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Tadashi Matsumoto and Mateo Ledesma Bohorquez

Climate shocks such as extreme floods and storms, droughts and heatwaves have complex, inter-connected and far-reaching consequences across multiple policy sectors and systems. Shocks in other systems, such as financial or health crises, can, in turn, affect climate challenges. Applying a systems approach to climate change helps policymakers understand linkages between issues that are treated separately and propose cross-sectoral, multi-disciplinary solutions in cities. This paper proposes a four-pronged policy framework to disentangle the different elements of economic, social, environmental, and other systems operating in cities, maximise co-benefits and manage trade-offs across systems, and build systemic climate resilience in cities. It summarises the contribution of the Working Party on Urban Policy and the Regional Development Policy Committee to the 2021-2022 OECD Horizontal Project on "Building Climate and Economic Resilience in the Transition to a Low-Carbon Economy".

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Executive Summary

Climate shocks such as extreme floods and storms, droughts and heatwaves have complex, interconnected and far-reaching consequences across multiple policy sectors and systems. For example, in Europe, extreme heat in cities in the summer of 2022 resulted in multiple effects, ranging from increased mortality and health issues to infrastructure breakdowns and power outages. In 2021, severe winter storms and extreme cold in Texas (United States) led to significant energy blackouts, leaving more than 10 million people without electricity and disrupting key public services such as water treatment and medical facilities.

Shocks in other systems, such as financial or health crises, can, in turn, affect climate challenges. For instance, the COVID-19 pandemic has not only had socio-economic impacts but also a wide range of environmental impacts. Lockdown-induced CO_2 reductions and improved air quality were swiftly undone as restrictions lifted. Such impacts may jeopardise or slow down cities' efforts to adapt to climate change or to drive the transition towards net-zero emissions. The pandemic has also evidenced the agility of cities to respond to multiple, concomitant crises in the short term, and to shape long-term recovery and resilience strategies. At the same time, cities hold critical policy competencies (e.g., land use planning) that can influence climate outcomes, and together with other sub-national governments, they are responsible for the bulk of climate-significant investments in 30 OECD countries (69% in 2019) with available data.

To help both national and local governments adopt a systems approach to climate change, this paper proposes a four-pronged framework to disentangle the different elements of economic, social, environmental, and other systems operating in cities, maximise co-benefits and manage trade-offs across systems, and build systemic climate resilience in cities:

- **Interaction across different urban policy sectors**. Recognising how climate impacts intersect with societal challenges such as health, labour productivity or social marginalisation enables cities to prioritise climate actions with broader objectives, creating co-benefits. For instance, policies addressing extreme heat can help reduce its impacts on workers to safeguard productivity. Additionally, urban greening enhances city resilience to extreme weather while improving physical and mental health by reducing pollution and providing recreational spaces.
- **Interaction across diverse actors**. Systemic resilience in cities demands various forms of collaboration among diverse actors. These encompass collaboration between governments, the private sector, civil society and local communities, city networks, working collectively to identify and implement appropriate solutions to address the complexity of climate impacts. Moreover, it is imperative to prioritise the active engagement of local communities in the initial stages of national disasters risk management strategies, as they serve as the first responders in the event of a disaster.
- **Direct vs. cascading and compounding impacts (from infrastructure to services)**. Beyond *direct* impacts of climate change such as global temperature and sea level rises, *cascading* impacts in cities are observed when a climate shock first damages buildings and urban infrastructures, then leads to a disruption of urban services such as transport, energy, water and food provision, resulting in significantly stronger impacts than the initial one. *Compounding* impacts are observed when the impacts of a climate shock interact with, and are exacerbated by, pre-existing inequalities

and vulnerabilities. For instance, extreme cold weather may hit low-income families who live in poorly isolated homes and cannot afford spending more on heating. Assessing such diverse impacts based on robust data on local hazards can help cities better prepare by putting in place effective adaptation and resilience policies.

- **Asymmetric impacts across people and places**. Climate shocks hit differently across places (e.g., low-lying areas, urban centres) and across people (e.g., vulnerable population groups), due to varying vulnerability, exposure, and adaptive capacity. Systemic climate resilience in cities requires a renewed appraisal of the scale at which climate shocks should be addressed and by which actors, and context-specific solutions supported by local data and evidence. For instance, the impacts of extreme heat are frequently more severe in cities due to the "urban heat island" effect – some urban centres in Japan, Spain and France are 5-7 °C warmer than their surrounding areas. The poorest neighbourhoods often have higher density and lack shade, green space and ventilation, leading to higher peak temperature and insufficient night-time cooling.

To implement this four-pronged framework, both national and subnational governments can use the following policy practices. Each policy approach is effective in advancing specific key elements. For instance, joint climate actions across levels of government enhance interaction across different actors, although one approach can often contribute to multiple elements of systemic climate resilience in cities:

To enhance interaction across different urban policy sectors

- **Prioritise investment in integrated urban development strategies benefitting multiple systems**. Integrated urban development strategies, as opposed to sectoral urban development strategies, can better address multiple policy objectives, generate co-benefits, and manage complex trade-offs. Nature-based solutions (NbS) offer a unique opportunity to foster integrated urban development while fostering adaptation-mitigation synergies. For instance, between 2016 and 2019, the city of Medellin (Colombia) transformed 18 roads and 12 waterways into a 20km-long green space, yielding a reduction of 3.5°C in urban heat island intensity.

To enhance interaction across diverse actors

- **Develop joint climate actions among all levels of government**. Collaborative arrangements between national, regional and local governments (and other relevant stakeholders) such as partnerships, contracts, or joint programmes can be used to join up climate actions. Capacity building and financing are two major areas that need to be exploited in such governance arrangements. For instance, England (UK) adopted a Green Infrastructure Framework in 2022 to support cities in meeting the requirements for green infrastructure development set by the National Planning Policy Framework.
- **Engage local communities throughout the policy cycle.** Engaging a wide range of stakeholders can help governments identify specific needs and target and adapt policy responses more effectively. For instance, the US Community Development Block Grant Disaster Recovery (CDBG-DR) emphasises the active and important role of the communities most affected by disasters throughout the planning and implementation process. This mechanism allocates flexible grants to various states, cities and counties to aid their recovery efforts and effectively address the unmet needs arising from disasters.

To address cascading and compounding impacts

- **Expand risk and vulnerability assessment to cascading and compounding impacts**. Expanding the scope of risk and vulnerability assessments beyond direct impacts with robust local data and evidence can pave the way to developing more comprehensive climate resilience strategies. For example, the renewed Resilience Strategy of Rotterdam (The Netherlands) has broadened its original scope from climate resilience and proposes interconnected interventions to address ecological (biodiversity), energy, social, economic, and digital resilience.

To address asymmetric impacts across people and places

- **Develop climate adaptation and resilience strategies at the metropolitan (functional urban area) scale**. Metropolitan adaptation and resilience strategies can leverage the spatial continuity and functional relationships between urban and rural areas to better identify and address climate shocks, as the geographic reality of their impacts often cuts across administrative boundaries. For instance, the State of Jalisco (Mexico) has adopted an Agenda for Water Resilience of the Guadalajara Metropolitan Area spanning across nine municipalities within the metropolitan area, harmonising actions in the drainage basin and in urban areas.
- **Localise National Adaptation Plans and Strategies (NAPs/NAS)**. NAPs/NAS offer a unique opportunity for national governments to interact more proactively with cities in the adaptation planning, monitoring and evaluation of adaptation goals. Some countries have recognised the role of cities in climate adaptation and put emphasis on multi-level governance aspects in their NAPs/NAS. For example, Ireland has established Climate Action Regional Offices to provide cities with financial and technical support for the design and implementation of local adaptation plans aligned with the National Climate Action Framework.

1 Context: the climate urgency and the need for systemic resilience in cities

Climate change: a systemic challenge

Climate-related hazards (hereinafter referred as climate shocks) such as extreme floods and storms, droughts and heatwaves have far-reaching consequences that span across multiple policy sectors. These shocks can impact, often simultaneously, different sectors such as energy, water management, health, and agriculture, among others. For example, an extreme rainfall producing massive flooding can disrupt transportation and energy systems, cause crop failure and increase the risk of disease outbreaks.

The impacts of climate shocks can have cascading and compounding effects on different systems and generate multiple interconnected consequences. On the one hand, climate shocks are proven to be harmful for our economies as they are leaving long-lasting economic effects. As an example, in 2021 alone, the global direct costs of climate shocks were estimated at USD 280 billion (Munich Re, 2022[1]). On the other hand, climate shocks can also have significant and damaging impacts on social systems including public health and social equity. For instance, a flood can lead to population displacement, forcing people to flee their homes in search of new livelihoods, and droughts and water shortages can jeopardise food production, leading to increased food prices (FAO, 2022[2]). These impacts can be further compounded by factors such as poverty, weak governance, and inadequate infrastructure, which can make it more difficult for policymakers, and most importantly, communities, to cope with and recover from the impacts of climate shocks.

