Extended version: *Global Research and Action Agenda on Cities and Climate Change Science*

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Cities have the potential to be major catalysts of change in the implementation of recent international agreements such as the Paris Agreement, the 2030 Sustainable Development Agenda, the New Urban Agenda and the Sendai Framework for Disaster Risk Reduction. Actions to address climate change through adaptation and mitigation at the city level will make crucial contributions to the national efforts aimed at fulfilling international commitments. **The role of cities in addressing climate change is especially important within the context of urban population expansion, which is expected to result in 68% of the world's population living in cities by 2050** (UN DESA 2018).

Laying the foundation

At the 43rd Session of the IPCC in Nairobi, the IPCC recognised the key role of cities in the global response to climate change and proposed that the seventh assessment cycle include a Special Report on Climate Change and Cities.

To stimulate knowledge exchange, and the production of evidence-based reports and peer-reviewed publications on cities and climate change, at its 44th Session in Bangkok the IPCC approved a proposal for the co-sponsored International Conference on Climate Change and Cities (renamed and branded Cities and Climate Change Science Conference - CitiesIPCC for communication purposes), which was subsequently held in Edmonton, Canada, from the 5–7th March 2018. The aim of the conference was to assess the current state of academic, policy and practice-based knowledge on cities and climate change, and to identify key gaps to inspire research and the development of knowledge in critical areas.

The Conference was co-sponsored by multiple international groups, Cities Alliance, C40, Future Earth, ICLEI-Local Governments for Sustainability, Sustainable Development Solutions Network (SDSN), United Cities and Local Governments (UCLG), United Nations Environment Programme, United Nations Human Settlements Programme (UN-Habitat) and the World Climate Research Programme (WCRP). Conference participants represented 64 countries and all six continents, 32% of which were from the Global South and 49% of which were women. Science, policy and practice communities were all present, distributed as 46% academia/research, 21% urban practitioner, 20% policy and 13% other. Private sector and civil society organisations were under-represented in general.

More than 700 academics, leaders, innovators and influencers attended this landmark conference providing insights that informed and shaped this co-produced *Global Research and Action Agenda on Cities and Climate Change Science*. The breadth of information presented at the Conference spoke to the significant amount of work that has already been achieved by the scientific, urban practice and policy communities to address climate change in cities. The high level of interest in attending the conference and subsequent constructive debate and discussion during the conference highlighted the strong willingness for collaboration between these communities. Furthermore, the diversity of conference participants ensured a strong move towards more balanced and robust collaboration, which will help to catalyse evidence-based research, funding and knowledge sharing,

and to prepare the groundwork for the Special Report on Climate Change and Cities, which will be produced during the IPCC's Seventh Assessment Cycle.

To build the *Global Research and Action Agenda on Cities and Climate Change Science,* the SSC (see full list Annex D), with support from co-sponsoring organisations, compiled and synthesised input from all conference plenaries, parallel sessions, posters, pre-conference commissioned papers, and discussions during the conference, regarding knowledge gaps and key recommendations.[1] This information was synthesised to shape this Research and Action Agenda by the SSC, with contributions from co-sponsoring organisations and external experts (see authors list, Annex A), who represented diverse disciplines, perspectives, and areas of expertise. Examples used throughout this agenda were discussed at the Conference and are meant to be illustrative. In no way are they meant to be prescriptive or representative of all examples or best practices in the field.

The Conference and the resulting Research and Action Agenda can be considered steps in a longer journey to explore the opportunities offered by evidence-based knowledge in helping address challenges associated with climate change in urban areas. Experience from cities with diverse and distinct characteristics including size (small, medium, large and mega cities), growth patterns (rapidly expanding, sprawling, or stagnating), geography (coastal, dryland, highland, etc.) and contexts (Global North, Global South, high income, high inequality, etc.) were represented at the Conference. The Research and Action Agenda is meant to be applicable across these variations, however it is clear that some aspects may be more relevant for certain cities and countries. Note that the agenda enriched and expanded on the six research priorities identified by Bai et al. (2018) in the course of preparation for the Conference.

This document aims to serve and support national governments, local and municipal authorities[1], researchers and scientists, the planning and design communities, private sector enterprises, international organisations (including international cooperation and development banks) and civil society including indigenous peoples, in developing blueprints and action plans for developing new evidence-based research and knowledge that supports effective climate action strategies in cities. This document signposts key issues that will require research to help guide effective policy development for climate action in cities.

This ambitious agenda attempts to be holistic, inclusive, responsive and solution oriented. It seeks to enable co-design and co-production of knowledge, to encourage system-based approaches, and to highlight the importance of urban processes in facilitating a global climate change response.

The *Global Research and Action Agenda on Cities and Climate Change Science* is organised into three sections: 1. crosscutting issues and knowledge gaps; 2. ley topical research areas; and 3. suggested approaches to implement the Research and Action Agenda. The structure of the Research and Action Agenda is illustrated in Figure 1.

[1] A compilation table of some of the major points, knowledge gaps and recommendations, and their links to the sections of this document will be included in the full report to IPCC.

