti, M., Elmqvist, T., Weber, C., Haase, D., Breuste, J. and Qureshi, S., 2016b. Advancing Urban Ecology toward a Science of Cities. BioScience, 66(3): 198-212.
McShane, K., 2017. Values and harms in loss and damage. Ethics, Policy & Environment, 20(2): 129-142.
Meerow, S., 2017. Double exposure, infrastructure planning, and urban climate resilience in coastal megacities: A case study of Manila. Environment and Planning A: Economy and Space, 49(11): 2649-2672.
Meerow, S., Newell, J.P. and Stults, M., 2016. Defining urban resilience: A review. Landscape and urban planning, 147: 38-49.
Mees, H., 2017. Local governments in the driving seat? A comparative analysis of public and private responsibilities for adaptation to climate change in European and North-American cities. Journal of Environmental Policy & Planning, 19(4): 374-390.
Mehran, A., AghaKouchak, A., Nakhjiri, N., Stewardson, M.J., Peel, M.C., Phillips, T.J., Wada, Y. and Ravalico, J.K., 2017. Compounding impacts of human-induced water stress and climate change on water availability. Scientific reports, 7(1): 6282.
Mehrota, S., Natenzon, C.E., Omojola, A., Folorunsho, R., Gilbride, J. and Rosenzweig, C., 2009. FRAMEWORK FOR CITY CLIMATE RISK ASSESSMENT, The World Bank.
Mekonnen, M.M. and Hoekstra, A.Y., 2016. Four billion people facing severe water scarcity. Science Advances, 2(2): e1500323-e1500323.
Melvin, A.M., Larsen, P., Boehlert, B., Neumann, J.E., Chinowsky, P., Espinet, X., Martinich, J., Baumann, M.S., Rennels, L. and Bothner, A., 2017. Climate change damages to Alaska public infrastructure and the economics of proactive adaptation. Proceedings of the National Academy of Sciences, 114(2): E122-E131.
Mentens, J., Raes, D. and Hermy, M., 2006. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? Landscape and Urban Planning, 77(3): 217-226.
Merhej, R., 2019. Dehydration and cognition: an understated relation. International Journal of Health Governance, 24(1): 19-30.
Merlinsky, M.G., 2016. Mists of the Riachuelo: River Basins and Climate Change in Buenos Aires. Latin American Perspectives, 43(4): 43-55.
Mersha, A.A. and van Laerhoven, F., 2018. Gender and climate policy: a discursive institutional analysis of Ethiopia's climate resilient strategy. Regional Environmental Change.
Michael, K., Deshpande, T. and Ziervogel, G., 2018. Examining vulnerability in a dynamic urban setting : the case of Bangalore ' s interstate migrant waste pickers migrant waste pickers. Climate and Development, 0(0): 1-12.
Michael, K. and Vakulabharanam, V., 2016. Class and climate change in post-reform India. Climate and Development, 8(3): 224-233.
Milken Institute of Public Health, 2018. Ascertainment of the estimated excess mortality from Hurricane María in Puerto Rico, George Washington University.
Miller, C., Munoz-Erickson, T. and Miller, T.R., 2017. Can Cities Get Smarter about Extreme Weather?, The Knowledge System Innovation Group.
Mima, S. and Criqui, P., 2015. The costs of climate change for the European energy system, an assessment with the POLES model. Environmental Modelling & Assessment, 20(4): 303-319.
Miralles, D.G., Gentine, P., Seneviratne, S.I. and Teuling, A.J., 2019. Land-atmospheric feedbacks during droughts and heatwaves: state of the science and current challenges. Annals of the New York Academy of Sciences, 1436(1): 19-35.
Mishra, V., Ganguly, A.R., Nijssen, B. and Lettenmaier, D.P., 2015. Changes in observed climate extremes in global urban areas. Environmental Research Letters, 10(2): 024005.
Mitchell, B. and Chakraborty, J., 2018. Thermal Inequity: The Relationship between Urban Structure and Social Disparities in an Era of Climate Change. In: T. Jafry (Editor), *The Routledge Handbook of Climate Justice*. Routledge, Oxon, pp. 330-346.
Mitchell, J.W., 2013. Power line failures and catastrophic wildfires under extreme weather conditions. Engineering Failure Analysis, 35: 726-735.
Mitchell, T. and Maxwell, S., 2010. Defining climate compatible development. CDKN ODI Policy Brief.
Moench, M., 2014. Experiences applying the climate resilience framework: linking theory with practice. Development in Practice, 24(4): 447-464.
Moftakhari, H.R., AghaKouchak, A., Sanders, B.F. and Matthew, R.A., 2017a. Cumulative hazard: The case of nuisance flooding. Earth's Future, 5(2): 214-223.
Moftakhari, H.R., Salvadori, G., AghaKouchak, A., Sanders, B.F. and Matthew, R.A., 2017b. Compounding effects of sea level rise and fluvial flooding. Proceedings of the National Academy of Sciences, 114(37): 9785-9790.
Moiseyev, A., Solberg, B., Kallio, A.M.I. and Lindner, M., 2011. An economic analysis of the potential contribution of forest biomass to the EU RES target and its implications for the EU forest industries. Journal of Forest Economics, 17(2): 197-213.

Molenaar, A., Aerts, J., Dircke, P. and Ikert, M., 2015. Connecting Delta Cities: Resilient cities and climate adaptation strategies. Connecting Delta Cities, Rotterdam.
Moloney, S. and Fünfgeld, H., 2015. Emergent processes of adaptive capacity building: Local government climate change alliances and networks in Melbourne. Urban Climate, 14: 30-40.
Montazeri, H., Blocken, B. and Hensen, J.L.M., 2015. Evaporative cooling by water spray systems: CFD simulation, experimental validation and sensitivity analysis. Building and Environment, 83: 129-141.
Montazeri, H., Toparlar, Y., Blocken, B. and Hensen, J.L.M., 2017. Simulating the cooling effects of water spray systems in urban landscapes: A computational fluid dynamics study in Rotterdam, the Netherlands. Landscape and Urban Planning, 159: 85-100.
Moore, F.C. and Lobell, D.B., 2014. Adaptation potential of European agriculture in response to climate change. Nature Climate Change, 4: 610.
Moore, T.L., Gulliver, J.S., Stack, L. and Simpson, M.H., 2016. Stormwater management and climate change: vulnerability and capacity for adaptation in urban and suburban contexts. Climatic change, 138(3-4): 491-504.
Mora, C., Dousset, B., Caldwell, I.R., Powell, F.E., Geronimo, R.C., Bielecki, Coral R., Counsell, C.W.W., Dietrich, B.S., Johnston, E.T., Louis, L.V., Lucas, M.P., McKenzie, M.M., Shea, A.G., Tseng, H., Giambelluca, T.W., Leon, L.R., Hawkins, E. and Trauernicht, C., 2017. Global risk of deadly heat. Nature Climate Change, 7: 501.
Moretto, L. and Ranzato, M., 2017. A socio-natural standpoint to understand coproduction of water, energy and waste services. Urban Research & Practice, 10(1): 1-21.
Morille, B. and Musy, M., 2017. Comparison of the Impact of Three Climate Adaptation Strategies on Summer Thermal Comfort – Cases Study in Lyon, France. Procedia Environmental Sciences, 38: 619-626.
Moser, S.C. and Hart, J.A.F., 2015. The long arm of climate change: societal teleconnections and the future of climate change impacts studies. Climatic Change, 129(1-2): 13-26.
Mubaya, C.P. and Mafongoya, P., 2017. The role of institutions in managing local level climate change adaptation in semi-arid Zimbabwe. Climate Risk Management, 16: 93-105.
Mueller, V., Gray, C. and Kosec, K., 2014. Heat stress increases long-term human migration in rural Pakistan. Nature Climate Change, 4(3): 182-185.
Muis, S., Güneralp, B., Jongman, B., Aerts, J.C.J.H. and Ward, P.J., 2015. Flood risk and adaptation strategies under climate change and urban expansion: A probabilistic analysis using global data. Science of the Total Environment, 538: 445-457.
Mulugetta, Y. and Broto, V.C., 2018. Harnessing deep mitigation opportunities of urbanisation patterns in LDCs. Current opinion in environmental sustainability, 30: 82-88.
Mulville, M. and Stravoravdis, S., 2016. The impact of regulations on overheating risk in dwellings. Building Research and Information, 44(5-6): 520-534.
Murdock, H.E., Gibb, D., André, T., Appavou, F., Brown, A., Epp, B., Kondev, B., McCrone, A., Musolino, E. and Ranalder, L., 2019. Renewables 2019 Global Status Report.
Musah-Surugu, J.I., Owusu, K., Yankson, P.W.K. and Ayisi, E.K., 2018. Mainstreaming climate change into local governance: financing and budgetary compliance in selected local governments in Ghana. Development in Practice, 28(1): 65-80.
Mustafa, D., Gioli, G., Qazi, S., Waraich, R., Rehman, A. and Zahoor, R., 2015. Gendering flood early warning systems: the case of Pakistan. Environmental Hazards, 14(4): 312-328.
Möller, I., Kudella, M., Rupprecht, F., Spencer, T., Paul, M., Van Wesenbeeck, B.K., Wolters, G., Jensen, K., Bouma, T.J. and Miranda-Lange, M., 2014. Wave attenuation over coastal salt marshes under storm surge conditions. Nature Geoscience, 7(10): 727.
Nagendra, H., 2016. Nature in the City: Bengaluru in the Past, Present, and Future. Oxford University Press, New Delhi.
Nagendra, H., Bai, X., Brondizio, E.S. and Lwasa, S., 2018. The urban south and the predicament of global sustainability. Nature Sustainability, 1(7): 341-349.
Nagendra, H. and Mundoli, S., 2019. Cities and Canopies: Trees in Indian Cities. Penguin Random House India Private Limited.
Nalau, J. and Becken, S., 2018. Ecosystem-based Adaptation to Climate Change: Review of Concepts, Griffith Institute for Tourism, Research Griffith University, Queensland, Australia.
Nalau, J., Becken, S., Schliephack, J., Parsons, M., Brown, C. and Mackey, B., 2018. The role of indigenous and traditional knowledge in ecosystem-based adaptation: a review of the literature and case studies from the Pacific Islands. Weather, Climate, and Society, 10(4): 851-865.
Namukombo, J., 2016. Information and communication technologies and gender in climate change and green economy: Situating women's opportunities and challenges in Zambian policies and strategies. Jàmbá: Journal of Disaster Risk Studies, 8(3).
Napawan, N.C., Simpson, S.-A. and Snyder, B., 2017. Engaging Youth in Climate Resilience Planning with Social Media: Lessons from #OurChangingClimate. Urban Planning; Vol 2, No 4 (2017): Social Ecology of SustainabilityDO - 10.17645/up.v2i4.1010.
Narain, V. and Nischal, S., 2007. The peri-urban interface in Shahpur Khurd and Karnera, India. Environment and Urbanization, 19(1): 261-273.

