CITIES
2018·CONFERENCE
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PROCEEDINGS DOCUMENT

INTERNATIONAL CONFERENCE ON CLIMATE CHANGE AND CITIES

UN HABITAT
FOR A BETTER URBAN FUTURE

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UN-HABITAT

International Conference on Climate Change and Cities

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FOREWORD

Message from His Worship Mayor Don Iveson

Our city has been a gathering place for thousands of years of civilization, a place where diverse groups have come together to trade, share ideas and learn from one another. Edmonton was honoured to host the inaugural CitiesIPCC conference as a continuation of this legacy, bringing together local leaders, global organizations and scientific experts to explore the challenges of climate change.

This was a conference of many firsts – the first time the scientific community focused its attention on the role of cities in combating climate change, the first time cities and city networks gathered with technical experts to align climate efforts, and the first concrete example of the multi-level collaboration enshrined in the Paris Agreement.

Cities are where innovation and progress happen. As hotbeds of research and collaboration, they are uniquely positioned to tackle the ever-evolving challenges of climate change. CitiesIPCC was an important step in bringing local government leaders and the scientific community together to address the challenges that lie ahead. Conversations and presentations at CitiesIPCC clearly demonstrated that municipalities must commit to a new kind of partnership with the scientific community – a partnership based on data, research and innovation – to guide investment and policy decisions.

One of the most important outcomes from CitiesIPCC was the Edmonton Declaration – a city-focused document that reaffirms the importance of science-based policy and decision making. It recognizes that powerful change is possible through the unified and consistent efforts of government, businesses and the scientific community.

This summary report provides a snapshot of the CitiesIPCC conference, along with key recommendations to guide local governments towards a more sustainable future. It will help keep the City of Edmonton, as well as communities around the world, focused on our efforts to address climate change.

I would like to extend a resounding thank you to the organizations of CitiesIPCC and the many sponsors and supporters who helped to make this inaugural event a resounding success. The work we do today as a result of this conference will have an enduring impact on the future of cities – and the world.

Don Iveson
Mayor

FOREWORD

The Paris Agreement in December 2015 has ushered in an era in which climate science is focusing increasingly on solutions to the challenges of climate change. There is also a growing awareness among both policymakers and the scientific community of the role that non-state actors can play in addressing climate change.

At its 43rd Session in April 2016 in Nairobi, Kenya, the IPCC decided to recommend, within the scoping processes, a stronger integration of the assessment on the impacts of climate change on cities and their unique adaptation and mitigation opportunities. The Panel decided to include a Special Report on climate change and cities in the Seventh Assessment Report cycle, and to consider working with academia, urban practitioners, and relevant scientific bodies and agencies, to organize an international scientific conference on climate change and cities early in the Sixth Assessment Report cycle, in order to stimulate scientific reports and peer-reviewed publications on this subject.

A proposal for an International Conference on Climate Change and Cities, submitted to the Panel, was approved at its 44th Session in October 2016 in Bangkok, Thailand.

Both cities and the scientific community are critical players in helping to identify solutions that not only address the challenges of climate change but also the broader sustainability imperatives of the Sustainable Development Goals.

The International Conference on Climate Change and Cities, held in Edmonton, Canada, in March 2018, brought these important players together to identify the critical knowledge gaps that need to be filled if the opportunity of urban climate action at scale is to be harnessed.

The IPCC welcomed the partnership with the nine other organizations in delivering this milestone event. The research agenda emerging from this conference will contribute to scientific literature in areas that future IPCC assessments can consider.

Hoesung Lee
Chair of the IPCC

FOREWORD

At UN-Habitat, we recognize climate change as one of the fundamental challenges faced by countries, cities and all human settlements around the globe. Cities, the people that live in them, and our common habitat, are vulnerable to climate change. This brings unprecedented challenges, increasing the frequency and intensity of known disasters on one hand, and bringing new forms of disasters on the other. Losses in terms of property and economic assets; infrastructure destruction; and disruptions in people's lives and livelihoods are the consequences of climate change.

Often, it is people that are already living in disadvantaged locations that suffer the most. One must look no further than to informal settlements in developing countries to understand the challenge of protecting all people from climate change. At the same time, it is understood that human activities in cities are also the source of a significant portion of global greenhouse gas emissions. With the Paris Agreement as the guiding framework, positive action at the level closest to the people, is becoming the new norm and focus of the global community.

What are the options and solutions to adapt to, and mitigate, climate change in the world's diverse cities and human settlements – whether large and small, developed and emerging? As much as we need to embrace, scale-up and accelerate known climate solutions, we also need to be equally open and search for new solutions and innovation in climate action. We need to support science and knowledge, underpinning local climate action. To this end, we need to strengthen the ties between decision makers, practitioners and scientists to provide a rigorous evidence-base for better informed urban climate policy-making, as well as adaptation and mitigation action.

In line with this, UN-Habitat is actively engaged in supporting science and innovation, contributing to scientific publications and supporting research and researchers. In 2017, we partnered with the Intergovernmental Panel on Climate Change and other leading institutions in the field of cities and climate change to organize a dedicated International Conference on Climate Change and Cities – CitiesIPCC. This conference was in direct support of the development of a global research and action agenda, to advance the science, we need for the cities we want.

The CitiesIPCC conference in Edmonton, Canada in March 2018 brought together practitioners, policy makers and scientists to develop a global research agenda for advancing the science, and to inform the Intergovernmental-Panel on Climate Change about the state of knowledge today, as well as potential key areas of future focus in the field of cities and climate change.

The conference – and this publication, presenting its key findings – seeks to contribute to a positive and integrated engagement between the scientific community, urban practitioners and policy-makers. In today's reality, the way we plan, develop and manage our cities is crucial for sustainable development and for addressing the climate challenge.

UN-Habitat remains committed to implement the Research and Action Agenda in partnership with academia, urban practitioners, local authorities, and the scientific community.

Ms. Maimunah Mohd Sharif
Under-Secretary-General and
Executive Director, UN-Habitat

ACRONYMS

AR	Assessment Report
GHG	Greenhouse gases
IIASA	International Institute for Applied Systems Analysis
ICLEI	International Council for Local Environmental Initiatives
IPCC	Intergovernmental Panel on Climate Change
SDGs	Sustainable Development Goals
SLPCs	Short-lived climate pollutants
SR	Special Report
SSC	Scientific Steering Committee
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WG	Working group
WMO	World Meteorological Organization

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Boys running through a market during rain in Taveta, Kenya © Shutterstock

INTERNATIONAL CONFERENCE ON CLIMATE CHANGE AND CITIES CONFERENCE PROGRAMME

The programme of the International Conference on Climate Change and Cities can be found below. This programme includes the pre-conference session, held on 4 March 2018 and extends through to the end of 7 March 2018. Participants were also invited to register for local site visits, coordinated by the City of Edmonton which took place 8 March 2018.

Sunday, 4 March	
13:00-17:00	**Pre-Conference Session: A Village of Hope** [separate registration required]
17:30-20:00	**Edmonton Opening Reception:** *Collect 20:00 your registration package early and take the opportunity to sample refreshments and interact with tradeshow exhibitors* [**Hall A**]
17:30	**Poster Set-up** · 1.5 hrs [**Hall B**]

Monday, 5 March	
07:30	**Breakfast** · 60 min [**Hall D**]
08:30-10:00	**Opening Plenary** [**Hall D**]
10:00	**Refreshment Break** · 30 min [**Hall A Foyer**]
10:30-12:00	**Theme 1 Plenary** [**Hall D**]
12:00	**Lunch** · 60 min [**Hall D**]
12:00	**Poster Set-up** · 60 min [**Hall B**]
13:00-14:30	**Parallel Sessions Theme 1**
	Cities and the Global Agendas: SDGs, Paris Agreement, New Urban Agenda, Sendai Framework and Convention on Biological Diversity [**Salon 5**]
	Embedding Practitioner Evidence into the IPCC Process [**salon 6**]
	iDoc Workshop: Speculating on future energy systems [**Salon 8**]
	Financing Climate Risk at the City- level: Promoting dialogue between public and private actors [**Salon 9**]
	Inclusion and Informality [**Salon 10**]
	Co-benefits for Emerging Economies: Practical experiences and policy imperatives [**Salon 11**]
	Application of Multiple Knowledge Systems for Evidenced-Based Decision Making: Opportunities and challenges for ensuring resilient communities [**Salon 12**]
14:30	**Refreshment Break** · 15 min [**Salon Level**]
14:45- 16:15	**Parallel Sessions Theme 1 + 2**
	Environmental Justice and Urban Climate Change: How can we ensure an equitable future? [**Salon 5**]
	We Are Still In: The political and practical potential of non-state actor collaboration [**Salon 6**]
	Big Data: Understanding risks and resilience in cities [**Salon 8**]
	Delivering Air Quality Health, and Climate Co-Benefits [**Salon 9**]
	The Role of City Networks in Supporting Policy-Practionner- Academia Interactions [**Salon 10**]
	Mapping the Greenhouse Gas Data Landscape [**Salon 11**]
	Urban Climate Information to Support Decision Making: From local to global [**salon 12**]
16:15	**Refreshment Break** · 15 min [**Hall D Foyer**]
16:30-18:	**Theme 2 Plenary** [**Hall D**]

Tuesday, 6 March	
08:00	**Breakfast & Posters** · 60 min [**Hall B**]
09:00-10:30	**Theme 3 Plenary** [**Hall D**]
10:30	**Refreshment Break** · 30 min [**Salon Level**]
11:00-12:30	**Parallel Sessions Theme 2**
	Research Priorities and Multisectoral Collaborations Needed to Support the Most Vulnerable People in Cities [**Salon 10**]
	Climate Risks and Vulnerabilities in Coastal Communities [**Salon 6**]
	Guide for Integrated Urban Weather, Environment and Climate Services (IUWECS): How it can best meet the needs of researchers and stakeholders [**Salon 8**]
	How Data Aggregation Can Support Subnational Actors in Framing Climate Policy [**Salon 9**]
	Human Health Impacts of Climate Change [**Salon 5**]
	Mainstreaming Urban Governance and FEW Systems Towards Climatic Risk Reduction [**Salon 11**]
	Climate Response Actions in Cities: Enabling resilience building [**salon 12**]
12:30	**Lunch & Posters** · 60 min [**Hall B**]
13:30-15:00	**Parallel Sessions Theme 3**
	Promise of Green Infrastructure to Combat Climate Change in Cities [i] [**Salon 8**]
	Smart Cities and Their Promise for Addressing Climate Change in Cities [**Salon 6**]
	Interactions of Climate Mitigation and Adaptation in Cities: Synergies and trade-offs [**Salon 5**]
	Transforming the Built Environment: Research and experience [**Salon 9**]
	Climate Chance and Equity in the Context of SDGs [**Salon 10**]
	Urban Heat Island Effect and Climate Change in Cities [**Salon 11**]
	Climate Change and the End of Consumer Society [**Salon 12**]
15:00	**Refreshment Break** · 15 min [**Salon level**]
15:15-16:45	**Parallel Sessions Theme 3 + 4**
	Infrastructure Transitions and Urban Form [**Salon 5**]
	Promise of Green Infrastructure and Nature-Based Solutions to Combat Climate Change [**Salon 8**]
	Energy Systems and Buildings [**Salon 6**]
	Climate Change and SDG interactions in Cities: How much transformation is needed? [**Salon 9**]
	Governing Climate Change in Complex Urban Settings: Resilience through social innovation [**Salon 10**]
	Urban Mobility and Climate Change in Cities [**Salon 11**]
	Strengthening and Accelerating Effective Climate Action in Cities [**Salon 12**]
16:45	**Refreshment Break** · 15 min [**Hall D**]

17:00-18:00	**SSC Led Plenary** [**Hall D**]
18:00-2030	**Edmonton Gala Reception**
	Enjoy excellent food, company and entertainment. This social highlight of the conference will be celebrated in Rogers Place in the heart of downtown and home to Edmonton's National Hockey League Team. [**Rogers Place**]. *For those attending the conference, this event is included in your registration and bus shuttles will be available.*

Wednesday, 7 March

08:00	**Breakfast & Posters** · 60 min [**Hall B**]
09:00-10:30	**Theme 4 Plenary** [**Hall D**]
10:30	**Refreshment Break** · 30 min [**Salon Level**]
11:00-12:30	**Parallel Sessions Theme 4**
	Urban and Rural [**Salon 5**]
	Informal Settlements and Economies: Means for transformative climate action [**Salon 11**]
	The Importance of Monitoring and Reporting (M&R) for the Aggregated Impact of Local Climate Action and the Assessment of Covenant of Mayors Initiative [**Salon 8**]
	From Science to Action - Making estimates for multiple benefits of urban climate action accessible for decision makers [**Salon 9**]
	Climate Adaptation Finance: Urban perspectives [**Salon 10**]
	What Does the Transition to a 1.5 °C City Look Like? [**Salon 12**]
12:30	**Lunch & Posters** · 60 min [**Hall B**]
13:30-15:00	**Parallel Sessions Theme 4**
	Challenges and Opportunities for Locking-In Positive Climate Responses in Cities [**Salon 5**]
	Youth Voices and Climate Change Knowledge: Empowering youth in conversations on climate impact and vulnerabilities [**Salon 10**]
	Initiating Climate Awareness in Urban Planning Practices Through Participatory Action Research [**Salon 8**]
	Climate Change Adaptation in Cities: Insights on actors, institutions and agendas [**Salon 9**]
	Supporting National Determined Contributions (NDCs) Implementation in Urban Areas and Vertical Integration of Climate Actions [**Salon 6**]
	Cities and the Challenge of 1.5 °C: Assessing modes mechanisms and manifestations of coordination in global urban climate governance [**Salon 11**]
	Raising and Steering Finance for Climate Action in Cities [**Salon 12**]
15:00	**Refreshment Break** · 30 min [**Salon Level**]
15:30-16:30	**SSC/OC Led Parallel Sessions**
	Enhancing Data and Data Infrastructure for Urban Community [**Salon 5**]
	Finance [**Salon 6**]
	Future Research Agenda [**Salon 8**]
	Developing Novel Assessment Frameworks [**Salon 9**]
	Developing Partnership Based Platform for Better Information [**Salon 10**]
	Transforming Cities for 1.5 Degree World [**Salon 11**]
	Climate Change and Informality in Cities [**Salon 12**]
16:30	**Refreshment Break** · 30 min [**Hall D**]
17:00-18:00	**Closing Plenary** [**Hall d**]
18:00-19:30	**Closing Reception** [**Hall D Foyer**]

Thursday, 8 March

Edmonton Sustainble Site Tours

[as per registration instructions]

CITIES 2018·CONFERENCE IPCC

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Beautiful sunset above the windmills on the field © Shutterstock

INTRODUCTION

Recognising the important role of cities in the global climate change response, the Intergovernmental Panel on Climate Change (IPCC) at its 43rd Session (Nairobi, Kenya, 11 – 13 April 2016), decided under the **Decision IPCC/XLIII-6. Sixth Assessment Cycle (AR6) Products. Special Reports:**

i. To recommend, within the AR6 scoping processes, a stronger integration of the assessment on the impacts of climate change on cities and their unique adaptation and mitigation opportunities and make more robust the consideration of cities in the treatment of regional issues and in chapters that are focused on human settlements, urban areas and the like, including through the enhanced engagement of urban practitioners.

ii. That the Seventh Assessment Cycle (AR7) report will include a Special Report on climate change and cities.

i. To consider working with academia, urban practitioners, and relevant scientific bodies and agencies, to organise an international scientific conference on climate change and cities early in the AR6 cycle, in order to stimulate scientific reports and peer reviewed publications on this subject.

At its 44th Session (Bangkok, Thailand, 17 – 20 October 2016), the IPCC approved the proposal for an International Conference on Climate Change and Cities, co-sponsored by Cities Alliance, C-40 Cities Leadership Group, Future Earth, International Council for Local Environmental Initiatives (ICLEI)-Local Governments for Sustainability, Sustainable Development Solutions Network (SDSN), United Cities and Local Governments (UCLG), United Nations Human Settlements Programme (UN-Habitat), United Nations Environment Programme, and the World Climate Research Programme (WCRP). The International Conference on Climate Change and Cities, which was co-sponsored by the IPCC and the nine partners specified above was hosted by the City of Edmonton, Canada from March 5th- 7th 2018.

