

FINDINGS FROM INNOVATE4CITIES 2021 AND UPDATE TO THE GLOBAL RESEARCH AND ACTION AGENDA

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GLOBAL COVENANT
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CLIMATE & ENERGY

Findings from Innovate4Cities 2021 and Update to the Global Research and Action Agenda

This report has been developed by the Global Covenant of Mayors for Climate & Energy (GCoM) and UN-Habitat based on the outcomes of 2021 Innovate4Cities Conference co-sponsored by UN-Habitat, GCoM and the Intergovernmental Panel on Climate Change. It is intended to inform research, policy and public discussions on the global research and action agenda for cities and climate change science. The authors have sought to ensure the accuracy of the material in this document, but they will not be liable for any ramifications incurred through the use of this report.

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EXECUTIVE SUMMARY

According to the most recent UN estimates approximately 56% of the world's 7.9 billion inhabitants live in cities and their extended urbanised regions (UN DESA, 2019). It has become clear that cities represent both a significant challenge and opportunity for those focused on addressing the climate change crisis. Small and medium sized cities in the Global South, for example, have high levels of vulnerable populations and limited response capacity. Additionally, cities, their stakeholders and leaders are very innovative with respect to climate change adaptation and mitigation

After a proposal for a Special Report was put forward by the government of South Africa during the 6th assessment cycle (AR6), at the 43rd Session, the Intergovernmental Panel on Climate Change (IPCC), committed to a Special Report on Climate Change and Cities as part of the AR7. To stimulate knowledge exchange, and the production of evidence-based reports and peer-reviewed publications on cities and climate change, at its 44th meeting, the IPCC approved a co-sponsorship proposal for an international Cities and Climate Change Science conference, held in Edmonton, Canada in March 2018. Urban policymakers, urban practitioners, researchers and other societal actors came together to. The primary output of this conference was the Global Research and Action Agenda on Cities and Climate Change Science (GRAA) (World Climate Research Programme, 2019) which emphasized the research needs for increased action on climate change in cities.

In the months following the conference, the Global Covenant of Mayors for Climate and Energy (GCoM) launched the Innovate4Cities initiative to support and expand the research and action called for within the 2018 Cities and Climate Change Science conference's GRAA. The first Innovate4Cities conference (Innovate4Cities 2021) was held virtually in October 2021 by GCoM and UN-Habitat, and co-sponsored by the IPCC, bringing together representatives from academia, the private sector, NGOs, local governments, national governments, city networks, youth, international organisations and other stakeholders engaged in addressing climate change in cities. Building on the Global Research and Action Agenda, the Innovate4Cities 2021 conference was centred on the nexus between science, practice and innovation vital to realizing ambitious climate change action in cities across the globe, with a strong focus on local and regional voices. The Innovate4Cities 2021 conference had 6901 registered participants from 159 countries and featured 886 speakers across 191 sessions.

The Innovate4Cities 2021 conference was an important stocktaking of progress in the production of evidence-based reports and peer-reviewed publications on cities and climate change, and emerging research gaps which have come about since the Cities and Climate Change Science conference, and which can contribute to the preparation of the AR7 Special Report on Climate Change and Cities.

CATALYSING ACTION AND IMPLEMENTATION

While the 2018 Cities and Climate Change Science Conference discussions focused on bringing together the scientific community, practitioners and policymakers to discuss the next frontier of research on cities and climate change, Innovate4Cities 2021 focused on research and innovation as well as closing the gap between ambition and implementation. To catalyse action to close the implementation gap, new research and knowledge on methods to change the mindset of urban stakeholders around addressing climate change

and the tools and processes to do so, as illustrated in figure 1 came through very strongly as needs throughout the Innovate4Cities 2021 conference. This initial section in this Findings report is a new addition to the research and action agenda. It is an important framing from which to view the new and updated research gaps identified during Innovate4Cities 2021 to support urgent and widespread uptake of climate change mitigation and adaptation actions, and important factors to consider in filling many of these gaps.

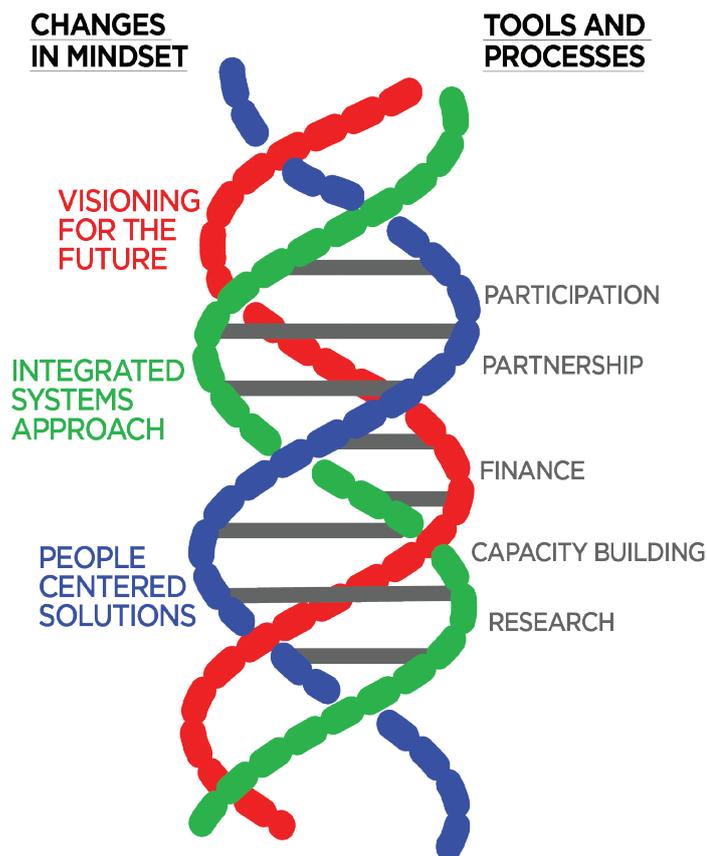


Figure 1: Changes in Mindset and Tools and Processes to catalyse action and implementation.
Designed by Barbara Summers

RESEARCH GAPS: TOPICAL RESEARCH AREAS AND CROSS CUTTING ISSUES

The second section focuses on the new and emerging research gaps for the topical areas and cross-cutting issues identified in the Global Research and Action and Agenda and the Innovate4Cities process, including the addition of a new topical research area on History and Cultural Heritage (see Figure 2).

The research gaps identified within each topical and cross-cutting issue reflect a wide array of challenges and efforts in addressing climate change that face the diversity of stakeholders in cities across the world. The research gaps also demonstrate the synergies and interconnectedness of many of these problems and solutions. The full list of new research gaps, with their synergies to other topical and cross-cutting issues as well as the gaps identified under these topics in the Global and Research Action Agenda for Cities and Climate Change are provided in Section 2 of the report.

The final section is another new addition which covers the regional insights on the topical and cross-cutting areas to highlight how research and implementation gaps vary with regional and local context across the ten regions of Latin America and the Caribbean, European Union and Western Europe, South Asia, North America, Africa, Southeast Asia, East Asia, Oceania, Middle East and West Asia, Eastern Europe and Central Asia.

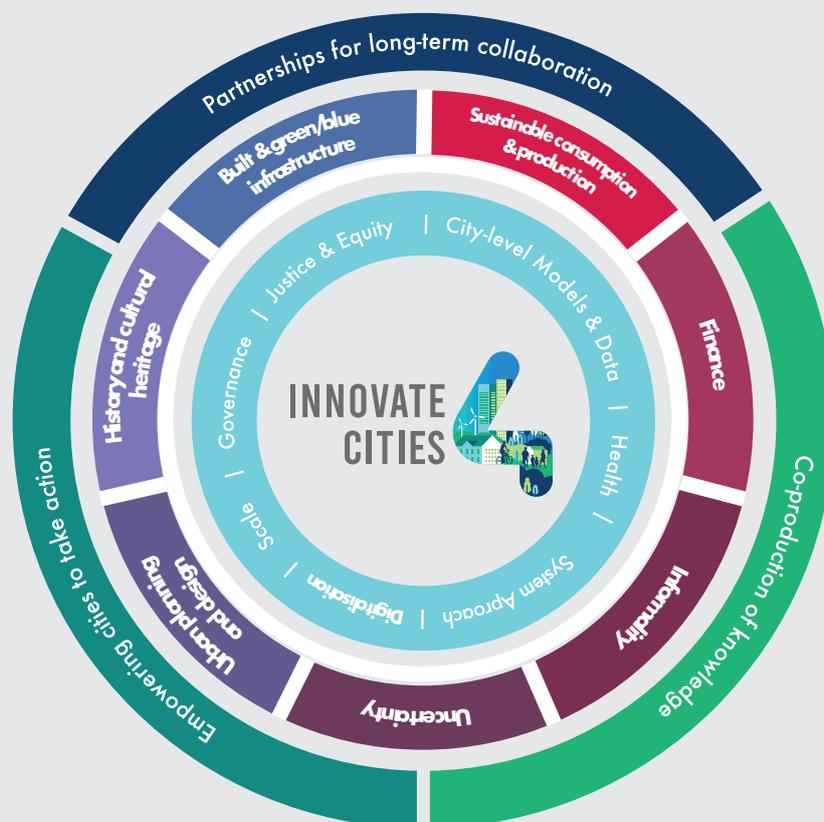


Figure 2: Updated Topical Research Areas and Cross cutting themes (inner ring), Topical themes (middle ring) and Delivery Approaches (outer ring). Modified from original GRAA graphic design by Amanali Cornejo V, World Climate Research Programme (2019).

CONTEXT AND PURPOSE

The world continues to experience rapid urbanisation. According to the most recent UN estimates approximately 55% of the world's 7.9 billion inhabitants lived in cities and their extended urbanised regions in 2018 (UN DESA, 2019). By the year 2050, it is projected that more than two-thirds of the population will live in these places and much of the population growth over the next 30 years will occur in cities (predominantly those of the Global South). As a well-recognized global mega-trend, it has become clear that cities and their expected growth represent both a significant challenge and opportunity for those focused on addressing the climate change crisis. Small and medium sized cities in the Global South, for example, have high levels of vulnerable populations and limited response capacity. At the same time, cities and their stakeholders and leaders have been well documented as being very innovative with respect to climate change adaptation and mitigation. It is in this multi-faceted and dynamic context that cities and their residents emerge as important actors in the global climate change response.

After a proposal for a Special Report was put forward by the government of South Africa during the 6th assessment cycle (AR6), at the 43rd Session of the Intergovernmental Panel on Climate Change (IPCC) in 2016, the IPCC committed to a Special Report on Climate Change and Cities as part of the 7th assessment cycle. To stimulate knowledge exchange, and the production of evidence-based reports and peer-reviewed publications on cities and climate change, at its 44th meeting, the IPCC approved a co-sponsorship proposal for an international Cities and Climate Change Science conference, to be held in 2018. The Cities and Climate Change Science conference was subsequently held in Edmonton, Canada in March 2018.

The 2018 Cities and Climate Change Science conference initiated a process of engagement between urban policymakers, urban practitioners, researchers and other societal actors involved in ensuring a safe transition to sustainable urban societies in the face of human-induced climate change. These groups came together to map and evaluate the state of research and progress on the intersection of cities and climate change with an emphasis on research needs for increased action. The primary output of this conference was the Global Research and Action Agenda on Cities and Climate Change Science (GRAA) (World Climate

Research Programme, 2019), which identified four cross cutting areas and six topical areas where research and knowledge were needed.

In the months following the conference, the Global Covenant of Mayors for Climate and Energy (GCoM) launched the Innovate4Cities initiative to support and expand the research and action called for within the 2018 Cities and Climate Change Science conference's GRAA. The Innovate4Cities initiative looks to define and address cities' knowledge and innovation opportunities and create partnerships between the scientific and academic community, businesses, and governments to overcome the challenges local governments face between their publicly reported ambition and full-scale implementation.

The first Innovate4Cities conference (Innovate4Cities 2021) was held virtually in October 2021 by GCoM and United Nations Human Settlement Programme (UN-Habitat), and co-sponsored by the IPCC, bringing together representatives from academia, the private sector, NGOs, local governments, national governments, city networks, youth, international organisations and other stakeholders engaged in addressing climate change in cities. Building on the 2018 Cities and Climate Change Science conference and the resultant Global Research and Action Agenda for Cities and Climate Change Science, the Innovate4Cities 2021 conference was centred on the nexus between science, practice and innovation vital to realizing ambitious climate change action in cities across the globe. The conference also examined local challenges and priorities, with a strong focus on local and regional priorities and voices, emphasised through the inclusion of a dedicated group of regional meeting curators spanning the globe. The recognition of the need for innovation at the city level to support the shift from business-as-usual and to overcome the challenges of incumbent/path dependent modes of production and consumption, and governance and policy making is important to take the research and action which began after the 2018 conference further. The Innovate4Cities 2021 conference was also an important stocktaking of progress in the production of evidence-based reports and peer-reviewed publications on cities and climate change which has occurred since the 2018 Cities and Climate Change Science conference, and which could be

assessed during the preparation of the 7th assessment cycle's Special Report on Climate Change and Cities.