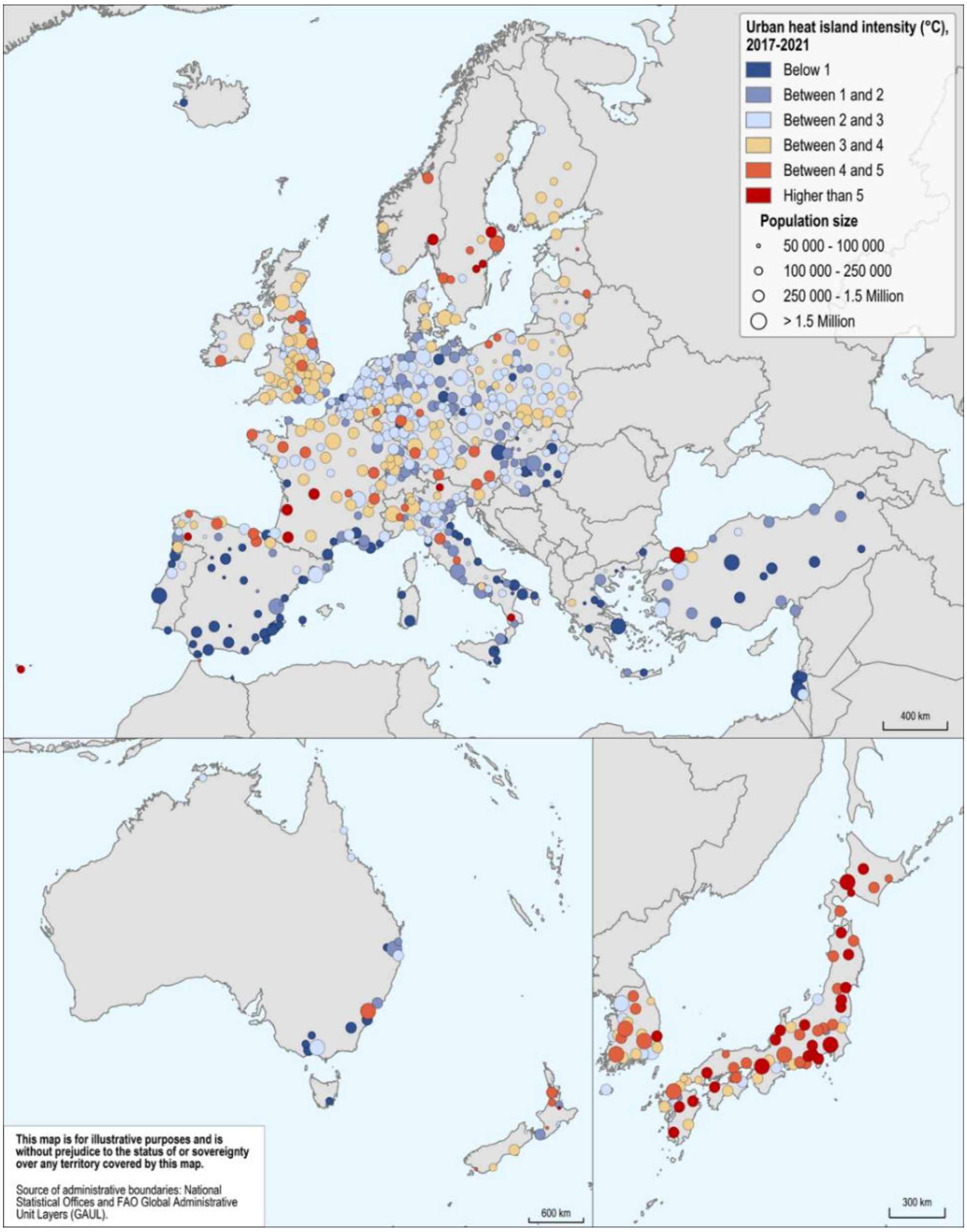
Climate shocks can also generate different impacts across people and places due to a range of factors, including differences in vulnerability, exposure, and adaptive capacity. Such factors can create significant asymmetries across people and places. For instance, low-income population groups are likely to be more exposed to and affected by climate shocks, as they often live in areas that are prone to climate change hazards or that are ill-equipped to face climate risks. Thus, they are likely to have a lower capacity to recover from climate shocks (OECD, 2017[3]).

The impacts of climate shocks imply interactions across different actors, including communities, governments, and businesses. Since climate change affects distinct parts of society, its response requires interaction and collaboration across different actors. For example, communities that are affected by a climate shock, businesses and governments can come together to share resources, knowledge, and experiences to design policy responses. Similarly, different levels of government need to collaborate to co-ordinate their response to climate shocks and share best practices.

Cities as a ‘system’ in the complex climate landscape

Cities concentrate people, infrastructure, and economic activities, but this concentration also comes with risks. People living in cities are exposed to climate shocks such as floods, storms, and heat waves. In fact, by 2050, over 570 low-lying coastal cities are projected to face a sea level rise of at least 0.5 metres (C40, 2018[4]). Similarly, extreme heat severely impacts urban areas. For example, in OECD cities, urban heat island intensity varies depending on the population size and the climate zone, reaching 5°C and even more than 7°C in some urban centres such as in Asahikawa (Japan), Ourense (Spain), and Bordeaux (France) (Figure 1.1). Cities with more than 250 000 inhabitants are on average 3°C warmer than their surrounding areas (OECD, 2022[5]).

Figure 1.1. Urban heat island intensity in Europe and Asia-Pacific (FUA, summer, daytime 2017-21)

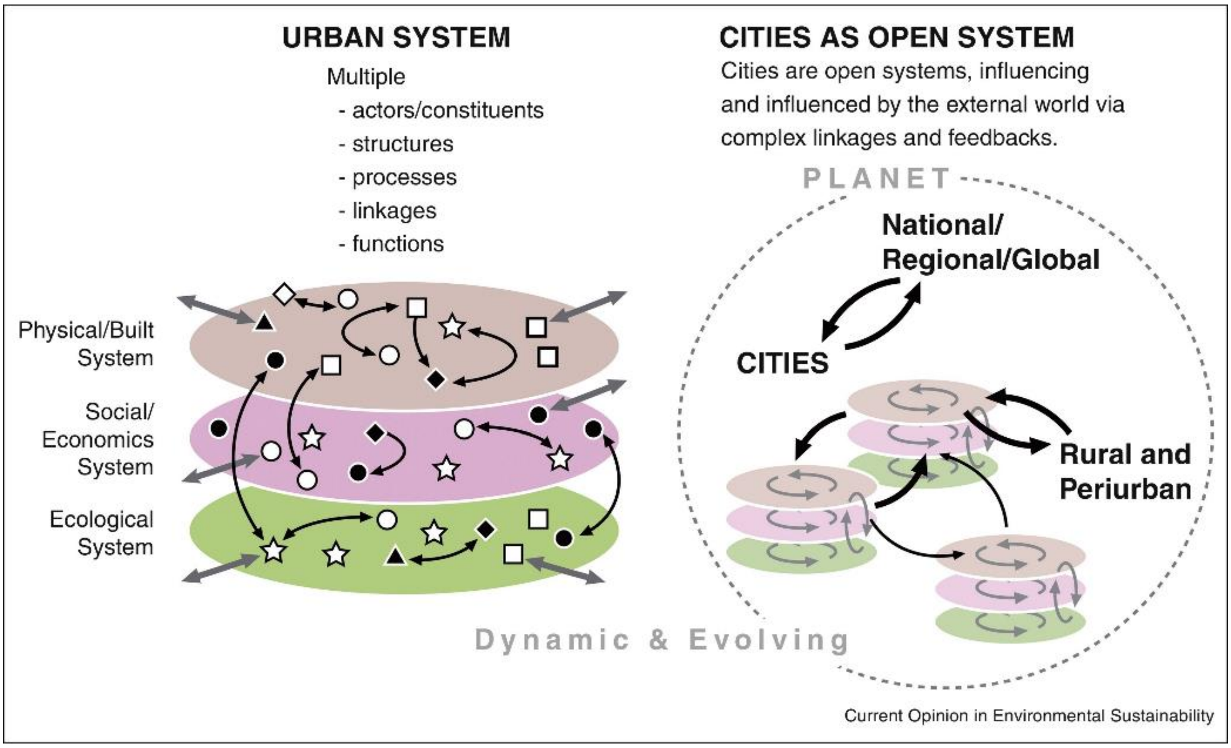


Source: (OECD, 2022[5]) *OECD Regions and Cities at a Glance 2022* https://doi.org/10.1787/26173212
Note: based on MODIS Aqua and Terra land surface temperature, and MODIS land cover data.

Nevertheless, cities are at the same time an essential part of the solution to address climate change and its impacts. First, they are responsible for critical policy domains that influence climate outcomes. Indeed, many of the domains that fall under the jurisdiction of cities – land use planning, zoning, water provision, sanitation and drainage, housing construction, urban regeneration, , economic development, public health and emergency management, transport, environmental protection – are directly vulnerable to climate change impacts, but also represent opportunities to develop adaptive capacities and strategies. Cities are therefore well positioned to integrate different policy sectors that are relevant for climate action on the ground. Second, cities discharge a high share of climate-significant investment, which makes them essential players in the implementation of mitigation and adaptation strategies. For example, in 2019, subnational governments accounted for 63% of climate-significant expenditure and 69% climate-significant investment, on average, in the OECD countries (OECD, 2019[6]) (IPCC, 2022[7]) (OECD, 2022[8]).

Against this backdrop, the geographical scale is a key element in understanding and addressing the complexity of climate shocks and their impacts. A city can be conceived as an urban system, where multiple systems interact, but also as part of an open system, where many cities are influencing and influenced among themselves and by other systems (Figure 1.2). For instance, in cities, a lot of people, money, information and materials (e.g., energy, water, plastics, carbon-, nitrogen-, phosphorus-bearing materials) gather and interact with each other in the most intensive, complex, and often unexpected ways, and decisions are taken at every moment across multiple scales (households, firms, rural, urban, regional, national and global).

Figure 1.2. Cities as urban systems



Source: (Bai et al., 2017[9]) *Defining and advancing a systems approach for sustainable cities* https://doi.org/10.1016/j.cosust.2016.11.010 (accessed on 14 December 2022)

The systems approach: an essential framework to build urban resilience

A systems approach can help better identify, analyse, and respond to complex challenges, such as climate change. It recognises that the social, economic, and ecological aspects of our societies are part of an interconnected system that is constantly changing (Ballew et al., 2019[10]). It provides a methodology to better understand the non-linear behavior of complex systems and better assess the consequences of policy interventions (Hynes, Lees and Müller, 2020[11]). Applying a systems approach can help policymakers understand linkages between issues that are treated separately within different specialisations and scientific and institutional silos. As a result, they can promote cross-sectoral, multi-disciplinary collaboration in the process of policy formulation. The OECD has been at the forefront of research and analysis of systems approaches to policy making, including in the field of resilience, under the framework of the *New Approaches to Economic Challenges (NAEC)* initiative. Most recently, the OECD *Horizontal Project on Building Climate and Economic Resilience in the Transition to a Low-Carbon Economy* has applied this framework to better connect climate and economic resilience; which this paper is leveraging for more granular and place-based analysis in cities (Box 1.1).

In cities, a systems approach can offer a unique opportunity for urban policy makers to understand and address the complexity of urban climate challenges. For instance, it could help avoid unintended consequences of urban climate adaptation and resilience policies, which in turn can drive sustainable urban development (Bai et al., 2017[9]). It can also reveal untapped opportunities to maximise co-benefits and synergies and manage inevitable trade-offs across economic, social, environmental, and other systems interacting in cities.

