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Accelerating climate research and action in cities through advanced science-policy-practice partnerships

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Cities have become increasingly recognized as key sites for climate research and action. Recently, these efforts have been significantly advanced through science-policy-practice partnerships. The objective of this paper is to assess how these partnerships are structured, the research and action agenda that underpins them, and how this agenda is being articulated and implemented. The assessment also helps to define some of the conceptual and operational gaps faced by the science-policy-practice community and how they can be addressed. The work evaluates the critical conditions for promoting these advances including the definition and fulfillment of knowledge needs, the integration of different perspectives and approaches, establishment of pathways to finance the urban climate research and action community, and creation and promotion of new partnerships. The paper concludes with a series of strategies and recommendations for how targeted policy adjustments can accelerate and support the production of actionable knowledge and this integrated researcher-policymaker-practitioner community.
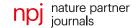
Recent reports and studies, such as the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5 °C, have ushered in a new and more intense period of climate research and identified where action is most urgently required[1]. The need to accelerate climate adaptation and mitigation via science-policy-practice partnerships, especially in cities, has become much more evident in recent years, for example, as highlighted in the recent Global Research and Action Agenda on Cities and Climate Change Science[2] and the Urban Climate Change Research Network (UCCRN) Assessment Reports on Climate Change and Cities (ARC3)[3]. Cities and urban areas are recognized as globally significant sites of climate vulnerability and greenhouse gas emissions, but also low carbon and climate change adaptation innovation. However, these and other reports emphasize that solutions and resources for cities and by cities are not yet sufficiently prioritized in international policy development. While cities and urban areas have begun to be recognized within the United Nations Framework Convention on Climate Change (UNFCCC), an urgent need exists to fully mobilize multi-level climate action in which cities play a central role[4]. This paper introduces and assesses the emerging research and action agenda on cities and climate change, explores how knowledge needs can be filled, and presents concrete ways that the agenda can be implemented.

The cities and climate change community, made up of researchers, practitioners, policymakers, and enablers from action networks, has responded to the challenge of addressing climate change in cities by bringing this need for both more research and further action into climate change discourse around the globe. The work is being done in ways that prioritize partnerships and bring new voices (e.g., local/indigenous, Global South) into the discussion. The international Cities and Climate Change Science Conference co-sponsored by the IPCC and other international organizations, held in March 2018, highlighted these ambitions with the express goal of bringing together urban climate researchers, practitioners, and policymakers. The other

organizations included Cities Alliance, City of Edmonton, C40 Cities Leadership Group, Future Earth, ICLEI-Local Governments for Sustainability, Intergovernmental Panel on Climate Change (IPCC), Sustainable Development Solutions Network (SDSN), United Cities and Local Governments (UCLG), United Nations Environment Programme, United Nations Human Settlements Programme (UN-Habitat), and the World Climate Research Programme (WCRP); the Urban Climate Change Research Network also played an important role in shaping the conference and the ensuing research agenda. In the Conference Declaration there were 10 signees that included UCCRN.

From the March 2018 conference and follow-on engagements, a robust research and action agenda has begun to emerge, which has influenced and inspired individual and concerted city action, building strongly on efforts from the past two decades. The research and action agenda from the conference was specifically designed to spur research and knowledge generation to contribute to the IPCC Special Report on Cities scheduled for early in the 7th assessment cycle (AR7) and to help inform action at the city level. Defining what science-policy-practice partnership opportunities cities offer that position urban settlements at the forefront of climate change mitigation and adaptation has been a critical component of these discussions. The focus of this paper is to review the emerging research and action agenda, its requirements, and means of implementation, and to further explore the potential synergistic role of science-policy-practice urban partnerships in accelerating the ability to address the intensifying risks of climate change at a global scale through local action. Several intertwined processes will help enable the success of local action, including enhanced networking across multi-level governance structures. Interactions still need to be strengthened in some countries of the Global North and could be particularly transformative in many in the Global South, where support and integration among different spheres of government and actors are needed due to generally poor local capacities.