The overall objectives of the 2018 International Conference on Climate Change and Cities **(which for communication and branding purposes was later renamed Cities and Climate Change Science conference and tagged with the short title CitiesIPCC)** were to: (1) identify key research and knowledge gaps with regard to cities and climate change; (2) inspire global and regional research that will lead to peer-reviewed publications and scientific reports; and (3) stimulate research in Cities and Climate Change over the AR6 cycle.

The specific aims of the conference were to:

i. Take stock of the scientific literature, data and other sources of knowledge that have emerged around cities and climate change since the close of the Fifth Assessment Report (AR5) (i.e. March-October 2013[1]) and build on ongoing work as part of the AR6 cycle.

ii. Identify key gaps in the scientific literature, in keeping with the emphasis that arises from the scoping of the AR6 and its three Special Reports, and international, regional and national policy and implementation imperatives that emerge from 21st Session of the Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC), the Sustainable Development Goals (SDGs) and the New Urban Agenda.

iii. Identify key research and knowledge gaps, with the aim of stimulating new research, the findings of which to be assessed in AR7's Special Report on Climate Change and Cities[2].

iv. Develop novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between urban systems and climate change, especially action at the local scale.

v. Identify the research gaps in terms of policy and implementation in order to facilitate the consideration of such areas in anticipation of the Special Report on Climate Change and Cities.

vi. Bring together key urban and climate change stakeholders[3] to identify priorities for scientific and policy research during the AR6 cycle and to stimulate the co-design and co-production of actionable knowledge.

vii. Building on established United Nations, member state and research network initiatives help define appropriate global, regional and local monitoring systems and data architectures, including quality control, to facilitate scientific research and to help inform evidence-based policy development on climate change and cities.

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1 AR5 cut-off dates for literature to be considered: WG I: 15 March 2013; WG II: 31 August 2013 and WG III: 3 October 2013

2 Decision IPCC/XLIII-6 # 6 "AR7 cycle will include a Special Report on climate change and cities."

3 This includes UN member states, representatives of city and regional governments, UN and international organisations, representatives of the scientific community, universities and think tanks, urban and climate practitioners; organisations of the urban poor, development partners and donor institutions

viii. Establish a partnership-based platform to systematically accumulate, assess, analyse and disseminate information on science-policy-practice linkages that enable an upscaling and mainstreaming of urban climate actions at all scales.

The Conference Scientific Steering Committee (SSC) was responsible for the conference programme, and one of their primary goals was to foster as much discussion, exchange of knowledge and ideas between the research, policy and practice communities focusing on urban areas -the three communities who were the target participants of this conference- as possible. This focus was a line drawn through from the call for session proposals, through to the end of the conference. This resulted in a significant amount of rich information being generated from the conference.

This proceedings document is one mechanism which this detailed information will be shared following the conference. The second output of the conference, which is being prepared in parallel to these proceedings is the *Global Research and Action Agenda on Cities and Climate Change Science,* which has been submitted to the IPCC as part of the Conference Report, and was noted and approved by the Panel during the IPCC's 48th Plenary. This Research and Action Agenda is a synthesis of the research gaps which came out of the detailed inputs to the conference, found here. This proceeding will include a summary of each thematic plenary session as well as the SSC led plenary session held mid-way through the conference, which served to present what the SSC had heard to date and a platform for conference participants to bring up important questions which had stemmed from the information they had heard to date. It will also include parallel session summaries and answers to a set of questions posed to each parallel session convener, to bring forward research gaps related to the work which was presented in their session. It will also include posters which were presented at the conference, as well as the papers which were commissioned by the SSC in advance of the Conference.

This proceedings document is an important reference of the details which were presented at the International Conference on Climate Change and Cites, and will serve as a record and reference of these details moving forward.

Residents walk across a flooding street in Grogol, Jakarta, Indonesia © Shutterstock

Plenary Summaries

The CitiesIPCC Cities & Climate Change Science conference was a multi-day programme filled with inspiring plenary sessions, thematic parallel sessions, and poster sessions. Four themes were addressed:

Theme 1 Cities & climate change (Imperatives for action)

The Paris Agreement on Climate Change, Sustainable Development Goals, New Urban Agenda, and Sendai Framework for Disaster Risk Reduction are seeking to construct a new development trajectory. These global commitments both require – and will be supported by –addressing climate change in cities. In this Theme, we invite proposals for sessions and abstracts that specifically aim to exchange knowledge, lessons, and experiences on the impacts of climate change on cities and how cities (their local governments, businesses, and citizens) are adapting and responding to climate change. This theme seeks to map the mitigation and adaptation knowledge needs and the gaps being experienced by cities in the context of realizing global commitments. This Theme could also address the costs and benefits of climate action and inaction; the underpinning of ethics, equity and climate justice in the context of climate change, the role of city residents as agents of change, and the imperatives for actions that achieves low carbon, climate resilient urban pathways, and sustainable development in these contexts.

Theme 2 Urban emissions, impacts and vulnerabilities (Science and practice of cities)

As centers for population, infrastructure and economic activities, cities are key contributors to global emissions of greenhouse gases (GHG) and short-lived climate pollutants (SLCPs) as well as key hotspots of climate change impacts and vulnerabilities. Understanding the processes and interlinkages of climate science, emissions, impacts, risks and vulnerabilities are central for co-producing strategies and alternatives to adapt to and mitigate climate change. In this Theme, we invite proposals for sessions and abstracts that aim to provide a better understanding of current and future urban emission drivers and pathways, urban climate impacts, and risks and vulnerabilities in cities. This Theme focuses on how the science of cities can guide the reduction of GHG and SLCP emissions, climate vulnerability, differential risks and help improve resilience. The analysis of social processes driving the construction and reconstruction of urban space, of urban form, design and typology are key considerations. This theme will also include lessons learned from exposure to climate variability, extreme climate events and related responses, and focus on means to improve urban climate detection, attribution and climate information.

Theme 3

Solutions for the transition to low carbon and climate resilient cities (Science and practice for cities)

It is evident that cities need transformative solutions given the scale of the climate change problems. In this Theme, we invite proposals for sessions and abstracts that engage with deep decarbonization pathways for cities and regions; transformative adaptation and resilient urbanization, and the links between the two. This Theme will address sustainable cities from the viewpoint of mitigation-adaptation linkages, as well as the development-linkages (including poverty and inequality) of mitigation and adaptation pathways. Promises of disruptive technologies and innovations; urban infrastructure and design; political leadership; technical, social, policy, governance and institutional innovation and behavior changes are key to such pathways.

Theme 4

Enabling transformative climate action in cities (advancing science and advancing cities)

Climate action in cities will take place in a context of a diversity of social, environment, economic, and development objectives. The transformative climate change action required in the short and long term, needs enabling - both through knowledge and actions. In this theme, we invite session proposals and abstracts that share innovative practices, suggest new approaches or develop theoretical and methodological framings of transformative climate action in cities. Transformative climate actions should address poverty and inequality, re-shaping of power relations, and re-conceptualizing visions of what cities are, could be, and should be. Sessions and papers in this Theme may address innovative policies and practices (including policy instruments and insurance), governance and institutions, and leadership and political will. The sessions and abstracts may cover technological, institutional, and social innovation, technology transfer, and climate finance and investment including the issue of planning, implementation, monitoring, and evaluation of the Paris Agreement, the New Urban Agenda, the Sustainable Development Goals, and the Sendai Framework.

Each theme was introduced by a plenary session which brought together high-level experts for the research, policy and practice communities.

Each plenary opened with one or more keynote presentations, which were followed by a panel discussion. The conference participants also had the opportunity to ask questions to the panelist before the close of each plenary.

SUMMARY PLENARY THEME 1 - **CITIES AND CLIMATE CHANGE**

Keynote:
Aromar Revi, Director, Indian Institute for Human Settlements

Panelists:
Mark Watts, Executive Director, C40 Cities
Aromar Revi, Director, Indian Institute for Human Settlements
Peter Head, Ecological Sequestration Trust, Resilience Brokers
Amy Luers, Executive Director, Future Earth International
Nathalie Jean-Baptiste, Institute of Human Settlements Studies
Sheela Patel, Slum Dwellers International

Moderator:
Tom Dallesio, New City

Convener:
Cynthia Rosenzweig, Co-Director, UCCRN

The plenary opened with a recognition that global commitments like the Paris Agreement and the New Urban Agenda would require cities to implement new sustainable development trajectories that will help them adapt and respond to climate change.

The theme mapped gaps in mitigation and adaptation knowledge, including costs and benefits of climate action and inaction, and the importance of incorporating equity and justice lenses in the context of climate change. It also addressed the role of city residents as important vectors of change towards actions that achieve low-carbon climate resilient urban pathways and inclusive, sustainable development. It explored patterns in how and why cities are mitigating, adapting and responding to climate change and examined specific areas of informal settlements, inclusion, geographies, financing technology and the role of city networks.

The keynote, given by Aromar Revi of the Indian Institute for Human Settlements, touched on the informality, productivity and inequality that accompanies urbanization, and the importance of situating solutions in that context. The challenge to mitigate potentially negative consequences of accelerating urbanization in the coming decade, he argued, remains one of personal and cultural transformation, not simply energy transition. This is particularly true in Asia and Africa, where economic and population growth will be most pronounced. Three interwoven challenges must be faced: reducing consumption, decreasing population growth, and ending poverty.

He went on to explain that stranded assets are not simply on the books of fossil fuel conglomorates, but also in the form of coastal cities and communities - where a quarter of humanity resides - that will be lost to the rising tides. If infrastructure is not planned for next 100 years, current projects could lock us into long-term growing emissions without significantly improving resilience. Cities are positioned to address these issues because they understand integration and have experience making change and implementing transversal solutions on the ground level. What powers they are accorded vis-a-vis their national governments will determine their ability to act effectively.

He described the most promising catalysts for change as the enabling of disruptive technologies, the launching of local urban action research partnerships, and the allocation of sufficient funds to the necessary research. “We need transformative action, bottom up and top down.”

The period of exchange with the audience that followed raised a series of questions on the need for more work on behavioural science, to which Dr Revi enthusiastically agreed. Change is understood to be deeply cultural and the IPCC was trending in this direction as the recognition that physical sciences alone do not encompass all necessary research. He rejected the notion that we withdraw collectively from engaging with actors dependent on the broken model of linear consumption, and encouraged all to cultivate those relationships to exert influence from within.

Questions were also raised regarding power dynamics between levels of government and populations, with an understanding that this division of power needs to be renegotiated in many jurisdictions to reflect the ascendant economic and political role of cities. Leveraging economies of scale by allowing city governments to enact collective sustainable procurement policies would give a significant boost to green economy suppliers.

Panel Discussion

The panel addressed the question of how to bring together the Paris Agreement, the Sustainable Development Goals the New Urban Agenda, and the Sendai Framework to co-construct a new development trajectory.

As to the principal links between city actions and global agendas, panelists identified a number of points of current or potential convergence. Amy Luers of Future Earth mentioned the role of consumption; cultivation of local leadership; empowering local governments to achieve peak emissions by 2020 (North) & 2025 (South); communicating the co-benefits of improved quality of life; incentivization of open data; leveraging youth creativity and innovation; engaging with faith groups; involve residents of informal settlements as partners, not beneficiaries;

- Women & young people must transform their self-image as critical actors
- Change requires relationships & patience to ensure inclusion

Missing middle: bridging local and national

Engaging informality is valuable.

- What actions can be undertaken improve collaboration among the practitioner, policy-maker, and research communities to achieve lift-off? In effect, how do we get these going?

  – Peter: At Resilience Brokers we study this question and have done prototyping of this. We think of a collaborative laboratory "Collaboratory". A real opportunity is to have 1 city really looking for transformational change in each country that is really trying to lead this change. That will create shared knowledge, shared research, etc. All tools must be open sourced, free use, and scalable, and run with open data, and i think that's the way this can happen, where everyone can be involved in that, potential is to identify those 200 cities.

  – Nathalie: concrete example in Tanzania, preparing selves to go to Parliament, meet with policy makers commissioned to draft, this is a first step, from the policy researcher perspective. Btu also in terms of inclusivity. We cannot do much in the ground without including global government organization. They have the power to be quicker on the ground. They leap frog technocratic organizations - women federation. Finally, collaboration implies negotiation and tradeoff. In this it is fundamental to see between fact, sciences, and policies. Challenge housing, mitigating and adapting to CC.

- Q: Eric Doherty, can we stay below 2C without managing road space, what are the actual actions that need to happen?

  – Marc: simple answer is we do need to reallocate road space. Our modelling would show we need to get to 55/60% usage by 2030 for walking/ cycling/ mass transit. Difficult to make reduction. China activity trying to put cyclists to get back on the road?

- How can the city and global processes be more inclusive?

  – Sheela: Data, if you look at what is happening at almost all cities, there isn't a seriously well documented understanding of the presents of informality. Starts with who lives and works where informally? The government talks about transforming the job market, but if you don't document what happens and the parameters that produce the transformation, it won't change. First question about inclusion - acknowledgement and identity & voice. In the present structure this doesn't exist. SDI - works with mayors at the moment UCLG works with mayors to ask them to identify informal settlements and understand the problems they face. SDGs give us a good basis for local indicators that are or aren't working. Challenge of inclusivity related to the scale that's necessary to implement this transformation. 500 cities must simultaneously multiply. Exclusionary processes need to be broken down. Destruction necessary. Deeply embedded part of industrialization that needs to be addressed.

  – Peter: we totally agree, we did a prototype in Accra Ghana, 15 government structures in 1 metropolitan area. Systems modeling can link these and go across these barriers. Can reduce cost of achieving SDGs by 40% with this system

Twitter:
Jaga Datson: How to ensure diverse & inclusive modes of knowledge production in assessment reports?
Amy: the process of peer review, but also an increasing recognition of move towards grey literature and different types of knowledge. There is a challenge that we need to address.

2 points
1) how do you integrate knowledge to drive action?
2) How cities can learn from each other?

Doesn't need to be internationally assessed, can be less formal which are happening now with existing networks engaged in current conventions. Move from traditional modelling to collective intelligence effort leveraging systemic ways of regularly tapping into each other's knowledge. What is that informal network that we as a global community can work together. Future Earth working with centre of Collective Intelligence at MIT to develop the platforms necessary to establish that connection.

Sheela: I think what you bring out is also the need to be able to speak the language of each other. There are peer reviews of same people, you don't get all perspectives. You must be able to speak the language of what other people speak. That's the biggest challenge between scientific knowledge and popular knowledge. After so many generations of being told what to do, marginalized communities are understandably skeptical. So how do you create the new riches between these two things?

Government structures of knowledge production? Today you have leaders of social movements who are building their capacity to communicate their challenges

Deeper integration of all actors is necessary: other voices (practitioners & policymakers) need to feed into final reports.

Nathalie: Informal Housing and Settlements Chapter of the Second UCCRN Assessment Report on Climate Change and Cities (ARC3.2), it was a long process, but we needed to get the fundamental information from the ground. We had to consult the SDI in Tanzania, we had to conduct a number of workshops at the local level to bring out the information to feed that report. That is fundamental

Anu Ramaswami - US Network of cities supported by National Science: Sustainable, Healthy Cities. Comment: i really appreciate the comments on consumption and systems thinking, there is the consumption-based accounting looking at final consumers which is very valuable that looks at very valuable consumption, food supply.... Households consuming these sectors but also have production 6 or 7 sectors, these are the sectors that affect informality, lack services, affect health, adaptation, suggesting maybe focusing on life cycle transboundary perspective

Peter: When I gave up ARUP job to bridge middle gap: Connect economics, human health. Productivity becomes a powerful story. Not growth of consumption, but jobs, well, being. Growth of things that are good for us & for the biosphere.

How do we effectively communicate the linked city and global messages both within each community (research, practitioner, policy-maker) and across cities, nations, and international groups?

- Nathalie: This is a big Question because a number of different layers - effective communication and what looks like in Tanzania. Networking requires a number of different forms in Tanzania, the communication flow is incremental and needs to be broken down that are relevant for ppl in the current form. It needs to be unpacked from the abstract concepts. Laboratories in Dar Es Salaam we are initiating the city lab. Create a platform to navigate between dogmatic approaches & established institutions to facilitate multidisciplinary action. Actors can share comfortably their knowledge.