Innovate4Cities 2021 was guided by the Science and Innovation Steering Committee and Partner Network Organising Committee, the members of which regularly work on and research climate change and city issues, alongside the Global Covenant of Mayors' Research and Innovation Technical Working Group.¹ Science and Innovation Steering Committee members were nominated in their personal capacity and were selected due to their outstanding scientific contribution in urban climate science in the six topical research areas identified in the GRAA (urban planning and design, built and blue/green infrastructure, sustainable consumption and production, finance, informality and uncertainty) experience in guiding innovative processes, and in-depth experience and knowledge of urban development issues. Partner Network Organising Committee members were self-nominated or nominated by GCoM and UN-Habitat. The members were selected to ensure the group had a set of individuals representing organizations with global and regional representation and geographic balance, expertise on the different GRAA topics and additional topics identified in the Innovate4Cities City Research Agenda² as well as gender balance. Organisations who came together to host the 2018 Cities and Climate Change Science conference were also invited to nominate individuals to represent their organisations in the Partner Network Organising Committee. The purpose was to promote continuity between the two processes.

The Innovate4Cities 2021 conference had 6901 registered participants from 159 countries, 886 speakers across 191 sessions and over 20,000 site visits during the week of the conference. While the Innovate4Cities 2021 conference built on and advanced the discussion held at the 2018 Cities and Climate Change Science conference, the context within which the conference was held was fundamentally different.

¹ The Research and Innovation (R+I) Technical Working Group, established late 2018, steers Innovate4Cities, one of the key initiatives of the GCoM, focused on furthering its City Research Agenda.

² The Innovate4Cities Agenda was launched by GCoM in Sept 2018, after identifying that further consultation with city governments, the private sector, academia and urban practitioners was needed to further the research needs identified in the GRAA, and to promote implementation and action on urban climate change issues. The Innovate4Cities City Research Agenda prioritises evidence based action with significant focus on local context. It identified topical research areas for urban climate change science and innovation: urban planning and design, energy, waste, buildings, water, transportation and food and three cross cutting issues, finance, governance and public procurement as key to advancing urban climate change research and innovation.

The 2018 Cities and Climate Change Science conference was held prior to the release of the IPCC's Special Report on Global Warming of 1.5° C which clearly communicated the difference in impacts between 1.5 and 2 °C of global warming for the first time. At the 2018 Cities and Climate Change Science conference, 700 participants came together in person for three days, while the Innovate4Cities 2021 conference was entirely virtual because of the COVID-19 pandemic. A virtual meeting facilitated broader participation with a programme spanning all global time zones. However, it provided only limited opportunity for networking and informal discussions that often happen at an in-person event. The Innovate4Cities 2021 conference was held in the lead up to the Convention on Biological Diversity's COP 15 and the United Nations Framework Convention on Climate Change's COP 26 (both of which had been delayed from 2020 to 2021 due to the COVID-19 pandemic). The Innovate4Cities 2021 conference was also held shortly after the release of the IPCC's AR6 Working Group I main assessment report which utilized stronger and more direct language than had previously been used by the IPCC to communicate the unprecedented impacts of climate change that the world is experiencing and will continue to face in the future.

Between the two conferences there had also been a growing recognition of the importance and role of cities and local governments in addressing climate change globally. As an example, when the Innovate4Cities initiative launched in 2018, 9,098 cities had signed on to GCoM. By October 2021, the number of committed cities had grown to 11,714. Further, climate emergency declarations have begun to be adopted by local councils, with approximately 2,000 cities and regions having declared climate emergencies since 2019 (Climate Emergency Declaration, 2021). The United Nations Framework Convention on Climate Change's Race to Zero and Race to Resilience³ campaigns have also recognised the important role of cities, calling out cities in the Cities Race to Zero and Race to Resilience initiatives, which had 733 and 33 signatory cities respectively when the Innovate4Cities 2021 conference took place.

³ The Race to Zero is a United Nations Framework Convention on Climate Change initiative to bring together leaders in various sectors outside of national governments to commit to net zero carbon emissions by 2050, led by the the High Level Climate Champions for COP26 in 2021. The Race to Resilience campaign is a sister campaign bringing a strong focus from the same set of sectors and actors –again outside of national governments– around building resilience and adaptation to climate change. In both the Race to Zero and Race to Resilience initiatives, cities have been highlighted as a key sector and cities around the world have been invited to commit to these initiatives.

Over the past several years, there has been increased media attention and larger citizen mobilization around the issue of climate change, with strong calls for implementation of mitigation and adaptation actions. Especially from young climate activists with 'Fridays for Future' climate school strikes starting in the fall of 2018, now a well-recognized and widespread occurrence across the globe (Fisher, 2021). Concerns about historical and on-going inequities in cities that compound impacts of climate change on health have also broadened the discussion on the intersectionality of climate change and the need to address issues of justice, gender, inequality, and marginalization as part of climate responses (Waldron, 2021).

The last two years (2020–2021) have also seen the emergence of the COVID-19 pandemic. This resulted in the largest year on year decrease in CO2 emissions since World War II, with emissions dropping 5.8 % compared to 2019 (IEA, 2021). In 2021, global carbon emissions rebounded to their highest level in history (IEA, 2022). The COVID-19 pandemic has also negatively affected municipal budgets in many cities and resulted in shifting priorities in national budgeting to deal with the health and economic crisis (UCLG, 2021, European Union, 2021). In addition to the topical areas where future research is needed and cross cutting issues which were identified in the Global Research Agenda on Cities and Climate Change Science, three additional cross cutting areas were added as themes for the Innovate4Cities 2021 conference: Digitalisation and Smart Cities, Health and Wellbeing, and Justice and Equity.

The following sections present the discussion and findings from the Innovate4Cities 2021 conference, which add to and build on the 2018 Cities and Climate Change Science conference's GRAA. This report includes new and more action-oriented insights on strategic and effective research and innovation to address the risks and impacts of climate change in cities. With an overarching focus during the conference on how to use science and knowledge to inform the implementation of regionally appropriate climate change responses in cities at the scale and speed required (reflecting recent work on regionalising the Innovate4Cities City Research Agenda (Hadfield et al., 2021)), this update is intended to inform urban researchers, practitioners, and decision-makers about the options available to accelerate more integrated and holistic climate change mitigation and adaptation research and action.

Innovate4Cities 2021 had three primary objectives⁴,

- Advance progress towards meeting the research and knowledge gaps identified by the Global Research and Action Agenda, as well as newly identified gaps, especially in light of the COVID-19 pandemic
- Catalyse engagement between scientists and practitioners for inputs to the United Nations Framework Convention on Climate Change discussions and to support the strengthened focus on regional and urban issues in the IPCC AR6 cycle.
- To generate new platforms and partnerships and to strengthen those that already exist for the co-creation and dissemination of promising policy, technology and organisational innovations for climate neutral and resilient cities

Section 1 of this report, *Catalyzing Action and Implementation*, introduces the motivations and objectives of the conference. It also introduces one of the key overarching points of discussion evident throughout the conference: that while the 2018 discussions focused on cities increasing climate change action ambition, those at Innovate4Cities 2021 focused on closing the gap between ambition and implementation. In other words, putting solutions in place on the ground which mitigate the effects of climate change and build adaptive capacity in cities. This was specifically highlighted in the summary provided of the opening plenary. It detailed the key processes, tools, and challenges involved in achieving transformative change. That is, moving from incremental change to change at the level of systems at the city level and addressing the implementation gaps linked to climate change solutions for cities. Section 2 highlights the research gaps identified during the Innovate4Cities 2021 conference, noting synergies between other topical areas or cross cutting issues (of the GRAA). It also compares the research gaps identified at Innovate4Cities 2021 to those which were identified in the Global Research and Action Agenda on Cities and Climate Change Science. Finally, Section 3 explores more detailed insights into, and illustrative examples of, research and innovation needs associated with particular regions categorized by topical and cross cutting areas found in the GRAA.

⁴ In accordance with the conference co-sponsorship proposal and subsequent agreement submitted by UNHabitat and GCoM to the IPCC, these taken from shortened list of objectives for communication.

SECTION 1: CATALYSING ACTION AND IMPLEMENTATION

The conference engaged with a broad range of topics on cities, climate change science and innovation with nine Thematic Plenaries, acting as important touch points for discussions that had been conducted during parallel sessions across time zones. It also had three regionally focused Plenaries and six regionally focused Mayoral Receptions. Many of the ideas presented in the first section of this document were raised in these high-level Plenaries and elaborated in parallel and innovation lab sessions. The core writing team led the recording process for all sessions and hosted a post-conference workshop with the Science and Innovation Steering Committee, Partner Network Organising Committee and GCoM's Research and Innovation Technical Working Group to obtain feedback from these groups on the key messages and research gaps presented in this document. The section of the illustration created during the closing plenary highlighting the conference takeaways (Figure 1) captures many of the important messages highlighted in this section.

From the Opening Plenary and throughout the Innovate4Cities2021 conference, discussion focused on the implementation gap in cities related to climate change action and the need for research to support this action. During the Innovate4Cities 2021 conference's opening plenary, speakers identified the need for urgent, bold and ambitious responses to the climate change challenge; highlighting the stark reality of climate change risks and impacts for cities in the present and near-term and focused on the need for the implementation of solutions which facilitate climate change mitigation

and adaptation in cities. During the opening plenary, IPCC Lead Author, Francois Engelbrecht presented key takeaways of the recently released Working Group I contribution to the IPCC's Sixth Assessment cycle: "The Physical Science Basis" indicating that the world is very close to exceeding 1.5oC of warming, even with ambitious mitigation. Staying below 1.5oC of warming would require halving emissions by 2030

with continuous reductions until net zero emissions is achieved at the very latest by 2050. Realising this level of mitigation would require local governments and their cities to play a critical role in increasing global ambition. Governance challenges and barriers to change contribute to the implementation gap experienced by cities in addressing the climate change challenge. However, as was heard in conference discussions, in many cities it is evident that pushing for this change is not just about percent decarbonization or reaching net zero, as it can support making a more just and liveable city for all residents. As Mayor Pekka Timonen of Lahti, Finland said in the EU and UK Mayoral reception: "A sustainable city is a better city for people and businesses, not just in numbers".

Alongside the need for ambitious mitigation there is a need for increased adaptation as the world is experiencing unprecedented heatwaves, droughts, storms and other impacts that are expected to further intensify as global warming increases. The impacts of climate change are and will continue to be unevenly distributed – demonstrating the critical need for ongoing adaptation action in cities. Throughout the conference, it was recognized that cities are influential because of the number of people that live and congregate there, the concentration of



Figure 1: section from Graphic summary of the Closing Plenary, illustrator Desiree Llanos

infrastructure and businesses, and the intangible world of ideas, culture, art, etc. that combine to make cities hubs of innovation⁵. But at the same time this congregation and concentration of people and assets makes cities hot spots of climate risk. While recognizing that there is incredible diversity between and within cities in terms of size, density, history, demography, geographical location, economy and natural environment, it is clear that all cities will be impacted by the dangerous levels of warming and changes to the climate currently being experienced and projected for the future. Cities need to adapt to the rapidly changing climate and limit the adverse impacts especially for the poor and vulnerable human and natural communities.

Though cities are making increasingly ambitious mitigation and adaptation commitments, fundamental questions remain about how to translate this into action at the scale and speed required to achieve the emission reductions and increased resilience necessary for a sustainable and prosperous future. The stakeholders who came together at the Innovate4Cities 2021 conference presented solutions, frameworks, tools and granular data gained from physical and social science research, public consultation and other sources. With this large implementation gap never far from the minds of conference participants, two recurring areas of discussion in plenary, parallel and innovation lab sessions were identified as primary enablers for transformative change: (1) a shift in the mindset in stakeholders working to address climate change in cities and (2) the tools that these urban stakeholders need to realise transformative change.

Figure 2 uses a triple helix to illustrate these two key areas of discussion, with the backbones denoting the elements related to change in mindset and the rungs indicating the different tools to facilitate the advancement of city climate action, at the speed and scale needed. Visioning for the future, people centered solutions and an integrated systems approach – which are facilitated by the CHANGE IN MINDSET – are the **backbones** of the triple helix and are meant to shape how climate related decisions are put in place in cities, but also how the outcomes on the ground themselves look. The tools which are being called for to increase the speed and scale of climate action in cities – finance,

partnership, participation, research and capacity building – to realize this transformative change, are the **rungs** of the triple helix.