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The 2018 Cities and Climate Change Science Conference explicitly promoted an integration of the scientific, policy, and practice communities around the issue of climate change science and cities. The conference provided a benchmark that simultaneously illustrates the shift from a research agenda largely focused on projecting climate impacts on sectors and regions, to an adaptation science studying what to do about them. It also acknowledged the importance of collaboration and partnership between science, policy, and practice communities in enhancing agency and action.

This collaboration process embedded in the conference planning and execution resulted in the definition of a robust research and action agenda that included a key set of research themes and new pathways to develop knowledge with perspectives of science, policy, and practice embedded within its principles. The agenda strongly emphasizes the varying capacities and strengths present in urban areas in different contexts. Tailored approaches are needed that are sensitive to the level of resources available in different cities (e.g., large, medium, and small; high, medium, and low income; shrinking and sprawling cities; etc.) and support needed for cities of lower capacity to address these challenges. This new co-generated research ambition and knowledge base developed from scientists, policy-makers and practitioners will provide the scientific basis, i.e., the evidence base, for accelerated innovation at the city level for both climate change mitigation and adaptation, an effort that would certainly need despite its intrinsic challenges and paradoxes[5], the active participation of local inhabitants and grass root movements in order to respond better to local specificities, needs, and priorities. It is critical that knowledge sources developed by indigenous, local, and expert people via formal and informal mechanisms should be recognized early on in any partnership, accessed, and integrated.

Our objective here is to examine these new co-generated research ambitions, the requirements to analyze them, and how they can foster important new, co-produced knowledge and action –particularly given the IPCC's commitment to a Special Report on Cities during the AR7 as well as other similar reports such as UNEP's GEO for Cities – expected at the end of the 2020 – which reviews current environmental impacts of cities and identifies key urban realms and action pathways for urban transformation. Such advanced science-policy-practice interactions and partnerships will emerge from an iterative set of steps that include the development of new knowledge and processes to effectively apply this knowledge in a wide range of local biophysical, socioeconomic, political and cultural contexts.

These steps require support and nurturing through the application of cutting-edge methods and tools that promote interaction, dialog and trust, as well as parallel processes to build local-to-regional governance capacities and leadership where needed. These new methods and tools include ways to promote understanding of key knowledge needs, novel indicator and monitoring systems, advanced assessment protocols, emerging knowledge transfer mechanisms (such as benchmarked reports, expert panels, networks), and case study strategies developed and evaluated by the science, practice and policy communities collectively. The paper concludes with a series of strategies and recommendations derived from the scholarly and practitioner literature on how policy adjustments can accelerate and support the production of the knowledge that cities need to respond to climate change challenges.

NEW RESEARCH AND ACTION AGENDA

The new Global Research and Action Agenda on Cities and Climate Change Science[2] that emerged from the March 2018 conference identified a set of priorities that require additional study in order to inform action at the local level. Building on key

research areas identified at the meeting and in earlier assessments, the topics include broader-scale concerns and needs such as advanced thinking on urban systems and the capacity of critical infrastructure, communities, and institutions to respond in a coordinated way to shocks and stresses. Specific issues such as advancing urban climate science focused on the urban heat island, extreme events, and the connection between climate change, air quality and health concerns – that are increasingly evident in many rapidly urbanizing Global South cities – were also highlighted.

Besides the ambition of looking at urban climate questions through an urban systems lens, other cross-cutting themes include the role and significance of scale as a driver of urban function, change, and management; governance of cities through formal government structures (across urban areas, provincial, national, and international levels) and the vast number of informal structures such as civil society arrangements and collaborations; and the need and opportunity of city-level models (e.g., conceptual as well as computational) and data to best understand changes in urban systems and efficacy of planning and managing approaches and capacities[6].

However, care must be taken when generating data and information too complex for decision-making as, indeed, complexity can be the enemy of relevance when models as an end itself instead of finding the optimum balance with error[7]. It is also should be recognized that an informed public can be supportive of urban climate initiatives. In these contexts, national and local media and social media can play a significant role as the vehicle for the translation of new knowledge and practice to a mass audience[8,9].