To better understand a systems approach in the context of urban climate resilience and to maximise its potential benefits, the following questions need to be answered:

- What are the major climate shocks in cities? How do they affect multiple systems in cities, and more specifically, climate resilience?
- What does ‘systemic climate resilience’ mean in an urban context? What are the key elements to understand it?
- Which policy approaches, tools and processes can help address systemic climate resilience in cities?

The following sections of this policy paper aim to answer these questions, based on literature reviews, desk research, interviews with select experts, and peer-learning activities such as the OECD international workshop on building systemic climate resilience in cities held in July 2022 (online). The paper is a companion output to the OECD report *Net zero+: Climate and economic resilience in a changing world* (OECD, 2023[12]), where early findings were published.

Box 1.1. OECD's work on systems approaches to climate and economic resilience

New Approaches to Economic Challenges (NAEC)

OECD Members established the New Approaches to Economic Challenges (NAEC) initiative in 2012 to better understand the interconnectedness and complexity of the global economy. From its early days the initiative recognised that the economic system is inherently intricate and interlinked through financial markets, global supply chains, social networks, and a shared ecological foundation. Complex interactions at the individual level give rise to unstable properties at the macro level. Such a system is subject to crises and cascading failures, which can emerge from a variety of sources including financial crises, natural hazards, geopolitical tension, cyber-attacks, and pandemics.

The NAEC initiative has analysed how relevant shocks such as the financial crisis and the COVID-19 pandemic affected our societies while also investigating how resilience approaches can help governments to navigate future shocks. Resilience is defined from a systems point of view as the capacity of a system to recover in the midst of shocks and stresses over time. Such a recovery implies multiple interactions between factors, actors, scales, and sub-systems, which are usually unexpected and complex in nature. It therefore requires an understanding of the complex and interconnected nature within which most individuals, organisations, and activities operate.

OECD Horizontal Project on Building Climate and Economic Resilience in the Transition to a Low-Carbon Economy (2021-2022)

This project aims to provide a whole-of-OECD perspective on tackling climate change in the aftermath of COVID-19, with a particular focus on economic resilience. It seeks to help ensure that an effective response to climate change is at the heart of government's efforts to improve economic and societal resilience after COVID-19. It aims to both ensure a resilient transition to net-zero emissions – with a focus on ensuring fiscal sustainability and macroeconomic stability – and effective adaptation to the impacts of climate change.

The project concluded with the publication of a synthesis report *Net zero+: Climate and economic resilience in a changing world* with state-of-the-art evidence-based analysis and guidance for governments on developing effective planning, financing, and policy coordination mechanisms to help them better mitigate, prepare for, recover from, and adapt to economic and social shocks related to climate change.

Source: (OECD, 2021[13]) *Integrating Climate and Economic Resilience* https://www.oecd.org/environment/cc/brochure-horizontal-project-on-climate-and-economic-resilience.pdf (accessed on 3 February 2023); (OECD, n.d.[14]) *New Approaches to Economic Challenges* https://www.oecd.org/naec/resources/Briefing-Note_New-Approaches-to-Economic-Challenges.pdf (accessed on 3 February 2023); (OECD, 2019[15]) *Resilience Strategies and Approaches to Contain Systemic Threats* https://read.oecd-ilibrary.org/view/?ref=131_131917-kpfefrdfnx&title=A-Systemic-Resilience-Approach-to-dealing-with-Covid-19-and-future-shocks (accessed on 3 February 2023); (OECD, 2023[12]) *Net zero+: Climate and economic resilience in a changing world*

2 Understanding and defining systemic climate resilience in cities

This section provides an overview of how major climate shocks and the COVID-19 crisis affected cities, including how they interact with other shocks compromising cities' ability to absorb, prepare for and recover from them.

Major climate shocks and their impacts in cities

Climate change is affecting many inter-connected urban systems, including economic systems (e.g., production, jobs), social systems (e.g., health, education, access to adequate and affordable housing and food), ecological systems (e.g., forests, agriculture, biodiversity, water) and urban infrastructure systems (e.g., transport, energy, water, and sanitation). Floods and storms, heatwaves, droughts, biodiversity loss and sea-level rise represent five major climate shocks (in the order from fast to slow onset) often observed in cities around the world. They illustrate the variety of types of impacts, from direct impacts to indirect, cascading and compounding impacts, as well as the impacts specific to location and people (Table 2.1).

Table 2.1. Major climate shocks and their impacts in cities

Shocks (from fast to slow onset)	Direct (single) impacts	Indirect, cascading and compounding impacts	Asymmetric impacts across places and/or people
Floods and storms	• Damages to urban infrastructure (e.g., roads, energy) and housing • Damages to schools and public health facilities • Disruption of urban services (e.g., water, energy, transport) • Damages to agricultural land • Degrading coastal ecosystems, such as mangroves or coastal reefs	• Disruption of urban services (e.g., health, food supply) due to damages on urban infrastructure (e.g., energy and transport) • Locational and investment decisions of firms (in the long term) • Emergence of waterborne diseases • Changes in the demand for goods and services • A disruption in manufacturing supply chains affecting local production as well in other places than the one where a flood/storm is occurring. • Loss of cultural assets artefacts • Loss of sense of security among citizens • Displacements due to climate migration create higher demand for public services and increase the population living in informal settlements.	• Economically and socially marginalised communities (living near rivers) may be more vulnerable to floods and damages to urban infrastructure. • Migration induced by floods affecting the most vulnerable. • Children affected and more vulnerable to waterborne diseases. • Where mangroves are already affected, there is increased vulnerability of coastal communities.
Heatwaves	• Heat stress on human health • Pressure on energy, water infrastructure and supply	• Decrease of general labour productivity for both manual and cognitive tasks	• Children and the elderly are more vulnerable to heat stress. • Low-income households living with inadequate housing conditions (e.g., without air

	• Damage to urban infrastructure	• Extended fire weather seasons (i.e., periods of time where weather conditions are conducive to the outbreak of wildfires) • Increased morbidity from vector-borne diseases	conditioning) are more vulnerable. • Psychological or mental health impacts on the most exposed population
Droughts	• Impacts on food supply system in cities. • Water shortages affecting the population access to safe drinking water.	• Limiting the hydropower capacity of dams. • Changes in ecosystems' functioning • Changes in labour and agricultural productivity • Land degradation • Impacts on food production leading to rise in food prices	• Disruption of agricultural production leads to severe and more chronic food insecurity, increasing the propensity of malnutrition, as well as rise of food prices. This problem is strongly concentrated in vulnerable populations.
Biodiversity loss	• Loss of ecosystems services, such as carbon sequestration and the capacity to further adapt to climate change	• Limitations for the discovery of potential treatments for diseases and health problems	• Food and nutritional security impacts may disproportionally affect vulnerable population
Sea-level rise	• Potential damages to urban assets in coastal areas • Impacts on urban land use and infrastructure investment strategies. • Accelerated coastal erosion	• Coastal defenses become increasingly expensive to adapt and to maintain over time • Decrease of tourism-related activities	• Vulnerability is higher in Small Islands Development States, where the most vulnerable area is the low-lying coastal zone

Source: Author's elaboration based on (OECD, 2021[16]) *Managing Climate Risks, Facing up to Losses and Damages* https://dx.doi.org/10.1787/55ea1cc9-en (accessed on 3 May 2022); (OECD, 2021[17]) *Nature-based solutions for adapting to water-related climate risks* https://doi.org/10.1787/2257873d-en (accessed on 3 May 2022); (OECD, 2021[18]) *Adapting to a changing climate in the management of coastal zones* https://doi.org/10.1787/b21083c5-en (accessed on 3 May 2022); (OECD, 2021[19]) *Enhancing the effectiveness of sub-national biodiversity policy: Practices in France and Scotland, United Kingdom* https://dx.doi.org/10.1787/1a8c77b7-en (accessed on 3 May 2022).

The complexity and inter-connectedness of climate shocks and their impacts on cities are exemplified by three recent large-scale climate shocks (extreme heat, extreme cold and floods) across Europe, North America, and Asia.

Case 1: Extreme heat in cities in various parts of Europe (July-August 2022)

In 2022, Europe experienced one of the hottest summers in history. The extreme heat led to record-breaking temperatures – reaching 40°C for the first time – across several cities including Nantes (France), Rome (Italy) and London (UK). This generated serious impacts on many cities, ranging from increased mortality and health issues to infrastructure breakdowns and electricity blackouts, which were exacerbated by the "urban heat island effect" – a phenomenon that results from high building density, heat from human activities, building materials and limited vegetation (OECD, 2022[5]).

Between July and August 2022, the extreme heat caused around 4 500 deaths in Germany, more than 1 000 in Portugal, 4 000 in Spain, and more than 3 200 in the UK (WHO, 2022[20]). It also heavily affected urban infrastructure. For instance, in London (UK), the Luton Airport had to restrict flights after its runway had melted during the extreme heat recorded in July 2022 (Rodas, Lombardi and Ledesma, 2022[21]). In Italy, the City of Trieste experienced an outage caused by a fire in Karst – a region extending across the border of southwestern Slovenia and north-eastern Italy (Trieste Prima, 2022[22]). The extreme heat also brought a severe drought causing devastating wildfires and risking energy and food security. In France, the wildfires affected Landiras, a town south of Bordeaux, forcing the closure of roads and evacuation of around 500 residents (France24, 2022[23]). In Italy, a drought resulted not only in decreased hydropower electricity production, but also in a sharp drop in harvest by 30-40% in the Po Valley, which accounts for 35% of Italian agriculture and 50% of Europe's rice (Happé and R., 2022[24]).

Although the impacts on vulnerable population are not well documented yet, if cities do not adapt properly to future heatwaves, these will disproportionately hit socially and economically marginalised urban residents, as outlined by recent studies. For example, one study suggests that in the future, extreme heat events in Europe are likely to happen more frequently and become more intense. Indeed, the number of citizens in the EU and the UK who are exposed to extreme heat is expected to grow from 10 million per year (average 1981-2010) to nearly 300 million, or more than half of the EU population, in a scenario with 3°C global average warming by the end of the 21st century. This could result in 96 000 fatalities per year from extreme heat, compared to 2 750 annual deaths in 2020. Curbing global warming to 1.5°C could limit mortality from extreme heat to around 30 000 per year (Naumann et al., 2020[25]). Another study suggests that communities of lower socio-economic status often have less and lower quality green space, limiting their ability to mitigate the effects of extreme heat (EEA, 2022[26]), and their capacity to cope with the increase in electricity prices is also limited.