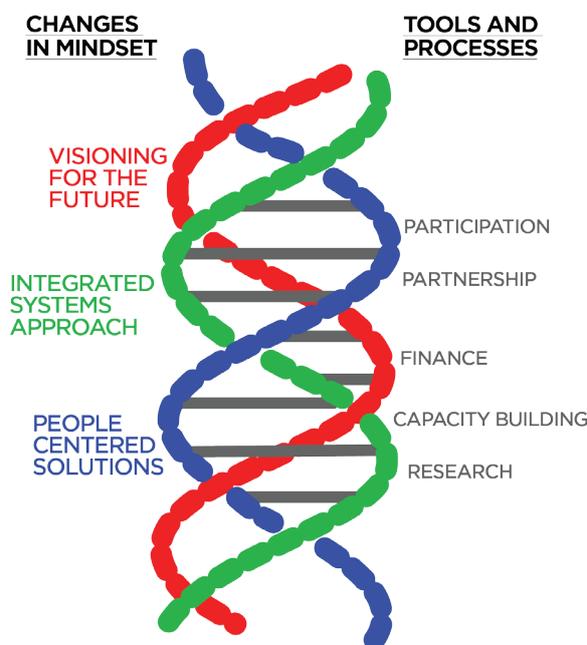


Figure 2: Changes in mindset & the Tools and Processes to close the implementation gap on climate change action in cities.

Graphic designed by Barbara Summers

There are three elements to how **changes in mindset** can guide the closing of the implementation gap for more equitable and holistic outcomes in cities, illustrated as the backbones of the double helix:

- 1. People centered:** *People, development, justice and equity are important considerations in developing urban climate solutions that address historical injustices, incorporate cultural heritage and Indigenous knowledge and provide equitable and sustainable benefits.*
- 2. Integrated systems approach:** *An integrated systems approach that considers interactions, interdependencies, and connections within cities is critical for innovative solutions to the climate crisis.*

⁵ GCoM's Research and Innovation Technical Working Group understands 'innovation' broadly defined as a "new idea, method, or device" and a "change made to an existing product, idea, or field" (Merriam-Webster 2020). In practice, city governments and other urban actors can engage in many forms of innovation spanning problem-solving, creativity, leadership, multidisciplinary approaches, visioning, and diffusion of alternative policies, processes and products.

3. **New visions of the future:** *Instead of focusing on where cities are now, envision a city transformed and not limited by the current reality.*

In addition, there are five **Tools and Processes** for closing the implementation gap which are depicted as the rungs of the triple helix (1) participation (2) partnership (3) finance (4) capacity building (5) research

Changing the Mindset: Integrated, people centered visions for the future of cities

At approximately the halfway point of the conference, the 5th Plenary introduced the provocative title: *Beyond Silos, Beyond Pilots: targeting systems transformations in cities*. The first of the catalysts for action and implementation that were identified during the conference: the need for a CHANGE IN MINDSET was heavily featured by speakers in this plenary, and others throughout the conference as participants considered how to enable transformative change within cities and communities.

As stated by Edmonton City Councillor Ben Henderson in the Opening Plenary, when the local government in Edmonton wrote and committed to the Edmonton Declaration⁶ in 2018, they discovered that they needed a completely different mindset and framing to implement their plan than it took to envision where they wanted to go. The Councillor stated that this ‘...meant that we needed a rigour of our own. We couldn’t just put something down on paper and then continue to do what has been the history in cities of not meeting those goals and those targets.’ In Edmonton they shifted to working on a carbon budget, as inspired by the city of Oslo, Norway to allow them to see how much carbon they had available per year, and then asked city staff to go back and rethink financial budgeting and other processes to fit within this carbon budget.

This process of shifting the mindset from setting ambitions to developing rigorous, data driven action plans for implementation to meet a city’s climate goals year-on-year will likely be unique to each individual

6 The Edmonton Declaration is “a bold call-to-action for mayors to take the mantle of leadership on climate change, and amplify the message that rising greenhouse gas emissions severely impact cities”. This Declaration came together in the Edmonton Change for Climate Mayor’s Summit which was held March 3rd and 4th 2018 to provide input into the Cities and Climate Change Science conference. The Declaration includes a commitment to a 1.5 degree pathway by city signatories as well as a call for partnership to achieve the goals of the Cities and Climate Change Science.

city; however, sharing and dialogue between cities can help catalyse this evolution. Shifting mindset also involves an ability to think about different time scales within the same planning and implementation framework – determining not only what to do next year but being able to re-evaluate those actions with respect to goals on 5-, 10- and 20-year horizons, a point raised by Prof. Kim Cobb from the Georgia Institute of Technology in the North American Regional Curator’s Mayoral Reception. This involves critical evaluation of options, using evidence-based approaches and climate models and projections to help inform future implementation, and current response action to deal with ongoing climate impacts.

Transformative Processes to Close the Implementation Gap

Transformative change is defined in a recent IPCC report as “A system-wide change that requires more than technological change through consideration of social and economic factors that, with technology, can bring about rapid change at scale” (IPCC, 2018). At the Innovate4Cities 2021 conference, transformative change was discussed in many sessions, and several processes to enable this change are elaborated below.

Diverse local participation and co-creation

There was increased recognition at the conference that having all relevant actors – with special attention needed regarding marginalized stakeholders – involved in the discussions and decisions relating to climate change responses is essential and can expand the range of benefits achieved beyond those related to climate change. This inclusion of additional voices can expand the solution space – in terms of set of possible solutions or methods of implementation – and lead to innovation. Whether acting at the mega city scale or the neighbourhood level, innovative methods to foster discussion and education are useful in ensuring that community members understand the contexts, both local and global, of a changing climate. For example, in the Africa Regional Curators Mayoral Reception, Patrick Njoroge, a community mobilization expert from Kenya, suggested implementing targeted educational campaigns that increase the climate knowledge of specific community members who can then champion and share knowledge in a locally contextual and culturally appropriate way within their community to encourage local climate action.

Understanding existing power dynamics within a city, and an ability to be flexible and to work within these dynamics can also pave the way for innovation. However, existing dynamics and structures have in some cases resulted in exclusion and marginalization, and shifting these power dynamics so that youth, Indigenous, non-fossil fuel/extractive industry, and non-capitalistic interests etc. can meaningfully participate to strengthen co-created solutions. There is a growing history of the youth, climate activists, and Indigenous groups mobilising to raise awareness and influence policy that could help in identifying and informing priorities for climate action and implementing this change. Other critical groups that have been under-represented in formal processes, but are critical agents of change for cities include residents of informal settlements, workers in the informal economy, and migrants, examples of which were seen in the session Harnessing Informal Innovation: Lessons from Three Climate Resilient

Development Projects in Pacific Island Cities and Towns and Urbanisation and Climate Change Adaptation in Coastal Areas of the Caspian Sea. Furthermore, diverse representation in terms of gender, age, socio-economic background, ethnicity, place of origin, expertise and profession helps to ensure that processes are not dominated by homogeneous groups. This can support more just and equitable implementation of climate solutions. To solve the climate crisis, everyone has a role to play. However, this requires opportunity and access to decision making and resources to participate meaningfully.

As participation in climate change planning and implementation processes grows, it will be important to understand how participatory processes are designed, whether they are effective in reaching all members of different communities, how the approach can be improved, and how techniques vary between different



Figure 3: Graphic summary of Plenary 6 on Emerging Topics for Future Science and Innovation, as drawn by conference illustrator Lulu Kitololo

cultural contexts, city typologies etc. Sharing these findings between cities can also help support a culture of not being afraid to experiment and fail, as well as provide useful examples of where previously used systems have been transformed, and new structures and forms of governance tested at the city scale. Learnings from other cities on how implementation has progressed on the ground can be shared and help other cities to avoid the same mistakes and can assist in driving implementation at scale. Plenary 6, which focused on addressing emerging topics for shaping future science and innovation, emphasized that bringing people together and a whole society approach are critical for future innovations in addressing climate change in cities (see Figure 3).

Finance

Financial flows remain concentrated at the level of international and national government making direct action in cities difficult to fund (CPI, 2021). This is especially the case in cities that have limited own-source revenue or access to private capital even though research has shown that local level action delivers long term, and impactful benefits for informal settlements in the areas of poverty reduction, disaster risk reduction and climate change adaptation (C40 Cities, 2019). Currently just 10% of climate finance reaches the local level (Soanes et al., 2019). The significant finance gap for implementation of climate solutions at the city scale was identified in many plenaries and parallel sessions (Figure 4 is a graphic summary of the Finance Plenary). It was noted in Plenary 4 on Informality and

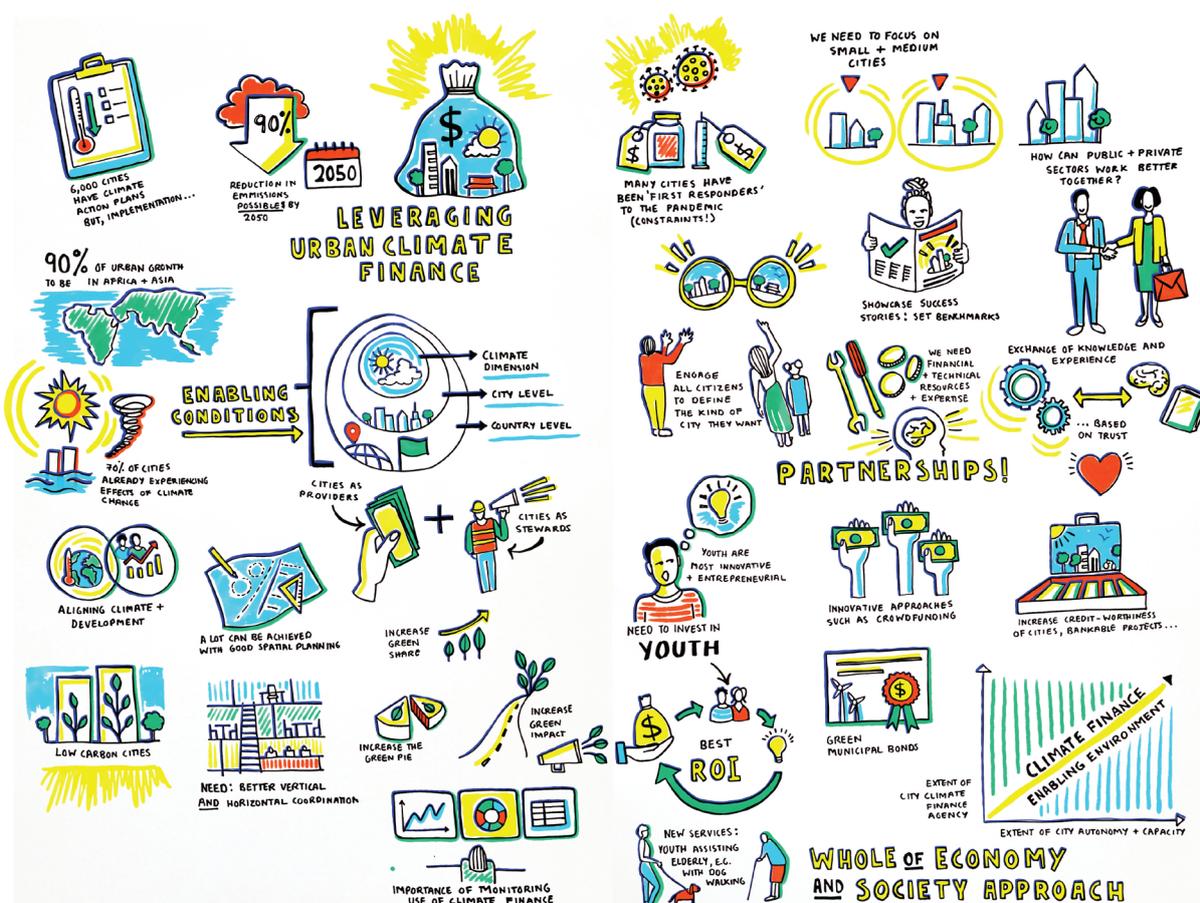


Figure 4: Illustration from Plenary 7 Financing the Transition and Mobilizing Urban Climate Finance capturing the diversity of aspects to consider in increasing and improving the ways in which urban climate finance is provided, as drawn by conference illustrator Lulu Kitololo

Equity, as well as at other sessions that an increase in finance was needed, but that different mechanisms for cities to access finance were also needed. A better understanding of how to address the barriers faced by cities in accessing finance, such as lack of direction of public funding of climate finance from the national to the city level, inability for cities to access credit markets, the lack of appropriate mechanisms to fund adaptation measures, and limited private sector investment is needed.

Questions of how to fund the solutions which are fit to purpose in a city (facilitating a just transition and supporting other development goals) and how to bring together the actors needed for implementation were also highlighted as priorities. In addition to thinking about how funding is delivered, discussions on the incentives for different stakeholders in terms of how current climate finance is structured at the city scale and how this could be modified were also heard through several Plenary and parallel sessions. Several of these aspects are elaborated upon in Section 2 on Research Gaps, where finance is highlighted as a topic for further research. However, Knowledge gaps relating to finance are also present in the Built and Blue Green Infrastructure, Urban Planning and Design and Governance topics, highlighting the need for further mainstreaming of finance for urban climate action planning and implementation, and the elevation of this topic in urban climate change discussion since the 2018 Cities and Climate Change Science Conference (Priour-Richard, 2019).