Cities as nodes of multifaceted interdependencies, can therefore benefit from networked capacity building at local as well as at other levels of governance, from the subnational and national, to the regional and international, which in turn requires a more robust science-policy interface. This in has been demonstrated during the COVID-19 pandemic when local governments were forced during lock down, on one hand, to (re)learn about the interlinkages between urban systems (e.g., transport and public health), while at the same time building cooperation arrangements (e.g., with other levels of governance and the private sector) that in some cases were not possible before. The territorial dimension of COVID-19 impacts and mitigation strategies may thus be a window of opportunity to further improve alliances for urban transformation, including ambitious climate action[10,11].

The research and action agenda also defined a set of topical areas such as informality where new knowledge and assessment is urgently needed to accelerate effective climate responses in cities. Informality within the agenda relates to those settlements or neighborhoods that have developed outside formal systems –not necessarily illegally– regarding land ownership, land tenure and a range of regulations related to planning and land use, build structures, health and safety[12,13]. The role and significance of informality is evident especially within economic development, housing, and governance among other sectors, financing for climate action in private, public and non-governmental and community-based organizations (NGOs/CBOs)[14], and for sustainable consumption and production within and across cities and between cities and supply-side exurban and rural areas. Additionally, the agenda explored the effectiveness and opportunities presented by emerging and new-built sustainable design methods and practices including green/blue infrastructure, urban planning and design including district, city, and metropolitan-scale efforts[15,16], and conditions of uncertainty in changes in climate risks and human and institutional response capacities in the short and long term. Deep uncertainty associated with high-risk scenarios was of particular concern. Deep uncertainty can defined as the 'condition in which analysts do not know or the parties to a decision cannot agree upon (1) the appropriate

models to describe interactions among a system's variables, (2) the probability distributions to represent uncertainty about key parameters in the models, and/or (3) how to value the desirability of alternative outcomes[17].

ACHIEVING THE NEW RESEARCH AND ACTION AGENDA

Several key conditions should be present to enhance the likelihood that the new urban climate change research and action agenda will be implemented, achieve meaningful results, and accelerate action. These conditions, highlighted in section 3 of the Global Research and Action Agenda on Cities and Climate Change Science include understanding the divergent and convergent language and knowledge needs of the three communities, – scientists, policy-makers, and practitioners – the incorporation of new and emergent methods, and sustained models of research, interaction, and action financing.

Knowledge needs

A critical component of realizing progress on the new research and action agenda will be translating it to specific local contexts and identifying the knowledge needs of specific user communities either through informal or formal mechanisms (e.g., knowledge-sharing, global or regional networks, and regional information hubs such as those developed by the UCCRN, C40, ICLEI, and Future Earth).

Mexico City is a case in point. The translation into Spanish of the Research and Action Agenda resulted in a meaningful conversation among scientists, practitioners and policy makers who identified central challenges, opportunities and action pathways for promoting an urban transformation towards more sustainable and climate-ready scenarios. Following that discussion, the Mexican Talanoa Dialogue took place and a Knowledge Platform for Urban Transformation was launched with the support of the International Network for Government Science Advice and the International Development Research Centre and sponsored by ICLEI and the National Autonomous University of Mexico[18]. Its goal is to enhance the interface between policy-making and evidence-based research and knowledge for supporting climate and environmental action in cities.

One of the preliminary outcomes of this experience in Mexico City was a base-line evaluation of local institutional capacities for climate and environmental action at the city and metropolitan level[19]. This has been beneficial for developing both a more refined language to describe the challenges and channels of communication that facilitate the identification of climate and environment-related knowledge gaps and needs, and the evaluation of local institutional capacities needed for more successful and coordinated action. Among the more relevant issues identified were limited funding, inefficient administration, persistence of old-fashioned practices and inertia, out-dated planning instruments, and limited coordination among the 76 local governments that comprise the metropolitan region of Mexico City[19].