But cities also have been implementing innovative solutions to prepare for and respond to heatwaves. For example, the cities of Seville (Spain) and Athens (Greece) are using a system to categorize and name heat waves, recognising the potential of an extreme heat event to cascade into a health emergency. The system analyses locally specific weather conditions and daily health and mortality data to estimate the human health outcomes of forecasted weather conditions. This local and historical analysis also allows policy makers to categorize the severity of forecasted heat waves, thus giving officials an opportunity to provide the most effective, appropriate, and actionable recommendations to their citizens (Ayuntamiento de Sevilla, 2022[27]) (Adrienne Arsht Rockefeller Foundation Resilience Center, 2022[28]).

Case 2: Extreme winter storms and cold weather, United States (February 2021)

In mid-February 2021, a historic cold wave and winter storm hit the south-central part of the United States. It has been considered the coldest winter storm event on record in the country, with temperatures falling between 14 and 28°C below the normal averages. In addition, the duration of the cold was exceptional: many weather stations in these States broke records for the highest number of consecutive days below freezing. Some stations even registered 16 consecutive days (Bolinger et al., 2022[29]).

The energy sector was the most affected by this climate event, as the accumulation of thick ice on trees and power lines caused over 1 000 power generator outages and deratings across the region (Levin et al., 2022[30]). Despite the skyrocketing heating needs, the cold had significant impact on the exposed equipment such as wellheads, thereby affecting the electricity generation capacity of natural gas, coal, and nuclear power plants. Wind turbines were also affected due to the accumulation of ice on blades. The impacts of energy outages were not only local but nationwide, since the State of Texas produces nearly 25% of the United States' total natural gas. Consequently, the extreme cold left more than 10 million people without electricity at its peak for several days (Bolinger et al., 2022[29]; Busby et al., 2021[31]).

In addition, the energy outages had cascading impacts on other services reliant upon electricity such as water treatment and medical services. Hospitals had to relocate patients, as the water and electricity outages affected their boilers and heating systems. In residential areas, frozen water pipes burst upon thawing, causing additional damage. The storm conditions also created significant obstacles, in terms of access to schools and workplaces, provision of emergency services, disruption of food supply chains and closure of grocery stores (Busby et al., 2021[31]; Smith, 2022[32]; City of Austin & Travis County, 2021[33]).

The severity and duration of the extreme cold caused several human and economic losses, hitting hard the most vulnerable. Evidence suggests that more than 210 Texans died, and economic losses estimated to around USD 130 billion in Texas and USD 155 billion in the whole country. The extreme cold significantly affected low-income families living in older and poorly insulated homes without adequate plumbing, and those who have limited resources to relocate, repair the damage to their homes, or replace spoiled food. Since vulnerable population groups were already suffering from the consequences of the COVID-19 crisis, the effects of the extreme cold were compounded and affected their physical wellbeing and finances even harder. For instance, homeless people faced limited options to feed and warm themselves, as some shelters were completely shut down due to the power failure. These shelters were already facing capacity challenges imposed by the social distance measures of the COVID-19 crisis (Busby et al., 2021[31]; Bolinger et al., 2022[29]; Pezenik and Ebbs, 2021[34]). Scientists also pointed out a lack of preparedness, as no adequate warning from public officials to prepare for the storm was provided and little information on how households could protect themselves or reduce energy demand was made available (Busby et al., 2021[31]).

Case 3: The 2022 flooding in Pakistan (June-August 2022)

Pakistan has been severely affected by the impacts of climate change, specifically floods, as evidenced by multiple flooding events in recent years, with the most recent and severe occurring in 2022. One-third of the country has been under water, and 33 million people have been affected. Nearly 8 million people have reportedly been displaced and more than 1 700 people lost their lives, one third of which were children. Half of the districts (first tier of local government) in the country declared the “calamity hit”, with the cities in the Sindh province such as Mehar, Qambar, Larkana, Sukkur, Sehwan, Khairpur Nathan Shah being among the most affected (Bhargava et al., 2022[35]) (The Government of Pakistan/Asian Development Bank/European Union, 2022[36]). However, the impacts of the floods were felt throughout the country. For example, a recent study focused on the City of Lahore – the second most populated city in Pakistan – revealed that citizens reported disruptions in water, electricity and gas supply and damages to their properties during and after the flood event (Zia et al., 2023[37]).

The impacts of flooding cascade into other sectors, including education and healthcare, as well as in energy and transport infrastructures, thus leading to total economic losses of about USD 15.2 billion. More than 17 000 public schools and universities have been affected, of which around 6 200 got fully destroyed, affecting more than 2.6 million enrolled students. In addition, floods severely affected 13% of the health facilities, which in turn interrupted service delivery and increased the risk of waterborne diseases (e.g., cholera, malaria, and dengue) that could have long-lasting implications for the country (The Government of Pakistan/Asian Development Bank/European Union, 2022[36]). UNICEF reported that (as of August 2022) more than 3 million children were at risk of waterborne diseases and the Pakistani health authorities reported over 90 000 cases of diarrhoea (in Sindh province only) in one day (UNICEF, 2022[38]; British Red Cross, 2022[39]). On the transport side, approximately 8 330 kilometres of roads (about 3.2% of total in-service roads) and 3 127 kilometres of railway track (around 40% of total in-service railways) have been damaged to various extents due to the flood, limiting the access to affected areas and hindering the support to affected population (The Government of Pakistan/Asian Development Bank/European Union, 2022[36]).

The flood started with the phenomenal heatwave experienced in April and May 2022. During that period, temperatures reached above 40°C for prolonged periods in many places. For example, in the City of Jacobabad, the temperature reached 51°C. Such unusual and extreme heat melted glaciers in the northern mountainous regions, increasing the amount of water flowing into tributaries that eventually make their way into the Indus River. The Indus is Pakistan’s largest river, and runs from north to south, feeding towns, cities, and large swathes of agricultural land along the way (Mallapaty, 2022[40]). The 2022 flooding has further exposed underlying institutional and systemic challenges, including poor urban planning and water resource management, lack of systems for infrastructure maintenance, complex governance, structural inequalities, and limited disaster risk reduction capacity (The Government of Pakistan/Asian Development Bank/European Union, 2022[36]).

The impacts of global crises on climate challenges in cities

While climate shocks affect social, ecological and health systems (Table 2.1), shocks in other systems (e.g., financial or health crises) in turn also affect climate challenges. The COVID-19 pandemic started from a public health crisis before escalating into an unprecedented social and economic crisis, demonstrating the complex interaction of different systems. To some extent, it also demonstrated how over-emphasis on efficiency and cuts in public expenditures over the past years (e.g., health infrastructure and staff) has put in jeopardy the resilience of key systems to shocks, allowing failures to cascade from one system to others (OECD, 2020[41]).

- In cities, the COVID-19 pandemic generated not only socio-economic impacts but also a wide range of environmental impacts. The crisis also differentially affected people, firms, and places (Table 2.2). Such impacts may threaten or slow down the journey of cities towards adapting to climate change, or towards driving the net-zero transition.
- The COVID-19 pandemic led to lockdowns in cities, resulting in both positive and negative environmental consequences. There were massive reductions in CO_2 and improved levels of air quality. However, these gains were quickly offset when restrictions of movement were lifted, and individual car use increased due to challenges related to maintaining physical distance in public transport. In some countries such as Australia, Egypt, France, New Zealand, the Netherlands, and Sweden, car use has rebounded faster than public transport use (ITF, 2023[42]). However, in cities such as Bogota (Colombia) and Brussels (Belgium), cycling has increased after the pandemic (Bogota Mayor Office, 2021[43]) (l'Observatoire du vélo Région de Bruxeles, 2023[44]). Additionally, e-commerce and the management of the pandemic led to increased levels of non-recyclable waste such as disposable masks, gloves, and packaging, which in turn has increased levels of pollution. Lockdowns have also prompted people to rediscover the value of proximity, accelerating the shift from a focus on increasing mobility towards enhancing accessibility and revisiting public space, urban design, and planning (OECD, 2020[45]).
- The rise of remote working and digitalisation has brought changes to urban mobility and space. Remote working has been associated with immediate environmental benefits of lower air pollution and GHG emissions. However, some studies suggest that in the long term, there may be a rebound effect due to increases in non-work travel, and residential relocation leading to car dependence. This could reverse or negate some of the benefits (ITF, 2023[42]) (EEA, 2022[46]) (Hook et al., 2020[47]). The OECD research has found that after the COVID-19 outbreak and the rise of remote working, house prices have been growing faster in the suburbs compared to the central neighbourhoods (OECD, 2022[5]). While it is too early to know if these changes are here to stay, evidence suggests that remote working may influence the relocation of people and firms. For example, smaller cities in the United States offering significant urban amenities attracted remote workers during the pandemic (ITF, 2023[42]). If not managed properly, these relocation patterns could potentially lead to urban sprawl and inefficient use of urban space, increasing CO_2 emissions.
- Both the lockdowns and the rise of remote working have affected people, places, and firms differently. Low-income and marginalised groups living in poor housing conditions were more at risk of contagion and were less able to take advantage of remote working. Cities with a high concentration of service-related jobs (e.g., tourism) have seen major reductions in economic activity and associated revenues. Similarly, the disruption of value chains disproportionately affected SMEs, which in turn impacted their finances. These SMEs were also less prepared to adopt remote working practices.