Narain, V., Ranjan, P., Vij, S. and Dewan, A., 2017. Taking the road less taken: reorienting the state for peri-urban water security. Action Research: 147675031773637-147675031773637.
Narain, V. and Singh, A.K., 2017. Flowing against the current: The socio-technical mediation of water (in)security in peri-urban Gurgaon, India. Geoforum, 81: 66-75.
Narain, V. and Singh, A.K., 2019. Replacement or displacement? Peri-urbanisation and changing water access in the Kumaon Himalaya, India. Land Use Policy, 82: 130-137.
Narayan, S., Beck, M.W., Wilson, P., Thomas, C.J., Guerrero, A., Shepard, C.C., Reguero, B.G., Franco, G., Ingram, J.C. and Trespalacios, D., 2017. The value of coastal wetlands for flood damage reduction in the northeastern USA. Scientific reports, 7(1): 9463.
Nassis, G.P., Brito, J., Dvorak, J., Chalabi, H. and Racinais, S., 2015. The association of environmental heat stress with performance: analysis of the 2014 FIFA World Cup Brazil. British Journal of Sports Medicine, 49(9): 609.
Nastiti, A., Meijerink, S.V., Oelmann, M., Smits, A.J.M., Muntalif, B.S., Sudradjat, A. and Roosmini, D., 2017. Cultivating Innovation and Equity in Co-Production of Commercialized Spring Water in Peri-Urban Bandung, Indonesia. Water Alternatives-an Interdisciplinary Journal on Water Politics and Development, 10(1): 160-180.
National Research Council, 2014. Reducing coastal risk on the east and gulf coasts.
Naturally Resilient Communities, 2017. Riverfront Park, Nashville, Tennessee. Naturally Resilient Communities.
Naveed, M. and Siddle, D., 2013. Investigations into the initial refractivity gradients and signal strengths over the English Channel, Proceedings of 7th European Conference on Antennas and Propagation (EuCAP). IEEE.
Nawrotzki, R.J., Hunter, L.M., Runfola, D.M. and Riosmena, F., 2015. Climate change as a migration driver from rural and urban Mexico. Environmental Research Letters, 10(11): 114023.
Nazarian, N., Dumas, N., Kleissl, J. and Norford, L., 2019. Effectiveness of cool walls on cooling load and urban temperature in a tropical climate. Energy and Buildings, 187: 144-162.
Nazif, S., Tavakolifar, H. and Eslamian, S., 2017. Climate change impact on urban water deficit. In: S. Eslamian and E. F.A. (Editors), *Handbook of Drought and Water Scarcity*. CRC, Boca Raton, pp. 81-106.
Nche, G.C., Achunike, H.C. and Okoli, A.B., 2019. From climate change victims to climate change actors: The role of eco-parenting in building mitigation and adaptation capacities in children. The Journal of Environmental Education, 50(2): 131-144.
Ncube-Phiri, S., Mundavanhu, C. and Mucherera, B., 2014. The complexity of maladaptation strategies to disasters: The case of Muzarabani, Zimbabwe. Jàmbá: Journal of Disaster Risk Studies, 6(1): 1-11.
Necefer, L., Wong-Parodi, G., Jaramillo, P. and Small, M.J., 2015. Energy development and Native Americans: Values and beliefs about energy from the Navajo Nation. Energy Research & Social Science, 7: 1-11.
Neset, T.-S., Wiréhn, L., Klein, N., Käyhkö, J. and Juhola, S., 2019. Maladaptation in Nordic agriculture. Climate Risk Management, 23(December 2018): 78-87.
Neumann, J.E., Price, J., Chinowsky, P., Wright, L., Ludwig, L., Streeter, R., Jones, R., Smith, J.B., Perkins, W. and Jantarasami, L., 2015. Climate change risks to US infrastructure: impacts on roads, bridges, coastal development, and urban drainage. Climatic Change, 131(1): 97-109.
Nevens, F., Frantzeskaki, N., Gorissen, L. and Loorbach, D., 2013. Urban Transition Labs: co-creating transformative action for sustainable cities. Journal of Cleaner Production, 50: 111-122.
Newell, J.P. and Cousins, J.J., 2015. The boundaries of urban metabolism: Towards a political–industrial ecology. Progress in Human Geography, 39(6): 702-728.
Nik, V.M. and Sasic Kalagasidis, A., 2013. Impact study of the climate change on the energy performance of the building stock in Stockholm considering four climate uncertainties. Building and Environment, 60: 291-304.
Niles, M.T., Lubell, M. and Brown, M., 2015. How limiting factors drive agricultural adaptation to climate change. Agriculture, Ecosystems & Environment, 200: 178-185.
Nissan, H., Goddard, L., de Perez, E.C., Furlow, J., Baethgen, W., Thomson, M.C. and Mason, S.J., 2019. On the use and misuse of climate change projections in international development. Wiley Interdisciplinary Reviews: Climate Change, 10(3): e579.
Nolon, J.R., 2016. Enhancing the Urban Environment Through Green Infrastructure. 46 Environmental Law Reporter, 10071.
NOOA, 2019. NOAA Coastal Resilience Grants Program. US NOAA Office for Coastal Management.
Nordgren, J., Stults, M. and Meerow, S., 2016. Supporting local climate change adaptation: Where we are and where we need to go. Environmental Science & Policy, 66: 344-352.
Nordström, M. and Wales, M., 2019. Enhancing urban transformative capacity through children's participation in planning. Ambio: 1-8.
Norris, T., Vines, P.L. and Hoeffel, E.M., 2010. The American Indian and Alaska Native Population: 2010 Census Briefs, U.S. Census Bureau, U.S. Department of Commerce
Economics and Statistics Administration.
North, P., Nurse, A. and Barker, T., 2017. The neoliberalisation of climate? Progressing climate policy under austerity urbanism. Environment and Planning A: Economy and Space, 49(8): 1797-1815.
Norwegian Red Cross, 2019. Overlapping vulnerabilities: the impacts of climate change on humanitarian needs, Norwegian Red Cross, Oslo.
Nugraha, E. and Lassa, J.A., 2018. Towards endogenous disasters and climate adaptation policy making in Indonesia. Disaster Prevention and Management: An International Journal, 27(2): 228-242.

NYCPCC, 2019. New York City Panel on Climate Change 2019 Report, New York City Panel on Climate Change, New York.
O'Brien, K., Selboe, E. and Hayward, B.M., 2018. Exploring youth activism on climate change: dutiful, disruptive, and dangerous dissent. Ecology and Society, 23(3).
O'Hare, P., White, I. and Connelly, A., 2016. Insurance as maladaptation: Resilience and the ‘business as usual’ paradox. Environment and Planning C: Government and Policy, 34(6): 1175-1193.
Obradovich, N. and Fowler, J.H., 2017. Climate change may alter human physical activity patterns. Nature Human Behaviour, 1(5): 0097.
Obradovich, N., Migliorini, R., Paulus, M.P. and Rahwan, I., 2018. Empirical evidence of mental health risks posed by climate change. Proceedings of the National Academy of Sciences, 115(43): 10953.
Odemerho, F.O., 2015. Building climate change resilience through bottom-up adaptation to flood risk in Warri, Nigeria. Environment and Urbanization, 27(1): 139-160.
Odhiambo Sewe, M., Bunker, A., Ingole, V., Egondi, T., Oudin Åström, D., Hondula, D.M., Rocklöv, J. and Schumann, B., 2018. Estimated effect of temperature on years of life lost: a retrospective time-series study of low-, middle-, and high-income regions. Environmental health perspectives, 126(1): 017004.
OECD, 2016. African Economic Outlook 2016. Sustainable Cities and Structural Transformation. OECD.
OECD, 2017. Financing Climate Futures. OECD.
OECD/UCLG, 2019. Report of the World Observatory on Subnational Government Finance and Investment – Key Findings. Organisation for Economic Co-operation and Development and United Cities and Local Governments, Paris and Barcelona.
OECD/UN-Habitat, 2018. Global State of National Urban Policy, OECD Publishing, Nairobi and Paris.
Ofcom, 2012. Modelling Rain Rate Maps for Fixed-Link frequency Assignment Procedures, Ofcom contract No: 796.
Ogato, G.S., Abebe, K., Bantider, A. and Geneletti, D., 2017. Towards mainstreaming climate change adaptation into urban land use planning and management: the case of Ambo Town, Ethiopia, Climate Change Adaptation in Africa. Springer, Cham.
Ojea, E., 2015. Challenges for mainstreaming Ecosystem-based Adaptation into the international climate agenda. Current Opinion in Environmental Sustainability, 14: 41-48.
Oke, T.R., Mills, G., Christen, A. and Voogt, J.A., 2017. Urban Climates. Cambridge University Press, Cambridge.
Okotto, L., Okotto-Okotto, J., Price, H., Pedley, S. and Wright, J., 2015. Socio-economic aspects of domestic groundwater consumption, vending and use in Kisumu, Kenya. Applied Geography, 58: 189-197.
Olazabal, M., Galarraga, I., Ford, J., Sainz De Murieta, E. and Lesnikowski, A., 2019. Are local climate adaptation policies credible? A conceptual and operational assessment framework. International Journal of Urban Sustainable Development: 1-20.
Opdyke, A., Javernick-Will, A., Koschmann, M., Palagi, S., Su, Y., Tabo, P., Groen, R. and Mangada, L., 2017. Typhoon Haiyan: Shelter Case Studies.
Orleans Reed, S., Friend, R., Toan, V.C., Thinphanga, P., Sutarto, R. and Singh, D., 2013. “Shared learning” for building urban climate resilience – experiences from Asian cities. Environment and Urbanization, 25(2): 393-412.
Orlove, B., Lazrus, H., Hovelsrud, G. and Giannini, A., 2014. Recognitions and responsibilities: on the origins and consequences of the uneven attention to climate change around the world. Current Anthropology, Forthcoming.
Oropeza-Perez, I. and Østergaard, P.A., 2018. Active and passive cooling methods for dwellings: A review. Renewable and Sustainable Energy Reviews, 82: 531-544.
Orru, H., Ebi, K.L. and Forsberg, B., 2017. The Interplay of Climate Change and Air Pollution on Health. Current Environmental Health Reports, 4(4): 504-513.
Osman, M.M. and Sevinc, H., 2019. Adaptation of climate-responsive building design strategies and resilience to climate change in the hot/arid region of Khartoum, Sudan. Sustainable Cities and Society, 47: 101429.
Ostrom, E., 1996. Crossing the great divide: coproduction, synergy, and development. World development, 24(6): 1073-1087.
Oswin, N., 2018. Planetary urbanization: A view from outside. Environment and Planning D: Society and Space, 36(3): 540-546.
Oxford Economics, 2017. Global Infrastructure Outlook, Oxford Economics Global Infrastructure Hub.
Ozarisoy, B. and Elsharkawy, H., 2019. Assessing overheating risk and thermal comfort in state-of-the-art prototype houses that combat exacerbated climate change in UK. Energy and Buildings, 187: 201-217.
O’Neill, B.C., Kriegler, E., Ebi, K.L., Kemp-Benedict, E., Riahi, K., Rothman, D.S., van Ruijven, B.J., van Vuuren, D.P., Birkmann, J., Kok, K., Levy, M. and Solecki, W., 2015. The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. Global Environmental Change, 42: 169-180.
O’Neill, D.W., Fanning, A.L., Lamb, W.F. and Steinberger, J.K., 2018. A good life for all within planetary boundaries. Nature Sustainability, 1(2): 88.
Paavola, J., 2017. Health impacts of climate change and health and social inequalities in the UK. Environmental Health, 16(1): 113.
Pachauri, R.P., Meyer, L.A., Barros, V.C. and al., e., 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, IPCC, Geneva.

Padgham, J., Jabbour, J. and Dietrich, K., 2015. Managing change and building resilience: A multi-stressor analysis of urban and peri-urban agriculture in Africa and Asia. Urban Climate, 12: 183-204.
Palin, E.J., Thornton, H.E., Mathison, C.T., McCarthy, R.E., Clark, R.T. and Dora, J., 2013. Future projections of temperature-related climate change impacts on the railway network of Great Britain. Climatic Change, 120(1-2): 71-93.
Palla, A. and Gnecco, I., 2015. Hydrologic modelling of Low Impact Development systems at the urban catchment scale. Journal of Hydrology, 528(Complete): 361-368.
Palmer, M.A., Filoso, S. and Fanelli, R.M., 2014. From ecosystems to ecosystem services: Stream restoration as ecological engineering. Ecological Engineering, 65: 62-70.
Palmer, M.A., Liu, J., Matthews, J.H., Mumba, M. and Odorico, P., 2015. Manage water in a green way. Science, 349(6248): 584.
Panda, S., Modak, S., Devi, Y.L., Das, L., Pal, P.K. and Nain, M.S., 2019. Access and Usage of Information and Communication Technology (ICT) to Accelerate Farmers' Income. *Journal of Community Mobilization and Sustainable Development*., 14(1): 200-205.
Pant, R., Hall, J.W. and Blainey, S.P., 2016. Vulnerability assessment framework for interdependent critical infrastructures: case-study for Great Britain's rail network. European Journal of Transport and Infrastructure Research, 16(1).
Panteli, M. and Mancarella, P., 2015. Influence of extreme weather and climate change on the resilience of power systems: Impacts and possible mitigation strategies. Electric Power Systems Research, 127: 259-270.
Panteli, M., Trakas, D.N., Mancarella, P. and Hatziargyriou, N.D., 2016. Boosting the power grid resilience to extreme weather events using defensive islanding. IEEE Transactions on Smart Grid, 7(6): 2913-2922.
Paprocki, K., 2018. Threatening dystopias: Development and adaptation regimes in Bangladesh. Annals of the American Association of Geographers, 108(4): 955-973.
Paprotny, D., Vousdoukas, M.I., Morales-Nápoles, O., Jonkman, S.N. and Feyen, L., 2018. Compound flood potential in Europe. Hydrology and Earth System Sciences Discussions(April): 1-34.
Park, M. and Hanna, J., 2017. Puerto Rico suffering humanitarian crisis after María, San Juan mayor says CNN.
Parker, E. and Maynard, V., 2015. Humanitarian response to urban crises: a review of area-based approaches, IIED, London.
Parnell, S., 2016. Defining a Global Urban Development Agenda. World Development, 78: 529-540.
Parsons, M., Nalau, J., Fisher, K. and Brown, C., 2019. Disrupting path dependency: Making room for Indigenous knowledge in river management. Global Environmental Change, 56: 95-113.
Pasquini, L., Ziervogel, G., Cowling, R.M. and Shearing, C., 2015. What enables local governments to mainstream climate change adaptation? Lessons learned from two municipal case studies in the Western Cape, South Africa. Climate and Development, 7(1): 60-70.
Patt, A., Pfenninger, S. and Lilliestam, J., 2013. Vulnerability of solar energy infrastructure and output to climate change. Climatic change, 121(1): 93-102.
Patterson, J., de Voogt, D.L. and Sapiains, R., 2019. Beyond inputs and outputs: Process-oriented explanation of institutional change in climate adaptation governance. Environmental Policy and Governance.
Patterson, J.J. and Huitema, D., 2019. Institutional innovation in urban governance: The case of climate change adaptation. Journal of Environmental Planning and Management, 62(3): 374-398.
Pató, B.S.G., 2015. The Effect of Climate Change on Distribution Logistics. *International Journal of Business Insights & Transformation*, 8(2).
Paulson, K. and Al-Mreri, A., 2011. Trends in the incidence of rain height and the effects on global satellite telecommunications. IET microwaves, antennas & propagation, 5(14): 1710-1713.
Pauw, P. and Pegels, A., 2013. Private sector engagement in climate change adaptation in least developed countries: an exploration. Climate and Development, 5(4): 257-267.
Pauw, W.P., 2015. Not a panacea: private-sector engagement in adaptation and adaptation finance in developing countries. Climate Policy, 15(5): 583-603.
Pearce, T., Ford, J., Willox, A.C. and Smit, B., 2015. Inuit traditional ecological knowledge (TEK), subsistence hunting and adaptation to climate change in the Canadian Arctic. Arctic: 233-245.
Pechan, A. and Eisenack, K., 2014. The impact of heat waves on electricity spot markets. Energy Economics, 43: 63-71.
Pelling, M., 2010. Adaptation to climate change: from resilience to transformation. Routledge.
Pelling, M., Leck, H., Pasquini, L., Ajibade, I., Osuteye, E., Parnell, S., Lwasa, S., Johnson, C., Fraser, A. and Barcena, A., 2018. Africa's urban adaptation transition under a 1.5 climate. Current Opinion in Environmental Sustainability, 31: 10-15.
Pelling, M., O'Brien, K. and Matyas, D., 2015. Adaptation and transformation. Climatic Change, 133(1): 113-127.
Penning-Rowsell, E.C., Sultana, P. and Thompson, P.M., 2013. The 'last resort'? Population movement in response to climate-related hazards in Bangladesh. Environmental Science & Policy, 27: S44-S59.
Perera, N.G.R., 2016. Urban climate mapping in the tropics. In: R. Emmanuel (Editor), Urban Climate Challenges in the Tropics: Rethinking Planning and Design Opportunities. Imperial College Press, London, pp. 205-254.
Perera, N.G.R. and Emmanuel, R., 2018. A "Local Climate Zone" based approach to urban planning in Colombo, Sri Lanka. Urban climate, 23: 188-203.