One issue that has been extensively discussed by local governments of the metropolitan area of Mexico City is that climate action, particularly adaptation action, is difficult to embed in institutional and governmental practices. This is often because action plans are not formulated clearly enough or because the time frame for their implementation and demonstrable outcomes transcends local political administrations. Local environmental agendas, such as clean air quality, are thus seen as a more concrete way of advancing both the environmental and climate change agendas in a context of limited resources, capacities and time for implementing actions. Still, short-term visions often prevail, which in turn impact the type of actions being implemented.

In addition, lack of coordination at the local and regional levels is a challenge. Although it is recognized that it would be desirable to exploit further synergies and co-benefits there are no formal incentives for cross-governmental level collaborations. State or regional governments, who may have more capacity to promote coordinated efforts, have not yet been successful in connecting national goals and incentives with local needs and actions. However two key issues seem to be advancing such state-regional coordination: (1) Air quality concerns, which led to the creation in 2013 of the Megalopolitan Environmental Commission (still with limited results due to political issues and limited capacities), and (2) Health emergencies such as COVID-19, that have resulted in fast-track administrative coordination of several local, state and federal level entities to enable an integrated metropolitan action plan.

The follow-on efforts from the March 2018 cities and climate change conference also have focused on a variety of pathways and mechanisms for enhancing research and action. While many are driven by individual cities, cities within specific countries, and researcher-focused enterprises, large-scale efforts are often motivated by networks of city mayors. The Innovate4Cities initiative of the Global Covenant of Mayors for Climate and Energy (GCoM), one emergent example of this trend, is focused on the research and innovation critical to drive climate action in cities.

GCoM is the largest global alliance for city climate leadership, built upon the commitment of over 10,000 cities and local governments. These cities hail from 6 continents and 139 countries. In total, they represent more than 800 million people.

The initiative grew out of the Cities and Climate Change Science conference and operates under the guidance of GCoM's Research and Innovation Technical Working Group (R + I TWG). In the two years since the Conference, the R + I TWG has developed a multi-year research and innovation strategy for urban climate action based on priority needs determined by cities, city networks, scientists, and leading private-sector entities through a series of data-gathering processes and analyses. Vital research priorities include better generation of city-scale data, public procurement methods to prioritize sustainability, water management in cities, climate-relevant data for and on vulnerable communities, urban planning for informal settlements, creating closed-loop waste systems, and community-based innovation in food systems.

It is clear from these examples of a city and a global network responding to the demands of the March 2018 meeting, that researchers need to have cutting-edge understanding of the relevant climate, vulnerability, impact, adaptation, and mitigation science, identified areas of critical unknowns linked to practitioner priorities, and associated methodologies to investigate them. For example, recent assessments of sea level rise projections have accelerated the research community's investigation of the low-probability, high-consequence climate scenarios such as rapid ice melt scenarios and the potential shifts in flood frequency in low-lying coastal cities. The New York City Panel on Climate Change (NPCC), as illustration, in its most recent report developed an Antarctic Rapid Ice Melt (ARIM) scenario in order to raise awareness of the growing risks for the metropolitan region[20].

Practitioners, conversely, require actionable, consensus-focused, evidence-based science to implement mitigation and adaptation actions, with careful assessment of synergies and trade-offs of particular actions. While there is general interest by practitioners in the full range of risks, often they are most interested in projections, information, and data on those conditions with the highest likelihoods and greatest certainty that will affect their cities. City stakeholders frequently want to know the 'worst case' scenario that their city is facing, such as was developed for the Climate Ready Boston report that included high-end projections out to the year 2200[21].

City policymakers also require concrete examples of what other cities are doing and how they have and have not been effective. They need context and guidance to frame overall directives for their cities to follow, not only within the domain of climate change but also with its likely interactions with the complex socio-ecological urban system. City action networks, such as C40, ICLEI, GCoM and the Coalition for Urban Transitions play an important role in providing this context and guidance for their member cities, for both practitioners and policymakers[22]. This role is enriched by local policymakers' networks such as the Argentinean, Portuguese, South African or Chilean networks of municipalities for climate action that open up sharing and collaborative spaces, usually with the support of international coalitions and cooperation agencies[23,24].