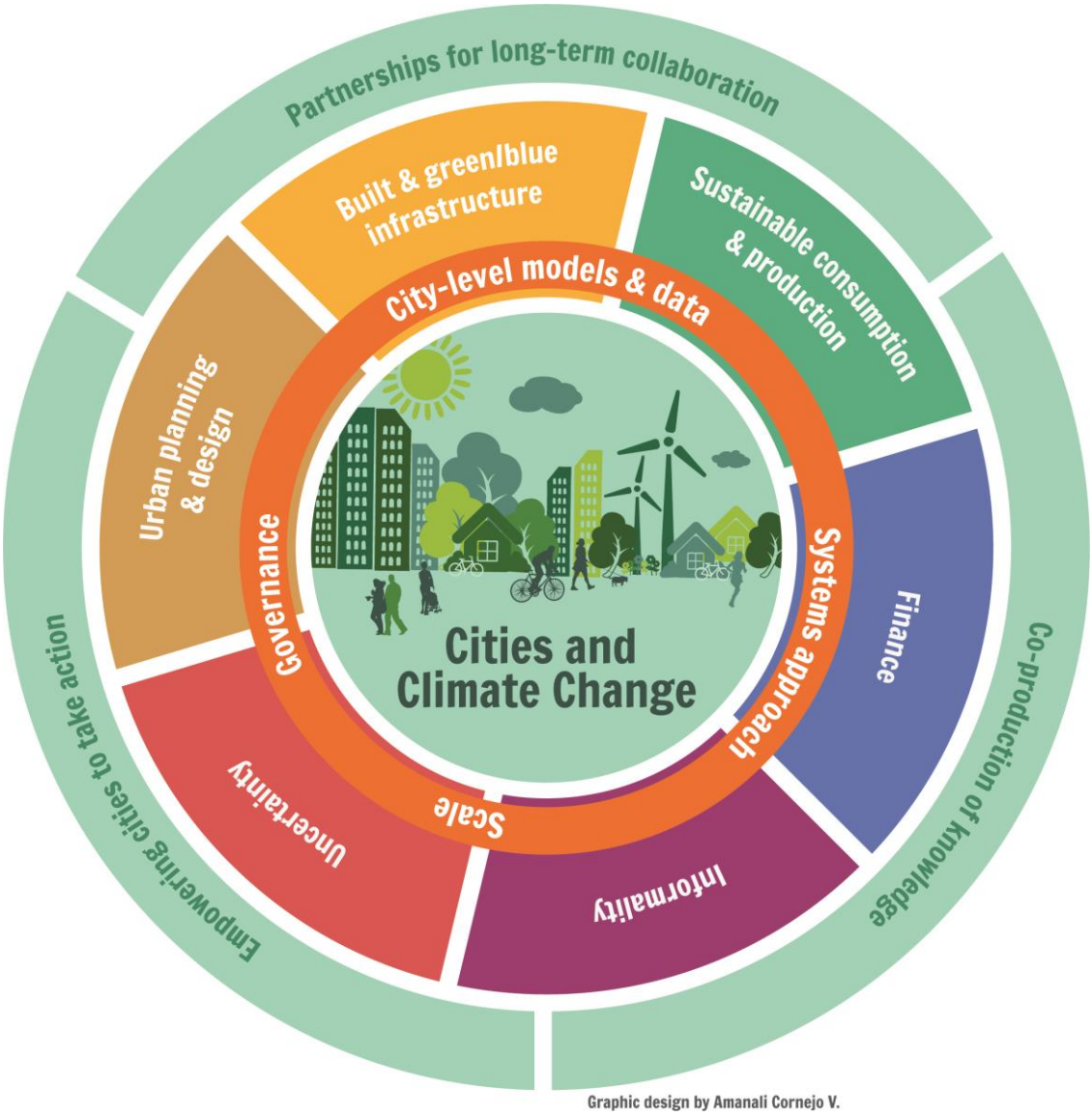

Figure 1. Pathways for climate adaptation and mitigation in cities

This figure presents the structure of the *Global Research and Action Agenda on Cities and Climate Change Science*. The inner circle (orange) presents key crosscutting issues and knowledge gaps for a step-change of knowledge generation on cities and climate change. The middle circle (multi-coloured) presents six topical research areas where more evidence is needed to inform action. The external circle (green) presents three suggested approaches that may facilitate implementation of this Research and Action Agenda.

1. Crosscutting knowledge gaps

The Conference highlighted a range of broad, crosscutting issues that underpin efforts to respond to climate change in cities, such as the capacity of local institutions, the interconnectivity of different sectors, the impacts of scale and data availability. For each of these foundational issues, there are knowledge gaps related to methodology and understanding that would benefit from better uptake of existing science and knowledge, new research and new perspectives.

1.1. Systems Approach

Taking a systems approach to explore solutions for cities is particularly important for climate change mitigation and adaptation strategies. A systems approach recognises the interaction and interdependent nature of cities within their regions and countries. Cities are open, complex, self-organising, adaptive and evolving formations that are embedded in broader social, ecological, economic, technical, institutional and governing structures. A systems approach allows various (possibly conflicting) issues to be addressed simultaneously, can help to create more balanced solutions, for example, by combining a climate change perspective (both adaptation and mitigation) with human, ecological, biodiversity and economic development factors, avoiding unsustainable development scenarios while meeting the needs of the disadvantaged. Traditionally, much urban research and action has taken place in various silos (either adaptation or mitigation, or limited to specific sectors, academic disciplines or policy-making units). As a result, many systemic opportunities and risks have been overlooked. Research identifying synergies and trade-offs between adaptation and mitigation in urban areas in different regions could create valuable precedents for urban areas seeking to create climate change agendas.

Knowledge is needed on how to use a holistic approach to capture and weave together or integrate diverse forms of knowledge and data from a wide range of sources and perspectives. Climate change is an extremely crosscutting societal issue. It influences and is influenced by such a vast range of factors, that it cannot be addressed with silo-style analysis. However, approaches to capture and integrate such diverse data sources as climate metrics, qualitative socio-economic data, informal knowledge (local, indigenous, traditional, feminist, social, political, community, etc.), collective intelligence, Big Data and experiential evidence on nature-based solutions, among others, are only beginning to be explored. Methods for protecting and promoting indigenous practices that have been used for generations when faced with environmental change and those which contribute to adaptation, also need to be included. Generating knowledge on societal transformation requires various facets of the problem to be integrated and considered simultaneously. More analysis is needed to improve knowledge in these research areas, which could lead to a step change in building options for climate action in cities and understanding implications of actions.

Systems knowledge is needed on important interactions, inter-dependencies and resource flows between natural, built and social systems, and between urban areas and the rural hinterlands. Oftentimes, mitigation and adaptation actions can compound each other. The potential co-benefits and synergies, as well as trade-offs, cancelation and carbon lock-in[3] effects of such actions, are increasingly recognised (Ürge-Vorsatz et al. 2018). With a systems approach, urban scale mitigation and adaptation are positioned in a broader spatial context, considering the flow of resources, energy and waste in and out of cities, and the associated environmental, economic and social impacts of cities on hinterlands, and *vice versa* (Delgado-Ramos and Guibrunet 2017). However, the complex interplay between urban systems (social, economic, political, geographical etc.) and between urban and peri-urban areas, as well as the broader regional effects, have not been described or explicitly mapped. Therefore, the impacts of various interventions cannot be predicted accurately. Future research using a systems approach offers a new way to understand complex causes and effects within and outside city limits when planning and implementing climate change adaptation and mitigation measures.

New methods need to be developed to incorporate integrative measures of valuation, bringing together quantitative, relational, distributional, behavioural and economic values[2] **to assess synergies, trade-offs and co-benefits and potential maladaptation between interventions the respond to climatic and non-climatic hazards.** A core challenge facing decision-makers is identifying and prioritising climate change interventions in specific contexts. Calculating costs, co-benefits and trade-offs is often difficult, because many components have no clear monetary value. The total and true 'value' of an action or intervention could be derived by, for example, assessing reduced mortality and morbidity, reduced energy consumption, protected biodiversity or infrastructure, the various benefits of nature-based solutions, socio-cultural well-being, cleaner air, etc. (e.g.,

[2] For a more detailed definition of these terms, see (Pascual et al. 2017).

Hallegatte et al. 2013; Masson et al. 2014; Lemonsu et al. 2015)). New systems-based valuation approaches need to provide and compare valuation of adaptation and mitigation actions, between various systems and regions, and within specific national contexts. Research in this direction could strengthen contributions to climate change action in urban areas.

Advancements in action-oriented research are needed, focusing on multiple impacts, assessing how uncertainty can be reduced, providing options for transformative climate action plans, and highlighting co-benefits for achieving the SDGs and other global agendas, within the context of rapid urbanisation. Rapidly growing and developing urban areas stand to reap long-term rewards from investing early in a systems approach when designing mitigation and adaptation strategies. Within a broader development framework, synergies and co-benefits of systems-based solutions for urban areas can help achieve many SDGs. Research is needed on how different SDGs and their targets interact and interface with other global agendas, in terms of possible co-benefits and trade-offs. Integrating and comparing targets pertaining to cities under different SDGs could allow for the development of possible optimal solutions to meet mitigation and adaptation targets within other global agendas (Sanchez Rodriguez et al. 2018). Further research using a systems approach is also needed that identifies maladaptive and mal-mitigative pathways and demonstrates possible alternatives. Considering climate change within a systems approach can also help avert compounded and aggregated risks of climate and non-climate hazards in cities. A systems approach is key in delivering the climate change agenda as well as the UN's New Urban Agenda, the SDGs (Bai et al. 2016) and the Sendai Framework for Disaster Risk Reduction.