- Mark: Following on from that - I'd like to focus on comm between scientific community and mayors - we've got some challenges but very important. Aromar referred to the lack of city scale scientific scale at the moment. Mayors need that, especially acute to real poverty of data in informal sectors. I think mayors could bring scientists into the decision-making process. Mayor Iveson said: transcending populism with science & data. Mayor of NY has scientific committee. Oslo: Climate Bugeing process. Science driving fiscal decisions. Third thing, biggest, is to address miscommunication between scientific and political level. Mayor of Chicago talking about experiencing 7 1 in 100-year events in the last several years. So, this information is incredibly useless to scientific information. Current risk models are useless, a poor guide for policy-making. Good politicians listen to scientific advice, but it needs to be carefully communicated.
  Scientific community talk about urgency much greater than what is apparent and written down to policy makers. Policy hears "we are basically on the right way" science says "we are way off topic"

- Which city will be first to hire a chief scientist? Contact Tom to have that story told!

• What are the major knowledge gaps? And how can they be filled?

  - Amy: this has been a theme and will be one for rest of conference. But i see several categories. The first one is around data, we of course live in a data age and as was said there is equity in the data collected and how reflects society about us above us, below us, but we're not using the data effectively. Not just about how to collect data, but how to turn that data into knowledge. Local level data & global data that has local implications. Other knowledge gaps: Systems risks and opportunities. 3 level of issues. 1 is at local level, in cities a lot is managed in silos (water, energy, planning etc). There is importance in connections not just city to city but in city to other regions around the world. Understanding those systems and integrating / capturing. Capturing and tracking climate measurements in production & consumption is a systems-based approach to manage mitigation.

  - Other knowledge gaps: governance. Cities are grappling with challenges (cc & others) but aren't supported/ empowered by national and international institutions to take on their role as change-makers. Are there cities that can learn from each other?

  - Behavioural Science: building social movements: create incentives & understanding dynamics formal & informal sectors to implement solutions.

- Q: University of Minnesota: How to include smaller cities, which lack implement and adopt the actions. So, what is the mechanism to help the smaller 2.5, 3 million size?

- Alex Boston from Renewable Cities: Appreciate emphasis on systems thinking, harnessing capacity from national and sub-nationals. Working across silos. Affordability agendas are in cities are correlated with cities that have good climate agendas. Why aren't these people working together? Affordability & Climate solutions. Can't resolve these issues without looking at them together, holistically. How can C40 help cities build planning Capacity to work with each other across these silos?

- Question: Harriet Bukle, Durham (>) University. Can we have our cake and Eat it? Data, economics, innovation, how do we prioritize balance between data science and more social side, politics, interest.... Perhaps the braver city has a chief social scientist

Smaller cities & engagement?

- Sheela: Small towns try to imitate big cities. But they don't always learn the right lessons. Consumption world not something to be imitated. Poor cities don't have same institutional capability. Not sufficient support for smaller towns & cities. Greatest potential for transformation lies in small towns/cities. Must encourage associations to equip & empower smaller cities & towns.

Peter: Trust is key when building knowledge in communities. Create gaming versions for young people to use in school. Even slum youth have access to phones. If these marginal communities better understand the issues, they can advocate for their interests.

Natalie: Trust & social science: addressing land, government, cc. Not easy. How can social scientists & climate scientists work together? Africa is largely rural: how to address the questions of sustainability and resilience in these small towns/villages

Mark: setting good data, tools, collaboration

Cross-silo collaboration?

Mark: C40 is doing this by encouraging its member cities to meet across departments to tackle challenges that touch every area of city operations.

Cake & eat it to?

- Mark: WE can have our cake and eat it to. Economic opportunities are possible due to efficiency gains in tandem with emissions reductions. Deadline 2020 helps cities find those win-win points of convergence. Busting silos & encouraging various departments to talk about challenges that they can.

- Amy: we have to eat it too - otherwise we won't get people on board with this. Engaging social & biophysical scientists in Obama administration: we hope to do the same in Future Earth's work with cities moving forward.

- This these seek to map gaps in mitigation & adaptation knowledge in context of realizing global commitments; Costs of inaction; Equity & Climate Justice; Role of City residents & networks.

Ideas emerging as imperatives for action...

1. Cities role in global agendas
2. Behavioural change
3. Sustainable consumption
4. Power dynamics
5. Bottom up and top down approaches
6. Youth education
7. Role of informal settlements
8. Sustainable consumption and production; circular economy; lifestyle perspective
9. Knowledge gaps - data, systems, governance, and behavioural science

SUMMARY PLENARY THEME 2 - **URBAN EMISSIONS, IMPACTS AND VULNERABILITIES**

Speakers:
Debra Roberts, eThekwini Municipality, South Africa, IPCC co-chair WG II
Emilia Saiz, Secretary General, UCLG
Prof. Tong Zhu, Peking University

Panelists:
Valérie Masson-Delmotte, LSCE, IPCC co-chair WG I
Prof. Mark Pelling, King's College, London
Mayor Stephanie Uy Tan, City of Catbalogan, Philippines
Maria Amparo Martinez Arroyo, National Institute of Ecology and Climate Change

Moderators:
Dr. Megan Melamed, International Global Atmospheric Chemistry
David Miller, C40 Cities

This plenary opened with an introduction and framing of Theme 2: Urban emissions, impacts and vulnerabilities by Megan Melamed, International Global Atmospheric Chemistry and CitiesIPCC SSC member. This was followed by three keynote speeches and a panel discussion moderated by David Miller.

Debra Roberts began her presentation by identifying this as the century of disruption with three modern disruptions, urbanization, climate change and globalization. She highlighted the fact that cities had been around for thousand years, and that urban practitioners had accompanied cities through various industrial transitions. Priorities have shifted from the need for a secure city, to the revolution brought on by atomization, and further understanding of threats to citizens within city boundaries, to the technological revolution with the development of computers and now to the era we are in now, dominated by the internet of things.

She went on to emphasize that in this era, we are experiencing the most significant event of urbanization in history. Due to their nature, urban areas are vulnerable hotspots for the impacts of a changing climate. The impacts of increased emissions happen not to the city, but to its people and ecosystems. Giving an example of these effects, she noted that Cape Town, South Africa would be the first major city to run out of water. The development and infrastructure deficits during urbanization have led to widespread poverty, and this continued trend in urbanization stands in the way of achieving many of the SDGs.

Debra drew attention to the fact that to address climate change and the SDGs, we must draw on the strengths of the secure city, the sustainable city but also the scientific city. Urban practitioners understand the what and the why of climate change in cities, but also need to understand the solution and implementation options, the why, when, where and how to address and mitigate impacts of climate change in cities. Urban practitioners deal in these impacts in their day to day work, and can make important contributions to the scientific endeavor. Climate change scientists need to also embrace the practitioner, indigenous and informal knowledge as partnerships and multidisciplinary teams will be needed to carry out both climate change and development agendas.

Emilia Saiz went on to explain the importance of climate change becoming embedded in the urban policy agenda. She emphasized that we are at a tipping point where science will have the tools, models available that cities need to predict and plan sustainable urban spaces. In terms of building a global agenda which supports both the north and the south, she states that climate change has been a large equalize in terms of development. The emphasis needs to be placed on promoting and creating strategies, in partnership with the scientific community on how we shift the trends in development so that they support improving quality of life, but don't define this by owning three cars. Science will play a large role in developing, legitimizing and highlighting these strategies. Governance will also be crucial in promoting transformation, and a wide variety of actors, including those representing informal settlements and communities is needed to help develop and implement these models.

There is also an important role for financial investment, and science can help answer questions of in what and when should investments be made to build more sustainable cities. Developing predictions which emphasize the cost of inaction will also be important in incentivizing transitions.

These models for cities cannot be developed without science and she makes a call for urban researchers to place an emphasis on developing the predictive models to support cities on the city scale.

Tong Zhu started by highlighting an important area where partnership between science and policy has been effective in addressing climate change. Co-benefits of reducing emissions on human health have begun to be widely cited by policy makers in China. There climate change is not a priority, but air pollution is seen as a significant issue. The reduced air quality has caused public pressure on government and urban practitioners, so much so that practitioners can lose their jobs if they do not reduce levels of air pollution. Models developed and various measurements collected which can reduce air pollution. But taking advantage of these co-benefits can be highly important for addressing many issues which we are currently facing, including climate change and air pollution. He closed by highlighting the importance of bringing linking policy in areas where we could take advantage of these co-benefits.

The panel of Valérie Masson-Delmotte, Mark Pelling, Mayor Stephanie Uy Tan and Maria Amparo Martinez Arroyo started the discussion by highlighting the need for an expanded capacity at the city level and the need for partnership between researchers, urban practitioners and policy makers to develop a holistic approach to developing the science needed for cities to make predictions and plans for future climate change within their cities. A strong emphasis was also placed on the importance of people, in involving and educating citizens about the importance of mitigation and adaptation in ways which are currently not addressed in by the IPCC, through peer reviewed literature. The need for people to information on co-benefits, and reason for action and tangible consequences of inaction were also strongly recommended. They called for knowledge from different sources, such as indigenous and local knowledge, as well as peer reviewed literature to be shared with city stakeholders and citizens in a way that they could understand and act upon. When shared in this way, science can help give a voice to the constituents of a wide variety of networks and organizations within cities.

The panel also took questions from the audience. The first question deepened the discussion on how to draw people in to listen to the science and make the major changes necessary. The SDGs and Paris agreement were notes as agreements which could very generally involve, and draw in a broad community. Communication was highlighted as key, keeping up the arguments, and making people see themselves in the issues and the solutions. Trying to start bridging the time scales of scientific assessments and city decision making was also highlighted by Mayor Tan as important. These time scales often play in to the power dynamics involved in policy co-production. In Mexico City, Amparo Martinez highlighted, social dialogues as well as showing benefits of actions once policy was enacted were important in developing buy-in for co-generation from all communities.

The conversation closed with a clear call to facilitate ways for people to have a voice in decision making in the city, particularly as it pertains to climate change adaptation and mitigation.

Towards a research agenda

The following research gaps and recommendations were identified in the theme 2 plenary.

- Understanding finding ways to emphasize the co-benefits of adaptation and mitigation, e.g. air pollution / health, cost savings.

- A holistic approach to understanding the 'science' going on in a city – almost a stocktake of what information is available and known in each individual city.

- Cities as integrated re-knowledge sharing centres, need a platform to engage wider organizations, i.e, education centres, museums, to reach out to citizens. Showing the benefits of action.

- Scientific understanding followed by governance to understand the 3 Rs: risk, reason, response. This understanding then needs to be shared with citizens in ways they will be able to relate to. A common language/ dialogue that all can understanding will be important to make progress.

SUMMARY PLENARY THEME 3 - **SOLUTIONS FOR THE TRANSITION TO LOW CARBON AND CLIMATE RESILIENT CITIES**

Speakers:
Dr. Andrew Gouldson, Professor of Environmental Policy, University of Leeds, UK
Dr. Jurgen Kropp, Professor, Potsdam Institute for Climate Impact Research (PIK)
Dr. Shobhakar Dhakal, Professor, Department of Energy, Environment and Climate Change, Asian Institute of Technology

Panelists:
Dr. Shuaib Lwasa, Associate Professor, Makerere University
Dr. Lan Marie Nguyen Berg, Vice Mayor for Environment and Transport, Oslo Municipality, Norway
Mehrnaz Ghojeh, Senior Urban Development Specialist, Buro Happold
William Cobbett, Director, Cities Alliance
Prof. Dr. Diana Ürge-Vorsatz, Professor Central European University, Hungary, vice-chair IPCC WG III

Moderator:
Dr. Jim Skea, Co-Chair, IPCC WGIII

Jim Skea, Co-Chair, WGIII, Intergovernmental Panel on Climate Change (IPCC) opened the plenary session with an introduction to Theme 3 Solutions for the transition to low carbon and climate resilient cities (Science and practice for cities). He highlighted the importance of the theme in IPCCs sixth Assessment Cycle (AR6) and a more explicit focus on cities. There is a special focus on demand, Services and social aspects of mitigation including sustainable consumption and production, culture, social norms, policies facilitating behavior and change

The first keynote speaker Andrew Gouldson spoke about the role of role of city level partnerships in transformational change. He discussed briefly ten key themes and challenges for city level partnerships and how these relate to transformative change. Several city level case studies and plans are emerging including several successful examples on low carbon transformation and resilience around world. He stressed on the importance for providing an evidence base to understand the impact of these policies and plans. can support decision making with a stronger evidence base. By forming a partnership and bringing different communities to review, input and advance the database City level partnerships can help take better decisions. City level partnerships help to provide information on the successes highlighting how existing projects can support the development priorities, contributing to social wellbeing, public health and reducing congestion.

There is a need to explore financing options and business models to deliver transitions. Once the low hanging fruits are taken, and it gets to the deeper stages, it gets harder and more challenging politically and socially. we need more innovative business models. Re-thinking policy and governance interventions for cities, institutional infrastructures for delivery and new financing models would be required to facilitate such a transition.

Mainstreaming climate change in the heart of urban policies and governance process. Find ways and approaches to move away from siloed approaches to bring in every sector and actor in the city. Ensuring a buy-in from all stakeholders including senior level support from mayors and city level leaders. An inclusive agenda by securing support from mayors and city level leaders, communities and all the stakeholders can be brought into the agenda. A compelling argument to convince stakeholders on why climate change needs to be a part of that.

Re-scaling and multi-level alignment policy mapping exercise to see the levers at different levels across the governments, coordination and alignment across different government. Expand policy and governance. Two thirds of emissions of consumer cities are consumption based. This is an important area to explore to address innovative ways to address consumption-based emissions. When it gets to deeper stages of transition when the cheaper options are exhausted, need for innovative financing and business models to facilitate the transformative transition. What are the institutional infrastructures for delivery. City level partnerships can play a key role in building capabilities- to bring public and private stakeholders together. Early stage can be facilitated through incremental efforts. The challenges require going beyond incremental efforts towards more transformative changes. Finally, he stressed on the need to have a post-evaluate case studies to assess their impacts to facilitate cities and across cities.

The next speaker Jurgen Kropp started with the scale of investment required for building infrastructure for 700 billion people. He emphasized that such a massive scale-up could create adverse consequences. Doubling the density could be an option to reduce emissions but whether this was desirable. He discussed the need to identify potential trade-offs and benefits. He emphasized the advantages of poly centrism especially in the context of food and resources consumption in cities. There is a need to understand how cities will grow and develop in future. The talk emphasized the need to integrate urban design and planning with the urban hinterland

The third keynote presentation was delivered by Shobhakar Dhakal. He started with a discussion on the rapid transition to low carbon cities and the lessons learnt in the last few assessments. There is knowledge on best practice technologies and their potentials, functioning of urban sectors and what has and hasn't worked. There is scope for undertaking a systematic assessment. He emphasized a research gap on understanding systematic linkages in cities, including the interaction between and within urban sectors. There are knowledge gaps around the multiple drivers to shape transformative change, systemic options and their potentials and policies with economy wide impacts and their effective implementation. Little systematic assessment on the implementation of cities climate actions. Avoiding lock-in in rapidly urbanizing regions: Urban design, spatial planning infrastructure, population, density, mixed land use accessibility.

The keynote presentations were followed by a panel discussion comprising five panelists- Shuaib Lwasa, Lan Marie Nguyen Berg, Mehrnaz Ghojeh, William Cobbett, Diana Ürge-Vorsatz. The panel emphasized touched upon issues of planetary health and intergenerational equity. The emphasis and effort on health and wellbeing and the need for ensuring participation of different communities in the planning process. There exist challenges of low carbon planning however, a common purpose and shared action could help achieve goals. The panel agreed on the need to ensure significant behaviour change at all levels

Lan Marie highlighted Oslo's target of 95% emissions reduction by 2030 among the most ambitious climate targets. She highlighted that Oslo was the only city with a target in line with 1.5 °C budget. She emphasized on a system where climate reporting was given equal importance as economic reporting resulting in transparency and accountability. The city uses the strongest tools they have to implement this. Cities are increasingly realizing the co-benefits of substantially increase quality of life, health and social inclusion. There is a difference between possibilities in rich countries compared to developing countries. Therefore, cities in developed world with higher capacities have responsibility to pave the way.

There exist different tiers of opportunities to synergize mitigation and adaptation actions. The question is to scale up individual successes. Such opportunities could result in development opportunities such as increased jobs for example the sanitation and water sector. Key opportunities for transformative change include accelerated green infrastructure replacement, efficiency, best practices and new technologies, drivers such as lifestyle and consumption and finally he emphasized the role of governance to tap the systemic high-level solutions. Disruptive innovations, technologies and behaviour were identified as key themes going into the future.