The knowledge demands of the science, policy and practitioner communities may differ, but it is important to recognize that their knowledge needs do overlap as well as diverge, and that these wants may shift over time as new issues emerge. For example, urban ecology and urban ecosystem services issues within urban climate research were fringe topics in the early 2010s, while today they have moved to the center of practitioner interest[15] with increased attention on nature-based solutions (NbS) for both mitigation and adaptation in cities[25].

An additional challenge is how to promote partnerships among policy-makers, scientists and practitioners in a sustained way for the mid and long term. Political timeframes and practitioner dynamics usually diverge from scientific timeframes-which are typically longer. Scientists need to translate and coproduce knowledge and solutions faster, while policymakers and practitioners must operate in the short term but without missing a long-term perspective of the climate change challenge. In that sense, there is a demand for knowledge brokers that can guide the process not only at the international level, but also at the subnational levels as well to facilitate co-creation and use of new knowledge. The Future Earth Knowledge platforms, for instance, were designed as a way to link knowledge and action, but to date the Urban Knowledge Action Network has been largely unable to achieve this goal, primarily due to lack of adequate resources and difficulties in engaging the practitioner community. This indicates the challenges encountered in building these new integrated systems. It is also recognized that increased collaboration and partnership among these organizations will foster increased trust, empathy, and shifts in perspective that can create more opportunity for the harmonization of the actors and their differing timeframes and professional protocols.

Perspectives and methods

An explicitly stated dimension of the urban climate research and action agenda is that it should incorporate a range of perspectives to be meaningful and successful. Knowledge cannot only be generated from experts and climate professionals but also from a variety of local and indigenous formal and informal knowledge sources[26]. The cogeneration of knowledge during which scientists listen and understand the existing insights, experiences, and needs of urban residents is now recognized as critical to advancing the coproduction of new science and enhancing the capacity for successful action. Furthermore, the work needs to recognize upfront issues of equity and justice particularly with respect to climate impacts and vulnerabilities and implications of public policy[26,27]. Equity and justice concerns are not only present across and between communities but also at global scales (i.e., involving debates between the Global North and Global South countries)[12].

A range of research methods is being developed and applied to address these issues. These methods provide opportunities for new data and information gathering (e.g., robust sensor networks linked via satellite and social media platforms) as well as advanced approaches to knowledge building and theory development including co-generation techniques designed to more meaningfully link scientists, policymakers, and practitioners. Decidim, a web-based platform, is one such vehicle being used for public dialog, consultations and decision-making, participatory budgeting, and monitoring actions and outcomes by cities such as Barcelona, Helsinki, Castilla-La Mancha, Pamplona, among others defined by platforms like decidim.org, an free open-source participatory democracy for cities and organizations.

From the science side of the discussion, research increasingly is being organized into multi-disciplinary, interdisciplinary, and transdisciplinary frameworks that allow for inquiry in new ways that identify innovative approaches to urban climate analysis while incorporating multiple voices – particularly those outside the academic sphere – in the research process. The growing range of professional networks that explicitly link climate specialists at city, regional, national and global scales also are further accelerating the opportunities for collaborative research and action. The recently formed UN-HABITAT Planners for Climate Action initiative (www.planners4climate.org) is a case in point as it seeks to advocate the role of climate action in urban and regional planning practice, capacity-building and research. The Urban Climate Change Research Network (www.UCCRN.org), now over ten years old, is a robust horizontal network that connects climate researchers with municipal and organizational officials and representatives in hundreds of cities simultaneously. Several networks also focus on linking local university expertise with city-level practitioners and policy-makers. EPIC-N (Educational Partnerships for Innovation Communities – Network) for example has focused extensively of promoting urban sustainability partnerships. Originating in the U.S. with several dozen partners, it is rapidly expanding internationally. In early February 2020, a meeting was held in Durban, South Africa to expand the EPIC model to 22 cities throughout Sub-Saharan Africa[28].