Capacity

Development of capacity (such as skilled personnel, organisational resources, informational and research capabilities and financial resources and their management) within local government, and amongst other stakeholders was also raised as a key enabler to accelerate implementation. Ensuring that the right capacity, data and finance are available at the right time, was highlighted as critical in Plenary 3. Increased capacity and data can help local governments invest their limited resources strategically or apply for other funding sources more effectively. Lack of capacity can make it difficult to explore, understand and implement suggestions emerging from the latest climate science

and to understand where gaps exist, and innovation may be needed. Employing systems thinking and ensuring that capacity building, data collection and funding decisions are not occurring in silos can allow local governments to move to large scale implementation and ensure solutions are more impactful.

Some key stakeholders such as the youth were identified as not having the power, funds, access and networks required to implement the radical changes they are advocating for, as stated in the session led by Student Energy: *Achieving and Equitable and Sustainable Energy Transition*. This was highlighted as being particularly challenging for many cities in Africa and Asia that will be affected the most by climate change and where the majority of the population is below the age of 25. Educational programs at universities and other institutions can be very important to build capacity to respond to climate change and play an active role in providing knowledge necessary to advocate for and to implement urban climate change solutions. Funding for such programs and clear pathways from training to job creation should also be considered. To elevate the role of youth in responding to climate change in cities, Meredith Adler from Student Energy in Plenary 3 called for young people to have access to training to enable them to increase their influence and act effectively. The need for further support for the youth, including financial support, was also recognized in Plenary 7 on Finance.

Urban stakeholders who will be important in shaping current and future cities, like architects and engineers also need training to enable them to undertake the type of forward visioning envisaged at the conference. The systems thinking needed to implement climate change solutions in cities at the scale required must be underpinned by collaboration within and across disciplines, sectors and levels of government. In addition, as digitalisation continues to be important in advancing business, accessing information and connecting with solutions, there is a need for capacity building for local governments and communities to ensure that they can harness new digital technologies. This can allow them to take advantage of their potential to support the creation of partnerships and enhancing participation and collaboration instead of increasing the digital divide between and within cities and local government.

Partnerships

Partnerships between local governments, academia, the private sector, other levels of governments, civil society organisations (inclusive of marginalized populations, such as Indigenous peoples, women, youth, people with disabilities, informal settlers etc.), international bodies and other stakeholders were identified as being important in reducing risk, facilitating scaling climate change solutions across multiple cities and improving the effectiveness of implementation. Partnerships can be most beneficial when there is continued understanding, respect and learning from different communities within the partnership. The conference highlighted, during Plenary 8, that throughout history, cities have proven to be important places for collaboration, convening, listening and learning. In creating partnerships, however, a balance has to be found between the need for time and space for discussion and respect to be built, and the speed and scale of action required to respond to the implementation gap and **required** change.

One way to conceptualise these partnerships highlighted in conference discussions was thinking of a city's climate change response as a race, but not one that is carried out individually, rather a relay that involves a number of actors playing a role. Seth Shultz used this analogy in the closing plenary and highlighted that the race could not be finished successfully without each member of the team knowing their role and handing over to the person who would carry the responsibility for continuing the race. These hand-offs between partners require trust and care if they are to be effective. An example provided in the conference was the Philippines government shifting away from a conventional top-down approach in urban planning, towards a more participatory and risk-based approach

that uses nature-based solutions⁷ to climate change, which requires not only trust to expand into this new solution space but also the need to work with multiple partners and participants (from session *Financing Green Innovation for Climate Goals*).

The development of partnerships also requires a consideration of power relations and dynamics that can

enable action and or act as barriers to implementation. This requires an understanding of the incentives for different actors within a partnership and how these can be best aligned to deliver on the overall goal of scaled up, ambitious and rapid implementation, independent of the motivation of the different partners. Additionally, when an initiative is completed, evaluating whether the partnership was fit for purpose, and included consideration of all actors who may have benefitted the project is important and helpful to shape future partnerships and help to accelerate implementation. The overall lessons emerging around partnerships include the need for trust, being open to learning by doing, flexibility, willingness to do things differently, prioritising conversations about what is not working and involving all who can help to get across the finish line more quickly.

Collaboration can open up space for local entrepreneurs and social enterprises to innovate and drive forward climate action. Local governments can also innovate. For example, through changing their procurement processes to support low-carbon and climate resilient development. The training session Challenge Prizes: How to Design and Run Open Innovation Competitions to Develop & Test and Scale Innovative Solutions In Cities provided examples of local governments replacing standard procurement processes that focus on "terms of reference" with an approach that invites solutions providers to suggest ideas to meet the local governments challenges. There are also many opportunities for stakeholders to increase alignment of their work, for example, the recent Global State of National Urban Policy (OECD/UN-Habitat/UNOPS, 2021) report found that although 52 of the 67 countries surveyed include both mitigation and adaptation actions in their climate plans, only 30 had self-identified as having direct institutional arrangements between the leading National Urban Policy ministry/agency and their national environment ministry. The number of countries which engage in knowledge exchanges and capacity building across these ministries, was only 26. This lack of coordination could be addressed by acknowledging that there is a virtuous cycle of knowledge, and that no individual or group holds all the information. For example, approaches in which scientists and researchers can learn from Indigenous people and local governments can learn from entrepreneurs both in the formal and informal sectors in ways that are respectful and don't reinforce a hierarchy of knowledge and experience will help create knowledge and capacity to drive change.

⁷ Parties to the United Nations Environment Framework (UNEA), on March 2nd 2022 adopted an official definition of nature-based solutions, which is defined "as actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits". This is the definition which will be used for nature-based solutions through this document

Research

Research plays an important role in developing new ideas and innovations for urban climate change responses, but also helps to assess and compare solutions and describe and evaluate future climate scenarios, helping to understand how climate change will affect cities around the world. Ongoing collaboration and partnership between the research community and other urban actors can increase the understanding of the best options and uncertainties in mitigation, adaptation and building resilience. Research gaps identified during Innovate4Cities 2021 (see Section 2 for detailed theme by theme breakdown) showed an increase in synergies between individual topical and cross cutting themes (ie. research gap under Urban Planning and Design also having clear reference to urban climate finance), highlighting the need for a holistic, people-centered vision leading to increased action to addressing climate change in cities.

It was highlighted in the closing plenary – which called out the fact that there was only one single engineer at the Cities and Climate Change Science conference in Edmonton – as well as by Plenary 6 – featuring an archaeologist, architect, historian and academic with expertise in economics and physics – that there are still many academic communities that have not yet participated in urban climate change research and the partnerships undertaking this research. With one of the conference goals being to *Catalyse engagement between scientists and practitioners for inputs to the IPCC discussions and to support the strengthened focus on regional and urban issues in the IPCC AR6 cycle*, one of the ongoing challenges of the initiative started by the 2018 Cities and Climate Change Science conference and continued with the Innovate4Cities 2021 and any future iterations of this conference series is to bring new voices into the discussion with and within academia, to build stronger partnerships and strengthen research where more information is needed to effectively tackle climate change in cities around the world.

Recognizing and overcoming constraints to climate action in cities

There were many assertions of hope, possibility and excitement about changes and progress in cities addressing climate change during the Innovate4Cities 2021 conference, but there was also a recognition that there is still much work to be done. The gap between ambition and implementation was raised repeatedly during conference discussions. At the same time,

speakers also highlighted that the ambition of many local governments does not match what climate science suggests is needed, reflecting only what *seems* possible. As noted previously, sustainable transformations will not be attained if the possibilities for local government action are limited to those found within traditional path dependencies.

Large-scale implementation and innovation can be impeded because local and national governments are often constrained in their ability to explore new approaches and to take risks, by risk-averse institutional cultures, regulations, the risk of litigation and conservative attitudes to new or unusual thinking. Being forward thinking, using imagination and taking risks are not always things those working in local government are trained and incentivised to do, as highlighted by Kirsten Dunlop in Plenary 5. Many funding sources are risk averse which can lead to a fear of failure instead of incentives to act boldly and embrace setbacks and small failures as a way of learning and moving forward. Other stakeholders – such as entrepreneurs, civil society, youth and activists – who may have more experience with bold innovation should be encouraged to become partners and given the opportunity to help drive the innovation agenda forward with researchers, international organization and city networks. Local governments can also play a role in enabling and encouraging innovative practices and cultures and should be brought into discussions throughout the planning and implementation phase even when this is driven by other stakeholders.

A deep analysis of structural barriers to innovative action is also needed (taking into account culture and historical differences), as was highlighted in Plenary 6 by Indy Johar. How incentive structures manifest in short term political cycles; how city budget allocation influences decisions; how cities are treated as autonomous entities but also have limitations depending on their regional, state, provincial or national contexts, are some examples of the institutional factors that shape climate planning in cities. Recognition of such structural barriers and how they can be changed, challenged or overcome as well as the risks and costs of systems remaining the same are all areas that require better understanding.

There is increasing recognition from the global to neighborhood level, that difficult choices may lie ahead regarding the prioritisation of action. A critical examination of questions such as those below may be necessary to help prioritise actions that may best position local governments to respond to the broad and

increasing range of climate change risks and impacts that may now be inevitable in some places:

- How do we go beyond understanding just the climate and ecological tipping points to understand when stressors in society may cause volatility and social stress that fundamentally alters society?
- What are the societal tipping points that cities may confront in the face of growing impacts from climate change?
- How do we take into consideration some of the more extreme scenarios and the narrowing range of response options?

- How do we support cities facing existential threats such as cities in small island states?

Scaling up and increasing the speed of action to mitigate greenhouse gas emissions and adapt to climate change is not easy for any city whether it is a small to medium-sized city in Africa, a megacity in Asia or a large metropolitan area in North America. It requires knowledge, understanding, participation of diverse groups, collaboration and finance on a scale that currently does not exist. The collective power of cities and the opportunities for ingenuity and collaboration they create provide a global scale but time-limited opportunity to drive the change required to meet this challenge.

SECTION 2: RESEARCH GAPS BY GRAA TOPIC

Building on the overarching insights presented in Section 1, this section provides a summary of research gaps identified at the Innovate4Cities 2021 conference. It also revisits the research gaps identified in the GRAA, which emerged from the 2018 Cities and Climate Change Science conference (Priour-Richard, 2018). The research gaps are divided into the key topical areas where research is needed and cross cutting themes that were identified in developing the GRAA. Three cross cutting issues were added in the planning for Innovate4Cities 2021, these being Digitalization and Smart Cities, Health and Wellbeing and Justice and Equity. A stronger emphasis and understanding of

how culture and history can influence climate change impacts and responses in cities emerged during the 2021 conference and therefore History and Cultural Heritage is included as a new topical research area within this report. The original GRAA and newly introduced topic and cross cutting issues are illustrated in Figure 5, which is an update from the wheel diagram introduced in Figure 1 of the GRAA in 2018.

Throughout this section, synergies between research gaps found under other topical or crosscutting areas have been denoted on the right most column of the research gap tables.

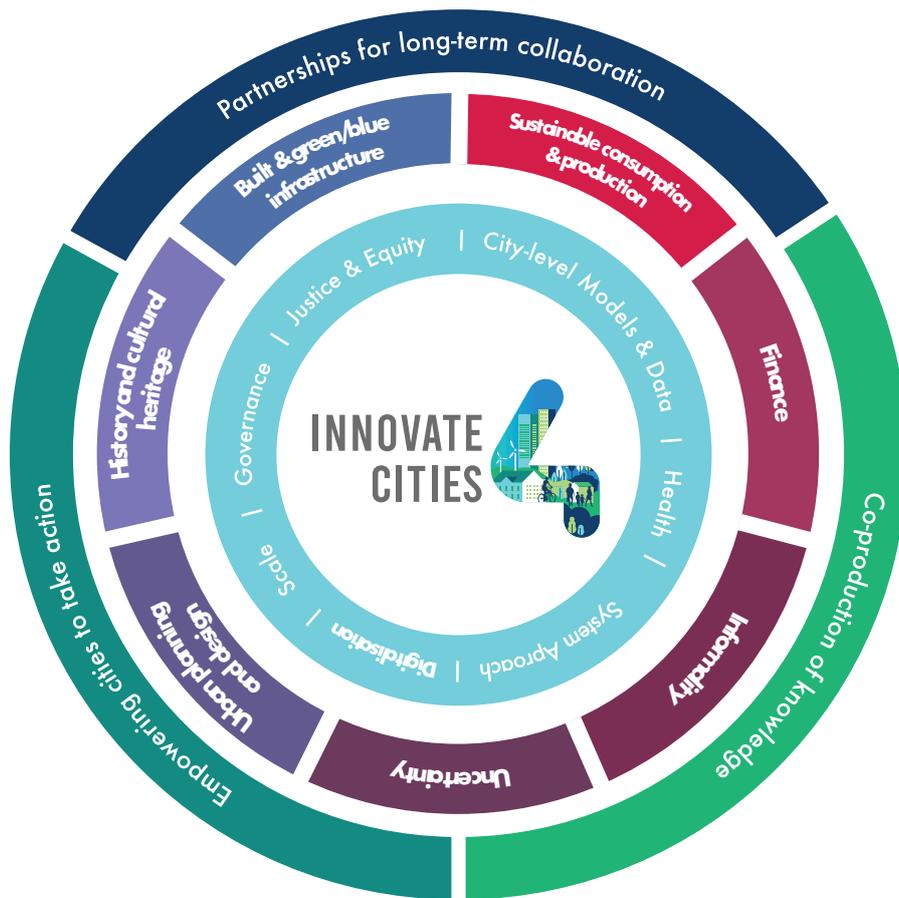


Figure 5: Expanded from Figure 1. Global Research and Action Agenda on Cities and Climate Change Science illustrating topical areas (middle ring) where research is needed, as well as cross cutting (inner ring) areas for action and delivery approaches (outer ring) Modified from original GRAA graphic design by Amanali Cornejo V, World Climate Research Programme (2019).