Table 2.2. The potential and observed environmental and asymmetric impacts of the COVID-19 pandemic on cities

COVID-19 shocks	Environmental impacts	Asymmetric impacts (across places, people, and firms)
Lockdowns	**Positive (+)** • Reduced transport has had a positive impact in air quality and CO_2 emissions (but rebounded after easing the restrictions). For example, New York City (US) has seen a 38% reduction of CO_2 emissions from the pre-pandemic level, and cities such as Madrid (Spain) and Milan (Italy) have seen a 70% reduction of PM_{10}. • Unveil the potential of proximity and accessibility which can contribute to an efficient land use and to reduce CO_2 emissions related to passenger transport. Indeed, walking and cycling gained popularity in some cities that created temporary/permanent bike lanes. • Less disturbance in both urban and remote areas gave ecosystems and habitats a chance to recover and provides new spaces and niches for species to occupy. • Reinforced the importance of local green and natural spaces for well-being. For example, around 9 in 10 people surveyed in the UK by Natural England in May 2020 agreed that natural spaces are good for mental health and wellbeing. **Negative (-)** • Air pollution and CO_2 rebounded after restrictions were eased. • Volumes of solid waste have risen, including unrecyclable waste such as mask and gloves which have been washing up on beaches around the world due to improper disposal. • E-commerce (e.g., retails, restaurants) increased volumes of non-disposable waste such as plastic packaging material. • Reduction of ridership in public transport and rise of private car use. In the United States, for example, by October 2022, the national average ridership was 71% of pre-pandemic levels, with differences across small and medium-sized cities (78-80%) and larger cities (69%).	**People** • People living in informal settlements and/or with poor housing conditions (e.g., overcrowded, incomplete plumbing facilities, not well ventilated, etc.) were more vulnerable to be infected than those living in more adequate conditions. • Low-paid workers, who are likely to have fewer savings and less likely to be able to telework, were severely hit by measures such as social distancing and closures in retail, transport, restaurants, and other services. • Homeless people had no or limited means of isolating and protecting themselves from infection. • Women have suffered disproportionate job and income losses because they are over-represented in the sectors hardest hit by the lockdowns (e.g., accommodation, food services and manufacturing), in addition to increasing risks of gender violence. • Uncertainty among population given the potential misalignment between levels of government decisions on lockdowns. • People exposed to air pollution before the pandemic were at a higher risk of hospitalization. **Places** • Cities marked with inequalities, inadequate housing conditions and high concentration of urban poor were more vulnerable than those better resourced, less crowded, and more equal. • Cities with high dependency on service sectors (e.g., tourism) have been more affected. **Firms** • Sharp decline in economic activities and employment, especially transport and tourism sectors. • Companies experienced a reduction in supply of labor, as workers were unwell or needed to look after children or other dependents while schools were closed, and movements of people were restricted. • Interruption of supply chains leading to shortages of goods and supplies. • Reduction of demand and revenue for SMEs severely affected their ability to function, and /or caused liquidity shortages.
Remote work / digitalisation	**Positive (+)** • Reduced commuting of teleworkers has reduced the associated energy demand and CO_2 emissions. • Reduction in office-based energy consumption **Negative (-)** • Increase in weekly travel due to longer commutes on non-teleworking days, or increase in trips taken • Increase in non-work travel by the teleworker • Increase in energy consumption at home for heating, cooling, lighting, and other uses • Locational preferences of people and firms may change (e.g., inflow of population into large cities has decreased in some countries such as Canada, France, Japan, and US), leading to urban sprawl and car dependency	**People** • Informal employers are more likely to be exposed to risks of COVID-19 infection. • Workers with a higher level of qualification were more likely to telework, than the least qualified employees. **Places** • Share of jobs amenable for remote work varies across places • Teleworking might be reshaping the demand for housing in metropolitan areas. In 14 OECD countries, house price inflation within metropolitan areas was lower in central neighborhoods, relative to the suburbs, after the COVID-19 outbreak. **Firms** • Teleworking was less adopted in small firms, reflecting their lower digital uptake and their specialisation in activities less amenable to remote working. • Some businesses do not have the means to provide their employees with the technology needed to telework.

Source: Author's elaboration based on (OECD, 2020[45]) *Cities policy responses* https://www.oecd.org/coronavirus/policy-responses/cities-policy-responses-fd1053ff/; (OECD, 2022[5]) *OECD Regions and Cities at a Glance 2022* https://doi.org/10.1787/26173212 (Bucklei et al., 2020[48]) *Addressing the COVID-19 and climate crises: Potential economic recovery pathways and their implications for climate change mitigation, NDCs and broader socio-economic goals* https://doi.org/10.1787/50abd39c-en; (OECD, 2020[49]) *Coronavirus (COVID-19): SME policy responses* https://www.oecd.org/coronavirus/policy-responses/coronavirus-covid-19-sme-policy-responses-04440101/; (OECD, 2021[50]) *Teleworking in the COVID-19 pandemic: Trends and prospects* https://www.oecd.org/coronavirus/policy-responses/teleworking-in-the-covid-19-pandemic-trends-and-prospects-72a416b6/; (Hook et al., 2020[47]) *A systematic review of the energy and climate impacts of teleworking* https://10.1088/1748-9326/ab8a84; (Boudreau, 2021[51]) *Shopping online surged during Covid. Now the environmental costs are becoming clearer* https://www.politico.com/news/2021/11/18/covid-retail-e-commerce-environment-522786; (Shreedhar, Laffan and Giurge, 2022[52]) *Is Remote Work Actually Better for the Environment?* https://hbr.org/2022/03/is-remote-work-actually-better-for-the-environment; (ITF, 2023[42]) *Shaping Post-Covid Mobility in Cities: Summary and Conclusions* https://www.itf-oecd.org/sites/default/files/docs/shaping-post-covid-mobility-cities.pdf; (UK Office for National Stadistics, 2021[53]) *How has lockdown changed our relationship with nature?* https://www.ons.gov.uk/economy/environmentalaccounts/articles/howhaslockdownchangedourrelationshipwithnature/2021-04-26.

The COVID-19 pandemic has also shown the potential for cities in addressing the complex impacts of the crisis and building long-term resilience by applying a systems approach. Cities were hit hard, but they were also at the forefront of the response. They played a key role to implement nation-wide measures and provided laboratories for bottom-up and innovative recovery strategies (OECD, 2020[45]).

- Recovery packages offered opportunities to invest in green and climate resilient infrastructure and many cities developed recovery strategies, with a broad range of stimulus measures, including for local business support and employment, affordable housing construction and renovation, as well as support to the most vulnerable parts of the population (OECD, 2020[45]). Subnational governments are instrumental to implement recovery strategies such as the *Recovery and Resilience Plan* funded by the EU Recovery and Resilience Facility (RRF). A positive trend has already been observed in some countries. In Italy, for example, the National Recovery and Resiliency Plan (Piano Nazionale di Ripresa e Resilienza) received RRF funding and included six instruments targeted to subnational governments. In France, the "France Relance" plan, endowed with a budget of EUR 100 billion over two years, allocates 30% of its resources to the ecological transition and funds seven climate-related instruments benefitting subnational governments (OECD, 2022[54]).
- In many cities in the world, there has been growing public awareness of green spaces as a major "refuge" during the pandemic, making investment in green infrastructure politically and socially more acceptable. Green spaces offered the possibility to urban residents to meet their recreational demands while navigating the lockdowns and restrictions of movement, becoming the enduring legacy of the pandemic (EEA, 2022[55]).
- Lessons for building systemic resilience include mapping the direct, cross-border and cross-sectoral impacts of potential climate risks, adopting adaptive risk management strategies that embrace heterogenous decision-making and uncertainty, and taking a people-centred approach to resilience that generates wellbeing, societal and ecological resilience (Andrew K. et al., 2022[56]).

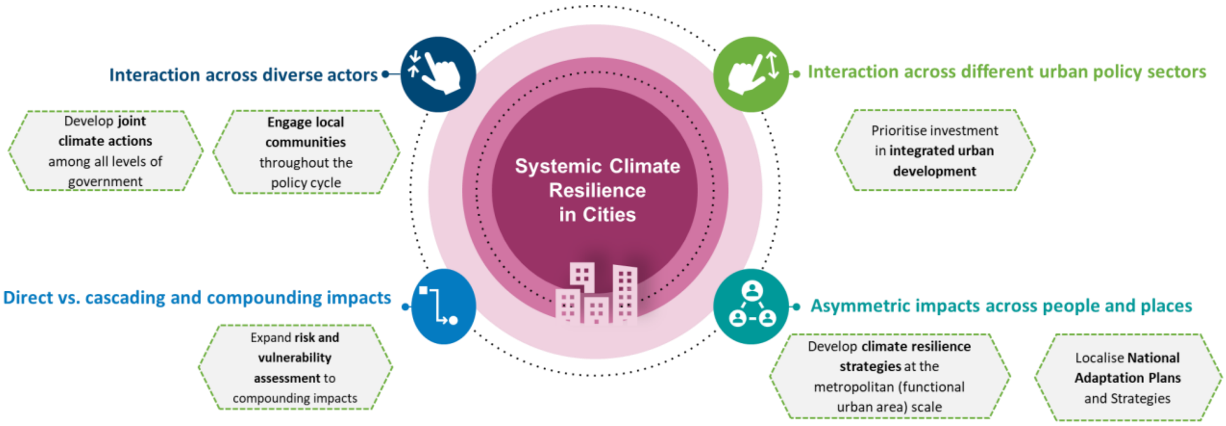
When the pandemic was relatively under control and recovery underway, another unexpected shock hit the world. In February 2022, Russia's war of aggression against Ukraine generated additional systemic impacts while throwing global economic recovery prospects from the COVID-19 pandemic off track. It has pushed prices up substantially, especially for energy, adding to inflationary pressures at a time when the cost of living was already rising rapidly around the world (OECD, 2021[57]). Moreover, the war shed further light on the world's dependency on fossil fuel consumption, especially oil and gas. Such economic disruption has amplified calls for an accelerated energy transition by diversifying the energy matrix and increasing energy efficiency. Therefore, the impacts of the war also accelerated the need for a green recovery in cities in the post-COVID-19 context (OECD, 2022[58]). This includes the need for investments in clean technologies and energy efficiency to reach net-zero goals and strengthen urban resilience. The impacts of the war have also reinforced the need to rethink the capacity of policymakers to address more frequent, more complex, and more interrelated shocks that can reverberate into a systemic crisis.

3 A policy framework to understand and enhance systemic climate resilience in cities

The previous section illustrated the complexity and uncertainties of climate and other shocks and their impacts in cities, which underlines the need for applying a systems approach to building resilience in cities. The OECD defines resilience form a systems point of view as the capacity of a system to recover amid shocks and stresses over time (OECD, 2023[12]). However, due to the complex nature of a systems approach, policymakers would require clearer understanding of what it means in the urban policy context and practical guidance on how to apply it on the ground.

In recent years, the need to advance systemic climate resilience in cities has been discussed by different institutions (Box 3.1). While they often stress the need for a systemic approach and focus on strategies and policy instruments, little guidance has been given to policymakers in terms of disentangling different elements of complex 'systems' in cities, identifying gaps and developing effective policy approaches to bridge the gaps. In this regard, this section proposes four key elements that are essential for understanding systemic climate resilience in cities, and six policy approaches that are considered as effective in enhancing systemic climate resilience in cities (Figure 1.1).