Financing of research and action

Cities often lack financial resources and extensive technical expertise to fully respond to environmental threats (such as climate risk) that their residents and critical infrastructure face. City governments typically do not have the legal authority to raise financial resources needed to address environmental risks and must heavily rely on state (provincial), national, regional (e.g., regional development banks) or international financial sources (e.g., World Bank, International Monetary Fund, Green Climate Fund) for large-scale climate adaptation and mitigation projects[14]. While international donors and financial institutions prefer to fund individual projects and infrastructure initiatives, it is clear that science-policy-practice partnerships help create conditions for increased effectiveness, success, and longevity of climate action through enabling increased capacity (i.e., through the utilization of available knowledge, providing legislation and regulatory support, and heightened public awareness over the long timeframes needed for climate change response).

Resources for timed capital investment upgrades (e.g., of critical infrastructure), and post-disaster recovery funds currently often remain the dominant sources of available funds. Other funding strategies such as public-private partnerships, green bonds Pension funds, city level emissions trading, and land value capture are seen as holding some future promise[14]. Some cities in Europe and North American have initiated green bond strategies. Cities in the Global South also have begun to use this strategy. For example, the Mexico City in 2016 launched a city- level green bond for one billion Mexican pesos to finance water supply infrastructure, sustainable transportation and energy efficiency. Tax subsidies and other regulatory measures also can promote and guide businesses action, including social businesses that

seem particularly promising in areas such as urban agriculture and low-cost rainwater harvesting systems and solar thermal systems.

The extent to which climate and sustainability issues are included within COVID recovery plans will be a key factor in accelerating the societal transformation needed, not only in the health sector[29–31]. City networks such as C40 have highlighted the need to ensure that there is no-return to business as usual[32]. It is clear that amount of commitment that is ear marked for climate mitigation/adaptation measures should be increased and dispersed in ways which focus on equity and just recovery, and building resilience. Given that investment choices will define the future of the climate-environmental agenda in the post COVID-19 era, a 'new green deal' is required for a sustainable and low carbon economic recovery that is supported by renewed multilateralism, democratic governance mechanisms, and social participatory frameworks[30,33].

New knowledge partnerships

Partnerships between local institutions of higher education and city governments are an example of how meaningful and effective strategies can be utilized to develop innovative, locally relevant, empowering, equitable, and co-generated solutions. City governments increasingly have recognized the value of connecting with local academic expertise as a means to develop meaningful climate information. In some cases, these partnerships have produced irregular or one-off reports, or a formal report sequence. In less typical situations, cities have created formal climate advisory panels that function as an independent science body that, by local law, directly responds to the city's science queries and requirements. In 2008, the City of New York created the New York Panel on Climate Change (NPCC) to serve the City with regular climate information updates. The City utilizes the panel in complex ways and the boundary between the two is fluid and at times porous but is always present. The discussion and debate between city officials and panel members typically is cordial but can get contentious and difficult. For example, some members of the NPCC have advocated for much faster programmatic climate change action by the City, while the City practitioners believe that they have proceeded on what they consider to be a concerted, yet realistic timetable, given other local issues that need to be addressed simultaneously. Despite such challenges, the NPCC has provided the science foundation for ten years of concerted action by the City government to develop climate resilience[34]. In other settings, Göpfert and others[35] observe in their analysis of 107 German cities a wide variety of climate panel organization structure and creative contestations between practitioner, policy-maker, and science communities.