1.2. Governance and Institutions

City governance of climate change is multilevel, multi-actor and multi-faceted. It is organised through formal and informal institutions operating across scales (from local and municipal authorities to national governments) as well as through networks and partnerships that operate within and between cities. While formal institutions can establish the legal and regulatory frameworks within which responses to climate change operate, governing climate change in cities also takes place through an array of interventions designed and implemented by non-state actors, including businesses, non-governmental organisations and communities. These actors are increasingly experimenting with ways to address this challenge in the context of their wider goals for sustainable development and social and environmental justice.

It is important to investigate the differential distribution of power among diverse actors, and how this shapes their capacity to act in response to climate change. Informal institutions, and their associated social practices, norms and path-dependencies, also structure the scope and nature of action on climate change in cities (see section 2.1 on Informality). Governance for climate change in cities is further complicated by limitations in human capacity, financing tools, urban planning and the application gap between policy and innovation, research and technology. Enabling policies and investments that foster capacity for cities to respond to climate change are critical.

There is a need to develop knowledge to understand the operational pathways and institutional structures for governance that effectively supports climate action in different urban contexts and that is inclusive of diverse priorities and voices in planning and decision-making. There will be no 'one size fits all' model of urban climate governance, rather a diversity of approaches is likely to apply in different contexts. Governance models will require the inclusion of diverse interests and voices in planning, decision-making, action and monitoring. They will also require recognition of the significance of path dependencies[2] which emerge from prior policy-making on issues as diverse as infrastructure, design and resource management. Additionally, generating knowledge on these path dependencies can demonstrate the constraints on climate resilient and equitable urban transformation, and on potential areas of vulnerability and risk.

Knowledge is needed on different forms of governance, including multilevel governance, that can best support climate action across a highly uneven institutional landscape. Existing evidence points to the importance of building governance capacity. Different institutions and actors have highly uneven access to the knowledge, resources and power required to engage with the climate change challenge. Cities in the Global South experience a significant deficit in governance

capacity compared to those in the Global North, with small and mid-size cities having even more asymmetrical governance capacities compared to large cities or capital cities in the same country. Multilevel governance arrangements for political and financial decision-making, long-term continuity and inter-municipal collaborations, as well as joint efforts between research institutions, decision-makers, practitioners and transnational city networks, are all potentially key factors. More evidence is needed to understand the impacts and effectiveness of different forms of governance, to solve tensions and reduce trade-offs, negotiate business practice and information use and create enabling conditions for effective city-based action.

Deeper understanding is needed of how transformative climate change responses can address urban inequalities and ensure inclusive modes of governance. Knowledge generation could shed light on how the capacity to act on climate change is distributed and on how political-economic structures, struggles and conflicts shape climate responses of public and private actors. It could also further understanding, and promote incorporation of the diverse perspectives of those often excluded from decision-making processes (including women, indigenous peoples, youth, minorities, economically or otherwise disadvantaged groups and people with disabilities). Addressing adaptation and mitigation at the urban scale raises significant questions of inclusiveness in these processes for current inhabitants and future generations, and thus on desirable urban futures.

1.3. Scale

All aspects of climate change risk, impact, vulnerability and response options are influenced by scale and scale interactions. The role of spatial (including different levels of governance) and temporal scale can have profound implications. The benefits of climate strategies implemented in the short-term might be different in the medium and long-term contexts. One of the major challenges is that actions and effectiveness of those actions at the local (city/neighbourhood) scale are influenced by decisions made at other scales (e.g., provincial/state, national, global). For example, national governments may set policies for transportation and economic development that influence investments in cities. Knowledge generation on the interplay of scale in the context of climate change would allow for more informed decision-making processes for urban areas and entities including neighbourhoods, municipal jurisdictions and metropolitan regions.

To inform integrated action, new knowledge and data are needed that are comparable across spatial scales and regions while remaining meaningful at the local scale. For instance, local weather or air pollution data are not easily translated into, or integrated with, long term and large-scale climate or emissions data (see also section 1.4 on data, modelling and scenarios). Local city or neighbourhood scale data can not necessarily be extrapolated to another region, context or spatial scale. Similarly, global and regional means tend to hide extreme local variability. This can hamper local and national planning, large-scale modelling and global assessments, and therefore data comparable across spatial scales could facilitate action.

New knowledge is needed to increase our understanding of the interplay between policies and actions taken at different scales, and how this affects the ability to take effective and coordinated climate action at the city scale. There is a need to develop further knowledge on the implications of multi-scale issues and decisions on effects of climate change at the urban scale. Currently, information on impacts of the changing climate tend to be available only in broad terms, with no clear consideration of scale. Expanding our knowledge on the interactions of decisions at multiple scales and the direct implication of these interactions for cities could allow local authorities to be responsive or proactive to decisions being made at other scales and informing better policies at the national level. In terms of vulnerability to hazard, for example, individuals may experience a hazard (e.g., flood or drought) as a threat to their health and livelihood, which in turn will depend on the specific individual and community capacities to respond (access to resources, basic services and information, relational capacities, etc.). The same hazard may exert a strain on essential services and management structures at the subnational level, impact the national budget at the country level, and lead to migration and conflict at the regional level.

Further collaboration between urban stakeholders and researchers to produce knowledge, data and information that is responsive to the temporal scales relevant to cities. Various climate

change patterns and events, natural systems, human systems, global agendas, national administrations, funding cycles, research agendas, municipal action plans, industrial systems and so forth, each operate on different time scales. This makes the planning, implementation, financing, monitoring and evaluation of adaptation and mitigation activities difficult. It is desirable that cities act in the most efficient and integrated manner possible, and therefore there is a need to develop new ways for cities and climate change science to work together with innovative, flexible and iterative processes to develop and implement solutions at the local level.

1.4. Observation, Data, Modelling and Scenarios at the City Level

To fully understand how cities impact, and are impacted by, climate change it is important to have observations, models and scenarios at relevant spatial and temporal scales. The need for more urban scale observations has been well argued in the urban climate literature (see, for example, (Grimmond et al. 2010; NRC 2012; Henderson-Sellers et al. 2012). Critical knowledge gaps exist relating to downscaling climate projections to the most local levels, as well as on how to improve confidence in future local projections (also see Section 2.6 on Uncertainty), with particular dearth of data in the Global South. Providing information that is spatially and temporally relevant to city-level actors requires the development of a new observation framework, advances in climate modelling and evaluation, and the development of scenarios at the city scale.

There is a need for an international and open-access observational framework for collecting key climate and socio-economic metrics at the city scale. Currently, both climate and socio-economic data remain scarce at the city and neighbourhood scales, particularly in the Global South. Climate-related metrics (such as emission factors and activity data, air quality, temperature, precipitation, soil moisture), socio-economic metrics (such as demography, income, informality, economics, architecture, health, mobility, consumption budgets), city-relevant data (such as state of infrastructure and services) and biophysical data (such as ecosystem services, geological and hydrological) often have insufficient resolution to be useful at the local level. This represents an important obstacle in improving and expanding knowledge generation. Future research efforts could consider creating an international city-scale observation framework capable of providing data on key metrics, which could be useful for informing the implementation, evaluation and adjustment of mitigation and adaptation strategies in urban areas.

Improving modelling capabilities is key to producing higher resolution data, predicting near term climate futures, and producing models that are customisable to specific cities. Key challenges for achieving the above-mentioned improvements are the required advances in modelling methods, increased computing power, data collection and storage needs. These advances can build on the substantial progress made over recent decades by the urban climate research community into developing micro- to neighbourhood-scale models and comprehensive evaluation research programmes documenting impediments to improved model performance (Best and Grimmond 2015).