Figure 3.1. A framework to understand and enhance systemic climate resilience in cities



Source: Author's elaboration

Box 3.1. Selected reports discussing systems approaches to climate resilience in the urban context

OECD "Net-zero+: Climate and economic resilience in a changing world"

This report defines systemic resilience as the ability of a system to anticipate, absorb, recover, and adapt to unforeseen shocks. Rather than attempting to identify specific shocks and mitigate their consequences, it assumes that shocks are inevitable, their consequences large, and their origins unpredictable. As such, systemic resilience is "risk agnostic;" rather than tuning a system to withstand a specific impact, it is the ability of a system to recover from any given shock and adapt to the resulting new circumstances. This definition is adopted by this paper as mentioned earlier.

World Economic Forum "Delivering Climate-Resilient Cities Using a Systemic Approach"

This paper focuses on the inter-connectedness across urban infrastructures (energy, buildings, transport, water, solid waste management, green, and digital). It defines a systems approach to climate resilience as the one that takes advantage of the interconnected and interdependent relationships – including reinforcing and balancing feedbacks – among multiple infrastructure sectors. It points out that a systems approach requires both horizontal and vertical collaboration because some infrastructure sectors extend beyond a city's jurisdiction. It encourages comprehensive engagement with multiple stakeholders to explore new, effective solutions. As a result, the systems approach can maximise multiple co-benefits (e.g., carbon mitigation, pollution reduction, improving well-being), and reduce potential harms (e.g., deepening social inequality) related to urban infrastructure services.

C40 & McKinsey "Focused adaptation: A strategic approach to climate adaptation in cities"

This report argues that a successful climate adaptation plan includes both hazard-specific and systemic-resilience actions. On the latter, the report outlines four actions including i) performing climate risk assessments; ii) incorporating the results of risk assessment into city processes (e.g., budgets and urban planning policies); iii) developing early warning systems, and iv) enhancing financial and insurance programs.

World Resource Institute "Unlocking the potential for transformative climate adaptation in cities"

This paper underlines the need for addressing the systemic, multi-scalar and interregional drivers of climate risks and vulnerabilities. It uses the term "transformative urban adaptation" to describe the action needed to achieve deep, long-term, and systemic change. It highlights three actions that cities can focus on to help advance transformative urban adaptation: i) mainstreaming information on climate risks in the spatial planning and delivery of urban services; ii) partnering with vulnerable and informal groups to build their resilience; and iii) using nature-based solutions to respond to water, heat, and other risks.

Source: (WEF, 2022[59]) *Delivering Climate-Resilience Cities Using a Systems Approach: Insight report* https://www3.weforum.org/docs/WEF_C4IR_GFC_on_Cities_Climate_Resilience_2022.pdf (accessed on 16 December 2022); (Chu et al., 2019[60]) *Unlocking the Potential for Transformative Climate Adaptation in Cities. Background Paper prepared for the Global Commission on Adaptation* https://gca.org/wp-content/uploads/2020/12/UnlockingThePotentialForTransformativeAdaptationInCities.pdf (accessed on 16 December 2022); (C40/McKinsey, 2021[61]) https://c40.my.salesforce.com/sfc/p/#36000001Enhz/a/1Q000000A9MA/ZOxO84.z876AUV3tsOFiauSxBcppcUFz0tqEr5xFz7g (accessed on 16 December 2022) (OECD, 2023[12])

Key elements to understand systemic climate resilience

The examples discussed in the previous section highlighted four underlying aspects that can help policy makers to understand the systemic nature of resilience in cities.

Interactions across different urban policy sectors

Complex interactions take place across policy and governance scales and often imply trade-offs between policy objectives. However, siloed policy responses tend to ignore the complexity of urban systems by designing and implementing measures that serve individual systems (e.g., transport, water management) instead of considering the interactions among them. Climate shocks can add more complexity and uncertainty to how different urban systems interact in cities. Systemic climate resilience in cities thus requires a better understanding of the interactions between various dimensions, enabling policy instruments to address multiple objectives together, generating synergies and co-benefits, and minimising trade-offs. For instance, cities should explore the interactions between the impacts of climate shocks and other societal challenges such as health, social marginalisation, or labour productivity. Proper identification of such interactions would allow cities to prioritize climate actions that also benefit other social objectives. For example, policies addressing extreme heat must prioritise reducing its impacts on workers, considering its adverse effects on labour productivity. Likewise, greening urban spaces can contribute to the resilience of cities to extreme weather, but also provide physical and health benefits. They can mitigate this risk by directly increasing air quality, through capturing, dispersing and depositing air pollutants. Green spaces can create oases of better air quality in highly polluted areas of cities allowing citizens to reduce their exposure to harmful chemicals (IEEP, 2021[62]).

Interaction across diverse actors

Complex interaction across systems in cities involves a wide range of urban and rural actors – not only governments – but also the private sector, civil society and local communities, city networks, among others. All of these actors are equally important, as they are both part of the problem and integral to the solution Co-ordination mechanisms for climate resilient planning and investment across multiple sectors and among national, regional, and local governments are often lacking or not clearly defined. For example, local communities are not always offered opportunities to engage with the initial stages of disaster risk management strategies and frameworks, although they are the first responders in the event of a disaster. This underlines the need for policy co-ordination to align goals and incentives across different levels of government and across society at large. Systemic resilience in cities requires diverse urban and rural actors to collaborate, identify and implement appropriate solutions to address the complex interaction of climate and other economic, social and health systems.

Direct vs. cascading and compounding impacts

Systemic resilience in cities means a better understanding of diverse types of impacts, in particular cascading and compounding impacts of climate change. Cascading impacts in cities are observed when a climate shock damages buildings and urban infrastructures and leads to a disruption of urban services such as transport, energy, water, and food provision, resulting in impacts that are significantly higher than the initial impact. Compounding impacts in cities are observed when a climate shock interacts with pre-existing inequalities and vulnerabilities of urban residents exacerbating the efects. For instance, when low-income households living in homes without adequate insulation are hit both by extreme cold weather and an increase in energy prices. As cascading and compounding impacts of climate change span over a wide range of policy areas, assessing each type of risk and identifying solutions to minimise the negative impacts is critical. This can help increase preparedness for diverse climate shocks and identify a set of effective adaptation and resilience policies.

Asymmetric impact across people and places

Climate shocks and their consequences are unevenly distributed across places (e.g., low-lying areas, urban centres) and people (e.g., vulnerable population groups). The impacts are extending beyond the administrative boundaries of individual cities. Systemic climate resilience in cities requires renewed appraisal of the scale at which climate shocks should be addressed and with which actors, and context-specific solutions supported by local data and evidence. Indeed, it also means a better understanding of the asymmetric climate impacts across urban, peri-urban, and rural residents (particularly the most vulnerable) to facilitate place-based and targeted responses to specific needs. For example, the effects of extreme heat are frequently more severe in cities because cities generate "urban heat islands" due to population density and a concentration of structures and materials that retain heat and a lack of natural surfaces that dissipate it. According to the OECD data, cities with more than 250,000 inhabitants are on average 3°C warmer than their surrounding areas, and some are even warmer by 5-7 °C (OECD, 2022[5]). The poorest neighbourhoods often have higher density, and lack shade, green space and ventilation, leading to higher peaks temperatures and insufficient night-time cooling. Developing resilience strategies at different geographical scales is thus crucial, including regional, metropolitan, local and neighbourhood scales.

Effective policy approaches to enhance systemic climate resilience in cities

Following the four inter-related elements that are essential for systemic climate resilience in cities, this section analyses six policy approaches that are considered as relevant in relation to the four-pronged policy framework. For each policy approach, the analysis focuses on the rationale (i.e., why such an approach can enhance systemic climate resilience in cities); what policy reforms can unlock the potential, and how it is being put in practice by OECD countries. Through desk research and the inputs collected through two international workshops, this study presents leading practices from OECD countries, regions and cities corresponding to each approach (Table 3.1).

Each policy approach is considered as relevant and effective to advance one or more specific key elements as shown in Figure 3.1. For example, 'developing joint climate actions among national and local governments' is relevant to enhance interaction across diverse actors, and 'expanding risk and vulnerability assessments to compound impacts' is relevant to addressing 'diverse types of impacts'. However, in many cases, one policy approach can contribute to several elements of systemic climate resilience in cities, as is explained below.

Table 3.1. Leading practices to build systemic resilience in cities in OECD countries

Country/city	Case	Brief description	Reference
Prioritise investment in integrated urban development benefiting multiple systems			
Canada	Disaster Mitigation and Adaptation Fund	The Government of Canada through the "Disaster Mitigation and Adaptation Fund" committed CAD 2 billion over 10 years to invest natural infrastructure projects to increase the resilience of communities that are impacted by natural hazards triggered by climate change. Cities such as Halifax, Toronto, Vancouver have benefited from investments in green infrastructure that enabled them to prepare for extreme heat and coastal flooding.	(Canada's Ministry of Environment and Climate Change, 2020[63])
Medellin (Colombia)	Medellin's Green Corridor Programme	Medellin (Colombia), 36 city-wide green corridors were built between 2016-2019 as part of Medellin's Green Corridors Programme ("Corredores verdes") to provide an interconnected 20-km network of shade by transforming 18 roads and 12 waterways into a green space. After its completion, the project demonstrated successful results: it helped reduce the average temperature by 3.5°C (from 31.6°C to 28.1°C) and the average surface temperature by 10.3°C (from 40.5°C to 30.2°C). The levels of PM2.5 were also reduced by 1.55 µg/m3 (from 21.81	(Agencia de Cooperación Internacional Medellín, 2019[64])