Partnerships of this type provide research expertise and technical support for city agencies and departments while offering local academics an opportunity to do applied, societally relevant research. Networks of cities[17] that enable cross-city connections for sharing data, lessons learned, and problem-solving techniques also have been invaluable in overcoming local deficits in capacity and resources. Many other forms of urban climate networks are now present and can link governments and city officials, city-focused NGOs/CBOs, city-focused academics, and city-academic partnerships. Some of the connections are formal while many others are informal. For example, cities like Mexico City, Durban and New York City have begun programs for or host young and emerging researchers (including undergraduate and graduate students or postdoctoral students) to work in city agencies focused climate science-policy interface research issues.

While these strategies have begun to overcome some of the general knowledge gaps in cities, the availability of actionable knowledge (e.g., knowledge to design an effective, tailored climate adaptation project) for climate projects remains scarce across the thousands of small and medium-sized cities across the world.

ACCELERATING SCIENCE-POLICY-PRACTICE INTERACTION

A crucial question embedded in these aspirations is how to link the new co-generated research ambition and knowledge into the policymaking and practice arenas. To deliver the knowledge of the urban climate research and action agenda, science-policy-practice interactions will need to be functional and even accelerated. Science-policy-practice mechanisms will have to fulfill a variety of functions and promote engagement within cities and across cities to regional, national and global scales. These functions include the design of research and action agendas for urban areas; construction of science to meet the general requirements of cities recognizing the variety of local contexts; establishment of context-sensitive reflexive processes to identify knowledge gaps; provide continuity beyond normal political cycles; and build flexibility into solutions (termed Flexible Adaptation Pathways[36] as they will need to be evaluated and potentially modified as climate change progresses in individual cities. It is recognized that cities are context rich, and as a result, generic strategies need to be tailored for particular and unique urban settings. All of these functions are necessary to build long-term internal capacity in cities to respond to climate change challenges.

At the city scale, the effectiveness and timeliness of the collaboration among science, policy, and practice communities can be enhanced through a variety of strategies. Most importantly the collaboration should be synced with the city's specific requirements. For example, providing capacity wherever cities are in building their climate program will be critical. Those new to addressing climate action in their city need to start at the planning and scoping phase (such as many small and medium-sized cities), as opposed to those with moderately developed plans and those at a highly developed stage of climate action (early adopters such as Copenhagen, Durban, New York, Oslo, and Quito).

Balancing the ability to address low-hanging fruit while paving the way for basic development needs, greater resilience, and deep decarbonization and sustainable development is essential[9]. This includes progress toward the UN Sustainable Development Goals and other internationally agreed-on goals such as the Sendai Framework for Disaster Risk Reduction, New Urban Agenda, and the present demands of the COVID-19 pandemic, all while avoiding lock-in to high GHG-emitting long-term pathways. The same applies for short- and long-term adaptation strategies, either planned or autonomous (that increasingly will need to be integrated). Other beneficial strategies derived from the scholarly and practitioner literature include the following:

- Providing mechanisms to enhance self-determination of control of knowledge development process at the city level[27,37,38] with a focus on equity and power sharing with local and indigenous representatives.
- Engaging networks, particularly at the subnational level such as city, scientific, grassroot, and community organizations[12,26,39]. By definition, many of these networks are highly localized to specific cities or home regions (e.g., Durban (South Africa) Research Action Partnership, the Miami (Florida) Climate Alliance, and the Santiago (Chile) Climate Ambition Alliance).
- Assessing costs (including obstacles and barriers) and benefits (such as increased success in responding to extreme climate events) of generating this research[3,40,41].
- Identifying financial mechanisms to support this research effort[14,39,42] including donors, funding agencies, bonds, and tax levy sources.
- Building bridges linking the different communities through facilitators and boundary organizations[43–46] that provide a neutral space for discussion and problem-solving.

- Facilitating case studies/pilot project-sharing such as the UCCRN ARC3 Case Study Docking Station[47]; peer-to-peer learning[39,41,48]; and city-to-city learning and cooperation[49,50].
- Strengthening education through city initiatives and policies and for different audiences (e.g., youth, city planners, charity workers, small business owners, media, etc[51–53].
- Establishing mechanisms to monitor, evaluate and learn about impact and accountability of interventions[54–56].
- Encouraging civic universities (i.e., partnerships between universities and cities)[57–59] that catalyze human and educational resources for research and assessment.