Key Topical Research Areas

Built and Blue and Green Infrastructure

The built and blue and green infrastructure research area covers both the built infrastructure for transport, energy, and communications that deliver services across cities, as well as the natural environment that provides ecosystem services that support people, the economy and biodiversity.

Global Research and Action Agenda Research Gap, Cities and Climate Change Science Conference, 2018

Further exploration is needed of low-carbon and environmentally friendly infrastructure options that go beyond traditionally dominant grey infrastructure for transformational climate solutions in developed and rapidly developing urban areas.

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.

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.

Building from the 2018 Cities and Climate Change Science conference, interest in nature-based solutions has been on the rise, given the potential for adaptation and mitigation benefits as well as societal and economic benefits (Frantzeskaki et al. 2019). The potential for nature-based solutions to be utilized in cities to build resilience and enhance urban nature for the wellbeing of people and biodiversity across different types of cities was highlighted throughout the conference. It was also emphasized, however, that nature-based solutions should be developed for local contexts and planning for them should consider equity and justice, especially when working with local communities to use nature-based solutions in informal settlements and low-income communities.

The first two research gaps identified in the Innovate4Cities 2021 conference on this topic have a strong correlation to the research gap in the original GRAA with a focus on co-benefits. In general, there was more emphasis on blue/green infrastructure, under the scope of nature-based solutions emerging from the Innovate4Cities 2021 conference.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
Research is needed to better understand the benefits and diverse values of urban nature, including for health and wellness, and how these vary by socio-economic groups, including Indigenous peoples, within and across cities. Then building from this understanding further research is needed on how utilizing nature-based solutions can maximize benefits for climate, nature and people as well as how improving this understanding can reduce conflicts that may arise around approaches to conservation and restoration.	Justice & Equity, Health
Further research is needed to develop full cost benefit analysis of the built, blue and green infrastructure solutions to adaptation and mitigation, that includes financial and economic implications and social/societal co-benefits, at scale and across different urban environments is needed.	Finance
An improved understanding of lifecycle costs of blue/green infrastructure is needed to support planning for projects, better justify additional measures for green and resilient design and ensure maintenance can be sustained throughout the project lifetime to maximize outcomes and benefits.	Finance
Research is needed on ways in which communities can be empowered to lead on nature-based solutions for wide scale public participation and long-term support and sustainability of projects.	Justice and Equity
Further research/guidance is needed from urban ecologists that helps planners, designers and architects to mainstream urban nature in a way that is scientifically robust and leads to specific species and urban ecosystem regeneration and/or specific health or air quality benefits.	Urban Planning and Design

Urban Planning and Design

Global Research and Action Agenda Research Gap, Cities and Climate Change Science Conference, 2018

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.

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.

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.

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.

Urban planning and design are influential in setting the stage for effective climate change action in cities and can help both mitigate and adapt to climate change.

Critically, the most rapidly growing world regions have the fewest urban planners, architects and engineers, with the result that they struggle to define and adopt effective planning responses to climate change. All too often, planning systems are designed based on principles developed in industrialized countries or on colonial influences that do not adequately reflect the unique characteristics of low- and middle-income countries, and nations with transitional economies.

Sessions at the Innovate4Cities 2021 conference explored how traditional instruments of urban planning and design for example often do not integrate or coordinate with climate action plans produced in the same jurisdictions. Thinking on what decisions would be made if traditional urban planning offices and climate planning offices were better integrated could allow for considerations of different decisions, and best practices for mainstreaming climate action within a city.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
Further research and understanding are needed on how synergistic, and systems based urban planning and climate resilient design have been and can be enacted in cities, especially in different city contexts and planning practices, with a view to future urban growth.	Systems Approach
Further exploration is needed of how possibilities of ten- and 100-year weather/climate events should shape overall planning strategies of cities. Additionally, with climate hazards becoming more frequent, it is also important to gain a better understanding of how short-term uncertainty can be better incorporated into long-term planning.	Uncertainty
Further research into how climate change can be mainstreamed into city decision making, particularly within the context of integrating mitigation and adaptation considerations into comprehensive planning, and into capital investment plan/capital improvements programming of a city is needed.	Governance, Finance
Research is needed on best practices for how local government budgets can be climate smart, aligned and sensitive, and how this would vary based on the context of different cities.	Finance
There is a need for documentation and evaluation of early attempts to adapt cities to the impacts of climate change, including efforts at both fortification and retreat and different approaches to adaptation. This could include models for successful relocation from areas that will be uninhabitable due to climate change as well as methodologies for assessing and evaluating the effectiveness of adaptation options with the changing severity of impacts	Justice and Equity, History and Cultural Heritage
Better understanding is needed of the relationships between urban form and urban design and transportation systems in the context of greenhouse gas emissions. Land use patterns drive what is possible in terms of vehicle miles travelled, transit modal split, and bikeability/walkability. The implications of different density patterns, subdivision regulations, and street/corridor design in terms of transportation behaviours must be understood in different cultural and climate contexts as well as projected urban growth.	

The research gaps identified at the Innovate4Cities 2021 conference build on the ones identified in the original GRAA for example synergistic and systems based planning relates to the call for understanding the connections between urban planning, design, infrastructure and climate change which was a research gap in the 2018 GRAA. The role of urban and spatial planning for reducing vulnerability in both informal and formal settlements was another research gap in the 2018 GRAA which is related to the research gap to

better understand early adaptation efforts and long-term planning that better accounts for uncertainty and ten- and 100-year weather events to shape planning strategies for cities. From the 2018 GRAA, there was also a research gap under this urban planning and design related to health impacts and co-benefits of climate action, which while not explicit in the identified research gaps here, is taken up by the new cross-cutting area on Health and Wellbeing.

Informality

Global Research and Action Agenda Research Gap, Cities and Climate Change Science Conference, 2018

Further understanding and research is needed on how inhabitants of both informal settlements and slums are particularly vulnerable to the effects of climate change.

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.

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.

Informality – both in terms of informal economy and settlements – is a defining characteristic of many economies and cities in low- and middle-income countries. The inclusion of informality as a key research gap at the 2018 Cities and Climate Change Science conference recognized the importance of better understanding informality to inform the development of appropriate climate adaptation and mitigation strategies and harness the transformative potential of informality in the majority of cities around the world.

Informal settlements are particularly vulnerable to the impacts of climate change due to their often dangerous locations that may be exposed to climate related hazards (ravine flooding and sea level rise), sub-standard building materials, poor infrastructure, rapid expansion and precarious livelihoods. People working in the informal economy are also vulnerable to climate-related shocks and stresses and make up large portions of the workforce in several sectors that are critical to a low-carbon transition in many cities.

In the GRAA, one of the main research gaps identified focused on the relationship between climate change and the informal economy. There are synergies between this and two newly identified research gaps on the contribution of informal waste collectors to low-carbon and resilient cities and the need to better understand how informal workers are more vulnerable and/or more resilient to shocks and stresses. At the Innovate4Cities 2021 conference, there was a richness of experience shared from local contexts that demonstrated the importance of actions on the ground for improving people's lives and situations while current conditions constrain transformative change. It was again highlighted – as it had been in 2018 – that finance is urgently needed to address climate change challenges in informal settlements as is research and innovation to help understand how finance could best support the inhabitants of these communities.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
More research is needed, using evidence from the ground, based on experiences during the COVID-19 pandemic, on how informal work can be more vulnerable and more resilient to shifts in the global and urban context like those seen during the COVID-19 lockdown periods and successive economic downturns and how this resilience may be translated to shocks and stresses caused by climate change.	Health, Justice and Equity
Further study is needed on cases of effective community participation and models in informal settlement planning in the context of climate change, especially involving youth and children who make up a large proportion of populations in cities in developing countries.	Urban Planning and Design, Justice and Equity
Further information and data are needed on how the work of informal waste collectors contributes to low-carbon and resilient cities and the costs and benefits of these systems	Sustainable Consumption and Production, City level data and models
Research is needed to understand and document how potential technologies, for example drones, can inform planning within informal settlements, especially self-enumeration, and incorporate current and future impacts of climate change to improve adaptation efforts.	Digitalization, City level data and models
Further understanding of how partnership networks that are inclusive of informal settlers and those working in the informal economy can be designed so that implementation and data collection are done from the bottom up and top down, and how methods and planning informed from the bottom up and top down could result in design solutions that are equitable and people-centred, support development needs and build resilience to climate change.	Justice and Equity

Finance

The “finance gap” for investment in climate change mitigation and adaptation is recognised as a global challenge. City networks are calling for greater localisation of investment to support city climate policy implementation (CCFLA 2021). The finance gap between mitigation and adaptation is also significant with only 9% of all tracked urban project-level finance, USD 7 billion (EUR 6 billion) in 2017/2018, used for adaptation and resilience measures (CCFLA 2021). City authorities face a range of internal and external funding barriers to achieving their climate ambitions including siloed climate budgets, limited capacity to generate revenue, inadequate coordination of investment from higher levels of government, and a mismatch between standard financial metrics and necessary local

investments that may be small-scale or offer low financial returns compared with social and environmental benefits. The 2018 GRAA highlighted a need to understand how climate change can be effectively mainstreamed in fiscal and financial decision-making by local authorities, and how to improve public and participatory funding processes for public goods and services. This area of focus was discussed and elaborated at Innovate4Cities 2021 with new research gaps identified. Consideration of how cities contend with the economic impacts of COVID-19 and the fact that stimulus packages have fallen short of funding decarbonisation at scale was also raised as an area where research and knowledge were needed. In addition, as discussed previously (see Section 1) the importance of finance in transformative change and the need to involve marginalized urban residents such as the youth, picks up on the research gap from 2018 on engaging low-income and marginalized urban residents in fiscal decision making.

Global Research and Action Agenda Research Gap, Cities and Climate Change Science Conference, 2018

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.

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.

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.

Research is desirable on how to include low-income and other marginalised urban residents in fiscal and financial decision-making

Research on insurance options could empower cities to better address disaster risk.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
Further research is needed to better quantify the adaptation finance gap in cities and understand issues of finance accessibility at the local level. This could include an analysis of useful metrics for classifying and identifying urban adaptation finance at the local level for comparability of adaptation finance across cities, regions and globally, and best practices for financial mechanisms to effectively distribute across various levels of governments.	Governance
Further exploration of best practices for public procurement, and other available tools as well as the potential for tools that would unlock finance for local governments to increase implementation is needed.	Governance
Further research is needed to forecast how insurance companies will respond if loss and damage costs accelerate as the result of lack of adequate adaptation action within cities and projections of the implications that this could have on cities.	Built and Blue/Green Infrastructure
Scoping for a better understanding of the potential for digital finance, crowdsourcing and digital green bonds for urban climate change projects is needed.	Digitalization
Analysis is needed on how the availability of climate finance in developing and developed countries has been affected by the COVID-19 pandemic and the subsequent impact on climate plans and climate actions taken in cities.	Urban Planning and Design, Health
Investigation and further understanding of business models that could make innovation possible is required. How to enhance the confidence of potential investors in climate initiatives in cities should be considered.	

Uncertainty

Global Research and Action Agenda Research Gap, Cities and Climate Change Science Conference, 2018

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.

Further research should be conducted on tools that assess uncertainty considerations in different city contexts to strengthen decision-making in uncertain situations.

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.

Climate modelling and knowledge generation is predominantly global in nature, while as this conference underlined, the majority of climate actions will happen at the local level. Such actions need to be informed by scientifically sound, contextualised and tailored forecasting and interpretation of climate models so that the local level policies and actions are forward looking and build upon regional, and global synergies. At the 2018 Cities and Climate Change Science conference, the need for research into tools and methodologies to assess and understand uncertainty in different city contexts was highlighted. At Innovate4Cities 2021, there was a change in focus towards maximising use of existing local data, improving risk management in uncertain and changing conditions and uncertainties related to emissions projections.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
Research is needed on how to maximize the use of already existing local data and information within climate models, as well as the identification of additional localized data and information that are critical to understanding locally specific risks and uncertainty and tailoring locally appropriate adaptation measures.	City Level Data and Models
Increase understanding about how risk management and disaster planning data can best be used and developed by and within cities in the face of constantly changing conditions.	
More research is needed on innovative climate models and the emissions (savings) potential in each model as well as uncertainties in these emissions projections.	City Level Data and Models; Digitalization

Sustainable Consumption and Production

Global Research and Action Agenda Research Gap, Cities and Climate Change Science Conference, 2018

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.