Perez, A.C., Grafton, B., Mohai, P., Hardin, R., Hintzen, K. and Orvis, S., 2015. Evolution of the environmental justice movement: activism, formalization and differentiation. Environmental Research Letters, 10(10): 105002.
Pescaroli, G., 2018. Perceptions of cascading risk and interconnected failures in emergency planning: Implications for operational resilience and policy making. International Journal of Disaster Risk Reduction, 30(January): 269-280.
Pestoff, V. and Brandsen, T., 2013. Co-production: the third sector and the delivery of public services. Routledge.
Pestoff, V., Brandsen, T. and Verschuere, B., 2013. New public governance, the third sector, and co-production. Routledge.
Peterson, M.S. and Lowe, M.R., 2009. Implications of cumulative impacts to estuarine and marine habitat quality for fish and invertebrate resources. Reviews in Fisheries Science, 17(4): 505-523.
Pham, T.-T.-H., Apparicio, P., Gomez, C., Weber, C. and Mathon, D., 2014. Towards a rapid automatic detection of building damage using remote sensing for disaster management: The 2010 Haiti earthquake. Disaster prevention and management, 23(1): 53-66.
Phillips, H., 2015. The capacity to adapt to climate change at heritage sites – The development of a conceptual framework. Environmental Science and Policy, 47: 118-125.
Phung, D., Thai, P.K., Guo, Y., Morawska, L., Rutherford, S. and Chu, C., 2016. Ambient temperature and risk of cardiovascular hospitalization: An updated systematic review and meta-analysis. Science of The Total Environment, 550: 1084-1102.
Pk, S., Bashir, R. and Beddoe, R., 2018. Effect of climate change on earthen embankments in Southern Ontario, Canada. Environmental Geotechnics: 1-22.
Pochee, H. and Johnston, I., 2017. Understanding design scales for a range of potential green infrastructure benefits in a London Garden City. Building Services Engineering Research and Technology, 38(6): 728-756.
Pollard, B., Storey, M., Robinson, C. and Bell, T., 2014. The CARRA project: Developing tools to help heritage managers identify and respond to coastal hazard impacts on archaeological resources, 2014 Oceans - St. John's. IEEE, Newfoundland and Labrador, pp. 1-4.
Porio, E., 2011. Vulnerability, Adaptation, and Resilience to Floods and Climate Change-Related Risks among Marginal, Riverine Communities in Metro Manila. Asian Journal of Social Science, 39(4): 425-445.
Poulsen, M.N., McNab, P.R., Clayton, M.L. and Neff, R.A., 2015. A systematic review of urban agriculture and food security impacts in low-income countries. Food Policy, 55: 131-146.
Poulsen, M.N., Neff, R.A. and Winch, P.J., 2017. The multifunctionality of urban farming: perceived benefits for neighbourhood improvement. Local Environment, 22(11): 1411-1427.
Pourias, J., Aubry, C. and Duchemin, E., 2016. Is food a motivation for urban gardeners? Multifunctionality and the relative importance of the food function in urban collective gardens of Paris and Montreal. Agriculture and Human Values, 33(2): 257-273.
Powrie, W. and Smethurst, J., 2018. Climate and vegetation impacts on infrastructure cuttings and embankments. In: L. Zhan, Y. Chen and A. Bouazza (Editors), The International Congress on Environmental Geotechnics. Springer, Singapore, pp. 128-144.
Pregnolato, M., Ford, A., Glenis, V., Wilkinson, S. and Dawson, R., 2017. Impact of climate change on disruption to urban transport networks from pluvial flooding. Journal of Infrastructure Systems, 23(4): 04017015.
Pregnolato, M., Ford, A., Robson, C., Glenis, V., Barr, S. and Dawson, R., 2016. Assessing urban strategies for reducing the impacts of extreme weather on infrastructure networks. Royal Society Open Science, 3(5): 160023.
Preston, C.J., 2017. Challenges and opportunities for understanding non-economic loss and damage. Ethics, Policy & Environment, 20(2): 143-155.
Prieur-Richard, A., 2018. Global Research and Action Agenda on Cities and Climate. Change Science Future Earth, Montreal.
Princeti, S., 2016. Post carbon cities: Distributed and decentralized and demodernized? In: J. Evans, A. Karvnonen and R. Raven (Editors), The Experimental City. Routledge, London, pp. 236-250.
Pritchard, B. and Thielemans, R., 2014. 'Rising Waters Don't Lift All Boats': a sustainable livelihood analysis of recursive cycles of vulnerability and maladaptation to flood risk in rural Bihar, India. Australian Geographer, 45(3): 325-339.
Puente-Rodríguez, D., Van Slobbe, E., Al, I.A.C. and Lindenbergh, D.E., 2016. Knowledge co-production in practice: Enabling environmental management systems for ports through participatory research in the Dutch Wadden Sea. Environmental Science and Policy, 55: 456-466.
Puppim de Oliveira, J.A. and Doll, C.N.H., 2016. Governance and networks for health co-benefits of climate change mitigation: Lessons from two Indian cities. Environment International, 97: 146-154.
Pyhälä, A., Fernández-Llamazares, Á., Lehvävirta, H., Byg, A., Ruiz-Mallén, I., Salpeteur, M. and Thornton, T.F., 2016. Global environmental change: local perceptions, understandings, and explanations. Ecology and society: a journal of integrative science for resilience and sustainability, 21(3).
Pérez-Andreu, V., Aparicio-Fernández, C., Martínez-Ibernón, A. and Vivancos, J.-L., 2018. Impact of climate change on heating and cooling energy demand in a residential building in a Mediterranean climate. Energy, 165: 63-74.
Radhakrishnan, M., Pathirana, A., Ashley, R. and Zevenbergen, C., 2017. Structuring climate adaptation through multiple perspectives: Framework and case study on flood risk management. Water, 9(2): 129.
Rampurkar, V., Pentayya, P., Mangalvedekar, H.A. and Kazi, F., 2016. Cascading Failure Analysis for Indian Power Grid. IEEE Transactions on Smart Grid, 7(4): 1951-1960.

Ramseyer, C., Holliday, L. and Floyd, R., 2016. Enhanced Residential Building Code for Tornado Safety. Journal of Performance of Constructed Facilities, 30(4): 04015084.
Ramyar, R., Zarghami, E. and Bryant, M., 2019. Spatio-Temporal Planning of Urban Neighborhoods in the Context of Global Climate Change: Lessons for Urban Form Design in Tehran, Iran. Sustainable Cities and Society, 51.
Rashidi, K. and Patt, A., 2018. Subsistence over symbolism: the role of transnational municipal networks on cities' climate policy innovation and adoption. Mitigation and Adaptation Strategies for Global Change, 23(4): 507-523.
Rasul, G. and Sharma, B., 2016. The nexus approach to water–energy–food security: an option for adaptation to climate change. Climate Policy, 16(6): 682-702.
Raza, H., 2017. Using a mixed method approach to discuss the intersectionalities of class, education, and gender in natural disasters for rural vulnerable communities in Pakistan. Journal of Rural and Community Development, 12(1): 128-148.
Reckien, D., Creutzig, F., Fernandez, B., Lwasa, S., Tovar-Restrepo, M., Mcevoy, D. and Satterthwaite, D., 2017. Climate change, equity and the Sustainable Development Goals: an urban perspective. Environment and urbanization, 29(1): 159-182.
Reckien, D., Flacke, J., Olazabal, M. and Heidrich, O., 2015. The influence of drivers and barriers on urban adaptation and mitigation plans—an empirical analysis of European cities. PloS one, 10(8): e0135597.
Reckien, D., Salvia, M., Heidrich, O., Church, J.M., Pietrapertosa, F., De Gregorio-Hurtado, S., D'Alonzo, V., Foley, A., Simoes, S.G., Krkoška Lorencová, E., Orru, H., Orru, K., Wejs, A., Flacke, J., Olazabal, M., Geneletti, D., Feliu, E., Vasilie, S., Nador, C., Krook-Riekkola, A., Matosović, M., Fokaides, P.A., Ioannou, B.I., Flamos, A., Spyridaki, N.-A., Balzan, M.V., Fülöp, O., Paspaldzhiev, I., Grafakos, S. and Dawson, R., 2018. How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28. Journal of Cleaner Production, 191: 207-219.
Reed, S.O., Friend, R., Jarvie, J., Henceroth, J., Thinphanga, P., Singh, D., Tran, P. and Sutarto, R., 2015. Resilience projects as experiments: implementing climate change resilience in Asian cities. Climate and Development, 7(5): 469-480.
Reese, M., 2018. Climate Proofing of Urban Development: Regulatory Challenges and Approaches in Europe, Germany, and Beyond. In: S. Kabisch, F. Koch, E. Gawel, A. Haase, S. Knapp, K. Krellenberg, J. Nivala and A. Zehnsdorf (Editors), Urban Transformations: Sustainable Urban Development Through Resource Efficiency, Quality of Life and Resilience. Springer, Chur, Switzerland, pp. 339-362.
Reid, M.G., Hamilton, C., Reid, S.K., Trousdale, W., Hill, C., Turner, N., Picard, C.R., Lamontagne, C. and Matthews, H.D., 2014. Indigenous climate change adaptation planning using a values-focused approach: a case study with the Gitga'at nation. Journal of Ethnobiology, 34(3): 401-425.
Resilient Rotterdam, 2016. Rotterdam Resilience Strategy, Gemeente Rotterdam/100 Resilient Cities Program, Rotterdam.
Restemeyer, B., van den Brink, M. and Woltjer, J., 2017. Between adaptability and the urge to control: making long-term water policies in the Netherlands. Journal of Environmental Planning and Management, 60(5): 920-940.
Revi, A., Satterthwaite, D., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R.B.R., Pelling, M., Roberts, D., Solecki, W., Gajjar, S.P. and Sverdlik, A., 2014. Towards transformative adaptation in cities: the IPCC's Fifth Assessment. Environment and Urbanization, 26(1): 11-28.
Reyes-García, V., Fernández-Llamazares, Á., Guèze, M., Garcés, A., Mallo, M., Vila-Gómez, M. and Vilaseca, M., 2016. Local indicators of climate change: the potential contribution of local knowledge to climate research. Wiley Interdisciplinary Reviews: Climate Change, 7(1): 109-124.
Ribera, T., Sachs, J., Colombier, M., Schmidt-Traub, G., Waisman, H., Williams, J., Segafredo, L. and Pierfederici, R., 2015. Pathways to deep decarbonization, SDSN/IDDRI, New York.
Richards, J., Wang, Y., Orr, S.A. and Viles, H., 2018. Finding common ground between United Kingdom based and Chinese approaches to earthen heritage conservation. Sustainability, 10(9).
Richmond, A., Myers, I. and Namuli, H., 2018. Urban informality and vulnerability: A case study in Kampala, Uganda. Urban Science, 2(1): 22.
Rietig, K., 2019. The importance of compatible beliefs for effective climate policy integration. Environmental Politics, 28(2): 228-247.
Roberts, D., Boon, R., Diederichs, N., Douwes, E., Govender, N., McInnes, A., McLean, C., O'Donoghue, S. and Spires, M., 2012. Exploring ecosystem-based adaptation in Durban, South Africa:"learning-by-doing" at the local government coal face. Environment and Urbanization, 24(1): 167-195.
Roberts, D. and O'Donoghue, S., 2013. Urban environmental challenges and climate change action in Durban, South Africa. Environment and Urbanization, 25(2): 299-319.
Roberts, E. and Pelling, M., 2018. Climate change-related loss and damage: translating the global policy agenda for national policy processes. Climate and Development, 10(1): 4-17.
Robins, N., 2018. Financing the climate change triple jump: how to align capital with a 1.5°C world, LSE News and Commentaries. LSE.
Rockman, Marcy, Morgan, M., Ziaja, S., Hambrecht, G. and Meadow, A., 2016. Cultural Resources Climate Change Strategy, National Park Service.
Roders, M. and Straub, A., 2015. Assessment of the likelihood of implementation strategies for climate change adaptation measures in Dutch social housing. Building and Environment, 83: 168-176.