The presentations were followed by a round of question and answers. The first question was around building capacity by developing research networks and enhancing peer-to-peer learning mechanisms. Peer-to-peer learning is an effective way to transfer lessons between cities. This could be facilitated through development assistance and finance to bridge the north south divide. A question was raised around the choice of tools and methodologies for evaluation. Different tools and methods exist; however, the challenge is to find tools that can be easily adopted by the diverse stakeholders. In summary, the presentations and discussions reinforced the need to have an inclusive urban plan that identifies mitigation and adaptation opportunities, engaging all stakeholders, find innovative governance and financing models to implement these, and use collaborative models to draw lessons for replication.

Towards a Research Agenda

The following research gaps and recommendations were identified in the theme 3 plenary.

Systematic assessment of low carbon plans

A number of cities have developed and implemented low carbon and climate adaptation plans. Little systematic assessment on the implementation of cities climate actions. Future studies could look at evaluating these case studies to assess how and to what extent have climate action plans made an impact. Such a post evaluation could help understand cities are doing the things in line what is required to address climate change.

Assessing solutions for avoiding lock-ins

A large amount of infrastructure will be built in the future to address the demand, especially in developing countries. This brings a tremendous challenge for mitigation but a big opportunity. Future research could identify and assess solutions to avoiding lock-ins in rapidly urbanizing regions. For example, the mitigation potentials of modifying urban design, spatial planning infrastructure, population, density, mixed land use and accessibility.

Integrated and inclusive approaches

Such a change needs an assessment of the current status of cities. A knowledge gap exists about the systematic linkages in cities - the interaction of different urban sectors. There is an emerging need to understand what are the multiple drivers to shape transformative change. There are gaps in knowledge, capacity between north and south. Future research could focus on bridging this gap through cross-city learning, channeling investments and innovative financing models that can address cities at different levels of urbanization and development.

SUMMARY PLENARY THEME 4 - **ENABLING TRANSFORMATIVE CLIMATE ACTION IN CITIES**

Keynote speaker:
Dr. Cynthia Rosenzweig, Senior Research Scientist, NASA Goddard Institute for Space Studies

Panelists:
Gino Van Begin, Secretary General, ICLEI
Phillip Decorte, UN-Habitat
Mayor Jaiman Upadhyah, Rajkot, India
Dr. Priya Kurian, University of Waikato, New Zealand
Christopher Kennedy, University of Victoria, Canada

Moderator:
David Miller, C40 Cities

The plenary opened with keynote speaker, Dr Cynthia Rosenzweig, starting with a challenge to delve deep into the what, when and how of enabling transformation. Transformation – large abrupt and structural, transformation of biophysical and social systems – needs to be a priority for cities to address climate change. This involves integrating mitigation and adaptation into planning decisions, and the ambition to act. Dr Rosenzweig presented a diagram of the collapse, resilience, transformation continuum. Examples of cities already beginning transformations: Edmonton, Canada; Colombo, Sri Lanka; Medellin, Colombia; Copenhagen, Denmark.

She then presented on the Hurricane Sandy case study.

Gino Van Begin of ICLEI made the following observations: (1) There already are examples of robust climate change action in cities, representing over 25 years of capacity building in local governments. Through ICLEI, more than 1000 cities have reported their reduction targets and action plans, and the measurements and investments that they will take to achieve those actions. Action in Canada have worked with 300 cities. In the Global South they are working to build development plans that are resilient. C40 and ICLEI work together in GCM with 7,000 cities working towards CC resilience. But there are over 1 million jurisdictions out there, many of which need assistance. Through cooperation and dialogue with the scientific community, the humanitarian case needs to be made to reach out to them all., to gain a holistic picture of what is going on, at all scales. (2). Transformative climate action is more ambitious than just climate action. The next step is to bring beneficial information, evidence and research to the sustainability agenda at large to serve the people. This is a discussion since RIO.

Phillip Decorte of UN-Habitat spoke about realities to which transformation will have to answer: the global south is growing rapidly; urbanization may be rapid, but the impact of unsustainable actions will cost far more; many models used today are outdated and unsustainable and hard to retrofit over time; urbanization is closely tied to climate change and sustainability: we need to get people out of poverty without necessarily increasing their carbon footprint. To maximize added value, a truly integrated approach is needed, no more ivory towers but a true collaborative effort. These partnerships will not be easy, but they are necessary. Examples of such partnerships include (1) linking researchers and practitioners (see published the Quito papers in the New Urban Agenda); (2) partnerships between local and young researchers in the global south and research in the global north who can help build capacity. The experience of GS research needs to be captured in the global knowledge.

Dr Jaiman Updhay, made the following intervention in Hindi, which was translated to English on screens in the plenary hall.

The transcription of his intervention follows.

"Respected guests, experts, researchers and dignitaries from various cities. Thank you very much for inviting me to present here.

Cities globally have potential to diminish the cause and impacts of climate change in particular when supported through capacity building, networking, and public awareness. Rajkot is very fortunate that it receives continuous support from global networks like ICLEI since 2008, which provides technical support and capacity building for city administration.

Since 2008, support from ICLEI has helped Rajkot to imbibe knowledge and experience from best practices implemented by other cities, enhancing strategic capacity and motivating us to implement new initiatives and actions to promote low carbon development and energy conservation.

Rajkot is one of the 24 cities in India voluntarily sharing climate action information through the Carbonn Climate Registry, where more than 1000 cities, towns and regions from 86 countries report their GHG emissions, climate and energy targets and mitigation and adaptation actions.

Because of this, Rajkot can reach to global processes and make all data accessible to everyone. Rajkot is transforming itself and gaining importance nationally and internationally.

Here are some examples:

- Rajkot received support from the European Commission funded project- "Promoting Low Emission Urban Development Strategies and Emerging Economy Countries" implemented by UN-Habitat and ICLEI in India.
- Rajkot is one of the six cities in the world getting technical support for green building initiatives under "Sustainable Energy for ALL (SE4ALL) Building Accelerator (BEA) project" Supported by UN Environment.
- Rajkot has been selected to provide technical assistance and capacity building activities to local governments under the "District Energy Systems (DES) in Indian Cities" project supported by UN Environment.

- Rajkot is one of four cities from India to get assistance from the Swiss Agency for Development and Cooperation (SDC) and initiated the Capacity Building Project on Low Carbon and Climate Resilient City Development in India (CapaCITIES Project).
- Rajkot in India is one the twelve selected cities of World for the Regional GIZ Project "The Integrated Resource Management in Asian Cities the Urban Nexus".
- Rajkot has been awarded as "National Earth Hour Capital 2016" of India led under the One Planet Charter initiative of WWF globally.
- And since 2017, I have the honor to serve in the Founding Board of the Global Covenant of Mayors for Climate and Energy, the world's largest coalition of cities and their networks for climate action.

I again thank you all for inviting me here.

Priya Kurian, University of Waikato New Zealand spoke about social justice, gender, race and class, as they play out across these areas of environmental issues. Technological and scientific advancement is not enough; political, cultural and economic changes are needed. The discourse in the language of climate change shapes world view and action in the end. Talking about the Anthropocene depoliticizes the issue by describing the globe as though it is one unified space. It is not. From a justice and equity perspective, there are differences in wealth, power and access on all scales. Some humans, not all, are causing climate change. There is also a masculinization of environmental and climate change action processes, where women and indigenous peoples are often missing from these discourses. Seeing the third world and women as victims of climate change, takes away their agency. This has consequences for climate action. Critical social science discourse as noted in The Great Derangement, a crisis of culture, not just nature. Working with the Maui peoples in New Zealand they aim to create a culture framework for integration with climate change actions. She emphasized that just transition needs fundamental change in our institutions, in our cultures, a need to include minority voices, to creating deliberative spaces for a wide range of stakeholders, building political momentum and resisting capital. Success can be redefined as building local capacity, from the bottom-up. Success will be judged subjectively by different peoples in different ways.

Chris Kennedy spoke about how good policy involves generating multi benefits in every decision you do. For example, electrifying is a key to solving climate change. The conclusion from the feedback of 28 researchers around the world, and from collected energy use data, was that access to electricity also had the highest correlation to quality of life. It was a driver to making great economic development impact. Case studies show that every city has a unique approach to CC. The global urban energy system needs transformation. Bottom-up approaches are valuable, a common shared and global approach to climate change is important: decarbonize, substitute electricity, reduce energy. Collectively, cities need to start framing their mitigation strategies, to make this connection between the bottom-up and the top down (e.g. Boulder Colorado).

During the question and answer session suggestions were made as to what immediate interventions cities should consider. They include rapid (accelerated) decarbonization, electrification, focusing on efficient use of energy, water, reducing waste, construction using non-emitting concrete and other novel engineering solutions, retrofitting, reducing emissions from buildings, heat pumps, integrating biodiversity and ecosystems (nature based solutions), increased attention to conservation. Other questions and comments raised the importance of pluralistic approaches, including different ways of knowing, and the need for more social science research into what motivates people to act.

Towards a Research Agenda

The following action and research needs were identified in the theme 4 plenary.

Co-creation and Co-design: the need for the scientific community to partner with the leadership in cities to understand the baseline, and from there to make projections for transformative action, including risks, impacts, political projections, financial planning, etc. The timelines and language of research and policy need to converge. Existing networks can help build capacity at the local level.

There is a need for deliberative democracies, that include minority voices, create spaces for a wide range of stakeholders, identify common ground, build political momentum, resist capital and work toward social justice. There are differences in wealth, power and access on all scales. Some humans, not all, are causing climate change. Technological and scientific advancement is not enough; political, cultural and economic changes are needed.

The need for immediate, far-reaching transformation that answers both to climate adaptation and mitigation, as well as sustainable development, improved quality of life for the poor and future needs for urban expansion. For this increasing science-policy and inter-city cooperation will be needed, for information gathering and sharing, cross-sectorial co-created research, growing understanding of problems and opportunities in various contexts.

SUMMARY SSC LED PLENARY - MARCH 6TH 17-18 H

The plenary opened with an introduction and welcome by the SSC co-chair and IPCC WG III Vice-chair Diana Ürge-Vorsatz. The session was meant to take stock of what has happened so far through the first two days of the conference. It is an IPCC tradition to go through and synthesize what has been happening and review the discussion, this practice was brought to the CitiesIPCC conference as well. The session looks to inspire the rest of the discussion through the conference, and spur further discussion.

As the bulk of session under conference themes 1, 2 and 3 had already occurred at the time, the session started with a report back from the SSC Theme Champions for themes 1, 2 and 3.

Cynthia Rosenzweig (Co-Director of UCCRN) started with a summary of key messages and take-aways from the plenary session and nine parallel sessions from conference theme 1: *Cities and Climate Change Imperatives for action.*

- While climate change is a powerful motivator, an integrated framework across the global agendas would help cities to respond
- The informal sector needs a voice, acknowledgement, and identity
- There is an urgency for cities to energize sustainable consumption, production, and circular economies
- A balance of bottom-up and top-down approaches will enable transformation
- Innovative technologies are catalysts for rapid achievement of the 1.5°C goal
- Radically improved multi-level governance and private-sector involvement will greatly facilitate financing for mitigation and adaptation at the required scale
- Addressing the knowledge gaps for data, systems, governance, and behavioral science will significantly improve city achievements of the global agendas

SSC member Maryke van Staden gave the summary for theme 2 *Urban Emissions, Impacts and Vulnerabilities Science and Practice for Cities* included information from the theme 2 plenary as well as twelve parallel sessions.

- Cities are impact and action hotspots for climate change and air quality.
- Understanding urban emissions, climate change impacts, risks and vulnerabilities – in context of urbanization, globalization and climate change – can help define an effective response, also considering options that address uncertainties.
- Using a systematic approach and scientific evidence, can support informed decision-making in cities, where policy and practice guides research, establishing a feedback loop to address knowledge gaps.
- Combining bottom-up and top-down (multi-disciplinary) data and knowledge will enable more accurate observation and understanding, empowering people to co-design and co-own their response, reaping multiple benefits from action.

Richard Dawson followed this with an abridged summary of theme 3: *Solutions for the Transition to a Low Carbon and Climate Resilient Cities Science and Practice for Cities.* As theme three parallel sessions all occurred in the hours directly preceding this session, he was able synthesize information from the theme 3 plenary session, but only give a partial synthesis of theme 3's fourteen parallel sessions.

- Understanding and managing complexity
- Opportunities (and risks) from new and "old" technologies
- Thinking about the future - Modelling, Narratives, Visions
- Enabling change - Partnerships, governance and funding
- Monitoring, Evaluating, Learning and Accountability
- Limits to urban action - stimulating and joining up with action beyond the urban boundary

Diana also took a moment to thank the theme champions from the SSC, Cynthia, Maryke, Richard and William Solecki (representing theme 4) who have done a great deal to bring academic and intellectual contexts of themes together for the conference program.

The next part of the session went on to give a taste of the 4 Nature papers and the five commissioned papers that were published in advance of the conference. Many of the topics of these papers would be further elaborated in the final set of parallel sessions on the third day of the conference as they have been identified as topics which cut across many of the conference themes.

SSC member Xuemei Bai was invited to present the Nature Commentary piece. This paper is a co-production by 11 SSC members, including researchers, policy makers and urban practitioners, and is an example of co-design and co-production in action. The paper *Six Research Priorities for Cities and Climate Change,* published March 1st, and as of the morning of the session there were 1000 tweets about the paper, and it was in top 2 % of papers published in Nature this year- quite impressive as this topic is competing with biomedical research papers etc.

This paper was informed by the scientific vision of conference as well as a keyword analysis of the web of science literature from the last two decades on cities and climate change as well as the 800 + abstract submitted to the conference. Many of the large points in the paper have been resonating in our discussions. One of the key aspects: the importance of taking action now. The paper highlights the six research gaps below.

The first is a call to expand urban observation, observatories and urban data sharing, noting the largest data gap in the global south. The importance of reliable GHG and other urban emission inventories, and incorporating local narratives and knowledge in data collection was also highlighted. The next gap was around understanding climate indicators, with a specific need for high-resolution assessment of heat waves, coastal erosion and inundation. Models which take into account complex climate interactions in cities are needed to benchmark and compare information at the city scale. A specific focus was also placed on the study of informal settlements, which are projected to hold 3 billion urban inhabitants by 2050. Tailored models and analytical tools are needed to develop mitigation efforts which do not undermine livelihoods and the informal economy.

The fourth recommendation was to harness disruptive technology and do a thorough analysis of how we can take advantage of the digital world relating to the changing climate. Carbon neutral, affordable material and new technologies should be explored. Bold strategies and non-linear change are needed to transform lifestyles and consumption patterns in cities to those which put us in line with global targets, and therefore a recommendation was also made to find ways for support transformative change in research, policy and local initiatives. The last point was to recognize the global sustainability context, comprehending that cities are open, complex and dynamic systems with a global reach. They recommended that a systems approach should therefore be used in cities to explore interactions, trade-offs and synergies between urban processes and impact and use the nexus approach as cities expand.

Xuemei then highlighted some next steps to fill the gaps in the research for cities. Stronger partnership and co-production of knowledge will be key. One mechanism which was recommended for embedding science-policy partnership within a city is for the city to appoint a chief science officer. Thought data sharing is an important tool for cities, building networks of researchers, practitioners and policy-makers focused on urban issues, such as Future Earth's Urban Knowledge-Action Network was highlighted as being the type of initiative which should be fostered.

In addition to the Nature Commentary, a spotlight was also placed on the three Nature Climate Change articles, also published in the week leading up to the conference. The topics of the papers were jointly decided by the conference SSC.

The first paper is titled *Sustainable Development Goals and Climate Change in Cities* and focuses on how pairing addressing climate change issues in cities with how they can also address the goals established within the SDGs can increase momentum and action to accelerate action on both fronts.

The second paper, *City Transformations in a 1.5 °Warmer World* sheds light on the ways in which a world which is half a degree warmer can have significant effects on city life. The authors note that cities' poorest residents will be hit the hardest, and to avoid this and more significant warming in cities in the coming decades, transformation must accelerate to hyper speed especially in the global south.

The last paper, *Locking in Positive Climate Responses in Cities* discusses the ways in which actions associated with climate change mitigation and adaptation take place in a disconnect and may therefore compromise each other. However, there may be synergistic and if urban practitioners and policy makers could take advantage of these synergies, there is strong potential for mitigation and adaptation actions to catalyse each other. The authors were shocked to find that the term lock in was not mentioned in any of the titles of the 1000+ submissions to the CitiesIPCC conference. Filling the gap in knowledge on positive lock in has important practical considerations, especially if we would like to push for locking in pathways which could assist us in tackling climate change. The paper points to the lock in risk, choices that we make today and in the near future about adaptation and mitigation actions can determining the opportunities available to us for adaptation and mitigation for decades or centuries to come.