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.

Current methodological innovations in greenhouse gas emissions calculations could be improved by exploring the role of urban consumption.

It is estimated that cities account for about 60 % of total domestic material consumption of raw materials (production + imports – exports) (IRP, 2018). Resource use in cities under a business-as-usual scenario is

expected to grow substantially from 40 billion tonnes in 2010 to 90 billion tonnes by 2050 for a projected urban population of 6.3 billion (IRP, 2018). Such an increase in resource consumption translates into overexploitation of ecosystems, environmental degradation and greenhouse gas emissions that contribute to climate change. Urban circularity and the circular economy were continuously raised as important issues at Innovate4Cities 2021 within new models of thinking that embrace a systems approach and promote sustainable consumption and production. Fostering changes at the individual level and shifting from resource intensive lifestyles were also discussed picking up on research gaps identified in 2018. The consideration of locally specific contexts to maximize benefits and the value of community-based plans were emphasised during the Innovate4Cities 2021 sessions as well as the potential to share best practices between cities, countries and regions, while recognizing that significant tailoring of solutions to fit certain contexts may be needed.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
Further research is needed on how to best develop national government policy to fit the needs of local governments to maximize the potential for public procurement in building urban climate solutions. Exploring what options exist in terms of evaluation criteria that are not only based on lowest cost, for example, indicators to quantify mitigation and adaptation co-benefits included in project requirements/assessments.	Governance, Scale
There is a need for a better understanding of waste value chains and how they can contribute to low-carbon and circular economy transition, particularly in developing cities.	Informality
Further research is needed on how sustainable consumption habits can be fostered, and how local availability and potential for sharing can be better understood and supported through digital platforms. This could include how digital platforms can support growth of sustainable consumption habits from an individual scale to influence the community and city scales and beyond through personal relationships, friendly competition with neighbours etc.	Digitalization
Further research and information are needed to determine locally specific plans and the benefits of urban agriculture for climate mitigation, food security, local production, ecosystems and biodiversity.	Built and Blue/green Infrastructure, Justice and Equity
Research is needed on how circular economic principles have affected consumption and production in regions where this concept is most prevalent, and how this framework may need to be tailored for best impact in addressing climate change in cities where it has not been integrated in climate planning.	Systems Approach
There is a need to further investigate the potential of community based sustainable energy production to identify the best source(s) of energy production for the contexts of particular cities and communities, the impact that energy production can have in reducing emissions as well as the contributions it could have to other social and development dimensions at the local level (employment, community resilience, securing access to energy and reducing energy poverty).	

History and Cultural Heritage

Discussions at Innovate4Cities 2021 examined under-utilized opportunities to expand climate action in cities, which led to the identification of history and cultural heritage as a key topic and a potentially enabling condition for urban climate change action. Examining the histories of cities can help build a better understanding of power dynamics, who was involved in decision-making and how that has shaped the city, but also how those dynamics may influence future decisions.

Embedded in cities' institutions, norms and residents' memories is historical, cultural, and spiritual information on how cities have responded to past stresses and crises. These stories and narratives have been studied by many academic fields including anthropology, archaeology, geography, history, planning and the

rapidly emerging urban system science. Discussions at the Innovate4Cities 2021 conference focused on identifying these untapped culture and heritage sources, and how to utilise these resources to unlock their potential to promote transformation change.

Specifically, urban adaptation (what is feasible and possible) should be informed by a deep understanding of the nature of cities and the drivers of urbanisation, and such a perspective requires connection with a historical perspective. For example, what do we know about broad patterns of urban persistence, resilience, and collapse across different time scales and especially in the modern era? It is clear that climate action could be made more impactful through the integration of local urban cultural values and experiences, especially those of the urban poor.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
Research across fields and disciplines to bring together experts on past and current culture and heritage of a particular city with urban planning and climate experts for collaborative research is needed.	Urban Planning and Design
Further understanding is needed on how urban participatory planning processes to devise and implement climate change solutions can be shaped by culture, heritage and history and how these inputs can be considered in the participatory process to ensure that traditionally marginalized communities are included and past injustices recognized.	Urban Planning and Design
Research is needed on how culture and heritage can better inform place-based responses to climate change which better serve the needs of the community.	
Further incorporation and representation of oral histories - inclusive of Indigenous oral traditions - in research and the generation of urban climate knowledge and data.	

Cross Cutting Issues

Systems Approach

Global Research and Action Agenda Research Gap, Cities and Climate Change Science Conference, 2018

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.

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.

New methods need to be developed to incorporate integrative measures of valuation, bringing together quantitative, relational, distributional, behavioural and economic values to assess synergies, trade-offs and co-benefits and potential maladaptation between interventions that respond to climatic and non-climatic hazards.

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.

At the 2018 Cities and Climate Science Conference, the systems approach was discussed as a way of identifying and limiting negative externalities from various efforts or minimising negative spillover effects.

As highlighted in Section 1, addressing climate change requires deep transformations in every part of society including government, civil society, academia and business. Cities provide the living landscapes in which these transformations can be tested and scaled, interconnecting a system of systems.

Various sessions within the conference emphasized the growing applications for a systems approach and also noted interdisciplinary solutions being developed. The GRAA from the Cities and Climate Change Science conference included a research gap on a need for knowledge on important interactions, inter-dependencies and resource flows between natural, built and social systems. This was picked up at the Innovate4Cities 2021 in the research gap focused on the role of ecological placemaking, design and participatory planning. Additionally, much of the content in the final GRAA research gap on a systems approach, highlighting need for action-oriented research, focused on multiple impacts, and co-benefits was elevated in Section 1 of this document.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
Research is needed to better understand how to effectively design urban climate goals and actions that take on a systems approach by incorporating the multiple, locally specific climate and societal problems and pressures and the perspectives of different actors in cities	
Further information is needed on how city systems and systems of cities operate at different scales from the neighborhood scale to metropolitan regions and how this impacts regional and national scale decision-making and the implementation of climate change mitigation, adaptation and resilience solutions.	Sustainable Consumption and Production, Governance, Justice and Equity
Further work is needed to bring together different ways of thinking which currently contribute to how cities are built and shaped such as ecological placemaking, design and participatory planning to build new creative approaches and ways to think and plan a city system which increase resilience to climate change while also providing important co-benefits particularly for marginalized and vulnerable groups.	Urban Planning and Design
Exploration of how thinking using a circular economy and systems approach framework can open new possibilities, and allow for conceptualization about the future city, the different ways it may operate and the necessary solutions to achieve sustainable and resilient cities is needed.	Sustainable Consumption and Production

Health

Climate change is the single biggest threat to our health (WHO, 2021). Furthermore, there are clear links between the underlying drivers of ill-health and climate change. There are also synergies between solutions that promote better health and mitigate and facilitate adaptation to climate change, and therefore enormous potential to improve the health of people and planet simultaneously (Watts, et al. 2015, IPCC, 2022).

Health was not an explicit theme of the 2018 Cities and Climate Change Science GRAA, though it was discussed in sessions in terms of the co-benefits of climate action. It is included as a cross cutting theme in this report to reflect the increasing importance of

health within the cities and climate change agenda, as well as the associated challenges and research gaps (Hassan, 2021).

During the conference, health was a common, recurring topic both from a climate mitigation and adaptation perspective, and across a range of sectors including waste, air quality, nature-based solutions and green space, urban planning, food, housing and energy - and in relation to the COVID-19 pandemic. Health was discussed as a cross-cutting issue that requires a systems approach. Similar to climate, health was acknowledged as an issue of equity, with multiple references to how the most vulnerable are hardest hit by climate change and health crises.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
Further research is needed on ways to account for benefits to health and wellbeing of urban greenspace, including urban regeneration projects, in financial and other terms and there is a need to explore how accounting for these benefits can influence urban planning, especially in cities under-represented in existing research. Particular attention should be paid to effects on traditionally marginalized and vulnerable communities as they may have distinct benefits and trade-offs.	Urban Planning and Design, Built and Blue/Green Infrastructure, Justice and Equity
Further assessment of the benefits and best practices of integrating local air quality and climate change plans is required to understand how to maximize impacts and benefits for health and climate.	Justice and Equity
Research is needed on which innovative financing mechanisms can be utilized by cities to advance health and climate solutions.	Finance
Research is needed to better understand the co-benefits of climate and health policy, and a further understanding is needed on how to mitigate misalignment of these policies to promote synergies.	Governance

Scale

Global Research and Action Agenda Research Gap, Cities and Climate Change Science Conference, 2018

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.

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.

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

Spatial and temporal scale can have a major impact on mitigation, adaptation and resilience measures in cities. City decision making benefits from the best available knowledge to determine actions in the short term (1–5 years) to react to climate events, shocks and stresses while balancing the need to consider long term goals and scenarios. Though local governments can be nimbler in their responses, they are often also nested within provinces or states, regions and nations, and decisions made at these scales can impact how local governments are able to respond. In addition to

the actions that can be taken directly within a local government's power, it is also important to understand the influence of decisions at other spatial scales, advocating for decisions which would increase their ability to act, and which would better align urban, provincial/state, national and international climate efforts.

At the 2018 Cities and Climate Change Science conference, key research gaps were identified relating to comparability and ability to integrate data across scales and for different world regions, the interplay between climate policies developed at different scales and how they impact urban climate action as well as furthering work at time scales relevant to local governments' decision making.

At Innovate4Cities 2021, there was further discussion about how decisions over different timelines can affect the impacts of action and inaction, with a call for better integration of top down and bottom-up efforts to help close the implementation gap. Additionally, within the discussion around adaptation and adaptation financing – which received a greater emphasis at Innovate4Cities 2021 than in 2018 – there was a consideration of how co-benefits and trade-offs of particular adaptation efforts could affect spatial scales beyond that of the city boundary, and how this could be factored into decision making and cost analysis on adaptation.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
Further research is needed on how to calculate short- and long-term benefits of climate solutions and how factors such as cost, inclusivity, difficulty of implementation, effectiveness in increasing mitigative and adaptive capacity and sustainability of solutions should be weighed against the timelines for benefits (or the consequences in not acting) in order to prioritize implementation options.	
Increased learning from effective small-scale projects with significant community support is needed to better understand how community support can be built for projects with larger scale implementation potential.	Systems Approach
Further understanding is needed of the implications of delaying or accelerating climate action in cities, both within the city and how local government decisions would impact on territories and people outside of city boundaries.	Justice and Equity
Further understanding is needed of upstream and downstream impacts of adaptation projects in cities and how regional approaches could be employed to create more effective climate solutions.	

Governance and Institutions

Governance models and institutions that integrate multiple levels, include multiple actors, and can respond to a multitude of issues in a timely manner are essential for responding to the climate challenges in cities. Given the differences of local contexts, there is a diversity of governance approaches that can work to position a city on a pathway to effective climate action.

However, as described in Section 1, there are many areas such as capacity, finance, participation, and partnerships that are critical for effective climate change governance in cities. Section 1 also highlights that the distribution of power among diverse actors within formal and informal governance structures based on historical and structural factors can shape their capacity to participate and act in response to climate change.

As was reflected at the 2018 Cities and Climate Change Science conference, there is a continuing need to understand the operational pathways and institutional structures for governance that effectively support climate action in different urban contexts and that are inclusive of diverse priorities and voices in planning and decision making.

Global Research and Action Agenda Research Gap, Cities and Climate Change Science Conference, 2018

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.

Knowledge is needed on different forms of governance, including multilevel governance, that can best support climate action across a highly uneven institutional landscape.

Deeper understanding is needed of how transformative climate change responses can address urban inequalities and ensure inclusive modes of governance.

Governance at the Innovate4Cities 2021 conference was raised in discussions on policies, strategies and tools to support governance and a better understanding of how local governments are structured and function. Additionally, reflections on new models for collaboration and partnerships that are inclusive of non-state actors, especially marginalized communities came into many conference conversations. For example, how multilevel governance can help unlock the utility and regional scale support needed for carbon free energy which maximizes local supply and meets local demand, as well as how regulatory frameworks are needed for broad scale adoption of many climate solutions.