Suggested advancements include better spatial and temporal resolution, and integration of local geography. The current suite of global climate models produces outputs at spatial resolutions that are not fully applicable to cities. This suggests a need for improved downscaling methods. Cities across the world also vary greatly in terms of specific geographical features, requiring models to be parameterised to include specific geomorphologies.

Societal actors also request information on the effects of climate change at the city scale in the near term, whereas climate projections focus on the mid- or long-term. Modelling methods to develop near term climate information would be strengthened by a stronger emphasis on the specific needs at the city scale.

Future climate scenarios need to incorporate transdisciplinary approaches that integrate sociological, economic, climatic and ecological features applicable at the city scale (and that are informed by a range of expertise including indigenous knowledge and local knowledge), is crucial for scientific advancement. Scenarios often rely on many assumptions related to social factors such as urbanisation, demography, economics and innovation. For example, at the global scale, the Shared Socio-Economic Pathways were developed to encompass a plausible range of qualitative narratives regarding demographics, urbanisation, human development, economy and

lifestyle, policies and institutions, technology, environment and natural resources (O'Neill et al. 2014). Further research is needed focusing on new modelling methods that allow for assumptions and starting parameters to be scalable, based on actual local data. This would reduce the uncertainty in future scenarios and would make outputs more relevant and reliable in informing local city action, especially if climate and socio-climate metrics were to be monitored and modelled continuously at the city scale.

Research is needed on the effect of, and the dynamics between, adaptation alternatives for coastal cities. Complex and dynamic feedback systems can result in seemingly intuitive infrastructure solutions resulting in maladaptation. The complexity of coastal systems and islands impedes the development of wave impact and flood modelling and other relevant models and scenario simulations for coastal cities. Increasing understanding of these aspects could lead to better adaptation strategies. The impacts of sea level rise and other effects are distributed unequally across cities' populations, often concentrated in regions with existing social vulnerability. Co-producing models that integrate indigenous knowledge, local knowledge, marine, terrestrial and social research will therefore be essential for mapping the challenges faced in coastal cities due to climate change.

2. Key topical knowledge gaps

This section presents topical research areas where the availability of more evidence-based knowledge would support practitioners and decision-makers in addressing specific city-level challenges arising from climate change.

2.1. Informality

The way in which informal settlements[4] and the informal economy operate, and the ways in which governments respond to these, have significant implications for adaptation and mitigation. Informal settlements are urban settlements or neighbourhoods that have developed outside formal systems regarding land ownership, land tenure and a range of regulations related to planning and land use, built structures, health and safety. Informal settlements do not always occupy land illegally, but rather informality may arise from subsequent sub-divisions or sublets, which do not meet formal standards. Climate change often affects the inhabitants of informal settlements most severely – the poorest, most vulnerable and marginalised populations in the city, generally with low per capita carbon footprints. Furthermore, differences in the capacity to mitigate carbon emissions and risks while adapting to both rapid and slow onset events (e.g., floods and droughts) depend on differences in socioeconomic status, which in turn can be exacerbated by growing levels of social inequality. More research is needed to understand informality in the context of climate change given the scale of the issue. The population living in informal settlements globally was estimated to be between 881 million and one billion in t2014 (UN Habitat 2017). A possible tripling in the informal population is foreseen (see http://mirror.unhabitat.org/content.asp?typeid=19&catid=10&cid=928) in the coming years given the high rate of informality in Africa and Asia and that 90% of the urban population growth up to 2050 is expected to happen in these two continents (UN DESA 2014).

Further understanding and research is needed on how inhabitants of both informal settlements and slums are particularly vulnerable to the effects of climate change. Informal settlements are frequently located on land that is exposed to climate-related hazards (particularly riverine flooding and sea-level rise). This coupled with poor infrastructure, poverty and the limited adaptive capacity of most households, can create significant risks. Research could explore how informal settlements can be upgraded in ways that contribute to lower carbon and climate resilient lifestyles, at an affordable cost, particularly through retaining central locations that minimise energy use for travel, but also through the types of building materials employed. Decades of urban research studies document a progressive transformation of informal settlements into formal urban structure (Fernandes 2011). Research on these processes within the contexts of climate change could incorporate low carbon emission and resilience[5] strategies into this transition.

Research is needed to understand the extent and nature of the challenges posed by, and to provide evidence for policy interventions on informality that simultaneously respond to

climate change and *vice versa*. Informality is, and will remain, one of the defining features of many cities. In many countries around the world, especially in the Global South, most of the urban population lives in informal settlements and most of the workforce operates in the informal economy (Mitlin et al. 2018). This presents significant challenges in responding to climate change, as most of the approaches to mitigation and adaptation assume the existence of formal legal and planning mechanisms to create economic, social and behavioural change. At the same time, the characteristics of resourcefulness and flexibility that are demonstrated in informal settlements and economies hold the potential for rapid transformation to lower-carbon and more resilient human settlements. Developing knowledge on experiences from informal settlements and economies would also contribute to inclusivity and more efficient adaptation strategies.

Further research could investigate the relationship between climate change and the informal economy to understand how to increase adaptive capacity of informal sectors and how to scale-up low-carbon and climate resilient solutions from and for the informal sector. People whose livelihoods rely on the informal economy can be more vulnerable to climatic changes – for instance higher temperatures and extreme events – due to the lack of a regulatory framework and reliance on casual and intermittent employment. Developing knowledge and strategies for increasing adaptive capacity of informal businesses would reduce vulnerability. While some areas of the informal economy need low-carbon solutions to sustainably scale up business (such as sustainable energy to replace generators or reliance on biofuels), there are other sectors where current activity is already low-carbon in nature (e.g. waste pickers) and could be scaled-up to citywide level as part of a broader low-carbon strategy. For example, around the world, informal recycling businesses showcase positive environmental outcomes, which can be starting points for more expansive recycling initiatives (Delgado-Ramos and Guibrunet 2017; Botello-Álvarez et al. 2018). These activities could become more efficient through city-level adaptation and mitigation programmes and be integrated as an aspect of a citywide low-carbon transition.

2.2. Urban Planning and Design

Multi-dimensional urban planning is a crucial tool for addressing climate change adaptation and mitigation in cities, bringing together energy and transport sectors, inclusion of blue and green spaces and biodiversity, economic development as well as incorporating social and cultural contexts. Urban planning which integrates mitigation and adaptation should be inclusive of various kinds and sizes of settlements, and address the existing urban core, while remaining coherent with planning for the future city. The following research needs, and knowledge gaps can build on the significant and mature body of research from the urban climate research community. This research, and associated data and information, are important in linking urban scale climate science to the challenge of planning more sustainable cities.

Further development of more rigorous understanding and characterisation of the connections between urban planning, design and infrastructure and climate change mitigation and adaptation action is needed. While there is ample evidence, for instance, that urban form, density, mobility, land use and planning have strong implications on GHG emissions, there is little robust quantitative evidence and information on this relationship. Among others, models are needed that are better able to characterise the impact of urban form on emissions. Tools adapted to different contexts that can help urban planners understand the impact of different urban design options on emissions and implications for adaptation to climate change are also needed. Global mitigation scenarios need to incorporate urban planning better in mitigation options. Whereas different urban form for cities with similar climate, development status, wealth and population can result in an order of magnitude difference in per capita emissions, the implications of these choices for the urban areas to be built for the remaining billions of future urban dwellers have not been quantified. Further research in this direction will represent a valuable contribution.