Rojas, C., De Meulder, B. and Shannon, K., 2015. Water urbanism in Bogotá. Exploring the potentials of an interplay between settlement patterns and water management. Habitat International, 48: 177-187.
Romero-Lankao, P., Gnatz, D.M. and Sperling, J.B., 2016. Examining urban inequality and vulnerability to enhance resilience: insights from Mumbai, India. Climatic change, 139(3-4): 351-365.
Rosenzweig, C. and Solecki, W., 2018. Action pathways for transforming cities. Nature Climate Change, 8(9): 756.
Roshan, G., Oji, R. and Attia, S., 2019. Projecting the impact of climate change on design recommendations for residential buildings in Iran. Building and Environment, 155: 283-297.
Roth, D., Khan, M.S.A., Jahan, I., Rahman, R., Narain, V., Singh, A.K., Priya, M., Sen, S., Shrestha, A. and Yakami, S., 2019. Climates of urbanization: local experiences of water security, conflict and cooperation in peri-urban South-Asia. Climate Policy, 19(sup1): S78-S93.
Roy, J., Tschakert, P., Waisman, H., Abdul Halim, S., Antwi-Agyei, P., Dasgupta, P., Hayward, B., Kanninen, M., Liverman, D., Okereke, C., Pinho, P.F., Riahi, K. and Suarez Rodriguez, A.G., 2018a. Sustainable Development, Poverty Eradication and Reducing Inequalities, IPCC.
Roy, M., Hulme, D. and Jahan, F., 2013. Contrasting adaptation responses by squatters and low-income tenants in Khulna, Bangladesh. Environment and Urbanization, 25(1): 157-176.
Roy, M., Shemdoe, R., Hulme, D., Mwageni, N. and Gough, A., 2018b. Climate change and declining levels of green structures: Life in informal settlements of Dar es Salaam, Tanzania. Landscape and Urban Planning, 180: 282-293.
Ruckelshaus, M.H., Guannel, G., Arkema, K., Verutes, G., Griffin, R., Guerry, A., Silver, J., Faries, J., Brenner, J. and Rosenthal, A., 2016. Evaluating the benefits of green infrastructure for coastal areas: location, location, location. Coastal Management, 44(5): 504-516.
Rumbach, A., 2017. At the roots of urban disasters: Planning and uneven geographies of risk in Kolkata, India. Journal of Urban Affairs, 39(6): 783-799.
Runhaar, H., Wilk, B., Persson, Å., Uittenbroek, C. and Wamsler, C., 2018. Mainstreaming climate adaptation: taking stock about “what works” from empirical research worldwide. Regional Environmental Change, 18(4): 1201-1210.
Rutherford, J. and Coutard, O., 2014. Urban energy transitions: places, processes and politics of socio-technical change. Urban Studies, 51(7): 1353-1377.
Rydin, Y., Turcu, C., Chmutina, K., Devine-Wright, P., Goodier, C., Guy, S., Hunt, L., Milne, S., Rynikiewicz, C. and Sherrif, G., 2012. Urban energy initiatives: the implications of new urban energy pathways for the UK. Network Industries Quarterly, 14(2 & 3): 20-23.
Rydin, Y., Turcu, C., Guy, S. and Austin, P., 2013. Mapping the coevolution of urban energy systems: pathways of change. Environment and Planning A, 45(3): 634-649.
Saboohi, R., Barani, H., Khodagholi, M., Sarvestani, A.A. and Tahmasebi, A., 2019. Nomads’ indigenous knowledge and their adaptation to climate changes in Semirom City in Central Iran. Theoretical and Applied Climatology, 137(1-2): 1377-1384.
Sabri, A.K. and Ahmed, K.G., 2019. Replacing Land-Use Planning with Localized Form-Based Codes in the United Arab Emirates: A Proposed Method. Land Use Policy, 8(3): 47.
Safarzyńska, K. and van den Bergh, J.C.J.M., 2017. Financial stability at risk due to investing rapidly in renewable energy. Energy Policy, 108: 12-20.
Sailor, D.J., 2011. A review of methods for estimating anthropogenic heat and moisture emissions in the urban environment. International journal of climatology, 31(2): 189-199.
Sakano, T., Kotabe, S., Komukai, T., Kumagai, T., Shimizu, Y., Takahara, A., Ngo, T., Fadlullah, Z.M., Nishiyama, H. and Kato, N., 2016. Bringing movable and deployable networks to disaster areas: development and field test of MDRU. IEEE Network, 30(1): 86-91.
Salim, W., Bettinger, K. and Fisher, M., 2019. Maladaptation on the Waterfront: Jakarta’s Growth Coalition and the Great Garuda. Environment and Urbanization ASIA, 10(1): 63-80.
Salmond, J., Sabel, E.C. and Vardoulakis, S., 2018. Towards the Integrated Study of Urban Climate, Air Pollution, and Public Health. Climate, 6(1).
Salmond, J.A., Tadaki, M., Vardoulakis, S., Arbuthnott, K., Coutts, A., Demuzere, M., Dirks, K.N., Heaviside, C., Lim, S. and Macintyre, H., 2016a. Health and climate related ecosystem services provided by street trees in the urban environment. Environmental Health, 15(1): S36.
Salmond, J.A., Tadaki, M., Vardoulakis, S., Arbuthnott, K., Coutts, A., Demuzere, M., Dirks, K.N., Heaviside, C., Lim, S., Macintyre, H., McInnes, R.N. and Wheeler, B.W., 2016b. Health and climate related ecosystem services provided by street trees in the urban environment. Environmental Health, 15(S1): S36-S36.
Salthammer, T., Schieweck, A., Gu, J., Ameri, S. and Uhde, E., 2018. Future trends in ambient air pollution and climate in Germany – Implications for the indoor environment. Building and Environment, 143: 661-670.
Salvadore, E., Bronders, J. and Batelaan, O., 2015. Hydrological modelling of urbanized catchments: A review and future directions. Journal of Hydrology, 529: 62-81.
Santamouris, M., 2014. Cooling the cities–a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. Solar energy, 103: 682-703.

Santamouris, M., Cartalis, C., Synnefa, A. and Kolokotsa, D., 2015. On the impact of urban heat island and global warming on the power demand and electricity consumption of buildings—A review. Energy and Buildings, 98: 119-124.
Santamouris, M., Ding, L., Fiorito, F., Oldfield, P., Osmond, P., Paolini, R., Prasad, D. and Synnefa, A., 2017. Passive and active cooling for the outdoor built environment – Analysis and assessment of the cooling potential of mitigation technologies using performance data from 220 large scale projects. Solar Energy, 154: 14-33.
Santamouris, M. and Kolokotsa, D., 2015. On the impact of urban overheating and extreme climatic conditions on housing, energy, comfort and environmental quality of vulnerable population in Europe. Energy and Buildings, 98: 125-133.
Sari, A.D. and Prayoga, N., 2018. Enhancing Citizen Engagement in the Face of Climate Change Risks: A Case Study of the Flood Early Warning System and Health Information System in Semarang City, Indonesia. . In: S. Hughes, E.K. Chu and S.G. Mason (Editors), Climate Change in Cities: Innovations in Multi-Level Governance. Springer, Cham, pp. 121-137.
Sarzynski, A., 2015. Public participation, civic capacity, and climate change adaptation in cities. Urban Climate, 14: 52-67.
Sassen, S., 2015. Bringing cities into the global climate framework. In: Johnson, C., T. N. and S. H. (Editors), The urban climate challenge. Routledge, New York, pp. 34-46.
Sathaye, J.A., Dale, L.L., Larsen, P.H., Fitts, G.A., Koy, K., Lewis, S.M. and de Lucena, A.F.P., 2013. Rising temps, tides, and wildfires: Assessing the risk to California's energy infrastructure from projected climate change. IEEE Power and Energy Magazine, 11(3): 32-45.
Satterthwaite, D., 2016. Background Paper: Small and intermediate urban centres in sub--Saharan Africa. Urban Africa Risk Knowledge (Urban ARK) Working Paper, 6.
Satterthwaite, D., Dodman , D., Archer, A. and Brown, D., 2018. A Look at How Six Global Agreements Support Sustainable Urban Development.
Satterthwaite, D., McGranahan, G. and Tacoli, C., 2010. Urbanization and its implications for food and farming. Philosophical transactions of the royal society B: biological sciences, 365(1554): 2809-2820.
Sayers, P.B., Horritt, M., Penning-Rowsell, E. and McKenzie, A., 2015. Climate Change Risk Assessment 2017: Projections of future flood risk in the UK, London.
Schaeffer, R., Szklo, A.S., de Lucena, A.F.P., Borba, B.S.M.C., Nogueira, L.P.P., Fleming, F.P., Troccoli, A., Harrison, M. and Boulahya, M.S., 2012. Energy sector vulnerability to climate change: a review. Energy, 38(1): 1-12.
Schaltegger, S., Hansen, E.G. and Lüdeke-Freund, F., 2016. Business models for sustainability: Origins, present research, and future avenues. SAGE Publications Sage CA: Los Angeles, CA.
Scheffran, J., Ide, T. and Schilling, J., 2014. Violent climate or climate of violence? Concepts and relations with focus on Kenya and Sudan. The International Journal of Human Rights, 18(3): 369-390.
Scheffran, J., Marmer, E. and Sow, P., 2012. Migration as a contribution to resilience and innovation in climate adaptation: Social networks and co-development in Northwest Africa. Applied Geography, 33: 119-127.
Schinasi, L.H., Benmarhnia, T. and De Roos, A.J., 2018. Modification of the association between high ambient temperature and health by urban microclimate indicators: A systematic review and meta-analysis. Environmental research, 161: 168-180.
Schmeltz, M.T., Petkova, E.P. and Gamble, J.L., 2016. Economic Burden of Hospitalizations for Heat-Related Illnesses in the United States, 2001-2010. International journal of environmental research and public health, 13(9): 894.
Schmidt, C.W., 2015. Delta subsidence: an imminent threat to coastal populations. NLM-Export.
Schwan, S. and Yu, X., 2018. Social protection as a strategy to address climate-induced migration. International Journal of Climate Change Strategies and Management, 10(1): 43-64.
Schweighofer, J., 2014. The impact of extreme weather and climate change on inland waterway transport. Natural hazards, 72(1): 23-40.
Schweikert, A., Chinowsky, P., Espinet, X. and Tarbert, M., 2014. Climate change and infrastructure impacts: comparing the impact on roads in ten countries through 2100. Procedia Engineering, 78: 306-316.
Scoppetta, C., 2016. " Natural" disasters as (neo-liberal) opportunity? Discussing post-hurricane Katrina urban regeneration in New Orleans. TeMA Journal of Land Use, Mobility and Environment, 9(1): 25-41.
Scott, A.A., Misiani, H., Okoth, J., Jordan, A., Gohlke, J., Ouma, G., Arrighi, J., Zaitchik, B.F., Jjemba, E. and Verjee, S., 2017. Temperature and heat in informal settlements in Nairobi. PloS one, 12(11): e0187300.
Scott, A.A., Waugh, D.W. and Zaitchik, B.F., 2018. Reduced Urban Heat Island intensity under warmer conditions. Environmental Research Letters, 13(6): 064003.
Scovronick, N., Lloyd, S.J. and Kovats, R.S., 2015. Climate and health in informal urban settlements. Environment and urbanization, 27(2): 657-678.
Sedlbauer, K., 2002. Prediction of Mould Growth by Hygrothermal Calculation. Journal of Building Physics, 25(4): 321-336.
Sedlbauer, K., Hofbauer, W., Krueger, N., Mayer, F. and Breuer, K., 2011. Material Specific Isopleth-systems as Valuable Tools for the Assessment of the Durability of Building Materials Against Mould Infestation – The “Isopleth-traffic Light”, XII DBMC, International Conference on Durability of Building Materials and Components, Porto, Portugal.