		µg/m3 to 20.26 µg/m3), thus leading to health benefits as the city's morbidity rate from acute respiratory infections decreased from 159.8 to 95.3 (per 1 000 people).	
Melbourne (Australia)	Strategies for green space	City of Melbourne (Australia) has advanced three complementary strategies to increase the green space in the city: Grey to Green, Urban Forest Strategy and Total Watermark – City as a Catchment.” Combined they have resulted in reduced carbon emissions, increased permeable surfaces thus reducing flooding risk, and increased tree species diversity – with a resultant increase in wildlife species.	(WEF, 2022[59])
City of Mulhouse (France)	Mulhouse Diagonales project	The City of Mulhouse (France) started an ambitious project of EUR 32 million in 2019 to restore and redesign 10 km of the riverbanks to benefit local biodiversity. The project aims to result in better quality of life for citizens as they will have increased access to green public spaces. To date, a dense forest, levelled and diversified, has been planted on 8 000 m^2 and a total of 24 000 trees from 40 local species that are growing to create a major carbon storage site and building a natural protection from traffic.	(OECD, 2021[19])
New York (United States)	High-line Park	The High Line Park in New York City (United States) is a public park built on a historic freight rail line elevated above the streets on Manhattan's West Side, to improve public space and bring nature. Half of the High Line’s plants are native species, selected for being drought-tolerant, low-maintenance and a source of food and shelter for wildlife.	(OECD, 2021[19])
Rouen (France)	Eco-district Luciline	In Rouen (France) the former industrial area “Luciline”, along the Seine River, has been fully re-designed into an eco-district (“éco-quartier” in French) covering 125 000 m2 where a mix of green and blue infrastructures are improving drainage from the built environment, and generating groundwater geothermal energy to cool homes in summer, and heat them in wintery, thus reducing energy demand from residential buildings.	(OECD, 2021[19])
		Develop joint climate actions among all levels of government	
Basel (Switzerland)	Green Roof Strategy	The City of Basel (Switzerland) has been implementing a green roof strategy to increase the surface of green roofs to prepare and respond to urban flooding and urban heat island effects, offering a myriad of benefits in energy saving, climate adaptation and biodiversity. The city used both financial and regulatory schemes to actively promote green roofs. In the early 1990s, Basel implemented a law that required 5% of all customers’ energy bills to be put into an Energy Saving Fund. The Federal Department of Environment and Energy then decided to use the funds to promote the installation of green roofs. In 2002 (and reinforced in 2010), an amendment to the City’s Building and Construction Law stipulated that all new and renovated flat roofs must be greened. The Federal government also contributed to the implementation of green roofs measures in Basel. First, the Department of Environment and Energy conducted a poll with the Swiss population and created the enabling environment to provide financial incentives to increase roof coverage. Second, the government has been the main funder for research that aims to measure the benefits of green roofs in terms of biodiversity and in climate change. Thanks to such multi-level efforts, it is estimated that around 40% of roof surface in Basel is green, allowing the city to have the largest area of green roofs per capita in the world.	(Climate Adapt, 2021[65]) (Network Nature, n.d.[66])
Region of Flanders (Belgium)	Local Climate and Energy Pact	In 2021, the Flanders Regional Government (Belgium) created the Local Climate Pact (LEKP). The initiative currently involves 293 municipalities – representing 98% of the municipalities in the Flemish region – and is based on 4 main pillars (nature-based solutions, energy efficiency and renewable energy, urban mobility, and water management). The Pact aims to reduce the CO_2 emissions of the territory by 35% – the initial milestone – and 55% (aligned with the European goal). The Pacts sets concrete goals by 2030 including: one tree per inhabitant; 50 collective housing renovations per 1 000 housing units; one charging point for electric vehicles per 100 inhabitants; and 1 m3 rainwater collected per inhabitant.	(Vlaanderen, 2022[67]) (NetZeroCities, 2022[68])
Germany	Competence center for climate impacts and adaptation (KomPass)	In Germany, the German Environmental Agency (UBA) created a Competence center for climate impacts and adaptation (KomPass) to develop the German Adaptation Strategy (DAS) and promote its implementation. One of the main components of this work, is to establish a database of climate studies to inform sers about the state of knowledge of the expected effects of climate change in Germany. The platform can be accessed by anyone interested in climate research, including public officials from subnational governments wishing to use these studies in their adaptation plans and strategies.	(Umwelt Bundesamt, 2023[69])

Netherlands	Climate Adaptation City Deals	In the Netherlands, the former Ministry of Infrastructure and Environment (currently Ministry of Infrastructure and Water Management) hosted between 2016 and 2021 the Climate Adaptation City Deal. The initiative facilitated a collaboration between different stakeholders including civil society organisations, universities, private companies, and local governments to design innovative solutions to climate adaptation in cities. The initiative benefited several cities including The Hague, Amsterdam, Eindhoven, Dordrecht, Rotterdam, Breda, Zwolle, Amersfoort, Deventer, and Groningen, where different physical but also capacity-related activities were tested including permeable pavements to avoid risk flooding, and "water coaches" to inform house owners about water conservation methods.	(Kennisportaal Klimaatadaptatie, n.d.[70])
United Kingdom	Green Infrastructure Framework for England	In 2022, the United Kingdom – through Natural England (an executive non-departmental public body) – launched its new Green Infrastructure (GI) Framework for England, to support cities to meeting the requirements of considering green infrastructure established in the 2021 by the National Planning Policy Framework. The framework consists of five interlinked components: GI Principles, GI Standards, Mapping Database, Planning and Design Guide and Process Journeys. These aim to support local authorities wishing to develop green infrastructure policies, plans and strategies. It also provides practical guidance on how to plan and maintain GI to deliver multiple benefits for people and nature. For example, it includes suggestions on the quantity, size, proximity, capacity, quality, accessibility, and type of GI. The local authorities can also access a publicly available data and maps to inform their strategies and plans.	(UK Government, 2021[71])
Engage local communities throughout the policy cycle			
Australia	Disaster Ready Fund	The Commonwealth Government of Australia through the Disaster Ready Fund (DRF) has committed up to AUD 1 billion over five years from 2023-24 to support disaster resilience and mitigation projects across Australia to ensure Australia is better prepared to withstand the impacts of disasters. Under Round One of the DRF, AUD 200 million in Commonwealth funding is being invested in 187 projects to reduce risk and improve the resilience of communities against a range of natural hazards, including almost AUD 65 million for 74 infrastructure projects, almost AUD 84 million for 74 systemic risk reduction projects, and over AUD 51 million for 39 projects that will deliver both infrastructure and systemic risk reduction outcomes. Funding is being matched by state and territory governments and other project proponents, where possible, providing a combined investment of nearly AUD 400 million in disaster risk reduction initiatives across Australia in 2023-24.	(Australian Government National Emergency Management Agency, 2023[72])
United States	Community Development Block Grant Disaster Recovery (CDBG-DR)	In the United States, the Community Development Block Grant Disaster Recovery (CDBG-DR) is a grant fund to rebuild disaster-impacted areas and provide crucial seed money to start the long-term recovery process. The programme focuses on ameliorating inequity in disaster recovery processes by actively involving people who have been historically underserved, marginalised, and adversely affected by persistent poverty and inequality, and prioritising their needs throughout the planning and implementation. Citizen participation sits at the core from the very beginning in both the planning and launch phases of recovery.	(U.S. HUD, 2023[73])
Expand risk and vulnerability assessment to cascading and compounding impacts			
Copenhagen (Denmark)	Climate Adaptation Cloudburst Management Plans	The City of Copenhagen (Denmark) has a long history in climate adaptation and resilience planning that has transformed the city into one of the greenest cities of the world. In 2011, the city launched its Climate Adaptation Plan which assessed and proposed strategies for the management of cloudbursts and other climate socks. One year later, the city launched the Cloudburst Management Plan in response to the massive flood that affected the city in 2011. The plan went beyond the Climate Adaptation Plan and identified a threshold of 10 cm, as the maximum acceptable level of flood water level. Based on this, the city conducted a cost-benefit analysis for various scenarios to identify the gains of implementing adaptive measures.	(City of Copenhagen, 2012[74])
Paris (France)	Paris' Resilience Strategy	In 2017, the City of Paris (France) launched its Resilience Strategy, which identifies six priority challenges that includes climate (e.g., flood, heatwaves), but also other urban challenges including social and spatial inequalities and security. In October 2022, the city started a process to review the strategy by reviewing the level of implementation of the actions set in 2017. As part of the process, the city is working on several parallel products that will inform the renewed strategy including a few studies exploring the spatial distribution of the	(Mairie de Paris, 2022[75])

		impacts of climate shocks, and the socio-economic consequences of water stress (supported by the OECD).	
Rotterdam (Netherlands)	Resilience Strategy (2022-2027)	In 2022, the City of Rotterdam (Netherlands) launched its second Resilience Strategy for the next 5 years. The city has broadened the scope from climate resilience and proposes interconnected interventions to address ecological resilience (biodiversity crisis), energy resilience, social resilience, economic resilience, and digital resilience.	(City of Rotterdam, 2022[76])
Develop climate adaptation and resilience strategies at the metropolitan scale (functional urban area)			
Helsinki (Finland)	Adaptation strategy for the Helsinki Metropolitan Area	The City of Helsinki (Finland) has actively planned adaptation and resilience at the metropolitan scale. In 2012, the Helsinki Metropolitan Area was one of the first cities in the world pulling together an adaptation strategy with inputs from the four cities of the metropolitan area (Helsinki, Espoo, Vantaa and Kauniainen) and with the support of the Helsinki Region Environmental Services Authority (HSY). More recently, the actions set by the strategy were updated as part of the Sustainable Urban Living Programme (prepared between 2019-2021).	(HSY, 2022[77])
Metropolitan Area of Barcelona	Climate and Energy Plan 2030	In 2018, the Metropolitan Authority of Barcelona (Spain) launched the Climate and Energy Plan 2030. The plan proposes 43 adaptation measures, which include adapting buildings to extreme weather conditions, expanding green areas and improving ecosystem services. Its implementation spans across the 36 municipalities of the metropolitan area, covering an extension of 636 km^2 and a population of around 3.2 million inhabitants (one of the biggest metropolitan areas in Europe).	(AMB, 2018[78])
Metropolitan Area of Guadalajara	Agenda for Water Resilience	In 2023, the Guadalajara Metropolitan Region (Mexico) launched its Agenda for Water Resilience for the Metropolitan area. The strategy was designed collectively by the nine municipalities that compose the metropolitan area, covering an extent of 742 km^2, which is the second biggest metropolitan area of the country. The strategy combines actions at the drainage basin and urban area scale and identifies a set of projects to increase water resilience. It aims to strengthening water management, so that it can face the effects of climate change and the socioeconomic challenges that put at risk the sustainable access of the population, the agricultural sector, and industry to water resources	(IMEPLAN, 2022[79])

Source: Author's elaboration based on the references listed in the right column.