It will be increasingly important for both researchers and decision-makers to understand how urban micro-climates integrate into urban planning and design to simultaneously improve urban environmental outcomes, reduce risk and address the need to adapt to, and mitigate, climate change. From enhancing ventilation, increasing vegetation cover, maximising green and ecological infrastructure, to using strategic shading, understanding the configuration of the micro-

climate of an urban district is increasingly important for both researchers and decision-makers to develop responses to guide urban planning to address climate mitigation and adaptation challenges. In addition, the vast majority of our current understanding of heat risk in cities comes from studies in the United States, Europe and Australia, but cities in the Global South are unique in their climates, vulnerabilities and exposures. Foundational and actionable research on the best ways to define heat waves (e.g., determining relevant indices or variables), what thresholds are considered dangerous in different cities and how heat interacts with the built environment (e.g., corrugated metal roofs in slums) would provide important insight for adaptation and mitigation needs in the context of specific cities. The complexity of understanding and managing a city's micro-climate, both in urban areas in the Global South and Global North, calls for further research and the development of new methodologies for urban planning for mitigating of and adapting to climate change.

It will be important to explore the role of urban and spatial planning in reducing vulnerability and enhancing adaptation to climate change for both formal and informal settlements. Urban form and structure play a prominent role in shaping vulnerability, but informal settlements are often not considered in planning strategies. Encouraging research on how planning approaches can become inclusive of informal settlements for climate change adaptation would make a key contribution to reduce negative impacts of current and future urban growth. Further research is also needed to assess underlying causes of social vulnerability to climate change, particularly in small- and medium-sized urban areas in the Global South. The implications of exploring urban planning in reducing vulnerability could contribute many positive impacts, especially in towns and cities with high levels of informality, where planning and action cannot take place because of a lack of knowledge around risk awareness, threshold identification, forecast products and actionable guidance from the planning community. Accounting for predicted future population growth and land consumption while considering vulnerability and risk, could compliment vulnerability assessments of urban areas further enhancing the capacity of the planning community to address risks associated with climate change.

In planning for future urban expansion, there is a need to document and quantify the impacts of climate change on human health, and to map the full range of health co-benefits of adaptation and mitigation. Climate change presents complex threats for human health, both direct and mediated by natural and human systems. In cities, these threats are often amplified by high population density and vulnerability, systemic interdependencies, and by risk of flooding and inundation in coastal and low-lying areas. Urban planning and design can help address these threats especially where buildings, transport and infrastructures are yet to be built, or where informal and vulnerable areas are earmarked for upgrading or retrofitting. Health co-benefits of climate action can be immediately relevant and a potentially powerful motivator for investing in climate action. To support transformative change, there is an urgent need for detailed local information on the impacts of climate change on human health and potential co-benefits (for instance improved air quality, resilience to temperature extremes, reduced rate of death, injury or propagation of communicable disease due to climate disasters, avoiding system breakdowns with their downstream effects on food, water and energy security) which can be considered in future urban planning.

2.3. Built and Blue and Green Infrastructure

Infrastructure provides critical services such as shelter, mobility, thermal comfort, communication, illumination, sanitation and protection, which are essential for urban living. Closing the infrastructure deficit in the Global South is an essential component to providing critical urban services, reducing vulnerability and supporting adaptation to climate change within the context of sustainable development. However, if current levels of growth in building infrastructure alone are sustained in the Global South, this could release 226 gigatons of carbon dioxide by 2050; more than double the amount used to build existing global infrastructure (Bai et al. 2018). Further research is needed to determine how infrastructure can be developed differently to prevent negative infrastructure carbon lock-in.

Further exploration is needed on low-carbon and environmentally-friendly infrastructure options that go beyond traditionally dominant grey infrastructure[6] for transformational climate solutions in developed and rapidly developing urban areas. Urban development remains dominated by grey infrastructure – buildings, roads and associated infrastructure. The way urban

areas are designed, planned and maintained significantly affects urban emission levels (Seto et al. 2014). While there have been promising technological developments, more research is needed on low-carbon construction techniques, affordable low-carbon building materials, carbon storage in infrastructure, bioclimatic designed infrastructure, novel mobility paradigms and more environmentally-friendly planning and design, including blue/green infrastructure[7]. With the potential to reduce energy needs, high-carbon materials consumption and urban heat island effect and to increase urban resilience, these options could make a significant impact on rates of future global emissions. These effects also need to be better captured in emission scenarios.

Further research is needed to understand the co-benefits of blue/green infrastructure and ecosystem-based adaptation, and how mitigation projects could support decision-making in terms of future infrastructure priorities to address climate change in cities. Blue/green infrastructure such as open spaces, parks, indigenous biodiversity and bodies of water have a wide array of economic, social and environmental benefits, including, greatly improving urban form, and enhancing the effectiveness and/or reducing demand on other infrastructure sectors. Further research is needed on how to maximise their potential to improve the health and wellbeing of urban residents (Chu et al. 2004; Bowen and Lynch 2017) mitigate climate change through carbon sequestration (Liu et al. 2016; Pennino et al. 2016; Zuñiga-Teran 2017; Chenoweth et al. 2018; Bartesaghi Koc et al. 2017) and passively modulate the urban micro-climate. It will also be necessary to understand how blue/green infrastructure itself is vulnerable to future climate change, including increases in temperature, changes in precipitation patterns and more frequent and intense weather events (e.g., ice storms, hurricanes), with the goal of enhancing resilience and reducing maintenance costs of the blue/green infrastructure solutions. Study and development of innovative financial solutions for incorporating blue/green infrastructure is also crucial for cities, especially those that make these solutions affordable for cities in the Global South. Research on the cultural value of these ecosystem services is also key to a better understanding of their utilisation by urban inhabitants, particularly in the Global South, and will imply close collaboration with social sciences and humanities.

Research and knowledge which provides a more granular and location specific understanding of the carbon lock-in risks and opportunities for mitigation and adaptation to inform planning and policies for building and upgrading infrastructure is needed. Current and future patterns of urban growth will determine emissions, vulnerabilities and potentially constrain adaptation options for decades, sometimes centuries. Urban planning that integrates research and data, incorporating the carbon lock-in potential of infrastructure development, is essential for a low-carbon and climate-resilient urban future. Whereas conceptual research and knowledge have advanced, there is extremely limited literature on how these translate into concrete policy responses, and how positive carbon lock-ins can be maximised (Seto et al. 2016) (Ürge-Vorsatz et al. 2018).

2.4. Sustainable Consumption and Production

Cities are centres of economic, social and cultural change. As such they are well positioned to test interesting opportunities in production and consumption typologies and patterns that can greatly encourage the diffusion of low-carbon lifestyles, enable climate resilience, and could facilitate overall improvements in quality of life. In supporting these goals, a progressive transition towards more efficacious and sustainable production and consumption patterns is of specific relevance. Expanding knowledge on these patterns will focus on different aspects in the Global North and Global South, but both are relevant and crucial for supporting urgent climate action.