The research gaps identified under the cross-cutting theme of governance and institutions at the Cities and Climate Change Science conference in 2018 have a strong connection to several of the gaps identified during Innovate4Cities 2021. For example, the 2018 gap which called for understanding institutional structures that support inclusive voices and priorities relates to the gap identified in 2021 regarding the need for tools for public participation and consultation and inclusive organizational structures. The second gap in the 2018 GRAA focused on different forms of governance, including multilevel governance to best support climate change action which is reflected in two research gaps identified in the 2021 discussions, one on overlapping jurisdictions and the other on how national and regional policies might impact urban climate action by taking a territorial or landscape perspective.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
There is a need for information and research to support the co-creation of new models of collaboration at the urban scale, bringing in local and Indigenous experiences, as well as those with potentially different perspectives such as the private sector and industry.	
Further research is needed on innovative governance models which are most effective for cities who are prioritizing circular economic principles.	Sustainable Consumption and Production
There is a need for further research on how land governance is influenced by extractive and exclusionary principles and models, and how this affects decision making on climate change action at the local scale. Exploration of alternative models which include innovative ways to address property tax, different forms of property rights regimes, ways to de-fiscalize land use and enable broader horizontal distribution of resiliency are needed.	Justice and Equity, Finance
Research is needed on the barriers and blockages that prevent local governments from accessing capital to implement climate change initiatives as well as potential changes to governance models and other societal structures that could facilitate that access and how to address political issues and corruption, to facilitate flows of capital.	Finance
Increased understanding of how overlapping jurisdictions and agencies, neighbouring nations, and special-purpose districts interact to devise strategies to move climate change policy.	Scale
There is a need to understand the best tools for public consultation and consensus building, public participation, and conflict management as well as potential new, inclusive organizational structures. In particular, it is important to know how these methods work in varying contexts of gender, age, race, ethnicity, religion, Indigenous status, and (dis)ability.	Justice and Equity
Further research is needed on how national level climate change and regional development policies and strategies can incorporate a territorial or landscape perspective to support urban climate change action.	Scale
Deep analysis of structural barriers preventing action are needed – for example examining short term political cycles, budget allocation, autonomous cities lacking engagement with the regional level etc. and how combinations of these factors prevent action, and how overcoming barriers or changing paradigms could enable it.	Justice and Equity

Digitalisation and Smart Cities

Innovation in digital technologies offers many opportunities for implementing climate change action in cities through improved operational efficiency, real-time data and analytics to aid decision making and the creation of synergies between systems. In order to manage the dynamic nature of climate change, there is an urgent need to initiate innovative smart and digital solutions, and upscale the existing innovations developed based on cutting-edge digital technologies that are able to deliver services that were not previously feasible due to high financial costs and the long timeframes required to deliver results.

Digitalisation was not included as a cross cutting issue in the 2018 Cities and Climate Change Science conference's GRAA though it's potential was discussed in strengthening city level models and the data available. Since then, it has been increasingly recognized as an important feature in addressing climate change in cities, from the focus on Big Data in the Innovate4Cities City Research Agenda (Global Covenant of Mayors 2018) to the benefits of digitalization illustrated in addressing the COVID-19 pandemic.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
Further research is needed on how digitalisation of city-level data and solutions can improve key urban functions (water, waste, electricity management) increasing efficiency and contributing to mitigation, in addition to building adaptive capacity and resilience and providing other societal co-benefits.	City Level Data and Models
Exploration of how digital technology can support the creation of a co-produced database with innovative solutions and a function to sort and prioritize solutions according to criteria such as, transferability, scalability, replicability, circularity, sustainability, timeliness, mitigative and adaptive potential, evidence-based, inclusivity, gender and age-sensitive and fit for purpose in the context of a particular city to learn from past experiences and best practices in order to select the best solutions for local needs.	Justice and Equity
Research is needed on how dynamic climate action planning, which relies on crowd sourced, tailored and real time big data can be effectively used, and streamlined for the contexts of different cities around the world.	Urban Planning and Design, City Level Data and Models

Observations, Data and Modelling at the City Scale

Access to reliable multi-sector data at appropriate spatial and temporal granularities is a key resource for local governments in developing and implementing robust and effective climate change mitigation and adaptation action plans. Local policy needs to be grounded in sound, inclusive governance processes in which all actors have access to the best available scientific assessments of local climate-related risks and models and scenarios that support choices between possible local socio-economic pathways. At the 2018 Cities and Climate Change Science conference, it was recognised that there were considerable shortcomings in data and models to support local decision making on climate change issues. For example, the lack of downscaled climate projections and detailed socio-economic data at the local scale, especially in the Global South, were highlighted as well as the high level of uncertainty linked to downscaled projections. Also, suggestions were made to adopt more transdisciplinary approaches that would include Indigenous and local knowledge in data sets used for local modelling work, in particular for complex coastal city environments.

Global Research and Action Agenda Research Gap, Cities and Climate Change Science Conference, 2018

There is a need for an international and open-access observational framework for collecting key climate and socio-economic metrics at the city scale.

Improving modelling capabilities is key to producing higher resolution data, predicting near term climate futures, and producing models that are customisable to specific cities.

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 and local knowledge), is crucial for scientific advancement.

Research is needed on the effect of, and the dynamics between, adaptation alternatives for coastal cities.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
Further support is needed for local governments and partners to capture small scale case studies and research is needed on how these can be integrated and shared to inform decision making, providing information on best practices, barriers, failures, challenges and innovations in individual solutions which may apply across different contexts within different cities.	
Further research is needed on the potential for urban forests to contribute to mitigation efforts, inclusive of location, species specificity and how future climate conditions will affect growth and sequestration potential.	Built and Blue/Green Infrastructure
Research is needed on how mobile phone data can be used to understand exposure and citizen response to climate disasters and risks and inform policy to reduce future risk.	Digitalisation
Location specific data are needed on how the integration of particular topographical, geological, structural, social contexts influence the risk from climate hazards and how they may affect potential to respond to risk.	

Partnerships between local governments, scientists, the business community and citizens are key features of many city activities in which innovative information technologies, data and methodologies may be combined with Indigenous and local knowledge. The SMART city movement in which information and communications technology developments such as big data, artificial intelligence and machine learning, and 3D GIS is growing in importance and was prominent at Innovate4Cities 2021, and there are many synergies with the Digitalisation and Smart Cities cross cutting area and with that of Observations, Data Modelling and at the City Scale. Also prominent were examples of transdisciplinary approaches to data, modelling and

decision making in which the roles of local citizens and communities, from data collection, analysis, decision making and monitoring, were stressed.

In comparison to the research gaps identified at the 2018 Cities and Climate Change Science conference, gaps under Observations, Data Modelling and at the City Scale from Innovate4Cities 2021 call for an increase in specificity of needs, which is consistent with further development of city level data, as well as expansion of understanding, accessibility and use of data to an increasing number of urban actors.

Justice and Equity

Justice and equity need to be considered in every dimension of climate change responses. For example, who will be impacted, where and how, as well as considering co-benefits and trade-offs and the different risks and impacts of climate hazards. The recent COVID-19 pandemic and the Black Lives Matter movement have elevated and highlighted the importance of applying a justice and equity lens to climate change responses. Studies have shown that populations with higher exposure to air pollution are more likely to have severe consequences when contracting COVID-19 (Pegoraro, 2021). These communities are more likely to be marginalized. Urban planning practices such as red-lining have also contributed to a higher proportion of highly polluting sites, highways, landfills etc. being in neighbourhoods

which have higher proportions of people of colour in the United States (Gutschow et al., 2021). A recent study has shown that the particulate matter pollution caused by fossil fuel combustion resulted in 8 million deaths globally in 2018 (Vohra, 2021). Therefore, mitigating fossil fuel use can have significant contributions in reducing climate change and air pollution risks for vulnerable communities. Citizens who live in informal settlements often find themselves outside typical planning frameworks, and their particular needs and vulnerabilities are not addressed in urban climate change responses. With investments in cities to support a green and climate smart recovery from the COVID-19 pandemic, it is critical to ensure this delivers socially just and equitable outcomes. Adaptation and mitigation strategies need to be developed using participatory and inclusive structures, and deliver co-benefits such as improved health outcomes, economic development, jobs and gender and racial equity.

Innovate4Cities Identified Research Gaps	Synergies with other Topics
A better understanding of how historical inequities and intergenerational issues of justice and equity in cities are compounding current climate and environmental justice issues is needed.	History and Cultural Heritage
Further research is needed on how inequality is built into current urban planning cultures and norms and how reorienting towards an urban planning framework which takes a human rights approach could impact justice and equity issues in urban climate change planning.	Urban Planning and Design
Knowledge is needed on how interspecies impacts can be better included in urban climate action. Further understanding and knowledge to inform who should speak on behalf of other species in urban climate change decision making is also called for.	Built and Blue/Green Infrastructure
Research is needed to better understand the synergies between climate action, development and poverty reduction in cities, especially access to sustainable energy that would increase energy security as part of a low-carbon development pathway.	

SECTION 3: REGIONAL INSIGHTS

The Innovate4Cities 2021 conference sought to maximise geographical coverage in terms of content and participation, recognising the importance of local context in shaping the priorities and capacities of cities to respond to climate change and advance research and innovation. The conference was publicised in all world regions to take advantage of the reduction in travel time and costs associated with an online event and to include more speakers and participants from areas typically underrepresented at international conferences. Additionally, conference organisers invited four teams of regional curators from (1) Oceania and Southeast Asia, (2) East Asia, South Asia, Eastern Europe and Central Asia, (3) European Union and Western Europe, Middle East and West Asia and Africa and (4) Latin America, the Caribbean and North America. These teams were made up of researchers and local government leaders and practitioners and allowed them to submit regionally curated content for the conference program.

This section documents local insights that emerged from discussions at Innovate4Cities 2021. These are limited to documentation of conference proceedings by rapporteurs and session descriptions that reference localities and/or regional areas and are not intended to represent the priorities or consensus for an entire region. Especially as some regions were under-represented at

the conference (see Table 1). In addition, some topics - uncertainty, systems approach, and scale - do not include detailed local examples because of the lack of regional specificity in sessions on these topics. A breakdown of abstracts tagged to locations is provided in the table below.

Key Topical Research Areas

Built and Blue and Green Infrastructure

On the theme of *Built and Blue Green Infrastructure*, major themes at the regional level and with local examples include references to biodiversity and ecosystems, water management and coastal development, transport and mobility.

Biodiversity, ecosystems, urban greening, conservation and regeneration, and soil were identified across all **world regions**. Examples include:

- Understanding the potential of nature-based solutions in the context of **Sub-Saharan Africa** (as distinct from the Global North), including overcoming governance barriers and public perceptions, and basic services provision, resilience, and wellbeing outcomes in informal settlements;

Total number of conference abstracts that refer to particular regions

Region	Programme abstract references
Latin America and the Caribbean (LAC)	39
European Union and Western Europe (EUWE)	34
South Asia (SA)	34
North America (NA)	28
Africa (AFR)	25
Southeast Asia (SEA)	22
East Asia (EA)	10
Oceania (OCE)	10
Middle East and West Asia (MEWA)	8
Eastern Europe and Central Asia (EECA)	2

- Understanding the economic potential of nature-based solutions in contributing to just transitions in **Malmö, Sweden, New York City, USA, Rio de Janeiro, Brazil, and Busan, South Korea**;
- Understanding the effectiveness of geospatial data tools for prioritising urban canopy development relative to urban heat in **Caracas, Venezuela**;
- Understanding how nature-based solutions can be mainstreamed in different local contexts through co-design and foregrounding Indigenous perspectives, across **Australian cities**;
- Understanding the carbon drawdown potential of nature-based solutions in cities in **Southeast Asia**;
- Understanding the availability and potential of open-source technologies to support decision making and management of green spaces in cities in **Bangladesh**;
- Understanding the potential for the use of climate risk and vulnerability assessment as a way of prioritising afforestation in **Paqueta Island, Rio de Janeiro, Brazil**.

Similarly, water management and coastal development were repeatedly referenced in sessions from Africa, Southeast Asia and South Asia. For example:

- What is the potential for improved water system monitoring through digital technologies in poor African communities with limited water resources such as **Ndokayo, Cameroon**;
- Understanding (flood) risk relative to climate change projections in low-elevation coastal zones and possible solutions in **Southeast Asia**.

References to mobility and transport infrastructure were discussed in sessions across Africa, the European Union, Western Europe, Latin America, the Caribbean, the Middle East and West Asia. For example:

- How reductions in emissions, air, and noise pollution from road transport can be achieved through non-motorised transport facilities in

Makindye, Ssabagabo and Kira, Uganda, and better understood through digital simulation tools for decision-makers applied in **Kigali, Rwanda, Quito, Ecuador, and Kathmandu, Nepal**;

- Gaining better understanding of how the COVID-19 pandemic shifted perceptions of sustainable travel and behaviours to support new bike infrastructure in **Rome, Italy**;
- The role of public art in generating pedestrian-friendly streets in line with low carbon mobility in **Iran**.

Urban Planning and Design

The urban planning and design context varies greatly between regions and existing urban form and infrastructure influence what would be locally appropriate solutions for low-carbon and climate resilient development. The regional and local specific sessions covering urban planning and design emphasised differences in capacity, planning frameworks and planning with residents of informal settlements in the Global South and how this may influence implementation of adaptation and mitigation measures. For examples:

- Gaining a better understanding of significant limitations in city planning capacity relating to addressing climate change, especially in **Africa and South and Southeast Asia**.
- Need for regionally specific understanding of urban growth and planning, especially in regions of the **Global South** that may not have context-specific theoretical planning frameworks.
- Research is needed on the importance of understanding how planning for the changing climate will impact informal settlements in **Africa, Latin-America, and South/Southeast Asia**.
- Research is needed to understand best practices for planning in response to climate change impacts in **island nations**.
- How cities can deliver affordable and climate resilient housing for all, particularly across **Africa, Asia, and Latin America**.