This session of the conference finished by Shobhakar Dhakal SSC co-chair doing a speed round on the papers commissioned for the conference. The SSC did a strategic brainstorm to select five topics to tee up the discussions at the conference and put out a call within their communities for leads on topics selected. The commissioned paper titles and lead authors are found below:

Towards a Novel Assessment Framework for Cities and Climate Change ***Lead: Cynthia Rosenzweig***

Urban Data Science for Global Climate Solutions
Lead: Felix Creutzig

Responding to Climate Change in Cities and in their Informal Settlements and Economies ***Lead: David Satterthwaite***

Financing Low-Carbon, Climate-Resilient Cities
Lead: Sarah Colenbrander

Urban Climate Change Science, Impacts and Vulnerabilities: State-of-the-Art Findings and Key Research Gaps
Lead: William Solecki

This closed this part of the session, and the microphone was turned over to four additional SSC members, co-chair Seth Schultz, Lykke Leonardson, David Dodman and Aliyu Barau to hear questions from the audience, both those who were attending the conference, and those who were following along online through the CitiesIPCC Twitter feed. The SSC members made clear that this was a listening session, and that the priority would be to have time for the largest number of questions to be put forward from the conference's audience, and that the SSC would not be answering the questions, but that they would be shared for consideration in the final 24 hours of the conference, and could feed in as key conference gaps for the research and action agenda.

Bill Rees - *University of British Columbia:* I was intrigued by Diana's comment about being locked in or path dependence and that the planning community had received no submissions on this topic. Is the problem suffusing entire conference? Primary focus on data, science, finance, growth, formal institutional framing of industrial society causing this problem. Almost no emphasis on political context, institutional behaviour, need to recognize absolute limits to growth or the need to recognize the need for absolute reduction in the consumption of energy or material. Need for a steady state economy that works within the means of nature. Technology has increased consumption at every step increase in efficiency and will not take us where we want to go unless we begin to recognize the fundamental biophysical parameters that constrain us and the behavioural mechanisms driving this forward.

Halina Brown - *Clark University:* Overwhelming impression I had from the summaries is that if we all work together we will accomplish big things. Change of the kind we are seeking will not happen through collaboration and holding hands. It is a bloody think to make such a shift. I saw nothing in your summary that would say there will be confrontation, there will be contestations and we have to figure out how to work through this. I am sure if there is no bloody fight out there we are not accomplishing anything.

The question was put out on the CitiesIPCC Twitter feed: *What has been missing from the CitiesIPCC discussion in Edmonton, please share your thoughts.* Anyone who has spent much time on Twitter knows that this is very much like waving the proverbial red flag to the bull. It is almost like inviting aggressive negative comments such as those from climate deniers, and there have been some of these. It was highlighted as useful to read and think about some of the negative comments as they can be turn around and become useful for the community.

Comment 1: Reality, **Comment 2:** More reality

There was a reflection that their idea of reality different from ours, but this can serve as a good reminder to keep our discussions grounded in the realities of cities, current and cities of the future.

Next Comment: Request to include a discussion on human health. Health and urban health and its multiple relations with climate change in cities is important in a variety of ways, from the effects of pre-existing health effects of vulnerability to the importance of health co-benefits, related to reducing emissions and interesting points to highlight.

Next Comment: Where are the landscaping companies, electrical and construction companies. How will they implement the agenda coming out of this conference? Good reminder that these private enterprises and private sector should be brought further into the discussions.

Kate Noble - *City of Melbourne:* I want the climate scientist to know that cities and city practitioners are your allies. Not to say that we don't need to get better at science communications, it is about power and politics and conflicts and competing stakeholders and all these things. I think that I have really appreciated the social science perspective about theories of change and the psychology of climate change denial is very important. and it has been a very important part of the discussion. It is important to recognize that some of the climate change denial comes from a place of concern and we need to work with that. We can't ignore it, we need to have our eyes wide open, recognize this as well as the climate science and we are collaborators on that and want to find ways to move forward.

David Viner - Mott *MacDonald:* We deliver a lot the solutions required in urban space. One of the things we haven't heard, how we finance resilience and adaptation and how we finance and present this to our clients who want to know why. There is a very short investment cycle and it is hard to demonstrate to funders how this will contribute to resilience etc. in the long term.

Julie Arrighi - *Red Cross Red Crescent:* One observation cities in conflict affected places, large levels of vulnerability, climate is a threat multiplayer, conflicts are protracted lasting for decades can affect for decades, and have implication from a climate perspective. Also, even shorter conflicts can deal with these effects and another important aspect is we need to think about ways to rebuild in a climate smart way after short and long conflicts.

A few comments from women's groups, have been received on Twitter.

Women in Informal Employment Globalizing and Urbanising: Recycling leads to lower GHG emissions. Waste pickers often contribute to higher recycling rates, but they are often overlooked, mal-treated or even criminalized. Cities like Pun in India and Bogota in Columbia are seeing environmental, economic and social benefits to integrating waste pickers into the cities' solid waste management plans.

Next comment: To improve informal settlements and livelihoods work with communities to provide resilient alternative building technologies, use local knowledge for waste management, resettle to better located land, provide security and tenure to basic services.

Next comment: Excluding those affected by disasters during rebuilding will cause unintended harm.

Rachel Huxley - *C40:* We have heard a lot the need for systems and transformative change it is fantastic, backing up points we have heard that if we want transformative system change we have to change the system. Good to hear institutional and governmental changes are that we need beyond just the actions that cities need to take.

How do we make information accessible to staff in cities who are in the process of planning action and taking action? We all talk about big data but we are at the risk of drowning in information. How do we take the complex stuff and make it accessible for cities?

Yunus Arikan - *ICLEI:* When reading listening to presentations, the mayors summit and being involved in negotiations of UNFCCC for so long, one thing that has struck me, we have been addressing a point which is multilevel governments but did not make any specific recommendations on political scientists, and the political process and how we will influence them as this is still as scientific area. How will we address this, who will address this (local and regional governments?) and what will be the scientific implications of this? The world is in a system of change, how and who will address these ongoing changes with local and national different levels of governments who will need to change.

(Question from unidentified participant): My familiarity with IPCC is that there is a great marriage and language between scientists and social scientist for policy with respect to global climate change evadement policy at the national and international level. I suspect a formal involvement of urban planners and designers, those who are actors at that level may be necessary so that we ensure that the language that its communicated out of a conference and the IPCC with respect to cities is commensurate with planners at the city scale. As my feeling is that they speak in a language that is ultimately different than the language at the national policy scale and higher.

(Question with unidentified participant): This conference is in the first place concerned with cities. Cities function in a wider context of their hinterlands and that is an element that I am missing at this conference. Growth and production of cities is strongly related to what is happening in the hinterlands as well. Growth of large cities have left the rest of the country sucked empty and this causes problems both in the cities and in the countryside. A more balanced development would alleviate a lot of problems at the city and the rural level.

Going back to the twitter feed, one thing that has caught Lykke's attention was the discussion about the introduction of a chief science officer in cites. We have some varying feedback, with some people opposed to and pro this idea. Those pro said that this could be the same as chief financial advisor. The comments are divided and Lykke is also divided on this. There is a risk of them becoming disconnected to what happens on the ground and more like helicopters hovering over everything and not able to translate the science into cities. Science is not just science, whether we are talking about nature science, political science is very different and we want to make sure we have a much deeper conversation with cities and think that more than a chief science officer may be needed.

Julie Greenwalt - *Cities Alliance:* Tomorrow is International Women's Day and we are planning on having a photo later women involved in conference. It has been highlighted a few times how many women have been involved in the OC and SSC. However, there has not been a lot of discussion in gender disaggregated data, or gendered responses, the need for women's empowerment, it has been pretty quiet on this aspect. I would love to see more on gender mainstreaming, disaggregating of gendered data and how women's empowerment is important in responses to climate change.

Jennifer Ewing - *City from Bellevue Washington:* Similar chief science officer, one thing conference has sort of touched on but could be explored more: what is most effective way for academia to partner and work with cities. I have seen different models, but it is Challenging to make those connections and it needs to be explored more and think about how we could work together collaboratively. Chief science officer may be an option but may not be the most realistic option, would love to see more on what models for collaboration work best.

Julie Whipple - *Qlik Technologies:* I am a representative of the private sector here at the conference. My suggestions would be to look to the IPCC and the CitiesIPCC conference in particular as an opportunity to engage more with the private sector in particular. There are corporate responsibility programs and sustainability programs across every organisation these days. Would behove the IPCC and this conference to find a way to engage with the private sector as they would be open and interested in hearing this information discussed this week. Similarly, along the lines of the UN Global Compact as it relates to the SDGs.

To close out the question period, Seth Schultz make a few quick comments on process that which is being undertaken through the week, this session being an important part of it, and to give a reminder on where we are going. An important reminder that all information, from the posters, the parallel and plenary sessions to the questions that have been posed in this discussion will be fed into a large collection of data. There is a huge team of people working behind the scenes pulling that together the bulk of the detail will go into the *conference proceedings*. The SSC and other partners are also working together to land some of this information in *various special issues*, in journals going forward. One of the major points of this conference was also to bring stakeholders together to crystalize and mobilize the next decade for the *research agenda* as it pertains to climate change in cities. Participants were also encouraging to reach out to the session chairs, either in person or through email contactde personally or through the info@citiesipcc.org account if through your journey through sessions, interactions, if here is something that they felt strongly about and wanted to continue the discussion on. We hope the CitiesIPCC conference is only the beginning!

New York City - The People's Climate March in Manhattan during the UN Climate Summit in September 2014. Later that week, stakeholders launched several important multi-stakeholder initiatives related to cities and climate change. © a katz/Shutterstock

Parallel Sessions Summaries

Recognizing the importance of cities in both mitigating and adapting to climate change, the IPCC's Fifth Assessment Report (AR5) included a chapter on urban adaptation to climate change (Chapter 8 of Working Group II – Revi et al., 2014) and a new chapter on the role for spatial planning and urban areas in mitigating climate change (Chapter 12 of Working Group III – Seto et al., 2014).

However, there is still space for a stronger integration of the assessment on the impacts of climate change on cities and their unique adaptation and mitigation opportunities in future IPCC assessments.

This conference aimed to take stock of the scientific literature, data and other sources of knowledge that have emerged around cities and climate change since the close of the Fifth Assessment Report (i.e. September-October 2013) and build on ongoing work as part of the AR6 cycle and establish research and action agenda based on conference inputs and discussions, and stimulate new research, in advance of the Special report on Cities and Climate Change, which will be included as part of the IPCC's Seventh Assessment cycle.

The desired outputs of the Conference included:

- A global research agenda on cities and climate change that advances climate change science;
- Enhanced understanding of the impacts of climate change at the urban level, the range of possible responses and the role of cities in the implementation of the Paris Agreement; and
- Better informed climate decision-making at the local level, as a result of improved relations between the policy, practice and the scientific communities working on/in urban areas, through new projects, platforms and partnerships.

Session chairs were asked to provide a summary of their session and answers to questions relating to the research and action agenda. All submissions for these two requests are included in the following sections. We note that we did not receive inputs from some of the conference sessions, and only sessions who received input from have been included in this proceeding. The full conference program which includes a full list of parallel sessions is included as an Annex. Title, abstract and speakers for all sessions are currently available in the detailed conference program on the CitiesIPCC website.

SESSION TITLE: **INTERCONNECTIVITIES AND RESILIENCE: THE PRACTITIONER RESPONSE TO BUILD SOLUTIONS*** - MONDAY MARCH 5TH

Session Convenors and Sponsors:
David Viner and **Anne Kerr** (Mott MacDonald); **Candice Howarth** (University of Surrey); and **Dru Crawley** (Bentley Systems)

Student Scientist:
Kaelin Koufogiannakis

**(Note: this was incorrectly identified in the Programme as: Embedding Practitioner Evidence in the IPCC Process)*

Description of the Session

This session invited contributions from scientists, practitioners and policy makers working on solutions to implement the international 2030 Agenda for Sustainable Development in cities globally, including: the Paris Agreement on Climate Change; the Sustainable Development Goals; the Sendai Framework for Disaster Risk Reduction; and the New Urban Agenda. The session aimed to:

- Provide a review and highlight the wealth of evidence available from the practitioner community and how this can be collated;
- Examine how practitioner knowledge and evidence can be better incorporated into the IPCC and wider scientific process.
- Examine how the practitioner, policy and scientific community can foster collaboration
- Discuss the components required to establish a partnership-based platform to collate and disseminate information.

This session outcomes demonstrated the implications of "what if" scenarios in a visually stimulating manner, using state of the art modelling tools, to demonstrate for example "what if City X was redeveloped and densified such that populations increased by 30% in the next decade, where would the risks exist, what are the potential impacts, how these could affect the people living, working, visiting the city, and how resilience could be embedded to the system of systems which makes up a community.

The practitioner community has a great deal of embedded knowledge and expertise gained over many years of designing and building both large infrastructure projects that encapsulate how cities have evolved. Yet little, as a result of well documented mechanisms (Viner and Howarth, ***Nature Climate Change***, 2014) of this has fed into the IPCC process to date. The session was to:

- Examine how practitioner knowledge and evidence can be better incorporated into the IPCC and wider scientific process.
- Examine how the practitioner, policy and scientific community can foster collaboration.
- Discuss the components required to establish a partnership-based platform to collate and disseminate information.
- Encourage greater awareness of stakeholders within cities of the consequences in delaying taking action.
- platform to collate and disseminate information.

This is set in the context that the IPCC is policy relevant, not policy prescriptive.

SESSION TITLE: **IDOC WORKSHOP: SPECULATING ON FUTURE ENERGY SYSTEMS** - MONDAY 5TH MARCH 2018

Session Conveners:
Mary Elizabeth Luka, Sheena Wilson

Session Participants:
Natalie Loveless, Sourayan Mookerjea, Charles Stubblefield

Session Shepherd:
Gregory Reppucci, Cynthia Rosenzweig

Parallel session summary

Authors:
Natalie Loveless, Mary Elizabeth Luka, Sourayan Mookerjea, Charles Stubblefield, Sheena Wilson.

Session shepherd:
Gregory Reppucci, Cynthia Rosenzweig.

Session student notetaker:
Azadeh Mokhberi.

Session participants:
33 people attended the session, sitting in six groups of approximately six people each.

Grounded in the province of Alberta, the iDoc session demonstrated the use of a refined version of the National Film Board of Canada's Fogo Process of participatory action research to create critical reflection and dialogue in and about cities. Drawing on video recorded interviews with University of Alberta FES scientists and social scientists, City of Edmonton policy-makers and program officers as well as Edmonton based indigenous and non-indigenous activists, the session involved IPCC participants in an exploration of different perspectives on energy transitions and in an interrogation of various imaginaries of energy futures globally. The session contributed to the development of a multi-year critical exercise and systems analysis (2017-2023).

This 90-minute interactive workshop incorporated video playback of a select number of interviews, iterative demonstrations, and then invited participants to respond to provocations and possibilities offered by Future Energy Systems scientists and social scientists, as well as policy makers, and activists. The assemblies of videos demonstrated a range of divergent and convergent ideas that articulate the limits and promises of "disruptive technologies and innovations [for] urban infrastructure and design, [imagining the] political, technical, social, policy and institutional leadership and behavior changes required" (theme 3).

iDoc is an Energy Humanities (EH) research undertaking of the $75 million Future Energy Systems (FES) initiative at the University of Alberta, funded by the Canada First Excellence Research Fund. Some of FES's 45+ teams are focused on alternative energy technologies and plans for oil phase-out. iDoc showcases the perspectives of scientists, cities, activists, policymakers, and citizens. The intermedia documentary process probes the rhetorics and values of possible energy systems futures, and the technologies envisioned by the teams that they imagine will get us there. iDoc also connects to another FES Energy Humanities (EH) project, "Speculative Energy Futures", as well as to the SSHRC-funded "Feminist Energy Futures: Power Shift and Environmental Social Justice". These projects apply systems and social impact analysis through innovative, interdisciplinary methodology. Together, these research projects will culminate with a large-scale evidence-based art exhibition and other scholarly outcomes, bookending two IPCC gatherings: the Edmonton meeting in March 2017 and the 2022-23 meeting.

iDoc research mobilizes an updated social science methodology known as the Fogo Process (a community animation strategy created by exchanging moving image recordings). First developed by the National Film Board of Canada in 1967 (Wiesner, 2010) and since used around the world (Mookerjea 2009, 2010), the Fogo Process reciprocally shares recorded discussions among relevant community members, policy-makers, and researchers, to move towards resolution of seemingly intractable problems. The approach enables both technical energy literacy and deep energy literacy, which Wilson (2017) defines as the understanding that all of our institutions and relationships are the outcome of the energy systems that power them. Energy transition is, therefore, a social and political process. Cutting across themes one, three and four of the 2018 IPCC, the workshop explicitly addresses knowledge exchange around extant energy and social infrastructures, by imagining resilient urban transformations, and by articulating ways that we can re-shape power relations and re-conceptualize visions of future cities.