Further research is desirable on the implications of diverse types of urban economic structures, modes and patterns of production, and their associated lock-in effects, including regional, national and global relocation of manufacturing processes. In the Global North, three key aspects are identified: greater incentives and regulations for cleaner production (by supporting low-carbon and sustainable value chains based in circular economies and sustainable product design as well as on technological innovation and know-how), sustainable and resilient logistic systems that are anchored in visions of materially sufficient lifestyles, and preparedness to invest in new systems for sustainable provisioning. In the Global South, although the above is desirable, most of the short and mid-term opportunities are to be found in updating obsolete means of production and increasing production capabilities with cleaner technologies. In the mid- and long-term, opportunities for Global

South cities lie in moving their main economic structure towards low-carbon, sustainable and more knowledge-intensive options. This transition is of high importance as this is where most future population growth is expected. These cities represent a major opportunity to avoid repeating the high consumption and emission developmental pathways and subsequent high carbon lock-in of industrialised countries, and to be at the forefront of innovation. In any Global South transition, North-South and South-South cooperation seems to be crucial.

Research is required to better understand potential pathways for social change that promote lifestyles and cultures which are less resource intensive and that increase adaptive capacity and well-being. It is through consumption that people navigate their way in the world, create identity, express status and symbolically communicate with others. Yet these activities inflict a heavy burden often have in terms of energy and materials utilisation. High consumption patterns are particularly salient in the lives of urban populations, and especially prominent in the Global North, and need to be considered in meaningful climate-response programmes. Further studies could explore how diverse ways of organising community life – both the physical form and social relations – affect consumption as measured by GHG emissions, influence adaptive capacity and destabilise the long-standing connection between fossil fuels and urban development while ensuring urban liveability. Another aspect of this research would be to understand better the role of incentives, privileging investments, technological innovations, law, taxation, education and urban governance in influencing decisions made by people and communities, which orient choices towards reduced carbon and energy use, and towards more sustainable consumption. Research focusing on the transfer and adoption of consumption patterns in the Global North to cities in the Global South is also relevant for climate change agendas.

Current methodological innovations in greenhouse gas emissions calculations could be improved by exploring the role of urban consumption. Current methodological approaches often disregard energy embodied in consumer goods and services produced outside city limits. Alternative accounting systems, so-called consumption-based emission inventories, *de facto* assign responsibility for greenhouse gas emissions to consumers and suggest that true emissions attributable to cities are two or three times higher than supposed. This methodological innovation can be explored and applied further and improved as appropriate. Such inventories and related techniques like environmentally extended multi-regional input-output modelling have the potential to expand the circle of relevant actors, redefine the responsibility of citizen consumers, challenge energy and environmental analysis, and place demands on different components of the urban economy.

2.5. Finance

Implementing the Paris Agreement will require both a shift in the way that existing streams of finance are allocated, and a substantial increase in the total quantity of urban infrastructure investment. Mature cities will need to refurbish or replace existing infrastructures, and fast-growing cities will need to shift towards lower-carbon, more climate-resilient development pathways. Further research is needed for alternative financing opportunities and mechanisms to support urban climate change agendas.

Research is needed to inform the development of frameworks and tools that enable the integration of climate considerations into fiscal and financial decision-making at the city scale. If governments steer investment towards sustainable options through carbon pricing, green public procurement and accounting systems that capture physical, liability and transition risks, there are large opportunities for climate change mitigation and adaptation within cities. Policy frameworks and spatial plans can also methodically direct investment towards low-carbon, climate-resilient modes of urban development, while urban infrastructure strategies can be used to develop a clear pipeline of climate-compatible projects.

Further research is needed to explore how public budgets can be strategically used, including to crowd in private investment, to address the shortfall in sustainable urban infrastructure investment. Bankability and creditworthiness are prerequisites for private investors, who require either a sufficient return on investment based on project income flows or low-risk government debt repayments. Governments and development agencies play a role in structuring and packaging urban

infrastructure projects, using domestic and international public finance strategically to attract investment and lower the cost of capital (Floater et al. 2017). Cities could benefit from targeted research on how to strengthen the coherence and effectiveness of demand-side institutions (the project implementers) and the effectiveness of project preparation facilities.

Research is particularly needed on the role of public finance where projected returns are too low or perceived risks are too high to attract private finance at scale. In informal settlements, for example, low per capita incomes mean lower tax revenues and less ability to pay user fees and charges at a level that provides a sufficient profit margin for investors (Mitlin et al. 2018). Historically, only a small proportion of international climate finance has been disbursed to local governments or local civil society. However, the Green Climate Fund and Adaptation Fund (among others) are experimenting with "direct access" modalities and "fit-for-purpose" accreditation and approval processes to support more small projects managed by local entities. This could build adaptive capacity in urban areas both instrumentally (by financing new infrastructure) and transformatively (by strengthening delivery capabilities and local accountabilities) (Colenbrander et al. 2018). There is a need for further research on how municipal authorities and local civil society organisations could most efficiently access, use and scale these financial opportunities.

Research is desirable on how to include low-income and other marginalised urban residents in fiscal and financial decision-making. There is a specific need for climate-relevant investment in informal settlements, which typically have severe infrastructure deficits that increase residents' exposure and sensitivity to risk. In many cases, residents in informal settlements and workers in informal economies are already making significant innovations and contributions towards greener urban development (Brown and McGranahan 2016). Further research on alternatives and opportunities to involve these communities in planning, financing and delivering climate investments can increase their influence over decision-making and build their delivery capabilities. This can help redress the exclusion and inequality that contribute to climate vulnerability and injustice (Bulkeley et al. 2014). These participatory processes can also enhance the cost-effectiveness and transparency of infrastructure investment, so that scarce resources are used most efficiently (Cabannes and Lipietz 2018).

Research on insurance options could empower cities to better address disaster risk. Many urban areas will continue to have some exposure to climate hazards, even if resilience is mainstreamed into planning and investment. The insurance industry can play a key role in supporting cities to better prepare for and recover from disasters, both by incentivising better risk management through premiums and by sharing good practice in risk assessment and mitigation (Oberlack and Eisenack 2014). Research is needed to enhance the sophistication of risk modelling and to inform the optimal design of insurance instruments to share risk equitably (including with people living and working in the informal sector).

2.6. Uncertainty

The term uncertainty [8] can have very different meanings within and outside of the scientific community. For researchers, uncertainty relates to how accurately something is known or how unknown something is. This is sometimes shown by providing a range associated with a specific value; highlighting the degree to which this value could vary. Understanding uncertainty is an integral part of science and decision-making.

To avoid misunderstanding outside the scientific community, it is important to communicate clearly and transparently the level of confidence associated with findings, avoiding scientific jargon (e.g., likelihood scales) for probabilistic estimates, and instead report the chances in lay terms (e.g., 95% chance of something). It is important to understand how different societal actors define and assess uncertainty when developing climate change mitigation and adaptation strategies across the science, policy and practice communities.

Further research is needed to evaluate the 'fit-for-purpose' attributes of models and to provide guidelines for simplified approaches that would strengthen the evaluation of the confidence in projections and the associated uncertainties. Examples of such uncertainties include whether the sets of projections used in city scale models encompass the full range of relevant drivers (e.g.,

land use and aerosols at the regional scale, and greenhouse gases at the global scale), whether the methodologies encompass the full range of plausible climate variations on the near and long term, whether they include low probability, high risk, poorly known events (e.g., compound extreme events), and whether non-linear behaviours and risks of thresholds and abrupt shifts are accounted for. Developing simplified approaches that can be adapted to different city contexts, and that are informed by exhaustive assessments of sources of uncertainties and limits of complex modelling approaches is needed to account for the full spectrum of uncertainty to inform decision making.