Semarang City Government, 2016. Resilient Semarang: Moving Together towards a Resilient Semarang Semarang City Government, Semarang.
Seo, M., Jaber, F. and Srinivasan, R., 2017. Evaluating various low-impact development scenarios for optimal design criteria development. Water, 9(4): 270.
Serrao-Neumann, S., Renouf, M., Kenway, S.J. and Low Choy, D., 2017. Connecting land-use and water planning: Prospects for an urban water metabolism approach. Cities, 60(Part A): 13-27.
Sesana, E., Bertolin, C., Gagnon, A.S. and Hughes, J.J., 2019. Mitigating Climate Change in the Cultural Built Heritage Sector. Climate, 7(7): 90-113.
Sesana, E., Gagnon, A.S., Bertolin, C. and Hughes, J.J., 2018. Adapting cultural heritage to climate change risks: perspectives of cultural heritage experts in Europe. Geosciences, 8(8): 305-328.
Seto, K.C., Reenberg, A., Boone, C.G., Fragkias, M., Haase, D., Langanke, T., Marcotullio, P., Munroe, D.K., Olah, B. and Simon, D., 2012. Urban land teleconnections and sustainability. Proceedings of the National Academy of Sciences, 109(20): 7687-7692.
Sharifi, A., 2019. Resilient urban forms: A macro-scale analysis. Cities, 85: 1-14.
Sharifi, A. and Yamagata, Y., 2016. Principles and criteria for assessing urban energy resilience: A literature review. Renewable and Sustainable Energy Reviews, 60: 1654-1677.
Shaw, K., 2015. Planetary urbanisation: what does it matter for politics or practice? Planning Theory & Practice, 16(4): 588-593.
Sheffield, P.E., Herrera, M.T., Kinnee, E.J. and Clougherty, J.E., 2018. Not so little differences: variation in hot weather risk to young children in New York City. Public Health, 161: 119-126.
Sheller, M. and Urry, J., 2016. Mobilizing the new mobilities paradigm. Applied Mobilities, 1(1): 10-25.
Shi, L., 2019. Promise and paradox of metropolitan regional climate adaptation. Environmental Science & Policy, 92: 262-274.
Shi, L., Chu, E., Anguelovski, I., Aylett, A., Debats, J., Goh, K., Schenk, T., Seto, K.C., Dodman, D., Roberts, D., Roberts, J.T. and VanDeveer, S.D., 2016. Roadmap towards justice in urban climate adaptation research. Nature Climate Change, 6: 131.
Shi, L., Chu, E. and Debats, J., 2015. Explaining Progress in Climate Adaptation Planning Across 156 U.S. Municipalities. Journal of the American Planning Association, 81(3): 191-202.
Shi, Z., Watanabe, S., Ogawa, K. and Kubo, H., 2018. Structural Resilience in Sewer Reconstruction: From Theory to Practice. Elsevier, Kidlington.
Shiklomanov, N.I., Streletskiy, D.A., Swales, T.B. and Kokorev, V.A., 2017. Climate change and stability of urban infrastructure in Russian permafrost regions: prognostic assessment based on GCM climate projections. Geographical review, 107(1): 125-142.
Shooshtarian, S., Rajagopalan, P. and Sagoo, A., 2018. A comprehensive review of thermal adaptive strategies in outdoor spaces. Sustainable Cities and Society, 41(Complete): 647-665.
Shrestha, A., 2019. Which community, whose resilience? Critical reflections on community resilience in peri-urban Kathmandu Valley. Critical Asian Studies: 1-22.
Shrestha, A., Roth, D. and Joshi, D., 2018. Flows of change: dynamic water rights and water access in peri-urban Kathmandu. Ecology and Society, 23(2): art42-art42.
Shughrue, C. and Seto, K.C., 2018. Systemic vulnerabilities of the global urban-industrial network to hazards. Climatic Change, 151(2): 173-187.
Shuster, W.D., Bonta, J., Thurston, H., Warnemuende, E. and Smith, D.R., 2005. Impacts of impervious surface on watershed hydrology: A review. Urban Water Journal, 2(4): 263-275.
Sicotte, D., 2014. Diversity and Intersectionality among Environmentally Burdened Communities in the Philadelphia Metropolitan Area, USA. Urban Studies, 51(9): 1850-1870.
Sieber, J., 2013. Impacts of, and adaptation options to, extreme weather events and climate change concerning thermal power plants. Climatic change, 121(1): 55-66.
Silva, R., Martínez, M.L., Odériz, I., Mendoza, E. and Feagin, R.A., 2016. Response of vegetated dune–beach systems to storm conditions. Coastal Engineering, 109: 53-62.
Silver, J., 2015. Disrupted infrastructures: An urban political ecology of interrupted electricity in Accra. International Journal of Urban and Regional Research, 39(5): 984-1003.
Silver, J., 2017. The climate crisis, carbon capital and urbanisation: An urban political ecology of low-carbon restructuring in Mbale. Environment and Planning A, 49(7): 1477-1499.
Simatele, D. and Simatele, M., 2015. Climate variability and urban food security in sub-Saharan Africa: lessons from Zambia using an asset-based adaptation framework. South African Geographical Journal, 97(3): 243-263.
Simon, D., 2016. Rethinking sustainable cities: Accessible, green and fair. Policy Press.
Simon, D., Arfvidsson, H., Anand, G., Bazaz, A., Fenna, G., Foster, K., Jain, G., Hansson, S., Evans, L.M. and Moodley, N., 2016. Developing and testing the Urban Sustainable Development Goal's targets and indicators–a five-city study. Environment and Urbanization, 28(1): 49-63.
Simon, D. and Leck, H., 2015. Understanding climate adaptation and transformation challenges in African cities. Current Opinion in Environmental Sustainability, 13: 109-116.
Simon-Rojo, M., 2019. Agroecology to fight food poverty in Madrid's deprived neighbourhoods. URBAN DESIGN International, 24(2): 94-107.

Simpson, N.P., 2019. Accommodating landscape-scale shocks: Lessons on transition from Cape Town and Puerto Rico. Geoforum, 102: 226-229.
Simpson, N.P., Simpson, K.J., Shearing, C.D. and Cirolia, L.R., 2019a. Municipal finance and resilience lessons for urban infrastructure management: a case study from the Cape Town drought. International Journal of Urban Sustainable Development: 1-20.
Simpson, S.-A., Napawan, N.C. and Snyder, B., 2019b. # OurChangingClimate: Building Networks of Community Resilience Through Social Media and Design. GeoHumanities: 1-17.
Singh, C., Daron, J., Bazaz, A., Ziervogel, G., Spear, D., Krishnaswamy, J., Zaroug, M. and Kituyi, E., 2018. The utility of weather and climate information for adaptation decision-making: current uses and future prospects in Africa and India. Climate and Development, 10(5): 389-405.
Singh, S., Tanvir Hassan, S.M., Hassan, M. and Bharti, N., 2019. Urbanisation and water insecurity in the Hindu Kush Himalaya: insights from Bangladesh, India, Nepal and Pakistan. Water Policy.
Singh, S.J., Haberl, H., Chertow, M., Mirtl, M. and Schmid, M., 2012. Long term socio-ecological research: studies in society-nature interactions across spatial and temporal scales, 2. Springer Science & Business Media.
Skelhorn, C., Lindley, S. and Levermore, G., 2014. The impact of vegetation types on air and surface temperatures in a temperate city: A fine scale assessment in Manchester, UK. Landscape and Urban Planning, 121: 129-140.
Skougaard Kaspersen, P., Høegh Ravn, N., Arnbjerg-Nielsen, K., Madsen, H. and Drews, M., 2017. Comparison of the impacts of urban development and climate change on exposing European cities to pluvial flooding. Hydrol. Earth Syst. Sci., 21(8): 4131-4147.
Smith, B.J. and McAlister, J.J., 1986. Observations on the occurrence and origins of salt weathering phenomena near lake Magadi, Southern Kenya. Geomorphology, 30(4): 445-460.
Smith, B.J., Srinivasan, S., Gomez-Heras, M., Basheer, M.P.A. and Viles, H.A., 2008. Experimental studies of near-surface temperature cycling and surface wetting of stone and its implications for salt weathering, SWBSS, Copenhagen.
Smith, C.J., 2019. Pediatric Thermoregulation: Considerations in the Face of Global Climate Change. Nutrients, 11(9): 2010.
Smith, J. and Patterson, J., 2018. Global Climate Justice Activism: "The New Protagonists" and Their Projects for a Just Transition. In: S.R. Frey, P.K. Gellert and H.F. Dahms (Editors), Ecologically Unequal Exchange: Environmental Injustice in Comparative and Historical Perspective. Palgrave Macmillan, New York.
Smith, J. and Patterson, J., 2019. Global climate justice activism:"the new protagonists" and their projects for a just transition. In: F. R., G. P. and D. H. (Editors), Ecologically Unequal Exchange. Palgrave McMillan, Cham, pp. 245-272.
Smith, K.R., Woodward, A., Lemke, B., Otto, M., Chang, C.J., Mance, A.A., Balmes, J. and Kjellstrom, T., 2016. The last Summer Olympics? Climate change, health, and work outdoors. The Lancet, 388(10045): 642-644.
Smith, M.T., Reid, M., Kovalchik, S., Woods, T.O. and Duffield, R., 2018. Heat stress incident prevalence and tennis matchplay performance at the Australian Open. Journal of Science and Medicine in Sport, 21(5): 467-472.
Smolka, M., 2013. Implementing Value Capture in Latin America: Policies and Tools for Urban Development. The Lincoln Institute of Land Policy. Policy Focus Report, Cambridge, Massechuesetts.
Soares, M.B. and Dessai, S., 2016. Barriers and enablers to the use of seasonal climate forecasts amongst organisations in Europe. Climatic Change, 137(1-2): 89-103.
Soebarto, V. and Bennetts, H., 2014. Thermal comfort and occupant responses during summer in a low to middle income housing development in South Australia. Building and Environment, 75: 19-29.
Soga, M. and Gaston, K.J., 2018. Shifting baseline syndrome: causes, consequences, and implications. Frontiers in Ecology and the Environment, 16(4): 222-230.
Soga, M., Gaston, K.J. and Yamaura, Y., 2017. Gardening is beneficial for health: A meta-analysis. Preventive Medicine Reports, 5: 92-99.
Sohn, W., Kim, J.-H., Li, M.-H. and Brown, R., 2019. The influence of climate on the effectiveness of low impact development: A systematic review. Journal of Environmental Management, 236(Complete): 365-379.
Solecki, W., Rosenzweig, C., Dhakal, S., Roberts, D., Barau, A.S., Schultz, S. and Ürge-Vorsatz, D., 2018. City transformations in a 1.5° C warmer world. Nature Climate Change, 8(3): 177.
Solomon, D., Lehmann, J., Fraser, J.A., Leach, M., Amanor, K., Frausin, V., Kristiansen, S.M., Millimouno, D. and Fairhead, J., 2016. Indigenous African soil enrichment as a climate-smart sustainable agriculture alternative. Frontiers in Ecology and the Environment, 14(2): 71-76.
Soltesova, K., Brown, A., Dayal, A., Dodman and D., 2014. Community participation in urban adaptation to climate change. In: E.L.F. Schipper, J. Ayers, H. Reid, R. Huq and A. Rahman (Editors), Community-Based Adaptation to Climate Change. Earthscan Routledge, pp. 214-225.
Sou, G., 2018. Mainstreaming risk reduction into self-build housing: the negligible role of perceptions. Climate and Development, 10(6): 526-537.
Sovacool, B.K., Tan-Mullins, M. and Abrahamse, W., 2018. Bloated bodies and broken bricks: Power, ecology, and inequality in the political economy of natural disaster recovery. World Development, 110: 243-255.
Spaans, M. and Waterhout, B., 2017. Building up resilience in cities worldwide – Rotterdam as participant in the 100 Resilient Cities Programme. Cities, 61: 109-116.

Speckhard, D., 2016. World Humanitarian Summit: Laudable, but short on hard political commitments, Future Development. Brookings Institute, Washington DC.
Spencer, B., Lawler, J., Lowe, C., Thompson, L., Hinckley, T., Kim, S.-H., Bolton, S., Meschke, S., Olden, J.D. and Voss, J., 2017. Case studies in co-benefits approaches to climate change mitigation and adaptation. Journal of environmental planning and management, 60(4): 647-667.
Sperling, D., Pike, S. and Chase, R., 2018. Will the transportation revolutions improve our lives – or make them worse? In: D. Sperling (Editor), *Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future*. Island Press, Washington D.C., pp. 1-20.
Springmann, M., Mason-D'Croz, D., Robinson, S., Garnett, T., Godfray, H.C.J., Gollin, D., Rayner, M., Ballon, P. and Scarborough, P., 2016. Global and regional health effects of future food production under climate change: a modelling study. The Lancet, 387(10031): 1937-1946.
Srinivasan, S., Kholod, N., Chaturvedi, V., Ghosh, P.P., Mathur, R., Clarke, L., Evans, M., Hejazi, M., Kanudia, A., Koti, P.N., Liu, B., Parikh, K.S., Ali, M.S. and Sharma, K., 2018. Water for electricity in India: A multi-model study of future challenges and linkages to climate change mitigation. Applied Energy, 210: 673-684.
Srinivasan, V., Lambin, E.F., Gorelick, S.M., Thompson, B.H. and Rozelle, S., 2012. The nature and causes of the global water crisis: Syndromes from a meta-analysis of coupled human-water studies. Water Resources Research, 48(10).
Statistics Canada, 2016. Aboriginal peoples in Canada: Key insights from the 2016 Census. Statistics Canada.
Steele, W., Mata, L. and Fünfgeld, H., 2015. Urban climate justice: creating sustainable pathways for humans and other species. Current Opinion in Environmental Sustainability, 14: 121-126.
Stevens, A., 2017. *Temperature, wages, and agricultural labor productivity*. Berkeley.
Stevens, M.R. and Senbel, M., 2017. Are municipal land use plans keeping pace with global climate change? Land Use Policy, 68(Complete): 1-14.
Stewart, I.D. and Oke, T.R., 2012. Local Climate Zones for Urban Temperature Studies. Bulletin of the American Meteorological Society, 93(12): 1879-1900.
Stewart, M.G. and Deng, X., 2014. Climate impact risks and climate adaptation engineering for built infrastructure. ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering, 1(1): 04014001.
Stojanovski, T., 2018. How density, diversity, land use and neighborhood type influences bus mobility in the Swedish city of Karlstad: Mixing spatial analytic and typo-morphological approaches to assess the indirect effect of urban form on travel. Journal of transport and land use, 11(1): 769–789.
Storbjörk, S. and Uggla, Y., 2015. The practice of settling and enacting strategic guidelines for climate adaptation in spatial planning: lessons from ten Swedish municipalities. Regional environmental change, 15(6): 1133-1143.
Straka, M. and Sodoudi, S., 2019. Evaluating climate change adaptation strategies and scenarios of enhanced vertical and horizontal compactness at urban scale (a case study for Berlin). Landscape and Urban Planning, 183(Complete): 68-78.
Stringer, L.C., Dougill, A.J., Dyer, J.C., Vincent, K., Fritzsche, F., Leventon, J., Falcao, M.P., Manyakaidze, P., Syampungani, S. and Powell, P., 2014. Advancing climate compatible development: lessons from southern Africa. Regional Environmental Change, 14(2): 713-725.
Stuart, E. and Woodroffe, J., 2016. Leaving no-one behind: can the Sustainable Development Goals succeed where the Millennium Development Goals lacked? Gender & Development, 24(1): 69-81.
Suatmadi, A.Y., Creutzig, F. and Otto, I.M., 2019. On-demand motorcycle taxis improve mobility, not sustainability. Case Studies on Transport Policy, 7(2): 218-229.
Suckall, N., Stringer, L.C. and Tompkins, E.L., 2015. Presenting triple-wins? assessing projects that deliver adaptation, mitigation and development co-benefits in rural Sub-Saharan Africa. Ambio, 44(1): 34-41.
Suhelmi, I.R. and Triwibowo, H., 2018. Coastal Inundation Adaptive Strategy in Semarang Coastal Area. Forum Geografi, 32(2).
Sun, Q., Miao, C., AghaKouchak, A. and Duan, Q., 2017. Unraveling anthropogenic influence on the changing risk of heat waves in China. Geophysical Research Letters, 44(10): 5078-5085.
Surminski, S., 2013. Private-sector adaptation to climate risk. Nature Climate Change, 3(11): 943.
Surminski, S., Bouwer, L.M. and Linnerooth-Bayer, J., 2016. How insurance can support climate resilience. Nature Climate Change, 6(4): 333-334.
Surminski, S. and Thieken, A.H., 2017. Promoting flood risk reduction: The role of insurance in Germany and England. Earth's Future, 5(10): 979-1001.
Sword-Daniels, V., Eriksen, C., Hudson-Doyle, E.E., Alaniz, R., Adler, C., Schenk, T. and Vallance, S., 2018. Embodied uncertainty: living with complexity and natural hazards. Journal of Risk Research, 21(3): 290-307.
Szibbo, N., 2016. Lessons for LEED® for Neighborhood Development, Social Equity, and Affordable Housing. Journal of the American Planning Association, 82(1): 37-49.
Tai, A.P.K., Martin, M.V. and Heald, C.L., 2014. Threat to future global food security from climate change and ozone air pollution. Nature Climate Change, 4(9): 817.
Tait, L. and Euston-Brown, M., 2017. What role can African cities play in low-carbon development? A multilevel governance perspective of Ghana, Uganda and South Africa. Journal of Energy in Southern Africa, 28(3): 43-53.