Mookerjea, Sourayan. (2009). "Dalitbahujan Women's Video Experiments in Andhra Pradesh" in Globalization and Communicative Democracy, Ed. Kevin Howley, Sage Publications: London.

Mookerjea, Sourayan. (2010). "Autonomy and Video Mediation: Dalitbahujan Women's Utopian Knowledge Production". Indigenous Knowledges and learning: Perspectives on development, education, and culture. Eds. D. Kapoor & S. Jordan. Palgrave Macmillan. New York.

Wiesner, P.K. (2010). "Media for the People: The Canadian Experiments with Film and Video in Community Development." In Challenge for Change: Activist Documentary at the National Film Board of Canada. Eds., Thomas Waugh, Michael Brendan Baker, and Ezra Winton. Montreal & Kingston: McGill-Queen's University Press, 73-102.

Wilson, S. (2017, April 7-8). Paper Title: "Deep Energy Literacy: an Archaeology of Thought, a Forensic Analysis." Toxic Media Ecologies: Critical Cultural Practices in the Age of Alternative Facts. University of Alberta.

State-of-Knowledge Summary

Relevant Section of Existing IPCC reports:
Revi, A., D.E. Satterthwaite, F. Aragón-Durand, J. Corfee-Morlot, R.B.R. Kiunsi, M. Pelling, D.C. Roberts, and W. Solecki, 2014: Ch. 8 Urban areas. In Climate Change 2014. See especially Section 8.4.2, pp 580-584.

Contemporary research in the social sciences has clearly established that growing social inequality and intensifying intersecting systems of oppression are major problems facing humanity today; that social inequality and intersecting systems of oppression undermine social trust and exacerbate social conflict; that social conflict, inequality and oppression undermine social cooperation and therefore a city's capacity for resilience. Discussions with scientists, researchers, and political leaders at the IPCC, moreover, made clear that while technological innovation will be a crucial component of any strategy deployed to address climate change and ecological crisis, technological advancement, without a reform of the political economy of technology, provide inadequate paths for addressing the scope and range of the issues we face. The value and capabilities of technologies and their potentials to aid in addressing climate change are broadly appreciated by members of the science, policy, and practice community; and so too are the limitations of existing technologies. Many presenters, and our own participants, remarked upon the actual and potential impact of emerging technologies, but also mentioned that the social and political arrangements of cities and those cities own consumption either mitigated the impact of their technologies, exceeded the capabilities of technologies, or that technologies were incapable of addressing the diverse range of ecological issues arising from human production and consumption practices. Thus, the invaluable capabilities of technologies have been roundly appreciated, but the social, political, and economic forces in which these technologies are deployed remain opaque.

Questions being addressed by current research in our field include:

a. How can public trust in scientific institutions and scientific research be rebuilt through public engagement processes involving the collaboration of scientists, policy-makers, artists, civil society and community leaders? See: The Vaccine Project and Speculative Energy Futures
b. How can citizen engagement and deliberation processes for policy formation be made more effective? See: Alberta Climate Dialogue

Our workshop took essential first steps to both explore and widen the conceptions of energy transition held by our participants, and enabled them to engage with the ideas of other scientists, artists, activists, policy makers, communities' members, and researchers, through active watching of video interviews followed by focussed discussions. Through these video interviews, we shared the experiences and knowledges of a diverse range of individuals, regarding the uses and limitations of emerging technologies, the role of the economy and the city in the processes of over-production and consumption, the impacts cities have on the surrounding communities, including indigenous communities, the city as a politically constructed environment enabling and enforcing certain practices, and most pressingly the value and necessity to take seriously feminist and decolonial knowledges when making decisions regarding environmental issues and when attempting to create resilient cities. As such, our workshop addressed questions of the social impacts, political frameworks, and deficiencies of energy technologies and policy choices deployed to combat climate change. This sentiment was widely shared by our participants and was also expressed in a number of other presentations. Questions that are currently being addressed by the social scientific research on technological innovation include research on the importance of democratic deliberation regarding the design and implementation of new technologies. Many participants expressed the importance of incorporating feminist and decolonial critical analyses of technology and urban planning into forthcoming IPCC assessment reports.

Potential Frontiers and Future Research

More research is needed on how interlocking systems of oppression, especially sexism, undermine democratic engagement and participation with city scale governance and policy formation. More research needs to be done on women's participation in environmental social justice movements to understand better how feminist insights can contribute to more effective policy formation and program delivery. What governance principles of common pool resource management can be adapted for the governance of a decarbonized and diversified energy production commons at a city-region scale? What governance principles of common pool resource management can be adapted for the governance of city scale resilience commons? The vague and over-generalized conception of the private sector has to be disaggregated into more fine-grained understandings of power networks, social institutions, legal frameworks, and market positioning to understand better which elements of the private sector can aid resilience capacity building and which institutional agents erode such capacity? What are the limitations of the risk paradigm for understanding and responding to social crises, especially their gendered and subjective dimensions that determine how communities and social groups respond to policies, relate to norms, learn and teach communicative rationalities? What is the role of democratic and feminist environmental social justice movements in leading, supporting and accelerating city government climate change resilience policy formation and program delivery? What regulatory frameworks for the global political economy are able to mitigate the chaotic and contradictory effects of speculative bubbles in real estate, infrastructure, food, etc.?

Electric car at a charging station on the Glockengieserwall street near the Hamburg Kunsthalle, Hamburg, Germany. © d13/Shutterstock

SESSION TITLE: **CO-BENEFITS FOR EMERGING ECONOMIES: PRACTICAL EXPERIENCES AND POLICY IMPERATIVES** - MONDAY MARCH 5TH

Session Convener:
Dr Mahendra Sethi

Session Participants:
Jose A. Puppim de Oliveira, Getulio Vargas Foundation (FGV, Brazil),
Geng Yong (School of Environmental Science and Engineering, Shanghai Jiao Tong University, China),
Osman Balaban (Middle East Technical University - METU, Turkey),
Fee Stehle (University of Potsdam, Germany),
Jyoti Parikh (IRADE, India)

Session Shepherds:
Lykke leonardson and **Aliyau Barau**

Parallel session summary

Authors:
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Session Aims and Format

Cities in emerging economies face multiple challenges to address economic development needs, local environmental loss, poor-infrastructure and climate resilience, amongst increasing contributions to global GHGs. This is further accentuated by low performance of these cities on parameters of social development, equity, functional autonomy and financial capacity. In the last decade or so, co-benefits approach has proved to be a key mechanism that provides both vertical cross-linkages between institutions (global, national and local objectives) on the one end and horizontal interactions between mitigation and adaptation related policy sectors on the other. Paris Agreement, Urban SDGs, the New Urban Agenda, Sendai Framework emphasize greater collaboration between diverse communities, multi-level institutions and development sectors to co-generate positive impacts. It thus becomes crucial to assess the practical experience of co-benefits- lessons learned, scientific tools, knowledge gaps in the emerging economies with the overarching aim to discern policy imperatives that moderate current unsustainable pathways of urbanization.

The session presents the application of co-benefits as an approach in India, China, Brazil, Turkey, South Africa & Indonesia, which together comprise about half of global urban population, underpinning how to promote climate action based on scientific tools, different experiences and gaps identified so far.

State-of-Knowledge Summary

It is a known fact that persistent efforts to pursue just climate mitigation or adaptation have not lead to significant outcomes on the ground. Identifying multiple co-benefits of climate goals, development policies and local priorities is imperative to synergise and expedite climate action. Cities in developing countries till recently had a limited research on climate response, that too pre-occupied with adaptation agenda. Emerging economies and other developing nations have a huge potential to adopt climate mitigation (IPCC 2014a) as most of the new infrastructure, industries, housing, etc. that is going to be created in this century would be in the urban settlements of these countries (IPCC 2014b). This can have immense development related climate co-benefits.

As many of these developing countries are now harbouring fast growing economies, these would have to simultaneously respond to local development pressures, environmental issues and the test of global climate change. Thus, cities in emerging economies are in the right position to effectively assess multiple challenges and their trade-offs associated with rapid growth, sustainable development, mitigating excessive emissions and adapting to climate change (Sethi & Puppim de Oliveira, 2018). At the same time, there are several gaps in estimating and applying co-benefits in urban settlements. These include conceptual gaps, methodological gaps, empirical gaps and policy-governance gaps (Sethi 2018). Thorough identification of climate co-benefits in urban development projects and greater use of assessment tools to evaluate these is the most important aspect. This is directly relevant to imperatives for action.

The co-benefits approach is perhaps the only overarching assessment framework that proactively considers systemic linkages, synergies and trade-offs between cities and climate change. Climate co-benefits can leverage innovations and opportunities that promote clean energy generation (rooftop solar), public transport typically mass-transit, light-transit (as applicable), non-motorized transport, electric vehicles, cleaner cooking, energy efficient buildings or green habitats and waste to energy technologies, improve of public health and create socio-economic equity.

The science-policy-practice interactions are currently acting in a very limited and exclusive manner to deal with climate challenge. Many stakeholders are unaware of how this challenge could be converted into an opportunity to transform societies in adopting sustainable urban pathways- the way people live, work and recreate. There should be national level stakeholder workshops organized to enhance awareness and cooperation of these diverse groups that represent *science-policy-practice* along with the citizenry. Joint labs can be setup in established urban and engineering institutions with support from multilateral agencies, local or state governments, etc. where researchers could learn, collaborate and co-generate action based projects. Real climate action in developing countries depends on decentralization of governance systems and empowerment of local governments, through greater scientific/ technical assistance. The scientific community should focus on creating scientifically robust and yet practical decision-making tools on co-benefits that can steer greater policy action on climate change.

Ground mounted solar power plants in africa in south sudan and zimbabwe © Shutterstock

SESSION TITLE: **APPLICATION OF MULTIPLE KNOWLEDGE SYSTEMS FOR EVIDENCE-BASED DECISION MAKING: OPPORTUNITIES AND CHALLENGES FOR ENSURING RESILIENT COMMUNITIES** - MONDAY MARCH 5TH

Session Convener:
Dr. Frederick Wrona (Government of Alberta)

Session Participants:
Dr. Frederick Wrona (Government of Alberta); **Dr. Brenda Parlee,** (University of Alberta); **Dr. Igshaan Samuels** (Agricultural Research Council, South Africa); **Laura Lynes** (The Rockies Institute); **Dr. Leroy Little Bear** (University of Lethbridge); **Dr. Tero Mustonen** (Snowchange Cooperative); **Dr. Tirso Gonzales** (INTE-PUC).

Session Shepherd:
Sarah Cicchini (City of Edmonton)

Session student social scientist:
Irene Wolfstone (University of Alberta)

Parallel session summary

Session Aims and Format

The aim was to explore the challenges, opportunities, and best practices of braiding Indigenous and scientific knowledge systems to inform climate change adaptation and mitigation strategies and programs, particularly as they relate to enhancing resilience of the interdependent urban and rural Indigenous communities. This session was informed by the outcomes of the pre-conference session A *Village of Hope,* which brought together Indigenous Knowledge-holders and scientists to share their understanding. Three themes were highlighted at the session, *A Village of Hope*:

a. If Indigenous cultures and languages are lost due to climate, Indigenous knowledges of adaptation will not be carried forward.
b. Youth are the torchbearers for carrying forward Indigenous climate change adaptation knowledge and practices.
c. IPCC must modify its report process to welcome and braid Indigenous and scientific knowledge systems.

The format of the session, *Application of Multiple Knowledge Systems for Evidence-Based Decision Making: Opportunities and Challenges for Ensuring Resilient Communities,* was a panel discussion. Panelists presented topical information based on their experience and the Village of Hope discussions they all had participated in.

Summary

Applying a multiple evidence-based (MEB) approach to decision-making has received significant attention in the science-policy-practice community. The MEB approach weaves together Indigenous, local, and scientific knowledge for resilience and sustainability, while maintaining the integrity of each knowledge system.

Panelists in this session highlighted examples where science-policy-practice interactions are currently contributing or could contribute to the research gaps and recommendations related to the challenges and opportunities of weaving Indigenous and scientific knowledge systems to inform climate change adaptation and mitigation strategies and program.

Dr. Brenda Parlee, Panelist: In my research on the McKenzie River basin and its freshwater ecosystems in the Yukon and northern Alberta, I build relationships with Indigenous communities to braid their knowledge into my scientific research on climate change adaptation. Projects begin by consulting Elders who guide the strategic questions of the research. We work with local youth on our 29 land-based collaborative projects and the result is a place-based perspective. Every two years, we hold a Knowledge Fair where the youth involved come together to share knowledge. They are the knowledge holders and leaders in this process. Putting communities first in collaborative research is critical. There is a problem when research on bear and caribou populations does not always consider community knowledge as valid. Policy developers, universities and IPCC need to move beyond treating Indigenous knowledge as opinion or anecdotal. We need to understand it as science that is rigorous and experiential; it is based on thousands of years of observations.

Dr. Tirso Gonzales, Panelist: Indigenous Studies programs at universities have potential to braid multiple evidence-based knowledge systems on climate change by applying Indigenous theories and methodologies to counter-balance the Eurocentric and Anthropocentric perspectives of Western science. The "In Situ Conservation of Native Cultivars and their Wild Relatives" project, funded by the Global Environmental Facility, is a Peruvian project in the Andes that braids local Indigenous knowledge on seeds and plant breeds with scientific knowledge and national policy. IPCC's agricultural assessments need to include Indigenous agricultures understood in the broadest sense (hunting, gathering, farming, fishing), which are sustainable. Agriculture is a fundamental connection between rural areas and cities. The Andes Association and the Andean Project of Peasant Technologies (PRATEC) are examples of autonomous and sustained projects of community-based research and knowledge generation by and for Indigenous peoples, including climate change. PRATEC has a sophisticated approach that is successfully tested in 900 Indigenous Andean communities; it has systematized and digitalized invaluable community-based Andean Indigenous knowledge as part of a project of cultural affirmation and the nurturing of life as a whole.

Dr. Leroy Little Bear, Panelist: Braiding traditional Indigenous knowledge (native science) and Western science will improve environmental practices and aim to reduce the speed of climate change. We need to examine the metaphysics of Western science that is the way of thinking and the bias in scientific methods. First, we need a common language toward a unifying theory. Second, human language is primitive in comparison to species that have existed much longer and have a secure social identity (i.e. fish). The more we use a common language, the less there is a need to talk. We come to Be through Knowing, not Talking. Western science is good at separating into categories, differences, variations. Third, we need to abandon the Western hang-up about measurement that originated 500-600 years ago. It is as obsolete as an iPhone 4. The cosmos is not organized as a hierarchical or linear system. Mathematics and measurements prevent us from real Knowing. There is a different way of Knowing. The challenge of braiding Indigenous knowledge with Western science begins by interrogating the philosophical foundation on which Western science is built. Then we can move forward in ways that erase the boundaries between Western science disciplines and arrive at a place of Knowing Holistically.

Laura Lynes, Panelist: The Village of Hope pre-conference session was a dialogue between Indigenous knowledge keepers and scientists. The event was organized in consideration of Indigenous concepts of time in that it had a begin time and end time, but between those two points it was unstructured so that people could speak freely. Sharing food is an important feature of Indigenous knowledge-sharing events. As community agents of change, we must strip away layers of complexity to work on a very simple goal: survival. Colonial laws over 150 years have treated land and nature as a commodity, as property or as an object. Indigenous peoples all over the world are taking the lead in changing laws to protect lands and rivers. This is an example of weaving and braiding. Solutions to the climate crises cannot originate in the Western framework that created the problem – a framework that moves us faster along the trajectory toward extinction. It is our responsibility to brother and sister species to make a paradigm shift by braiding Indigenous knowledges that value life into scientific processes.