Further research should be conducted on tools that assess uncertainty considerations in different city contexts to strengthen decision-making in uncertain situations. New decision-making tools for risk assessment and adaptation planning include iterative risk management, real option analysis and robust decision-making approaches. Recent studies highlight barriers to using these decision-making tools in the Global South, despite their strong potential especially in situations of rapid urbanisation. Further research on adaptation/mitigation approaches requires: information on the future, usually informed by modelling scenarios; context-specific criteria to define robustness (e.g., performance over a wide range of plausible scenarios, and understanding of trade-offs associated with alternative options); and an iterative process that characterises uncertainty in the context of a specific decision, thus providing understanding of the key assumptions underlying alternative options.

Research is needed to develop methodologies to identify sources of uncertainty, to explore and understand the full range of uncertainty, and to reduce it, where possible. Uncertainty regarding projected future climate conditions, levels of risk and vulnerability, and effectiveness of adaptation and mitigation efforts, needs to be integrated into all aspects of urban climate action. The concept of deep uncertainty[9] has recently emerged in decision-making contexts but it has not yet been fully defined within IPCC assessment reports. Recent literature developments have used the deep uncertainty framing in relation with water management linked to drought and/or flood, risk management associated with ecosystems (e.g., forests, wildfires) and climate surprises (e.g., compound extreme events or abrupt change) and coastal management in relationship with sea level rise and storm surges. However, further research is needed on methodologies to fully account for uncertainties and report them, using a standard approach, so that knowledge from individual case studies can be assessed homogeneously. Characterisation of uncertainty in risk evaluation and risk management approaches would also be key to conduct.

3. Delivering on the Research and Action Agenda: Approaches to strengthen the science, practice and policy interface

This section focuses on options to support the implementation of the *Global Research and Action Agenda on Cities and Climate Change Science*. As illustrated in the previous two sections, there are still many knowledge, research and data gaps to be filled to advance climate action in cities. In this regard, the Conference represented a significant opportunity to bring together knowledge from the science, practice and policy communities, and provided a key step forward in understanding knowledge gaps. The conference also highlighted the large benefit of working together in building evidence-based knowledge for climate action in cities. To strengthen the collaborations of these communities on cities and climate change science, engagement is encouraged at the global, national and local level. This section provides possible avenues – but by no means an exhaustive list – that are available to enhance such collaboration.

3.1. Knowledge Co-Design and Co-Production

The co-design, co-production and sharing of knowledge and information by the research, practice and policy communities in an integrated manner will enhance the value of such knowledge in informing city level climate action. Co-design and co-production will be greatly improved for both Global North and Global South cities if the operational modalities of the three communities are adapted to support such cross-sector interactions.

Co-designed tools are needed for knowledge sharing, assessment, and for scoping of new priorities for knowledge generation and research by different initiatives and institutions within the science, urban practice and policy communities at the city scale. Different initiatives and institutions could help facilitate the co-design of such tools within these three communities, and with local urban communities and civil society organisations. For example, public-private partnerships in the form of city think tanks could focus on co-designing key research questions and assisting cities with limited resources in their work towards evidence-based solutions. City and scientific networks, such as C40, ICLEI, UCLG, Future Earth, SDSN and WCRP, could also facilitate, champion and provide opportunities for co-design exercises. However, it is essential to ensure that different local communities and actors are kept informed of outcomes of these processes and have opportunities to provide input on how these processes could be guided and improved to meet broader needs. Local research centres or universities, for example, could also be empowered to play this kind of facilitation role.

Ensure existing and future knowledge is synthesised and widely disseminated to support best practices. Global assessments of climate change and cities can help inform and enable the integration of social, ecological and technological systems in urban areas and provide guidance on transformational opportunities for urban climate adaptation and mitigation. Integrating adaptation and mitigation can help advance city responses beyond limited siloed approaches, which in turn can minimise unanticipated conflict and avoid carbon lock-in (Ürge-Vorsatz et al. 2018). A global scale urban assessment structure would facilitate collaboration and decision-making for the urban research, practice and policy communities. Tailoring assessments to multiple sets of societal actors and their interests, would ensure that the knowledge provided is salient, credible, legitimate and inclusive (Cash et al. 2003). Such assessments may be characterised by the following: involvement of societal actors to co-generate goals, an urban systems approach, integration of adaptation and mitigation, promotion of science-practice-policy partnerships that can then disseminate knowledge at the regional and local levels, and linkages to ongoing, benchmarked processes such as T*he Second Assessment Report on Climate Change and Cities* (ARC3.2) to provide input to the IPCC assessment cycles (Rosenzweig et al. 2011, 2018).

The co-production knowledge at the city scale can be enhanced through the inclusion of local communities and indigenous peoples, practitioners, city networks, policy-makers and researchers from social and natural sciences and the humanities. Urban practitioners, decision-makers and community members often possess knowledge on their city, which has not yet been incorporated into peer-reviewed literature or assessment. Insights from different knowledge holders, including but not restricted to, local and indigenous groups, women, youth, those living in informal settlements and other marginalised and vulnerable populations could also be brought to the forefront. The participation of a variety of actors representing diverse perspectives (including but not limited to those mentioned above) as knowledge is generated will add value, for instance in local and international meetings, to establish a dialogue, challenge *status quo*, stimulate action and share innovative ideas. More frequent international events and conferences which convene academic, urban practice and policy communities, and which are actively inclusive of other urban actors and research awards calling for active collaboration could be two approaches to encourage co-design and co-production.

Further research is needed examining how climate action is facilitated by- and what are the effective conditions for- evidence-based policy that integrates diverse perspectives through co-design and co-production. There are multiple cases within the contexts of different cities where the research, urban practice and policy communities and other urban stakeholders are working together under different institutional frameworks to co-design and co-produce evidence-based policy for cities to address climate change. However, a thorough assessment of the impact of evidence-based climate policies that have been implemented has not been performed. This global assessment could then highlight co-designed and co-produced policies which have led to most effective mitigation and adaptation and which allow for key co-benefits and synergies between mitigation and adaptation measures, and conditions in which these policies were developed. This could provide important insight for cities beginning to develop or looking to adapt (existing) evidence-based policy to address climate change.

3.2. Empowering Cities to Take Action

For national governments to implement the Paris Agreement, cities will need to be empowered both financially and politically to develop ambitious climate targets and take transformational climate action. Some aspects to consider when working to empower cities to take action can be found below and can be adapted and developed to suit local contexts.

Effective collaboration between national, sub-national, municipal and local governments to respond to climate change, would be facilitated by harmonising efforts that aim to address various global agendas, such as the Paris Agreement, the 2030 Sustainable Development Agenda, the New Urban Agenda and the Sendai Framework for Disaster Risk Reduction. Transformation could be accelerated if municipal and local authorities could directly provide knowledge co-produced by diverse city actors to inform national climate change policies. Strategies to identify and address barriers within multilevel governance (which may differ significantly between nations), and strategies to build capacity for different cities could be co-developed, tested and adapted, with experiences shared between cities. One element that may facilitate this process could be transparent assessments of the costs of climate action and inaction in cities, to illustrate monetary incentives for action from multiple levels of government on climate change adaptation and mitigation.