It also should be recognized that mechanisms to enhance the science-policy-practice linkage could occur at varying scales of action. At the global scale, methods include the creation of 1) Common science tools and protocols (e.g., for use of high-resolution, remotely sensed imagery, sensing devices and standards, downscaled global and regional climate models and scenarios); 2) Agreed upon sets of urban climate services[60] standards (e.g., for joint frameworks for collaborations, memoranda of understanding for knowledge transfer, and development of international city-relevant assessments); and 3) Regional Hubs that link global and regional networks (e.g., UCCRN Regional Hubs that provide knowledge generation and sharing functions over a wide swath of cities[3]). To foster all of these, an informal consortium of organizations (many of whose activities are described in this paper) has emerged consisting of academics/knowledge networks, city networks and urban practitioner networks with aligned goals or opportunities for national, regional and local governments to mobilize funding.

An exciting means to guide all of these efforts would be the development of a global Cities Academy of Sciences. Such an entity could serve as an international-scale boundary organization that would serve all cities and their partners. This academy can be partnered with Chief Science Officers in municipal governments and serve as a designated institution for benchmarked assessment, such as the UCCRN Assessment Reports on Cities (ARC3), and production of new knowledge on and for urban climate action. With such an institution, key partnerships will be relevant such as with the International Science Council, the International Network for Government Science Advice (INGSA) and others like national organizations, in addition to existing climate and urban networks.

CONCLUDING THOUGHTS

Promoting effective scientist-policymaker-practitioner collaboration on climate change at the city level is a recurring challenge and will need continual dialog and engagement. Many points of potential tension and misunderstanding exist and as a result those involved need to constantly communicate not only about the content of the conversation but also its context and their own positionality and power. Most important is transparency regarding whose voices are heard or not heard, and who has the capacity to control the dialog and process, and the creation of space for other less-heard voices.

Like other contentious issues, discussions linking science-policy-practitioner communities are never fully settled or resolved but require continual attention and dialog because the contexts are ever shifting, opportunity for failure is always present, and contestation over how disagreements are arbitrated can easily expose underlying tensions and power dynamics. Continual and inclusive dialog will potentially help move cities forward to more robust decisions, promote flexible solutions, and effective indicator and monitoring systems, even with existing uncertainties. At the same time, it will be necessary to keep the research independent, objective and value-free from the influence of

government and private interests and patronage. All of this is underpinned by the recognition that the overall cost of inaction on climate change increases over time and the important role that cities are and will play in climate change action should be maximized.

At the international scale, a body such as a Cities Academy of Science could help to legitimize global knowledge efforts with buy-in from the three actor groups – scientists, practitioners, and policymakers. And at the national and sub-national scales, mechanisms to increase science-policy-practice connections include engaging context-specific research councils and ministries; collaboration with boundary organizations, involving their regional centers and offices; and strengthening the role of climate centers in universities and linking them to cities through national education programmes for knowledge transfer, teacher engagement, and student training.

At the city-scale, mechanisms that have proved helpful include public-private partnerships and think tanks, formal partnerships between local universities and cities, including science councils such as city panels on climate change, and embedded scientists on city teams. Many of these approaches may be difficult to implement in small and medium-sized and low- and middle-income cities. However, knowledge action networks and regional information hubs can help to fill these ambitions and wants[3,61–64], if suitably resourced and supported.

The demand for ongoing partnerships for advancing foundational knowledge related to cities-focused climate science is clear. Modalities for success will differ according to local urban contexts but ensuring that the knowledge base for climate action is available to all cities is essential. Enhancing these partnerships bring out not only more rapid and targeted scientific research but also expanded and strengthened action at the urban scale in response to the climate change threat, as well as to other current and future risks and hazards.

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AUTHOR CONTRIBUTIONS

The authors met all basic criteria for contribution to the development of the manuscript. All authors contributed equally to its development.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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