Dr. Igshaan Samuels, Panelist: The Nama herders in South African and Namibia use their Indigenous knowledge system to adapt to climate change. Western science must braid Indigenous knowledges and science in the interest of getting the process right. The process of developing IPCC assessment reports must change in several ways. First, when two knowledge systems intersect, there is a power imbalance in which Western knowledge systems are treated as superior and Indigenous systems are viewed as backward. Second, committee composition must equitably balance Indigenous knowledge-holders and scientists, as well as gender. The participation of women is critical to climate change adaptation at the local level. We ask scientists to come to the table as members of communities, because this will help to build trust and the sense that we are in this together. Third, naming Indigenous knowledge holders as chapter leaders and authors ensures that Indigenous messages are communicated accurately. Fourth, Indigenous knowledge is often embedded in songs, stories and ceremonies, and IPCC reports need to incorporate this material, with informed prior consent. Fifth, we need to change scientists' attitudes that braiding knowledges is a waste of time. We can do this by inviting scientists to visit 'the field' where they can witness how Indigenous knowledge-holders observe, apply and transfer knowledge. Lastly, Indigenous communities need to validate the information that represents their input. This bottom-up validation counter-balances the top-down scientific validation process.

Dr. Tero Mustonen, Panelist: *Snowchange* is engaged in braiding Indigenous knowledge and science in our work with Inuit and Canadian First Nations, Maori, Australian Indigenous, Sami, Siberian, Finnish and Karelian peoples. In a few years, humanity will face a new sea that will change relationships with marine systems when the Arctic sea will be more ice free. The implications of this new vast sea area will be immense and have not been fully yet understood. Indigenous knowledges are potentially valuable to IPCC in that they establish baselines in areas where they have not been established by scientists. I offer two examples. First, NW Alaska researcher Henry Huntington worked with local Inupiaq Indigenous Elders who informed marine scholars that belugas were missing from their usual feeding grounds, and that, based on their observations, this was because beavers had set up dams in terrestrial freshwater rivers preventing fish migration to the sea bay, compelling the beluga to find another feeding area. This example underlines the unexpected linkages traditional ecological knowledge (TEK) can make between terrestrial and marine systems, often ignored by "western" science. Second, the Skolt Saami Indigenous peoples were the first to identify an early arrival of the southern Scarabaeid beetle to the Näätämö catchment area in Finland. This example demonstrates the capacity of Indigenous knowledge to convey new knowledge in different scales. The arrival of the beetle was then confirmed also by the scientific national insect database, thus braiding the Saami observation with natural sciences;

however, IPCC requires peer-reviewed scientific articles before it can accept information into its Assessments. One way to reform the process is to learn from the 1997 decision by the Supreme Court of Canada, which acknowledged Gitxsan oral histories as evidence. While this is a juridical ruling, the case establishes some criteria and a critical example of the reliable and community-based mechanisms of oral histories that could be utilized in the IPCC process alongside the peer reviews of science. Globally, environmental damages and much of the degradation of climate change has to do with the damages caused by men and historical, gendered power systems. Going forward, we need the expanded leadership of women to bring our world back into balance. We need Indigenous-led ecological stewardship to heal the land that has been destroyed. One way of achieving that is community-led restoration of degraded lands for example in the boreal, back into carbon sinks and biodiversity hotspots.

Other examples where the braiding of knowledge systems has provided a practical basis for policies that promoted mitigation and adaptation strategies:

Sheila Watt Cloutier and Inuit hunters provided pressure points for the UNFCCC process throughout the 2000s that affected the Paris Agreement (Mustonen). A Peruvian conservation project includes Indigenous community participants, as well as university, government and NGOs. Indigenous cosmology and ritual are used by all participants (Gonzales). Polar bears are not actually decreasing in Inuit territory, according to Indigenous knowledge-keepers. Politics and power play into whose ideas get attention and government funding (Parlee). When buffalo were re-introduced into Banff National Park, magpies demonstrated their memory of partnership with the buffalo, even though the buffalo had been absent for 100 + years (Little Bear).

Figure 1: Coasts risks and vulnerability Session participants (from left Tom, Dr. Ochanda, Felipe, Andyann, Ines, and Indasi)

SESSION TITLE: **A VILLAGE OF HOPE**

Session Convener:
Laura Lynes, The Rockies Institute

Session Shepard:
Sarah Cicchini, City of Edmonton

Session student social scientist:
Irene Wolfstone, University of Alberta

Session Participants:
Laura Lynes, L.L.M The Rockies Institute; **Diandra Bruised**, Head, B.Sc, Kainai First Nation; **Dr. Leroy Little Bear**, University of Lethbridge; **Kansi Fox**, B.Sc, Kainai First Nation; **Dr. Karl Van Orsdol**, The Rockies Institute; **Dr. Igshaan Samuels**, Agricultural Research Council, South Africa; **Dr. Mmoto Masubelele**, South African National Parks; **Dr. Tirso Gonzales**, INTE-PUC; **Mr. Andres Filella**, Métis Nation of Alberta; **Mr. Walter Andreeff**, Métis Nation of Alberta Region 5; **Dr. Frederick Wrona**, Government of Alberta; **Dr. Shawn Marshall**, The Rockies Institute; **Dr. Gleb Raygorodetsky**, Government of Alberta; **Travis Plaited Hair**, Kainai First Nation.

Session Aims and Format

The aim of Sunday's session was to create a space for Indigenous knowledge holders to share their views with the scientific community that in turn will a) provide IPCC with opportunities to understand climate change challenges from the perspectives of Indigenous communities; b) nurture a process for knowledge co-production between Indigenous and non-Indigenous knowledge holders that could be replicated in future IPCC meetings; and c) inspire Indigenous knowledge holders, including youth, to spur climate change action in their urban and rural environments.

The Village of Hope session informed the Monday March 5th session: Application of Multiple Knowledge Systems for Evidenced-Based Decision Making: Opportunities and Challenges for Ensuring Resilient Communities. The format of the Village of Hope was comprised of three sharing circles, each with a moderator posing questions to Indigenous knowledge holders and practitioners related to climate change:

Circle 1: The climate crises – Kainai (Blackfoot) build bridges between knowledge holders

Circle 2: Global North and South Indigenous Knowledge Sharing: South Africa and Kainai

Circle 3: Indigenous urban-rural relationships as a component of climate change

Summary

Circle 1: The climate crises – Kainai (Blackfoot) build bridges between knowledge holders

Laura Lynes, *President, The Rockies Institute. Moderator*

Transformation happens when we challenge assumptions about ways of knowing and analyzing that prevent us from addressing the challenge of integrating Indigenous knowledges into climate change decision-making. The lens of colonialism and the legal instruments that guide IPCC are written from an anthropocentric perspective. We make a difference when we integrate Indigenous knowledge about relationality with non-human species and with land.

Diandra Bruised Head, *Climate Change Coordinator, Kainai First Nation*

Kainai First Nation is implementing a climate change plan. Phase 1 offers education sessions to the community. In Phase 2, we hired a climate change coordinator who involved youth in an art project to gives climate change a face. Phase 3 will develop a botany project specific to plants and herbs on Kainai First Nation. Energy security is a huge issue and our challenge is to shift from reliance on oil and gas to renewable energy. We do not want to be left behind. Issues like over-grazing are referred to council policy makers. Through collaboration with The Rockies Institute, we incorporate science with our indigenous knowledge.

Kansi Fox, *Environmental Protection Manager, Kainai First Nation*

Our community climate change adaptation project works with Elders who have deep knowledge of the land and with youth who will carry the knowledge forward. We are educating the 12,000 community members. Climate change is causing emergencies such as wildfires and floods. Food security and water security are issues. We want to conserve and protect food and medicine plants on our grasslands so that our communities can be healthy. We observe and document changes in wildlife. We need solutions that braid together Indigenous knowledge and science. I hope IPCC will no longer meet without us because we have something to offer.

Dr. Leroy Little Bear, *Elder, Kainai First Nation*

The key problem is that the human species continues to act in ways that caused this climate event. If we want to survive, we need to change our practices. We owe our existence to a very narrow set of ideal conditions, and if those conditions are not met, the human species will go the way of dinosaur.

Humans flourish when we live in ecobalance. The Blackfoot paradigm is based on three conditions: flux (constant motion), energy waves (as opposed to matter) and animation in a web of relationships (all my relations). Without these conditions, life is not liveable. Blackfoot culture arises from a mutual relationship between cosmos, land and humans. Earth is our Mother – the giver of life – and inseparable from the identity of Being an embodied Blackfoot. For every change that is caused by global warming, we become a little less Blackfoot; globally, we become a little less human. When the buffalo were killed off, Blackfoot became a little less Blackfoot.

In Blackfoot cosmology of place and space, we know the balance of relationships in our traditional territory. All societies lay claim to a territory and, as Indigenous peoples in the Americas, we know that very well. Maintaining those relationships allows continuity. Language is a repository or container of traditional knowledges about environment that is passed on orally to our children through participatory stories, ceremonies, songs and dances. I recommend 'permaculture' as a metaphysic to replace the Western metaphysic of way 'advancement' which is merely accelerating extinction. Bill Mollison recommends 'permaculture' as a philosophy of working with land/nature that is based on thoughtful and protracted observation rather than protracted and thoughtless labour. An example is the restoration of the buffalo. Western neoliberalism is leading climate change science and it does not feel right. Let's change it.

Circle 2: Global North and South Indigenous Knowledge Sharing: South Africa and Kainai

Dr. Karl Van Orsdol, *Senior Climate Change Fellow. Moderator*

Indigenous peoples occupy lands with the greatest diversity of plants and animals, but only 3% of climate funding in Africa goes to Indigenous peoples. A key problem is that UN's top-down approach to knowledge production inhibits bottom-up, community-based action on climate change. We address 5 challenges: a) IPCC recognizes only peer reviewed literature; b) Indigenous cultures that live close to tourism industries and extractive industries receive no assistance from those industries in coping with climate change; c) Social needs are inseparable from climate change issues; d) cities are dependent on rural regions for recreation and food; and e) Indigenous communities cannot participate as 'sovereign states' in UN agreements.

Dr. Igshaan Samuels, *Arid Rangeland Ecologist*

In South Africa's Nama Indigenous community, the key challenges are that a) Indigenous knowledges are not well received by scientists and b) Indigenous communities receive only 3% of funding allocated to climate change. In a meeting with Nama Indigenous communities, we engaged with elders, youth, women, men and leaders. Adaptation issues include a) social issues such as theft of water infrastructure and loss of Nama language means loss of ecological knowledge needed for adaptation. Adaptation options are a) change our relationality with nature, b) weave Indigenous and science knowledge systems, c) establish learning centres for integrating climate knowledge locally in an accessible way and d) train youth to conduct vulnerability assessments that consider both social and ecological issues of women, men and youth. Climate resilient Indigenous communities in the global north and global south will benefit from a forthcoming exchange between Indigenous peoples of Nama and Kainai First Nation.

Dr. Mmoto Masubelele, *Landscape Ecologist*

In South Africa, the key problem is that the Environment Department leads the climate change strategy using a top-down approach from IPCC and the Paris agreement. People at the local level struggle to benefit from national initiatives, even though climate change impacts are felt locally. National parks were created with a protectionist approach that excluded Indigenous peoples and where park managers applied Western knowledge instead of local Indigenous knowledge systems. In a collaborative project with The Rockies Institute, a park manager is now asking the local community for input. Now we need to consider their socio-political issues of adapting to climate change as the land becomes desert under climate change.

Circle 3: Indigenous urban-rural relationships as a component of climate change

Dr. Tirso Gonzales, *Associate Researcher. Moderator.*

I am a Peruvian scholar from the Aymara people. I see climate change as an intersectoral issue that brings old agendas and new ones. The key problem is that the climate crisis is driven by Western anthropocentric values for the last 150 years. Indigenous peoples have adapted to climate changes in the past, but this climate event challenges even our capacity to adapt. We lack basic infrastructure. Urban cities can only respond to disaster if they have access to rural resources. Climate change resilience is as important for rural Indigenous on-reserve communities as it is for urban communities.

Andres Filella, *Climate Change Coordinator*

Originally from Ecuador, I now work on the Climate Change Action Plan for Metis Nation of Alberta. We educate the community on climate change and observe its impacts on members of the community.

Walter Andreeff, *Métis Nation of Alberta*

I am Métis and work with northern rural communities in Métis Nation of Alberta Region 5. I acknowledge this land and the elders here, as well as Elder Gullion from Slave Lake. In my work with communities, I include the animals as relations. The migration from rural to urban areas is driven by jobs, education and social services; it challenges cultural cohesion and resilience. We need to build capacity for better communications that respect cultural practices between rural and urban parts of community. Resilience is linked to kinship. In climate emergencies, you depend on those relationships. Climate adaptation strategies must be informed by kinship and relationality.

Kansi Fox, *Environmental Protection Manager, Kainai First Nation*

I have worked in environmental management with the Kainai for 13 years; we protect our land so that we can live healthier lives. Our community copes with climate change in several ways. We strengthen identity by honouring relationships between youth, elders and families. We work with those who were displaced by wildfires in 2011, fires. Most importantly, we build capacity to deal with climate change in a rural are where most climate change is felt, but our key challenge is that there are insufficient resources for capacity building. Building community is not a step; it is foundational to our programs.

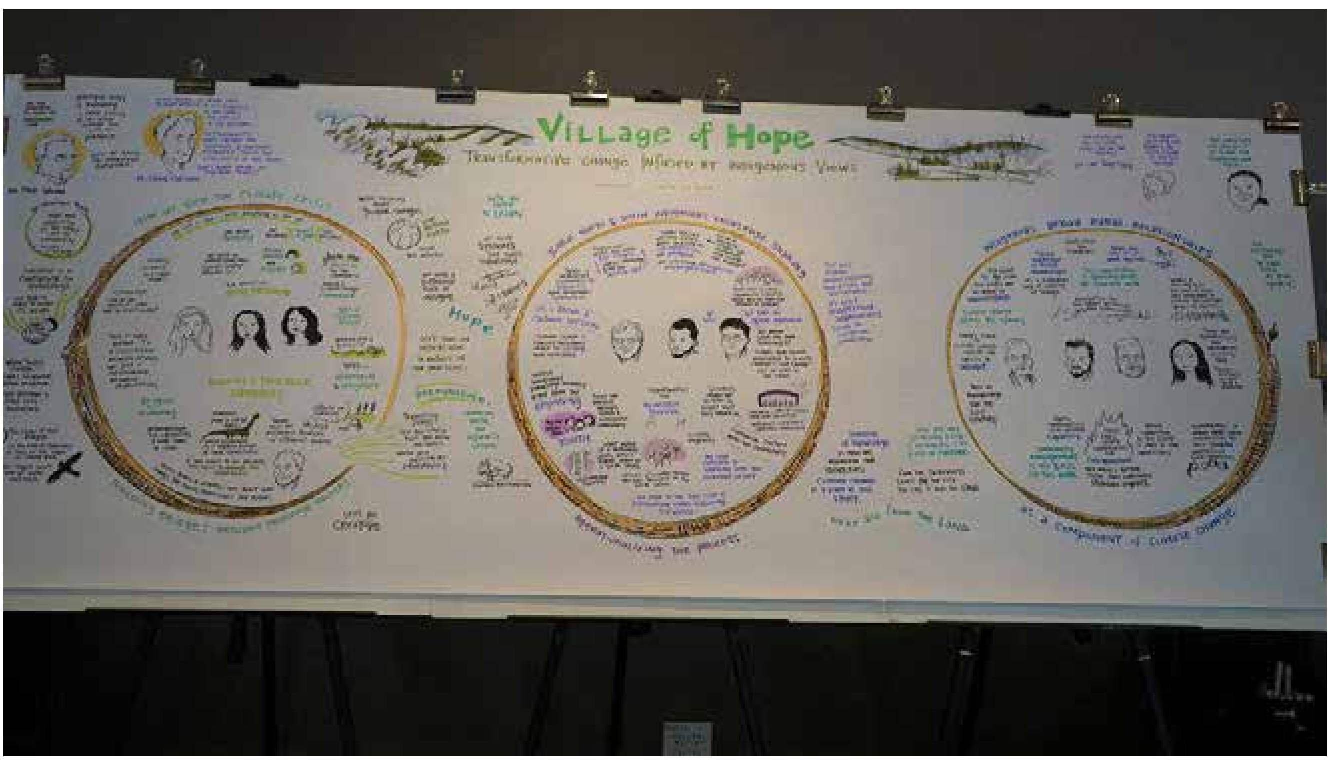
Discussion

Carole Mills: Gwich'in First Nation, we are the most northerly First Nation. Climate change is affecting our culture. We lost 2 elders to the ice, and that represents a loss of culture.