Taleghani, M., 2018a. Outdoor thermal comfort by different heat mitigation strategies- A review. Renewable and Sustainable Energy Reviews, 81: 2011-2018.
Taleghani, M., 2018b. The impact of increasing urban surface albedo on outdoor summer thermal comfort within a university campus. Urban Climate, 24: 175-184.
Taleghani, M., Marshall, A., Fitton, R. and Swan, W., 2019. Renaturing a microclimate: The impact of greening a neighbourhood on indoor thermal comfort during a heatwave in Manchester, UK. Solar Energy, 182: 245-255.
Tang, A.M., Hughes, P.N., Dijkstra, T.A., Askarinejad, A., Brenčič, M., Cui, Y.J., Diez, J.J., Firgi, T., Gajewska, B. and Gentile, F., 2018. Atmosphere–vegetation–soil interactions in a climate change context; impact of changing conditions on engineered transport infrastructure slopes in Europe. Quarterly Journal of Engineering Geology and Hydrogeology, 51(2): 156-168.
Taylor, J., Davies, M., Mavrogianni, A., Shrubsole, C., Hamilton, I., Das, P., Jones, B., Oikonomou, E. and Biddulph, P., 2016. Mapping indoor overheating and air pollution risk modification across Great Britain: A modelling study. Building and Environment, 99: 1-12.
Taylor, J. and Lassa, J., 2015. *How Can Climate Change Vulnerability Assessments Best Impact Policy and Planning?: Lessons from Indonesia*, International Institute for Environment and Development (IIED), London.
Taylor, J., Wilkinson, P., Picetti, R., Symonds, P., Heaviside, C., Macintyre, H.L., Davies, M., Mavrogianni, A. and Hutchinson, E., 2018. Comparison of built environment adaptations to heat exposure and mortality during hot weather, West Midlands region, UK. Environmental International, 111: 287-294.
Teixeira, E.I., Fischer, G., Van Velthuizen, H., Walter, C. and Ewert, F., 2013. Global hot-spots of heat stress on agricultural crops due to climate change. Agricultural and Forest Meteorology, 170: 206-215.
Tengö, M., Brondizio, E.S., Elmqvist, T., Malmer, P. and Spierenburg, M., 2014. Connecting diverse knowledge systems for enhanced ecosystem governance: the multiple evidence base approach. Ambio, 43(5): 579-591.
Tessler, Z.D., Vorosmarty, C.J., Grossberg, M., Gladkova, I., Aizenman, H., Syvitski, J.P.M. and Foufoula-Georgiou, E., 2015. Profiling risk and sustainability in coastal deltas of the world. Science, 349(6248): 638-643.
Thacker, S., Barr, S., Pant, R., Hall, J.W. and Alderson, D., 2017. Geographic hotspots of critical national infrastructure. Risk Analysis, 37(12): 2490-2505.
Thara, K., 2016. Protecting caste livelihoods on the western coast of India: an intersectional analysis of Udupi's fisherwomen. Environment and Urbanization, 28(2): 423-436.
The Global Commission on the Economy and Climate, 2016. THE SUSTAINABLE INFRASTRUCTURE IMPERATIVE - Financing for Better Growth and Development. The Global Commission on the Economy and Climate.
The World Bank, 2015. Indigenous Latin America in the Twenty First Century. The next decade. The World Bank, Washintgon DC.
Theisen, O.M., Gleditsch, N.P. and Buhaug, H., 2013. Is climate change a driver of armed conflict? Climatic Change, 117(3): 613-625.
Thomas, A. and Benjamin, L., 2018. Management of loss and damage in small island developing states: implications for a 1.5 C or warmer world. Regional environmental change, 18(8): 2369-2378.
Thomas, K., Hardy, R.D., Lazrus, H., Mendez, M., Orlove, B., Rivera-Collazo, I., Roberts, J.T., Rockman, M., Warner, B.P. and Winthrop, R., 2019. Explaining differential vulnerability to climate change: A social science review. Wiley Interdisciplinary Reviews: Climate Change, 10(2): e565.
Thomas, K., Hardy, R.D., Lazrus, H., Mendez, M., Orlove, B., Rivera-Collazo, I., Roberts, J.T., Rockman, M., Warner, B.P. and Winthrop, R., 2018. Explaining differential vulnerability to climate change: A social science review. Wiley Interdisciplinary Reviews: Climate Change: e565-e565.
Thorn, J., Thornton, T.F. and Helfgott, A., 2015. Autonomous adaptation to global environmental change in peri-urban settlements: Evidence of a growing culture of innovation and revitalisation in Mathare Valley Slums, Nairobi. Global Environmental Change, 31: 121-131.
Thorne, C.R., Lawson, E.C., Ozawa, C., Hamlin, S.L. and Smith, L.A., 2018. Overcoming uncertainty and barriers to adoption of Blue-Green Infrastructure for urban flood risk management. Journal of Flood Risk Management, 11(S2): S960-S972.
Thornton, P.K., Ericksen, P.J., Herrero, M. and Challinor, A.J., 2014. Climate variability and vulnerability to climate change: a review. Global Change Biology, 20(11): 3313-3328.
Thorsson, S., Rocklöv, J., Konarska, J., Lindberg, F., Holmer, B., Dousset, B. and Rayner, D., 2014. Mean radiant temperature–A predictor of heat related mortality. Urban Climate, 10: 332-345.
Tiwary, A., Reff, A. and Colls, J.J., 2008. Collection of ambient particulate matter by porous vegetation barriers: Sampling and characterization methods. Journal of Aerosol Science, 39(1): 40-47.
Tobón, A.S. and Barton, J.R., 2019. Assessing Climate Risk in Small and Intermediate Towns and Cities: A Preliminary Rapid Appraisal Tool and Its Application in Florencia, Colombia, Urban Climates in Latin America. Springer, pp. 379-406.
Tominaga, Y., Sato, Y. and Sadohara, S., 2015. CFD simulations of the effect of evaporative cooling from water bodies in a micro-scale urban environment: Validation and application studies. Sustainable Cities and Society, 19: 259-270.

Tomlinson, C.J., Chapman, L., Thornes, J.E. and Baker, C.J., 2011. Including the urban heat island in spatial heat health risk assessment strategies: a case study for Birmingham, UK. International Journal of Health Geographics, 10(1): 42.
Tompkins, E.L., Mensah, A., King, L., Long, K., Lawson, E.T., Hutton, C., Anh, V., Gordon, C., Fish, M., Dyer, J. and Bood, N., 2013. An investigation of the evidence of benefits from climate compatible development. Centre for Climate Change Economics and Policy(124): 1-31.
Toparlar, Y., Blocken, B., Maiheu, B. and Van Heijst, G.J.F., 2018. The effect of an urban park on the microclimate in its vicinity: a case study for Antwerp, Belgium. International Journal of Climatology, 38: e303-e322.
Torabi, E., Dedekorkut-Howes, A. and Howes, M., 2018. Adapting or maladapting: building resilience to climate-related disasters in coastal cities. Cities, 72: 295-309.
Torres Gotay, B., 2017. Irretrivable losses: María leaves thousands homeless and there are few options for those affected, El Nuevo Dia.
Tortajada, C. and Joshi, Y.K., 2013. Water Demand Management in Singapore: Involving the Public. Water Resources Management, 27(8): 2729-2746.
Tosun, J. and Schoenefeld, J.J., 2017. Collective climate action and networked climate governance. Wiley Interdisciplinary Reviews: Climate Change, 8(1): e440.
Toya, H. and Skidmore, M., 2015. Information/communication technology and natural disaster vulnerability. Economics Letters, 137: 143-145.
Triana, M.A., Lamberts, R. and Sassi, P., 2018. Should we consider climate change for Brazilian social housing? Assessment of energy efficiency adaptation measures. Energy and Buildings, 158: 1379-1392.
Turkelboom, F., Leone, M., Jacobs, S., Kelemen, E., García-Llorente, M., Baró, F., Termansen, M., Barton, D.N., Berry, P., Stange, E., Thoonen, M., Kalóczkai, Á., Vadineanu, A., Castro, A.J., Czúcz, B., Röckmann, C., Wurbs, D., Odee, D., Preda, E., Gómez-Baggethun, E., Rusch, G.M., Pastur, G.M., Palomo, I., Dick, J., Casaer, J., van Dijk, J., Priess, J.A., Langemeyer, J., Mustajoki, J., Kopperoinen, L., Baptist, M.J., Peri, P.L., Mukhopadhyay, R., Aszalós, R., Roy, S.B., Luque, S. and Rusch, V., 2018. When we cannot have it all: Ecosystem services trade-offs in the context of spatial planning. Ecosystem Services, 29: 566-578.
Turnheim, B., Berkhout, F., Geels, F., Hof, A., McMeekin, A., Nykvist, B. and van Vuuren, D., 2015. Evaluating sustainability transitions pathways: Bridging analytical approaches to address governance challenges. Global Environmental Change, 35: 239-253.
Twerefou, K.D., Chinowsky, P., Adjei-Mantey, K. and Strzepek, L.N., 2015. The Economic Impact of Climate Change on Road Infrastructure in Ghana. Sustainability, 7(9).
Tyusov, G.A., Akentyeva, E.M., Pavlova, T.V. and Shkolnik, I.M., 2017. Projected climate change impacts on the operation of power engineering facilities in Russia. Russian Meteorology and Hydrology, 42(12): 775-782.
UCLG, 2016. UCLG Inputs to Habitat III on the Discussion on Local Finance. Committee on Local Finance for Development. .
UCLG, 2017. Gold IV Report, UCLG.
Uittenbroek, C.J., 2016. From policy document to implementation: organizational routines as possible barriers to mainstreaming climate adaptation. Journal of Environmental Policy & Planning, 18(2): 161-176.
Uittenbroek, C.J., Janssen-Jansen, L.B., Spit, T.J.M., Salet, W.G.M. and Runhaar, H.A.C., 2014. Political commitment in organising municipal responses to climate adaptation: the dedicated approach versus the mainstreaming approach. Environmental Politics, 23(6): 1043-1063.
Ulpiani, G., Di Giuseppe, E., Di Perna, C., D'Orazio, M. and Zinzi, M., 2019a. Thermal comfort improvement in urban spaces with water spray systems: Field measurements and survey. Building and Environment, 156: 46-61.
Ulpiani, G., Di Perna, C. and Zinzi, M., 2019b. Water nebulization to counteract urban overheating: Development and experimental test of a smart logic to maximize energy efficiency and outdoor environmental quality. Applied Energy, 239: 1091-1113.
Ulriksen, M.S. and Plagerson, S., 2014. Social protection: Rethinking rights and duties. World Development, 64: 755-765.
UN Water, 2018. Sustainable Development Goal 6 Synthesis Report on Water and Sanitation, UN Water.
UN-Habitat, 2015. Slum almanac 2015–2016: Tracking improvement in the lives of slum dwellers. United Nations Human Settlements Programme (UN-Habitat) Nairobi, Kenya.
UN-Habitat, 2016. World Cities Report, UN-Habitat, Nairobi.
UN-Habitat, 2017. *Sustainable Urbanization in the Paris Agreement* UNHABITAT, Nairobi.
UN-Habitat, 2019. Urban-LEDS II Capacity Building training Workshop on Climate Change for Laos Cities. In: U. LEDS (Editor). UN-Habitat, Nairobi.
UNCTAD, 2019. World Investment Report 2019, UNCTAD.
UNDESA, 2014. World's Population Increasingly Urban with More Than Half Living in Urban Areas., United Nations Department of Economic and Social Affairs. .
UNDESA, 2018a. Revision of World Urbanization Prospects produced by the Population Division of the UN Department of Economic and Social Affairs.
UNDESA, 2018b. World Urbanization Prospects- the 2018 Revision, The Population Division of the Department of Economic and Social Affairs of the United Nations, NY.
UNEP, 2015. The Financial System We Need. Aligning the financial system with sustainable development, UNEP.