Accurate and scientifically robust monitoring and evaluation frameworks developed for and by cities would support them in showcasing the impacts of action. Systems that measure direct and indirect impacts of climate change action and inaction at the city level could empower municipal and local authorities by providing information for evidence-based decision-making. Some municipal and local authorities are developing innovative and transparent methods to monitor, evaluate and display different climate indicators/measures to provide accountability to its citizens with respect to their commitments to address climate change. These systems may be also developed, or supported, by city networks to facilitate sharing between member cities.

3.3. Fostering Long-Term Science-Policy-Practice Collaborations

As researchers, urban practitioners and policy-makers often operate at different time and spatial scales and use different vocabularies, it is important to distil the information already available to meet the immediate knowledge needs of cities, and to have a constructive, open, iterative long-term dialogue to match current and future knowledge needs, to respond specific city-level challenges arising from climate change. In the context of some cities, little initiative has been taken to build long term relationships between the science, urban practice and policy communities (for a variety of reasons, including the lack of opportunities or capacity), while in other cities, collaborations are long-standing. However, relationships that could withstand the different cycles (funding, electoral, project and publication) within which the communities operate, and that would incorporate continued feedback and flow of information between communities, would allow for progress in addressing climate change.

Fostering mutual understanding, through advancing co-production and co-generation of knowledge and further empowering cities to take action. Climate change action has tended to occur in silos, not only within the three communities, but also in the sectors and fields within them (e.g.; natural, social sciences and humanities). A first step towards fruitful and holistic collaboration would be to raise awareness of the personal competencies required to work across silos. Such competencies might include for example the ability to understand and navigate differences in organisational culture, ethical and normative issues, the ability to translate between different knowledge schemes, the necessary self-awareness to recognise gaps in capacity and the willingness to develop lacking capacities actively, by involving different perspectives. The recognition of the different level of detail needed and the different priorities of the three communities (e.g., different information needs of high level government officials looking to create new policy and practitioners implementing solutions on the ground) by all collaborating actors would facilitate dialogue. Identifying common ground on issues relating to mitigation and adaptation, and on how science and policy needs can best be aligned, would allow for cross community benefits to emerge on an ongoing basis.

City-to-city partnerships could encourage exchange of knowledge across cities and develop capacity in cities. City-to-city partnerships or 'twinning' refers to two cities in different countries/regions entering into a broad-based partnership, to promote the exchange of ideas, people and trade across the two geographies. Moving forward, formalised twinning arrangements between cities could be considered to foster accountability between city partners, to ensure more formalised modes of exchange, and to provide defined mechanisms through which smaller cities or those with less capacity can receive technical support to respond to the challenges of climate change, including climate adaptation and mitigation. These partnerships could encompass local and municipal authorities as well as city-level academic institutions. Under such an agreement, the mayor or highest level elected officials could sign a partnership agreement while the deans/presidents of their lead academic and research institutions, could commit to work with their municipal and local authorities, and with each other, to contribute to evidence-based responses to climate change.

Close interactions between cities and the scientific community can be fostered by providing opportunities for researchers to work in municipal and local authorities, and opportunities for practitioners and decision-makers to invest time in research projects. This could be facilitated by grants and fellowships for PhD or master students from both social and natural sciences and humanities to conduct research in local and municipal authorities' offices or to work as part of collaborative research projects. Another approach could be a chief scientist or a scientific advisory panel supporting a city on climate change issues (Bai et al. 2018). This would help the research community better understand city opportunities, challenges and constraints (e.g., timelines, priorities). Another option would be to have urban practitioners and decision-makers take a larger role in research projects or in the development of climate centres in research institutes to ensure they are better aligned with city challenges. Establishing living laboratories[10] could also facilitate this and increase understanding between disciplines and departments. These approaches would facilitate a deeper understanding of the processes in cities and the development of solutions based on scientific evidence.

Catalysing collaboration and knowledge production

Building on existing knowledge and action, the Conference and this *Global Research and Action Agenda on Cities and Climate Change Science* are two steps in a journey towards generating greater knowledge in support of practice and decision-making to address climate change challenges and opportunities in urban areas. The following are examples of forward-thinking initiatives that have recently emerged to continue this journey: (1) The Science we Need for the Cities we Want, signed by most of the Conference organising partners as well as Urban Climate Change Research Network (UCCRN) at the end of the Conference, and now signed by 24 organisations,[3]; (2) the Edmonton Declaration, which calls on cities to support evidence-based decision-making and action to address climate change in cities; (3) a national gathering of science, policy and practice in Mexico City (organised by the National Autonomous University of Mexico-UNAM) to discuss the outcomes of the Conference in the Mexican context; (4) Conference partners, especially ICLEI, together with the UNFCCC, working towards an annual gathering of UNFCCC members, city and research partners around cities and climate; (5) Innovate4Cities initiative from the Global Covenant of Mayors, to further develop this Research and Action Agenda with cities.

The Conference and this subsequent Research and Action Agenda have showcased not only the important role cities play in terms of climate impact and opportunities to address it, but the breadth of knowledge needed to support decision-makers and urban practitioners to tackle these challenges. The Scientific Steering Committee and Organising Partners are inviting their constituencies, the IPCC member countries and other science, practice and policy organisations and communities to implement and further develop the knowledge generation avenues proposed in this Research and Action Agenda. Together, continued collaborative participation in this journey can support effective, evidence-based climate action in cities.

[3] As of 3 Aug 2018

Glossary

[1] Municipal authorities	This term includes local and municipal governments.
[2] Path dependencies	The generic situation where decisions, events, or outcomes at one point in time constrain adaptation, mitigation, or other actions or options at a later point in time.
[3] Carbon lock-in	Where the inertia of technologies, institutions and behaviours individually and interactively inhibit innovation and competitiveness of low-carbon alternatives.
[4] Informal settlements	A term given to settlements or residential areas that by at least one criterion fall outside official rules and regulations. Most informal settlements have poor housing (with widespread use of temporary materials) and are developed on land that is occupied illegally with high levels of overcrowding. In most such settlements, provision for safe water, sanitation, drainage, paved roads and basic services is inadequate or lacking (IPCC 2014a)
[5] Resilience	The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation
[6] Grey infrastructure	Human-made, constructed infrastructure (European Environment Agency 2017)
[7] Green infrastructure	Green infrastructure refers to interventions to preserve the functionality of existing green landscapes (including parks, forests, wetlands, or green belts), and to transform the built environment through phytoremediation and water management techniques and by introducing productive landscapes (IPCC 2014b). This could be termed blue infrastructure if aquatic ecosystems are concerned (European Environment Agency 2017)
[8] Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g., a probability density function) or by qualitative statements (e.g., reflecting the judgment of a team of experts) (Moss and Schneider 2000; Manning et al. 2004; Mastrandrea et al. 2010)
[9] Deep uncertainty	The concept of deep uncertainty has emerged to refer to situations where decision-making is needed while there is no conceptual understanding of the key drivers of change; when

	there is no agreement on the probability distribution of key variables affecting the changing system; when there is no agreement on the desirability of alternative outcomes. The term deep uncertainty is particularly complex and in need of further specification. (Lempert et al. 2003) have defined deep uncertainty as “the condition in which analysts do not know or the parties to a decision cannot agree upon (1) the appropriate models to describe interactions among a system's variables, (2) the probability distributions to represent uncertainty about key parameters in the models and/or (3) how to value the desirability of alternative outcomes.”
[10] Living laboratories	Living laboratories are structures often operating in a territorial context, such as within a city or agglomeration, which seek to enhance collaboration between researchers and the end users or beneficiaries of research efforts, engaging community in every stage of development from concept to prototyping.

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