To enhance interaction across different urban policy sectors

Prioritise investment in integrated urban development benefiting multiple systems

The first policy approach is to prioritise investment in integrated urban development that can bring benefits to multiple systems. Integrated urban development implies a comprehensive and coordinated approach to planning, designing, and managing urban areas. This approach considers social, economic, environmental, and spatial considerations and requires the design and implementation of cross-sectoral solutions. Integrated urban development, as opposed to sectoral urban development, can better address multiple policy objectives, generate co-benefits, and manage complex trade-offs. It can often identify hidden complementarities across sectors. For example, addressing both climate mitigation and adaptation measures in a single, integrated urban development is likely to receive more political support and cost less money compared to implementing separate mitigation and adaptation measures. This can be promoted by the implementation of nature-based solutions and urban regeneration programs, which are typical examples of integrated urban development addressing climate resilience in cities while pursuing co-benefits in several systems. An illustrative example can be seen in Melbourne (Australia) where the city government has implemented three interrelated strategies aimed at enhancing the green spaces within the urban environment. These strategies, namely "Grey to Green," "Urban Forest Strategy," and "Total Watermark – City as a Catchment," collectively contributed to a series of positive outcomes. These include a reduction in carbon emissions, the expansion of permeable surfaces which mitigates the risk of flooding, and a notable increase in the diversity of tree species. Another relevant example of the benefits that can be achieved by the expansion of urban green areas can be found in the City of Medellin (Colombia). Between 2016 and 2019, the city undertook the construction of 36 city-wide green corridors. These corridors were designed to establish an interconnected network spanning 20 km transforming 18 roads and 12 waterways into a green space. This intervention yielded significant outcomes, marked by a noteworthy reduction in heat island intensity. The average ambient temperature saw a decline of 3.5 °C (from 31.6°C to 28.1°C), and the average surface temperature experienced and even more substantial drop by 10.3°C (from 40.5°C to 30.2°C) (Agencia de Cooperación Internacional Medellín, 2019[64]) (IGES/AD-PLAT, n.d[80]).

Cities need to find the appropriate financial arrangements to invest in integrated urban development. In this regard, the OECD Compendium of Financial Instruments for Subnational Climate Action[1] can provide national and subnational government with inspiration on the possible financial arrangements used in support to climate action. It provides an overview and analysis of some climate-related public revenue sources provided to subnational governments from national governments, and state governments in federal countries, including grants, climate funds and loans.

To enhance interaction across diverse actors

Develop joint climate actions among all levels of government

Aligning climate adaptation policies across levels of government is not enough to build systemic climate resilience if it is not complemented by concrete implementation actions engaging both national and subnational governments. A key policy option is to establish governance arrangements to foster the collaboration between national and local governments (and other relevant stakeholders) to develop joint climate actions, for instance in the form of partnerships, contracts, or joint programmes. Capacity building and financing are two major areas that needs to be exploited in such governance arrangements. They can be used to share lessons among different cities about their experiences in implementing local climate adaptation and resilience strategies, but also transferring financial resources for the development and implementation of new local adaptation plans, thus strengthening local capacities. One illustrative example is the Green Infrastructure Framework for England (UK) adopted in 2022. This initiative was launched to help urban policy makers to fulfil the obligations outlined in the National Planning Policy Framework of 2021, which emphasized the inclusion of green infrastructure. Comprising five interconnected elements—GI Principles, GI Standards, Mapping Database, Planning and Design Guide, and Process Journeys—the framework aims to assist local governments in shaping green infrastructure policies (UK Government, 2021[71]). Another example can be observed in The Netherlands, where the Ministry of Infrastructure and Environment (former Ministry of Infrastructure and Water Management) hosted the Climate Adaptation City Deals initiative from 2016 to 2021. This initiative aimed to foster cooperation among different local organisations including NGOs, universities, business, and local government agencies. The objective was to jointly develop innovative strategies for climate adaptation in urban areas (Kennisportaal Klimaatadaptatie, n.d.[70]).

Engage local communities throughout the policy cycle

Systemic resilience requires engagement from a wide range of stakeholders, in particular local communities to help governments identify specific needs and target/adapt policy responses more effectively. It can also help them to draw on community knowledge, including from vulnerable groups that may be disproportionately affected by policy measures pursuing city resilience. In practice, this means utilising the appropriate communication strategies such as awareness raising campaigns or participatory designing of activities to communicate the project impacts and trade-offs in a transparent manner and develop trust and confidence with citizens. Community engagement can also help identify potential trade-offs of policies and inform placed-based responses. For example, conservation measures often require

[1] For more information: https://www.oecd.org/regional/compendiumsubnationalrevenue.htm

the introduction of land use regulations to eliminate risks and exposure of people to specific climate hazards, requiring the relocation of residents, businesses, and infrastructures. This needs to be informed in a transparent manner to affected communities. Against this backdrop, participatory approaches are valuable to guide national and local adaptation planning and implementation. When securing citizens/community participation in adaptation and resilience planning, governments can also collect relevant information, and build a sense of ownership and obtain community support. Such engagement can also increase the awareness of local communities and enhance the preparedness for climate impacts. An illustrative example can be found in the United States, where the Department of Housing and Urban Development (HUD) is handling the *US Community Development Block Grant Disaster Recovery*. Through these funds, various states, cities, and counties receive flexible grants that they tailor to aid their recovery efforts following disasters. The allocated funds empower the recipients to take charge of designing and executing recovery initiatives that effectively address the unmet needs arising from the disasters. A key aspect of this approach is ensuring the inclusion of low-income residents throughout the process. To do so, the HUD developed two toolkits to enhance citizens participation processes (U.S. HUD, 2023[73]; U.S. HUD, n.d.[81]; HUD, n.d.[82]).

To address cascading and compounding impacts

Expand risk and vulnerability assessment to cascading and compounding impacts

Climate and urban development policies need to be better equipped to address growing uncertainty underlying local climate risks. This requires assessing all dimensions of climate risks, including how they are cascading and compounding to other climate and non-climate risks and across different geographical scales with robust local data and evidence. In turn, this can help policymakers set their policy priorities and design and implement their climate action more effectively. However, in practice, although climate risk and vulnerability assessments are increasingly becoming a common exercise at the city level, such assessments are not always covering different systems (e.g., economic, social) or to different geographical scales (e.g., regional, national, and international). Against this backdrop, some cities are using systems approaches to expand the scope of their resilience strategies beyond climate risks with increased focus on economic, social and energy challenges, which can pave the way to more comprehensive risk assessments in the future that considers both cascading and compounding impacts. For example, in 2022, the City of Rotterdam (Netherlands) unveiled its second Resilience Strategy, outlining its strategic direction for the upcoming five years. This comprehensive strategy marks a notable expansion in scope, transitioning beyond the singular focus on climate resilience. Instead, it introduces a systemic approach encompassing a spectrum of interconnected interventions aimed at tackling various facets of resilience. This new strategy aligns with Rotterdam's commitment to not only enhance climate resilience but also to address pressing challenges related to ecological, energy, social, economic, and digital resilience (City of Rotterdam, 2022[76]).

To address asymmetric impacts across people and places

Develop climate adaptation and resilience strategies at the metropolitan scale (functional urban area)

Urban and rural areas are spatially and functionally interconnected and dependent on each other (e.g., labour market, production and consumption of food and energy, water management, environmental amenities), implying the impacts of climate change may also span administrative boundaries and geographic realities. Leveraging the spatial continuity and functional relationships between urban and rural areas is thus a key strategy to build systemic climate resilience. This can be promoted by developing climate adaptation and resilience strategies at the metropolitan scale, which remains scarce in practice. Metropolitan governance arrangements would help to align policy objectives, draw on economies of scale and build on existing strengths and assets. This can be incentivised from different scales, from national to local. At the national level, government agencies can implement policy reforms to promote metropolitan governance, while at the local level, cities can adopt a functional urban area approach and develop resilience strategies at the metropolitan level to leverage the spatial continuity and functional relationships between urban and rural areas). In Federal countries, the regional/state governments can also guide promote and regulate metropolitan governance. For instance, the State of Jalisco (Mexico) adopted the Agenda for Water Resilience for the metropolitan area of Guadalajara spanning across nine municipalities within the metropolitan area, harmonising actions in the drainage basin and in urban areas, covering an extension of 742 km^2, which is the second biggest metropolitan area of the country. The strategy aims to strengthening water management, so that it can face the effects of climate change and the socioeconomic challenges that put at risk the sustainable access of the population, the agricultural sector, and industry to water resources (IMEPLAN, 2022[79]). Similarly, the Metropolitan Area of Barcelona adopted in 2018 the *Climate and Energy Plan 2030*, encompassing action for the 36 municipalities that compose the metropolitan area and covering an extension of 636 m^2 and a population of around 3.2 million inhabitants (AMB, 2018[78]).

Localise National Adaptation Plans and Strategies

National Adaptation Plans and Strategies (NAPs/NASs) provides a framework for countries to identify climate shocks and prioritise climate adaptation actions, strategies, and policies. However, given the roles subnational governments can play in implementing NAPs/NASs, aligning climate action across levels government is crucial. National governments can use the NAPs/NASs to engage regions and cities in the definition of climate adaptation priorities. They can use the existing local adaptation and resilience plans (when available) to understand the local needs and priorities. Moreover, they can create governance mechanisms to interact more proactively with cities in the adaptation planning, monitoring and evaluation of adaptation goals. For example, since monitoring and reviewing progress on adaptation span across sectors and levels of government, NAPs can create a dedicated team within the national agency or designate contact person responsible for informing and supporting the development of adaptation goals to cities, which in turn can also help to understand progress from different perspectives.

Some countries have recognised the role of cities in climate adaptation and put emphasis on multilevel governance aspects in their National Adaptation Plans and established coordination mechanisms with subnational governments. For example, the Government of Ireland created Climate Action Regional Offices to support cities for the design and implementation of local adaptation plans and mainstream adaptation considerations into local and regional policy frameworks.

Other countries have made explicit references in their national adaptation strategies to the importance of subnational governments' climate action such as risk-sensitive land use planning and infrastructure investment for flood-protection, which can pave the way for a more collaborative implementation of NAPs/NAS between national and subnational governments. For instance, Australia's National Climate Resilience and Adaptation Strategy 2021-2025 underscores the pivotal role played by subnational governments in terms of spatial planning and investments in public infrastructure (Government of Australia, 2021[83]).

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