UNISDR, 2015. Sendai Framework for Disaster Risk Reduction 2015-2030.
UNISDR, 2017. Disaster Resilience Scorecard for Cities, UN Office for Disaster Risk Reduction, Developed with the support of USAID, European Commission, IBM and AECOM, Geneva.
United Nations, 2015a. Addis Ababa Action Agenda of the Third International Conference on Financing for Development, United Nations, Addis Ababa.
United Nations, 2015b. The Paris Agreement: Agreement of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015, United Nations, Paris.
United Nations, 2015c. Transforming our World: the 2030 Agenda for Sustainable Development. United Nations, New York.
United Nations, 2016. New Urban Agenda : Quito Declaration on Sustainable Cities and Human Settlements for All (Habitat III) Quito.
Unnikrishnan, H., 2018. Thinking beyond fairy lights and fountains: lessons from the waterscape of Bengaluru. Ecology, Economy and Society—The INSEE Journal, 1(2): 95-99.
Unnikrishnan, H. and Nagendra, H., 2015. Privatizing the commons: impact on ecosystem services in Bangalore’s lakes. Urban Ecosystems, 18(2): 613-632.
Unterberger, C., Hudson, P., Botzen, W.J.W., Schroeer, K. and Steininger, K.W., 2019. Future Public Sector Flood Risk and Risk Sharing Arrangements: An Assessment for Austria. Ecological Economics, 156: 153-163.
Valencia, S.C., Simon, D., Croese, S., Nordqvist, J., Oloko, M., Sharma, T., Taylor Buck, N. and Versace, I., 2019. Adapting the Sustainable Development Goals and the New Urban Agenda to the city level: Initial reflections from a comparative research project. International Journal of Urban Sustainable Development, 11(1): 4-23.
Van Aelst, K. and Holvoet, N., 2016. Intersections of Gender and Marital Status in Accessing Climate Change Adaptation: Evidence from Rural Tanzania. World Development, 79: 40-50.
van den Hurk, B., van Meijgaard, E., de Valk, P., van Heeringen, K.-J. and Gooijer, J., 2015. Analysis of a compounding surge and precipitation event in the Netherlands. Environmental Research Letters, 10(3): 035001.
van der Heijden, J., Patterson, J., Juhola, S. and Wolfram, M., 2018. Special section: advancing the role of cities in climate governance – promise, limits, politics. Journal of Environmental Planning and Management: 1-9.
van Hooff, T., Blocken, B., Hensen, J.L.M. and Timmermans, H.J.P., 2014. On the predicted effectiveness of climate adaptation measures for residential buildings. Building and Environment, 82: 300-316.
Van Leeuwen, C.J., Koop, S.H.A. and Sjerps, R.M.A., 2016. City Blueprints: baseline assessments of water management and climate change in 45 cities. Environment, Development and Sustainability, 18(4): 1113-1128.
van Slobbe, E., Werners, S.E., Riquelme-Solar, M., Bölscher, T. and van Vliet, M.T.H., 2016. The future of the Rhine: stranded ships and no more salmon? Regional Environmental Change, 16(1): 31-41.
Van Vliet, M.T.H., Wiberg, D., Leduc, S. and Riahi, K., 2016. Power-generation system vulnerability and adaptation to changes in climate and water resources. Nature Climate Change, 6(4): 375.
Vandepitte, E., Vandermoere, F. and Hustinx, L., 2019. Civil Anarchizing for the Common Good: Culturally Patterned Politics of Legitimacy in the Climate Justice Movement. VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations, 30(2): 327-341.
Vanderschuren, M. and Baufeldt, J., 2018. Ride-sharing: A potential means to increase the quality and availability of motorised trips while discouraging private motor ownership in developing cities? Research in Transportation Economics, 69: 607-614.
Vanos, J.K., 2015. Children's health and vulnerability in outdoor microclimates: A comprehensive review. Environment International, 76: 1-15.
Vanos, J.K., Kosaka, E., Iida, A., Yokohari, M., Middel, A., Scott-Fleming, I. and Brown, R.D., 2019. Planning for spectator thermal comfort and health in the face of extreme heat: The Tokyo 2020 Olympic marathons. Science of The Total Environment, 657: 904-917.
Vardoulakis, S., Dimitroulopoulou, C., Thornes, J., Lai, K.-M., Taylor, J., Myers, I., Heaviside, C., Mavrogianni, A., Shrubsole, C., Chalabi, Z., Davies, M. and Wilkinson, P., 2015. Impact of climate change on the domestic indoor environment and associated health risks in the UK. Environmental International, 85: 299-313.
Vasconcelos, V.V., Santos, F.C. and Pacheco, J.M., 2013. A bottom-up institutional approach to cooperative governance of risky commons. Nature Climate Change, 3(9): 797.
Vasenev, A., Montoya, L. and Ceccarelli, A., 2016. A Hazus-based method for assessing robustness of electricity supply to critical smart grid consumers during flood events, *11th International Conference on Availability, Reliability and Security (ARES)*. IEEE, pp. 223-228.
Vedeld, T., Coly, A., Ndour, N.M. and Hellevik, S., 2016. Climate adaptation at what scale? Multi-level governance, resilience, and coproduction in Saint Louis, Senegal. Natural Hazards, 82(2): 173-199.
Vegt, A.K.V.d., 2006. From polymers to plastics. Delft University Press.
Vermeiren, K., Adiyia, B., Loopmans, M., Tumwine, F.R. and Van Rompaey, A., 2013. Will urban farming survive the growth of African cities: A case-study in Kampala (Uganda)? Land Use Policy, 35: 40-49.
Verner, G., Schütte, S., Knop, J., Sankoh, O. and Sauerborn, R., 2016. Health in climate change research from 1990 to 2014: positive trend, but still underperforming. Global Health Action, 9(1): 30723.
Victor, D., 2015. Climate change: Embed the social sciences in climate policy. Nature News, 520(7545): 27.
Vij, S., Narain, V., Karpouzoglou, T. and Mishra, P., 2018. From the core to the periphery: Conflicts and cooperation over land and water in peri-urban Gurgaon, India. Land Use Policy, 76: 382-390.

Visseren-Hamakers, I.J., 2015. Integrative environmental governance: enhancing governance in the era of synergies. Current Opinion in Environmental Sustainability, 14: 136-143.
Vitousek, S., Barnard, P.L., Fletcher, C.H., Frazer, N., Erikson, L. and Storlazzi, C.D., 2017. Doubling of coastal flooding frequency within decades due to sea-level rise. Scientific reports, 7(1): 1399.
Vodafone, 2019. *Annual mobile data usage worldwide from 2015 to 2021 (in thousand petabytes)*. In: Statista (Editor).
Voelkel, J., Hellman, D., Sakuma, R. and Shandas, V., 2018. Assessing Vulnerability to Urban Heat: A Study of Disproportionate Heat Exposure and Access to Refuge by Socio-Demographic Status in Portland, Oregon. International journal of environmental research and public health, 15(4): 640.
Vogt, N., Pinedo-Vasquez, M., Brondízio, E.S., Rabelo, F.G., Fernandes, K., Almeida, O., Riveiro, S., Deadman, P.J. and Dou, Y., 2016. Local ecological knowledge and incremental adaptation to changing flood patterns in the Amazon delta. Sustainability Science, 11(4): 611-623.
Voskamp, I.M. and Van de Ven, F.H.M., 2015. Planning support system for climate adaptation: Composing effective sets of blue-green measures to reduce urban vulnerability to extreme weather events. Building and Environment, 83: 159-167.
Voytenko, Y., McCormick, K., Evans, J. and Schliwa, G., 2016. Urban living labs for sustainability and low carbon cities in Europe: Towards a research agenda. Journal of Cleaner Production, 123: 45-54.
Véliz, K.D., Kaufmann, R.K., Cleveland, C.J. and Stoner, A.M.K., 2017. The effect of climate change on electricity expenditures in Massachusetts. Energy Policy, 106: 1-11.
Wachsmuth, D., Cohen, D.A. and Angelo, H., 2016. Expand the frontiers of urban sustainability. Nature News, 536(7617): 391.
Wahab, B. and Popoola, A., 2018. Climate-induced problems and adaptation strategies of urban farmers in Ibadan. Ethiopian Journal of Environmental Studies & Management, 11(1): 31-42.
Wahl, T., Jain, S., Bender, J., Meyers, S.D. and Luther, M.E., 2015. Increasing risk of compound flooding from storm surge and rainfall for major US cities. Nature Climate Change, 5(12): 1093.
Wahlström, M., Sommer, M., Kocyba, P., de Vydt, M. and al, e., 2019. *Protest for a future: Composition, mobilization and motives of the participants in Fridays For Future climate protests on 15 March, 2019 in 13 European cities*, Project Report. Protest for a Future.
Wamsler, C., 2015. Mainstreaming ecosystem-based adaptation: transformation toward sustainability in urban governance and planning. Ecology and Society, 20(2).
Wamsler, C. and Brink, E., 2014. Moving beyond short-term coping and adaptation. Environment and Urbanization, 26(1): 86-111.
Wamsler, C. and Pauleit, S., 2016. Making headway in climate policy mainstreaming and ecosystem-based adaptation: two pioneering countries, different pathways, one goal. Climatic Change, 137(1): 71-87.
Wamsler, C. and Raggers, S., 2018. Principles for supporting city–citizen commoning for climate adaptation: From adaptation governance to sustainable transformation. Environmental Science & Policy, 85: 81-89.
Wamsley, T.V., Collier, Z.A., Brodie, K., Dunkin, L.M., Raff, D. and Rosati, J.D., 2015. Guidance for developing coastal vulnerability metrics. Journal of Coastal Research, 31(6): 1521-1530.
Wang, J. and Ouyang, W., 2017. Attenuating the surface Urban Heat Island within the Local Thermal Zones through land surface modification. Journal of Environmental Management, 187(Complete): 239-252.
Wang, M., Zhang, X. and Yan, X., 2013. Modelling the climatic effects of urbanization in the Beijing–Tianjin–Hebei metropolitan area. Theoretical and applied climatology, 113(3-4): 377-385.
Wang, Y., de Groot, R., Bakker, F., Wörtche, H. and Leemans, R., 2017. Thermal comfort in urban green spaces: a survey on a Dutch university campus. International Journal of Biometeorology, 61(1): 87-101.
Ward, C.D. and Shackleton, C.M., 2016. Natural resource use, incomes, and poverty along the rural–urban continuum of two medium-sized, South African towns. World Development, 78: 80-93.
Ward, K., Lauf, S., Kleinschmit, B. and Endlicher, W., 2016. Heat waves and urban heat islands in Europe: A review of relevant drivers. Science of the Total Environment, 569: 527-539.
Warner, K. and Afifi, T., 2014. Where the rain falls: Evidence from 8 countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity. Climate and Development, 6(1): 1-17.
Watson, V., 2015. The allure of 'smart city'rhetoric: India and Africa. Dialogues in Human Geography, 5(1): 36-39.
Watts, G., Battarbee, R.W., Bloomfield, J.P., Crossman, J., Daccache, A., Durance, I., Elliott, J.A., Garner, G., Hannaford, J., Hannah, D.M., Hess, T., Jackson, C.R., Kay, A.L., Kernan, M., Knox, J., Mackay, J., Monteith, D.T., Ormerod, S.J., Rance, J., Stuart, M.E., Wade, A.J., Wade, S.D., Weatherhead, K., Whitehead, P.G. and Wilby, R.L., 2015. Climate change and water in the UK – past changes and future prospects. Progress in Physical Geography: Earth and Environment, 39(1): 6-28.
Watts, N., Adger, W.N., Ayeb-Karlsson, S., Bai, Y., Byass, P., Campbell-Lendrum, D., Colbourn, T., Cox, P., Davies, M., Depledge, M., Depoux, A., Dominguez-Salas, P., Drummond, P., Ekins, P., Flahault, A., Grace, D., Graham, H., Haines, A., Hamilton, I., Johnson, A., Kelman, I., Kovats, S., Liang, L., Lott, M., Lowe, R., Luo, Y., Mace, G., Maslin, M., Morrissey, K., Murray, K., Neville, T., Nilsson, M., Oreszczyn, T., Parthemore, C., Pencheon, D., Robinson, E., Schütte, S., Shumake-Guillemot, J., Vineis, P., Wilkinson, P., Wheeler, N., Xu, B., Yang, J., Yin, Y., Yu, C., Gong, P., Montgomery, H. and Costello, A., 2017. The Lancet Countdown: tracking progress on health and climate change. The Lancet, 389(10074): 1151-1164.