Informality

Recurrent references to informal settlements and informal economy emerged in sessions spanning **Africa, East Asia, Latin America and the Caribbean, and South Asian** contexts. For example:

- The potential for adoption of biophilic and circular economy principles and processes in informal settlements in **Cairo, Egypt**, urban green infrastructure for informal settlement upgrading in **Sub Saharan Africa**, and effective decision-making drawing on spatial data and collaboration to improve wellbeing of residents in informal settlements across **Africa**; and community-based mapping by residents to identify flood-prone areas in settlements in **Dar es Salaam, Tanzania**;
- Resident-to-resident learning to share best practice in scaling up waste management and recycling practice in **India**; and
- Effective replication of resilient housing programs established by cities in **Colombia**, and, similarly, how informal settlement upgrading through green infrastructure interventions can improve quality of life and local economic development in **Bucaramanga, Colombia**.

Sustainable Consumption and Production

There was a focus on food, energy and waste as critical to more sustainable consumption and production across multiple sessions and regions.

Localising food systems and achieving food security were commonly highlighted in the conference across **world regions** with the exception of North America and Oceania. For example:

- Peri-urban areas in **Uganda** are considered for their potential to support solar power based irrigation;
- Research is being conducted in response to the issue of food deserts (lack of local access to food) and food insecurity, to understand the potential for sustainable local food production in northern **Italy** in the context of COVID-19, and at the neighbourhood level in **Mexico City, Mexico**.

Sessions related to (renewable) energy are identified across **world regions** except for Eastern Europe, Central Asia, Oceania, Southeast Asia, and South Asia. For example:

- The need for more reliable and accessible energy provision to support water supply in cities in **Africa**;
- How local energy ownership adds value to renewable energy development and improves public perceptions in **Eeklo, Belgium**;
- Exploring potential for implementation of energy efficiency measures in **Karak, Jordan**; and in **Buenos Aires, Argentina** through an open data and co-creation platform;
- The potential for district cooling systems to address extreme urban heat in **Hong Kong, China**; and learning from a district heat and hot water pilot in **Victoria, Canada**.

Various forms of waste management and resource circularity are referenced across **world regions** except for East Asia, Eastern Europe, Central Asia, Oceania, and Southeast Asia. For example:

- Understanding the degree of material consumption in **Latin America and the Caribbean** and prospects for circular neighbourhoods; and a pilot citizen science study and comparison of plastic pollution in cities along the Mississippi River basin in **North America**;
- A gap analysis of waste management systems to address ocean plastic pollution in **Can Tho, Vietnam, Melaka, Malaysia, Panama City, Panama, Pune, India, and Semarang, Indonesia**, and investigating factors contributing to waste accumulation to inform policy implementation in **Thiruvananthapuram, India**.

Finance

Finance and funding were important topics across the majority of regions. The regionally and locally specific references provide examples of innovative finance mechanisms, sharing both lessons and barriers to finance. For example:

- The role of subnational development banks in providing fiscal support to local governments for sustainable urban infrastructure provision (providing access to finance, building local capacity for project preparation etc.) drawing on lessons from **Southeast Asia** and **Latin America**;
- The role of insurance and other financial mechanisms to support relocation of low-income residents facing “climate gentrification” in low-elevation coastal cities like **Miami, USA**;
- The role of municipal green bonds, revolving funds, and public private partnerships in supporting cities in **India, Portugal, and the Philippines** that lack credit ratings, face political instability, and other capacity limitations inhibiting low carbon and adaptive infrastructures;
- Understanding the effects of communicating social and environmental co-benefits to residents to fundraise for establishing green energy sources in cities in **Japan**.
- Additional insights include challenges and priorities in the **African** context in terms of lack of investment (in natural capital), support from initial financing to implementation, reducing public financial risk, and conforming to international finance institution regulations.

History and Cultural Heritage

As History and Cultural Heritage was not a theme identified prior to the conference, sessions were not classified according to this theme and as a result a full analysis was not done as to how it was represented across world regions. Nevertheless, the following examples were identified that demonstrate local application and interest in the topic.

- How traditional morphological design responds to solar radiation and how these insights can inform design guidelines in **Pune, India**.
- Potential for the reintroduction of ancient Indus Valley Civilisation (**South Asia**) drainage systems to mitigate flooding and improve sanitation.

Cross Cutting Issues

Health

Recurrent references to the public health dimensions of climate change adaptation and mitigation are identified in sessions spanning **Africa, the European Union, Western Europe, Latin America and the Caribbean, North America and Southeast Asia**. For example:

- The sanitation needs and benefits associated with low-cost internet-based water system monitoring in the **African** context;
- How green space improves air quality and decreases heart disease risk in **Louisville, USA**; and similarly, how city-level climate and clean air action planning can provide potential health and wellbeing benefits to city dwellers in **Madrid, Spain** and **Mexico City, Mexico**;
- How to use data mapping to detect and manage environmental health hazards, including mental health in **Florida, USA**;
- How urban green space has positive effects on mental health and can support treatment of depression in **Singapore**.

Governance and Institutions

Governance principles and processes informing city climate change research and action were discussed in sessions across **world regions**, except for East Asia, Eastern Europe and Central Asia, with comparisons and lessons shared across contexts. Examples include:

- How climate change challenge competitions can promote urban innovation through the development of demonstration projects with insights from **Makindye Ssabagabo, Uganda, Bristol, UK, Bogotá, Colombia, and Curitiba, Brazil**;
- How city contributions to the Sustainable Development Goals are driven by 'elevating' city-led science and technology in foreign policy and diplomacy in **Barcelona, Spain**;
- How integration of climate and clean air action planning in the case of **Madrid, Spain** and **Mexico City, Mexico** and climate change adaptation and mitigation in the case of **Ho**

Chi Minh City, Vietnam help overcome siloed governance;

- How cities can mainstream climate action by incorporating climate measures in fiscal policy and capital investment plans and budgets, based on examples from the **United States, Europe, the Middle East, Sub-Saharan Africa and South Asia**; and
- Effective models for collaboration between municipalities and local academic institutions to address issues of social justice, youth engagement, and COVID recovery in cities, with examples from **Canada, Norway and Australia**.

Digitalisation and Smart Cities

Digital technologies were less frequently referenced in session abstracts but they were identified in the context of Eastern Europe and Central Asia and the European Union and Western Europe:

- The use of a digital platform to support interdisciplinary collaboration on sustainability projects, with insights from **Leuven, Belgium, Oxfordshire, England, and Prilep, North Macedonia**; and
- How young and older residents can be engaged by city authorities through digital methods as a more inclusive approach to planning, with insights from **Liverpool, England**.

Observations, Data and Modelling at the City Scale

Recurrent references to city level models and data were identified in sessions across **world regions** except for Africa, Eastern Europe, Central Asia, the Middle East and West Asia. Examples include:

- How a Sustainable Development Goals Project Assessment Tool can support cities in aligning climate adaptation planning and design, with insights from a global programme spanning **Brazil, Indonesia, Nigeria, Malaysia, Myanmar, the Philippines, South Africa, Thailand, Turkey and Vietnam**;

- How a waste management gap assessment tool aids cities in identifying system challenges, vulnerabilities, and risks, informing the development of city proposals for funding, based on the experience of **Can Tho, Vietnam; Melaka, Malaysia; Panama City, Panama; Pune, India; and Semarang, Indonesia;**
- The use of high-resolution digital simulations to model outcomes of possible transport interventions and inform decision making in the case of **Kigali, Rwanda, Quito, Ecuador, and Kathmandu, Nepal,** scenario-modelling to provide recommendations to urban planners and policymakers on effective responses to extreme heat in the case of **Hong Kong, China,** and replication of downscaled climate change projections to inform local development planning and budgeting applied in **Labutta and Pakokku, Myanmar;**
- How blockchain and artificial intelligence (AI) can enhance weather prediction, greenhouse gas emissions tracking, and other climate modelling, assessment, and management, drawing on a microgrid example in **Brooklyn, USA;**
- What city-specific data are needed to accelerate and scale up emissions reductions in **Australian** cities compared with existing knowledge frameworks, as well as opportunities for peer-to-peer learning;
- The use of an Ecology Toolkit to bridge the building and system scale of environmental planning and development and inform architectural design in **Dhaka, Bangladesh.**
- The development and pilot of a coastal city climate risk profile and data tool in collaboration with local research institutions and governments to support strategy development and implementation, initially in **Castries Saint Lucia and Kingston Jamaica;** a climate risk atlas for **Chile;** and a digital dashboard combining risk and resilience indicators to optimise disaster preparedness across the city of **Shimla India;**

Justice and Equity

Justice and equity, including co-production of knowledge, was a widespread recurrent theme throughout the conference programme with a diversity of interpretations across regions. Examples include:

- Effective participatory planning approaches in the context of informal settlements in **African** cities, particularly involving youth, and forums for local open public dialogue in **Uganda;**
- How cities can contribute to ensuring equitable and high-quality employment and transference of skills for those affected by divestment from fossil fuels with insights from the **US, Italy and South Africa;**
- The role of non-state-led innovations like civil society centred nature-based solution initiatives in driving urban sustainability transitions in **China;**
- How a human rights framework can be used to assess social impacts of municipal government decisions in different climate change scenarios to ensure equity and justice based on the experience of **Ecuador;**
- How land-use plans can better integrate climate justice as a form of city innovation and to effectively direct climate adaptation investment towards low-income and disadvantaged communities in **California USA;**
- How diverse forms of knowledge and data can inform climate vulnerability assessments and action plans based on the experience of **Vanuatu, Solomon Islands, and Fiji (Pacific Islands),** and, similarly, the role of Community-based Disaster Risk Reduction initiatives among vulnerable populations in climate change adaptation in the **Philippines;**
- How low-income communities can be involved in air pollution measurement, interpretation, and problem-solving to develop city government responses in **Indore, India.**

METHODOLOGY

Several mechanisms were put in place before the conference to collect inputs from conference presentations and subsequent discussions during the conference which would feed into this report. The two lead editors of the report were supported by a core writing team who contributed throughout the writing process. A group of student volunteers were also recruited through an open Expression of Interest and coordinated by the Melbourne Centre for Cities at the University of Melbourne, which was shared within the network of the Science and Innovation Steering Committee, Partner Network Organising Committee, and GCoM's Research and Innovation Technical Working Group.

Session chairs and individual session presenters were provided with a questionnaire requesting that they identify research gaps and areas of innovation associated with their session. Student writers were also provided with a similar questionnaire and were asked to act as rapporteurs and note takers for all sessions. Questionnaires asked similar questions thereby supporting the student group in identifying research gaps and areas of innovation for each session.

Responses to questionnaires resulted in a data set which was used as a detailed reference to session discussions, which supported writing of this document. A subset of the student group used their inputs as the primary source for the Innovate4Cities Conference 2021: Student Led Final Report (Dickey, A., and Oke C. 2021), which also served as an important summary in finalizing this report.

In addition to detailed rapporteur notes and minutes taken by the student group and writing team, co-editors hosted five working sessions during the conference, where the writing team, the Science and Innovation Steering Committee, the Partner Network Organising Committee, and the GCoM's Research and Innovation Technical Working Group members and

student writers were invited to discuss the topics they were hearing emerge from conference discussions. Inputs were recorded using the MIRO platform and meetings were recorded for future reference by the writing team. In addition to this, three workshops were held in the week following the conference inviting the Science and Innovation Steering Committee, the Partner Network Organising Committee, and the GCoM's Research and Innovation Technical Working Group members to provide further insights on what they heard in conference discussions. Again, responses were recorded and the sessions were available for review by the writing team.

Participants in the conference were engaged to provide input to this document in several ways on the conference platform. A discussion board, divided by the conference themes was provided, and participants were prompted to write down research gaps and other important insights they had heard in conference discussions on the discussion board. Additionally, a short survey which asked conference participants to provide research and innovation gaps which they heard come through conference discussions was also available to all participants throughout the week of the conference.

Key messages and overall framing in Section 1 were informed by the discussions with the Science and Innovation Steering Committee, the Partner Network Organising Committee and the GCoM's Research and Innovation Technical Working Group members during and after the conference. Many of the examples in this section emerged from the conference's high level and overarching Plenary sessions. The detail and specificity seen through parallel session and innovation lab sessions are reflected more strongly in Sections 2 and 3 of the document. The responses to questionnaires provided by session chairs and student writers were relied upon more heavily within these sections, with regional analysis conducted by Dr Paris Hadfield.

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This report has been developed by the Global Covenant of Mayors for Climate & Energy (GCoM) and UN-Habitat based on the outcomes of 2021 Innovate4Cities Conference co-sponsored by UN-Habitat, GCoM and the Intergovernmental Panel on Climate Change. It is intended to inform research, policy and public discussions on the global research and action agenda for cities and climate change science.

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