Weinthal, E., Zawahri, N. and Sowers, J., 2015. Securitizing water, climate, and migration in Israel, Jordan, and Syria. International Environmental Agreements: Politics, Law and Economics, 15(3): 293-307.
Werrell, C.E., Femia, F. and Sternberg, T., 2015. Did we see it coming?: State fragility, climate vulnerability, and the uprisings in Syria and Egypt. SAIS review of international affairs, 35(1): 29-46.
Wesseling, C., van Wendel de Joode, B., Crowe, J., Rittner, R., Sanati, N.A., Hogstedt, C. and Jakobsson, K., 2015. Mesoamerican nephropathy: geographical distribution and time trends of chronic kidney disease mortality between 1970 and 2012 in Costa Rica. Occupational and Environmental Medicine, 72(10): 714.
Wesseling, J.H., Lechtenböhmer, S., Åhman, M., Nilsson, L.J., Worrell, E. and Coenen, L., 2017. The transition of energy intensive processing industries towards deep decarbonization: Characteristics and implications for future research. Renewable and Sustainable Energy Reviews, 79: 1303-1313.
Wester, P., Mishra, A., Mukherji, A. and Shrestha, A.B., 2019. The Hindu Kush Himalaya Assessment—Mountains, Climate Change, Sustainability and People Springer Nature, Cham.
Westerhoff, L., Keskitalo, E.C.H. and Juhola, S., 2011. Capacities across scales: local to national adaptation policy in four European countries. Climate Policy, 11(4): 1071-1085.
Westman, L. and Broto, V.C., 2018. Climate governance through partnerships: A study of 150 urban initiatives in China. Global Environmental Change, 50: 212-221.
Westman, L.K., Broto, V.C. and Huang, P., 2019. Revisiting multi-level governance theory: Politics and innovation in the urban climate transition in Rizhao, China. Political Geography, 70: 14-23.
Wheeler, S.M., 2008. State and municipal climate change plans: the first generation. Journal of the American Planning Association, 74(4): 481-496.
Wheeler, T. and Von Braun, J., 2013. Climate change impacts on global food security. Science, 341(6145): 508-513.
White, R. and Wahba, S., 2019. Addressing constraints to private financing of urban (climate) infrastructure in developing countries. International Journal of Urban Sustainable Development: 1-12.
White-Newsome, J., McCormick, S., Sampson, N., Buxton, M., O'Neill, M., Gronlund, C., Catalano, L., Conlon, K. and Parker, E., 2014. Strategies to Reduce the Harmful Effects of Extreme Heat Events: A Four-City Study. International Journal of Environmental Research and Public Health, 11(2): 1960-1988.
Whyte, K., 2017. Indigenous climate change studies: Indigenizing futures, decolonizing the Anthropocene. English Language Notes, 55(1): 153-162.
Wickman, T., 2018. Narrating indigenous histories of climate change in the Americas and Pacific. In: S. White, C. Pfister and F. Mauelshagen (Editors), The Palgrave handbook of climate history. Palgrave McMillan, London, pp. 387-411.
Wilby, R.L. and Keenan, R., 2012. Adapting to flood risk under climate change. Progress in Physical Geography, 36(3): 348-378.
Wild, M., Folini, D., Henschel, F., Fischer, N. and Müller, B., 2015. Projections of long-term changes in solar radiation based on CMIP5 climate models and their influence on energy yields of photovoltaic systems. Solar Energy, 116: 12-24.
Williams, D.S., Máñez Costa, M., Sutherland, C., Celliers, L. and Scheffran, J., 2019. Vulnerability of informal settlements in the context of rapid urbanization and climate change. Environment and Urbanization: 0956247818819694.
Willis, K.J. and Petrokofsky, G., 2017. The natural capital of city trees. Science, 356(6336): 374-376.
Wilson, J., 2018. Amazon Unbound: Utopian Dialectics of Planetary Urbanization, Public Space Unbound. Routledge, pp. 23-37.
Wilson, R.S., Pearce, T., Jones, K., Fleischfresser, S., Davis, B., Jones, G. and Lieske, S., 2018. Indigenous land management in peri-urban landscapes: An Australian example. Society & natural resources, 31(3): 335-350.
Winquist, A., Grundstein, A., Chang, H.H., Hess, J. and Sarnat, S.E., 2016. Warm season temperatures and emergency department visits in Atlanta, Georgia. Environmental Research, 147: 314-323.
Winsemius, H.C., Aerts, Jeroen C.J.H., van Beek, Ludovicus P.H., Bierkens, Marc F.P., Bouwman, A., Jongman, B., Kwadijk, Jaap C.J., Ligtvoet, W., Lucas, Paul L., van Vuuren, Detlef P. and Ward, Philip J., 2015. Global drivers of future river flood risk. Nature Climate Change, 6: 381.
Wolfram, M., 2016. Conceptualising Urban Transformative Capacity: A framework for research and policy. Cities, 51: 121-130.
Wolfram, M., Borgström, S. and Farrelly, M., 2019. Urban transformative capacity: From concept to practice. Ambio: 1-12.
Wong, L.P., Alias, H., Aghamohammadi, N., Aghazadeh, S. and Nik Sulaiman, N.M., 2017. Urban heat island experience, control measures and health impact: A survey among working community in the city of Kuala Lumpur. Sustainable Cities and Society, 35: 660-668.
Wong, T.H.F. and Brown, R.R., 2009. The water sensitive city: principles for practice. Water science and technology, 60(3): 673-682.
Wood, B., 2019. Teaching an active citizenship curriculum. Ethos, 27(1): 8-10.
Woodruff, S.C. and Stults, M., 2016. Numerous strategies but limited implementation guidance in US local adaptation plans. Nature Climate Change, 6: 796.
Work, C., Rong, V., Song, D. and Scheidel, A., 2018. Maladaptation and development as usual? Investigating climate change mitigation and adaptation projects in Cambodia. Climate Policy, 3062: 1-16.

World Bank, 2015. Global Monitoring Report 2014/2015: Ending Poverty and Sharing Prosperity, World Bank, Washington DC.
World Bank, 2016. Managing coasts with natural solutions : guidelines for measuring and valuing the coastal protection services of mangroves and coral reefs, World Bank, Washington DC.
World Bank, 2017. Low-Carbon Infrastructure Private Participation in Infrastructure (PPI) 2002 TO H1 2017, Washington DC.
World Bank, 2019a. The World Bank Group Action Plan on Climate Change Adaptation and Resilience, World Bank, Washington DC.
World Bank, 2019b. World Bank Data Indicator EG.USE.ELEC.KH.PC, World Bank.
World Bank Group, 2017. Climate vulnerability assessment: Making Fiji climate resilient World Bank Group, Washington.
World Health Organization, Nations, U. and Fund, C.s., 2017. Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines.
WorldByMap, 2017. World By Map version 2017-01-24. WorldByMap.
Wouters, H., De Ridder, K., Poelmans, L., Willems, P., Brouwers, J., Hosseinzadehtalaei, P., Tabari, H., Vanden Broucke, S., van Lipzig, N.P.M. and Demuzere, M., 2017. Heat stress increase under climate change twice as large in cities as in rural areas: A study for a densely populated midlatitude maritime region. Geophysical Research Letters, 44(17): 8997-9007.
Wright, L., Chinowsky, P., Strzepek, K., Jones, R., Streeter, R., Smith, J.B., Mayotte, J.-M., Powell, A., Jantarasami, L. and Perkins, W., 2012. Estimated effects of climate change on flood vulnerability of US bridges. Mitigation and Adaptation Strategies for Global Change, 17(8): 939-955.
Wyett, K., 2014. Escaping a Rising Tide: Sea Level Rise and Migration in Kiribati. Asia & the Pacific Policy Studies, 1(1): 171-185.
Xiao, X., Seekamp, E., van Der Burg, M.P., Eaton, M., Fatorić, S. and McCreary, A., 2019. Optimizing historic preservation under climate change: Decision support for cultural resource adaptation planning in national parks. Land Use Policy, 83: 379-389.
Xie, X.L. and Xin, Y., 2014. Urban Vulnerability and Non-engineering Coping Measures: Take Beijing as a case. Meteorological Soft Science: 154-160.
Xu, J., Grumbine, R.E., Shrestha, A., Eriksson, M., Yang, X., Wang, Y. and Wilkes, A., 2009. The Melting Himalayas: Cascading Effects of Climate Change on Water, Biodiversity, and Livelihoods. Conservation Biology, 23(3): 520-530.
Xu, X., Liu, S., Sun, S., Zhang, W., Liu, Y., Lao, Z., Guo, G., Smith, K., Cui, Y., Liu, W., Higueras García, E. and Zhu, J., 2019. Evaluation of energy saving potential of an urban green space and its water bodies. Energy and Buildings, 188: 58-70.
Xu, Z., Sheffield, P.E., Su, H., Wang, X., Bi, Y. and Tong, S., 2014. The impact of heat waves on children's health: a systematic review. International journal of biometeorology, 58(2): 239-247.
Yamamoto, L. and Esteban, M., 2017. Migration as an adaptation strategy for Atoll Island States. International Migration, 55(2): 144-158.
Yang, J., Chang, Y. and Yan, P., 2015a. Ranking the suitability of common urban tree species for controlling PM2. 5 pollution. Atmospheric Pollution Research, 6(2): 267-277.
Yang, J.Q., Kerger, F. and Nepf, H.M., 2015b. Estimation of the bed shear stress in vegetated and bare channels with smooth beds. Water Resources Research, 51(5): 3647-3663.
Yi, W. and Chan, A., 2017. Effects of heat stress on construction labor productivity in Hong Kong: a case study of rebar workers. International journal of environmental research and public health, 14(9): 1055.
Yiannakou, A. and Salata, K.-D., 2017. Adaptation to climate change through spatial planning in compact urban areas: a case study in the city of Thessaloniki. Sustainability, 9(2): 271.
Yon, A. and Nadimpalli, S., 2017. Cities for whom? Re-examining identity, to reclaim the right to the city for women. Australian Planner, 54(1): 33-40.
Yuniartanti, R.K., Handayani, W. and Waskitaningsih, N., 2016. Monitoring and evaluation effectiveness in flood early warning system project in Semarang City. International Journal of Society Systems Science, 8(1): 49-77.
Zander, K.K., Botzen, W.J.W., Oppermann, E., Kjellstrom, T. and Garnett, S.T., 2015. Heat stress causes substantial labour productivity loss in Australia. Nature Climate Change, 5: 647.
Zander, K.K. and Mathew, S., 2019. Estimating economic losses from perceived heat stress in urban Malaysia. Ecological Economics, 159: 84-90.
Zardo, L., Geneletti, D., Pérez-Soba, M. and Van Eupen, M., 2017. Estimating the cooling capacity of green infrastructures to support urban planning. Ecosystem Services, 26: 225-235.
Zhao, H., Roberts, H. and Ludy, J., 2014. Coastal green infrastructure research plan for New York City.
Zhao, L., Oppenheimer, M., Zhu, Q., Baldwin, J.W., Ebi, K.L., Bou-Zeid, E., Guan, K. and Liu, X., 2018. Interactions between urban heat islands and heat waves. Environmental research letters, 13(3): 034003.
Zhao, Y., Sultan, B., Vautard, R., Braconnot, P., Wang, H.J. and Ducharne, A., 2016. Potential escalation of heat-related working costs with climate and socioeconomic changes in China. Proceedings of the National Academy of Sciences, 113(17): 4640.

Zheng, F., Westra, S. and Sisson, S.A., 2013. Quantifying the dependence between extreme rainfall and storm surge in the coastal zone. Journal of Hydrology, 505: 172-187.
Zhou, Q., 2014. A review of sustainable urban drainage systems considering the climate change and urbanization impacts. Water, 6(4): 976-992.
Zia, A. and Wagner, C.H., 2015. Mainstreaming Early Warning Systems in Development and Planning Processes: Multilevel Implementation of Sendai Framework in Indus and Sahel. International Journal of Disaster Risk Science, 6(2): 189-199.
Ziervogel, G., 2019a. Building transformative capacity for adaptation planning and implementation that works for the urban poor: Insights from South Africa. Ambio: 1-13.
Ziervogel, G., 2019b. Unpacking the Cape Town Drought: Lessons Learnt, African Centre for Cities.
Ziervogel, G., Cowen, A. and Ziniades, J., 2016. Moving from Adaptive to Transformative Capacity: Building Foundations for Inclusive, Thriving, and Regenerative Urban Settlements. Sustainability, 8(9).
Ziervogel, G., Pelling, M., Cartwright, A., Chu, E., Deshpande, T., Harris, L., Hyams, K., Kaunda, J., Klaus, B., Michael, K., Pasquini, L., Pharoah, R., Rodina, L., Scott, D. and Zweig, P., 2017. Inserting rights and justice into urban resilience: a focus on everyday risk. Environment and Urbanization, 29(1): 123-138.
Zscheischler, J. and Seneviratne, S.I., 2017. Dependence of drivers affects risks associated with compound events. Science Advances, 3(6): e1700263.
Zscheischler, J., Westra, S., Van Den Hurk, B.J.J.M., Seneviratne, S.I., Ward, P.J., Pitman, A., AghaKouchak, A., Bresch, D.N., Leonard, M. and Wahl, T., 2018. Future climate risk from compound events. Nature Climate Change, 8(6): 469.
Zuccaro, G., De Gregorio, D. and Leone, M.F., 2018. Theoretical model for cascading effects analyses. International Journal of Disaster Risk Reduction, 30(May): 199-215.
Zölch, T., Wamsler, C. and Pauleit, S., 2018. Integrating the ecosystem-based approach into municipal climate adaptation strategies: The case of Germany. Journal of cleaner production, 170: 966-977.
Ürge-Vorsatz, D., Herrero, S.T., Dubash, N.K. and Lecocq, F., 2014. Measuring the co-benefits of climate change mitigation. Annual Review of Environment and Resources, 39: 549-582.
Ürge-Vorsatz, D., Rosenzweig, C., Dawson, R.J., Sanchez Rodriguez, R., Bai, X., Barau, A.S., Seto, K.C. and Dhakal, S., 2018. Locking in positive climate responses in cities. Nature Climate Change, 8(3): 174-177.