Keith from iHuman: Many cities and municipalities don't feel bound by the treaties and ignore them. Elders are asking us to find the sacredness in the city as well as on the land. There is no reconciliation without truth, which is not about asking First Nations people to come to your meetings.

Travis Plaited Hair: We maintain our identity by transfer of knowledge. Knowledge transfer is very important to identity. If we don't teach our knowledge to the youth, we will lose them. Climate change in the context of "all our relations" considers retention of language and relationality.

Councillor Lance Telfeters, Kainai First Nation: This is about building understanding. There are challenges as cultures and as humans. We need to understand histories. The common theme is sustainability of life forces.



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Plenary Summaries
Parallel sessions summaries
Conference Posters
References
Annexes

SESSION TITLE: **ENVIRONMENTAL JUSTICE AND URBAN CLIMATE CHANGE: HOW CAN WE ENSURE AN EQUITABLE FUTURE?** - MONDAY MARCH 5TH

Session Convener:
Dr. Diana Reckien (University of Twente in Enschede, the Netherlands), **Mr. Andres Filella** (Metis Nation of Alberta, Canada), **Mr. Juan Camilo Osorio** (Pratt Institute & Massachusetts Institute of Technology, USA)

Content:

Session title:
Environmental Justice and Urban Climate Change: How can we ensure an equitable future?

Session participants (convener, chair, speakers, discussants, etc.)
Dr. Diana Reckien, University of Twente in Enschede, the Netherlands (Convener, chair, speaker)
Mr. Andres Filella, Metis Nation of Alberta, Canada (Convener, chair, speaker)
Mr. Juan Camilo Osorio, Pratt Institute & Massachusetts Institute of Technology, USA (Convener, chair, moderator)
Ms. Lavinia Poruschi, The Commonwealth Scientific and Industrial Research Organisation, CSIRO, Australia (speaker)
Mr. Andres Filella, Metis Nation of Alberta (Convener, chair, speaker)
Ms. Crystal Lameman, Confederacy of Treaty Six First Nations (speaker)
Ms. Annel Hernandez, New York City Environmental Justice Alliance (speaker)
Mr. Ryan Chavez, UPROSE (speaker)

Parallel session summary

Session Aims and Format

Climate change is acknowledged as the largest threat to our societies in the coming decades. As urban areas house highly diverse people with differing vulnerabilities, climate change is likely to shift the focus of discussions from a general urban perspective to who in cities will be affected by climate change, adaptation and mitigation, and how. This brings the urban equity question to the forefront. This session highlights pressing equity and environmental justice issues in cities under climate change. This involves key inputs from research (e.g. UCCRN), communities (UPROSE, NY, Métis and First Nations Indigenous peoples, the urban energy disadvantaged), and policy informants (NYC-EJA, Métis and First Nations Indigenous governments). These key inputs are discussed among presenters, and the audience using the guiding questions. This session identifies major research and knowledge gaps related to equity issues under climate change. For example, a key research gap is the sustainable transformation of the urban energy systems in a manner that avoids exacerbating impacts on groups that already have a limited capacity to adapt. This session also touches on the challenges and gaps in the solution space between indigenous communities, indigenous traditional knowledge, and policy-making.

State-of-the art of the field

Summary of the contributions with regard to what do we know?

- Differential vulnerability of urban residents to climate change is driven by four factors: (1) differing levels of physical exposure; (2) urban development processes that have created a range of built-in risks, such access to critical infrastructure and urban services; (3) social characteristics that influence the al- location of resources for adaptation; and (4) access to power, institutions, and governance

- Climate change amplifies vulnerability and hampers adaptive capacity, especially for the poor, women, the elderly, children, and ethnic minorities, including native communities. These people often lack power and access to resources in cities, and in some regions of the world adequate urban services and functioning infrastructure. Gender inequality is particularly pervasive, contributing to differential consequences of climate changes.

- Some extreme climate events, such as droughts, can undermine everyone's resource base and adaptive capacity, including better-off groups in cities, which can increase the scale and depth of urban poverty over time as climate extremes become more frequent and intense.

Where are the frontiers of our knowledge in the field, in the different communities?

- Research to "Equity and Environmental Justice and Urban Climate Change" is currently pushing the research frontier of investigating side-effects (also connected to conflicts, and trade-offs) of climate change policy, i.e. unintended effects of adaptation and mitigation policies (i.e. maladaptation and malmitigation) with serious side-effects for disadvantaged groups, with the potential to undermine previous and current achievements in equity and environmental justice.

Where are we in terms of reaching global climate change goals such as in the Paris Agreement?

- While there has been important progress in building consensus among governments, including the creation of concrete targets to advance the mitigation and adaptation agendas (i.e. NDCs, etc.) there hasn't been as much consensus with local stakeholders in decision-making, nor implementation discussions.

- Frontline communities remain seen, at best, as potential partners supporting the implementation of these interventions. They are rarely seen as reliable research and/ or planning partners – despite the fact that some of them have already demonstrated the success of bottom-up innovative approaches to addressing climate change.

- Moreover, many community groups have already established local priorities that should be taken into account when setting city, regional and national goals.

- At the same time, community groups are often perceived as a monolithic body – where in reality, they represent many different interests that respond to the characteristics of different types of community. These bonds are based on multiple binding characteristics, like age (particularly vulnerable groups such as youth and seniors) racial, ethnic (including indigenous ancestry), gender, labor, immigration status, and others.

How can the knowledge in the topic of the session can help get closer to these goals?

- The session highlighted a number of current policy formations, established under the framework of climate change adaptation and mitigation, that are observed to have negative side-effects for households with lower income and other disadvantaged groups, for example, the unintended outcomes of renewable energy schemes on energy affordability, , the greenification of neighborhoods with implications on housing prices and rents, the establishment of traffic toll zones or vehicle charges on commuting prices, and the beautification of neighborhoods/ slums in the name of resilient development. Important to note, though, the session does not recommend to drop these policies, but at the contrary to improve these and other related policies and/or to establish accompanying policy schemes that are able to buffer the implications for the poor, low-income and disadvantaged households.

Which are the main (recent) past research directions?

Research to “Equity and Environmental Justice and Urban Climate Change” is currently pushing the research frontier of investigating side-effects (also connected to conflicts, and trade-offs) of climate change policy, i.e. unintended effects of adaptation and mitigation policies (i.e. maladaptation and malmitigation) with serious side-effects for disadvantaged groups, with the potential to undermine previous and current achievements in equity and environmental justice.

Towards a research agenda

- Which are the key unknowns in the field that have been identified by the session as important gaps in knowledge?

There seems to be consensus on the importance to diversity the decision-making process. However, there is a lack of clarity on how to get there. The following questions are some examples brought up during the session in this regard:

- How do you structure an equitable research partnership with climate-vulnerable communities?

- What protocols do you establish to implement a disaster mitigation and adaptation program in order to track the progress on adaptation and mitigation as well as its (side-) effect on poor, low-income, vulnerable and disadvantaged households/ communities? The same would account for mitigation policies and actions?

- How do you communicate findings to all relevant audiences, many of which do not work or communicate to each other?

How can the three communities best cooperate in order to best advance that research agenda?
The following strategies were brought-up at the panel, responding to the questions above, while suggesting additional strategic approaches to advancing the research agenda:

- Follow environmental justice principles elevating local leadership in decision-making and solutions, and partner with local groups with a track-record and capacity to carry out research.

- Identify overlaps of community concerns and existing research gaps, and increase government accountability to ensure climate and energy investments are equitably distributed and maximize co-benefits like improved air quality and job opportunities for frontline communities.

- Build strategic partnerships to identify synergy/conflicts between national goals with local community priorities – and plan consensus-based strategies to address them.

- Utilize integrated approaches to climate resiliency planning that support comprehensive neighborhood assessments for coastal resiliency, green space, renewable energy, energy resiliency, and community preparedness.

- Implementation plans need to be established well ahead of disasters, by creating demonstration projects to test ideas and involve frontline communities in the evaluation of these solutions. These efforts can elevate community expertise and community-led research, advocacy, and planning efforts.

– Identify target audiences in the local communities, research communities, and policymaking circles – and build effective tools to disseminate the information and engage multiple audiences in these discussions. Build power through coalitions with economic justice, labor unions, faith, and environmental organizations that adhere to the Jemez Principles.

Key messages from the session

- There is a lack of DATA, i.e. consistent evidence of climate change impacts, adaptation capacities and access, use and control of adaptation resources, assets and services in relation to gender, age/generation, race, ethnicity, social class, and demographic as well as native groups across cities and on fine-grained spatial distribution.

- There is a lack of METHODS to 1) assess the effects of mitigation and adaptation policies on equity issues in cities of both high- and particularly low-income countries; 2) enable capacity-building for urban stakeholders and authorities to mainstream gender, intersectionality, and other equity issues into their plans and actions; & 3) for communities to evaluate scope, extent and impacts, of nationally-established policies (i.e. NDCs) in relation to locally-established community priorities.

- There is still a lack of PRACTICE of integrating under-represented groups into policy-making spheres, particularly transcending numerical representation and encompassing issues of social empowerment and political influence for in particular hard-to-reach populations, and if it is done there is a lack of acknowledgement of these community processes and women's initiatives in the political circles. This includes a better understanding of the differences between specific interest groups, local agendas, and collective interests, that are often times blurred by external assumptions on who is the "community".


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SESSION TITLE: **THE ROLE OF CITY NETWORKS IN SUPPORTING POLICY-PRACTITIONER-ACADEMIA INTERACTIONS** - MONDAY MARCH 5TH

Session Convener:
Shannon Joseph, Project Director (Municipalities for Climate Innovation, FCM)

Session Shepherd:
Maryke van Staden (Low Carbon Cities Program Manager, ICLEI World Secretariat)

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Parallel session summary

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Session Aim

This session aimed at informing the AR6 research agenda by showcasing how City Networks can help facilitate dialogue between researchers, academic groups and practitioners in order to better integrate climate science into planning and decision-making, all the while providing pathways to improve climate science in order to better support and enable local governments.

Session Format

The panelists (urban practitioners & city networks members) engaged in an open format conversation dubbed the “Fish bowl”. Such a format enabled the expert panelists to first provide a snapshot of their work related to city networks and addressing climate change, thus setting the stage for a larger group discussion. Audience members were then able to contribute to the conversation about the next steps and actions to be taken for such city networks to better support policy-practitioner-academia interactions.

Introduction and rationale

The Paris Agreement helped highlight the leadership of local governments in addressing climate change. To help local governments achieve their climate-related objectives (either on adaptation, mitigation or both), global and national city networks are increasingly prominent in providing support and guidance with decision-making and technical activities such as developing GHG inventories, risk and vulnerability assessments, climate action plans, and accessing finance for local projects. Such elements require strong policy-practitioner interactions, yet there can often be a disconnect between researchers, policy-makers, and practitioners when understanding the challenges and designing solutions to transition to a sustainable future.

Forward-thinking pathways are therefore needed to better leverage city networks in facilitating such interactions, guiding the definition of research questions, as well as better understanding how the research agenda can feed in and out of cities. In order to address the role of city networks in supporting policy-practitioner-academia interactions, this session had the following three key objectives:

1. To provide an overview of how programs delivered by city networks such as FCM, C40, ICLEI and USDN can effectively support the integration of climate science into decision-making processes and planning (both on mitigation and adaptation to climate change);

2. To identify gaps in existing climate data, including the availability, quality, accessibility and applicability of climate data in various local governments, in order to provide feedback to the IPCC on how the 6th Assessment Report (AR6) can better support and enable local governments to reduce GHG emissions and improve resiliency, and;

3. To provide pathways that will foster more efficient researcher-practitioners-policy-makers interactions, as well as co-production of knowledge so that climate science can readily respond to the needs of local governments and better support their climate actions.

What is well-known on the importance of city-networks?

At the onset, it is important to emphasize that, although imperfect, city networks provide a good working model, as well as being beneficial in bridging some of the gaps between practitioners, researchers and policy-makers. As exemplified by the cumulative decades of experience by national and international organizations such as the Federation of Canadian Municipalities (FCM), ICLEI, C40, Future Earth and USDN/CNCA, significant progress in addressing climate change at the local/municipal level has been achieved through peer to peer learning facilitated by such city networks. The session confirmed the value of the peer to peer education model.

Through the efforts of city networks such as C40 that several major cities around the world have now committed to develop climate plans that are consistent with the Paris Agreement; in Canada, municipalities are increasing their capacity to integrate climate change considerations into their planning and asset management through the efforts of targeted programs such as the ones delivered by FCM, or are reducing their greenhouse gases emissions significantly (GHG) through a program such the Partners for Climate Protection (PCP), delivered jointly by ICLEI Canada and FCM; moreover, through peer-learning approaches, cities from around the globe are forming alliances to work on similar issues related to climate change, as demonstrated by the work delivered by USCN and CNCA.

Thus, city networks have not only been essential to leapfrog our global and local response to climate change, but are also proving to be great incubators of peer-learning experiences between cities/municipalities but also across disciplines, helping bridging the gap between practitioners, policy-makers and, to some extent, researchers. City networks and the cities that are part of them should most likely be seen as living laboratories for the research community and even stimulate that community to also adopt a similar approach (e.g. through research networks). City Networks have an important role to play in incubating climate-relevant lessons, sharing experiences and replicating successes.

What are the limitations and constraints of city-networks?

Although there are success stories on the role and importance of city networks at the national and international level, there is also a need to establish effective networks at the regional scale, which has been identified as lacking.

Also critical is the need to improve access to city networks, which can be challenging, especially for the research community. The session identified a tendency for city networks to hold on to data and the results of research they or their members have undertaken, and it was suggested that city networks could better support the work of researchers by making this information more readily available, where appropriate.

There was discussion about the role that city networks can play to facilitate better connections between cities and the scientific research community. It was acknowledged that research is taking place within universities, independent research institutes, government agencies and by the private sector. Institutionalizing the role of city networks as knowledge-brokers could enhance the active participation of the research community into such networks, thus providing stimulus to innovative and co-created solutions to address climate change.

Finally, as many cities and municipalities are part of multiple (and sometime overlapping) city networks (both at the national and international levels), considerations to create synergistic alignments between such networks may be one way forward in order to avoid duplication of efforts and increase the outputs and outcomes of those networks. The collaborative work of FCM and ICLEI Canada for the last two decades through PCP[4] is a good example of the positive outcome of combining forces at a national level. Suffice to say that the joint efforts of the organizing partners of the CitiesIPCC conference is perhaps the single best example of what can be achieved at the international level when collective interests of city networks are aligned in order the bring the much-needed innovation and transformation that cities and municipalities need in order to address climate change in a timely and effective manner.

Key gaps and challenges that need to be addressed

In order to make city networks even more efficient and relevant at the local government level and to develop fruitful interactions between practitioners, researchers and policy-makers, there are a number of gaps that need to be addressed.

First, the climate data that is being developed at both the global and national levels need to be more applicable in order for it to resonate and be useful for practitioners. As highlighted recently by Bai et al., "[…] the scope and applicability of urban research is stymied […]"[5]; therefore, there is a real need for the scaling down the knowledge gathered at the global level (e.g. Assessment Reports) to inform local design (e.g. infrastructures; resilience). Further to that, data not only needs to be more applicable, but it also needs to be made more accessible; there is already a wealth of climate data that exists but practitioners don't always know where to find it.

Next, as far as international big city networks are concerned, there is a need for local governments to better understand what the full benefits and impacts of engaging at the global level are when it comes to climate change; on the other hand, it would be equally important for city officials who are engaged at the international level to better grasp the impact of the global agenda at their local level.

Furthermore, given that climate action in cities happens in set organizational structures with embedded cultures, there is an

[4] http://www.icleicanada.org/programs/mitigation/pcp

[5] Six research priorities for cities and climate change - Nature, Vol. 555, March 1 2018 - https://www.nature.com/articles/d41586-018-02409-z

imperative to further develop assessment frameworks that take such contexts into consideration. Organizations change slowly and culture may often overrule strategy, therefore the development of assessment tools that would address how to achieve climate action in set systems is much needed.

Other gaps that city networks could help address by improving the linkages between researchers, practitioners and policy-makers, are: 1) the inclusion of the relationship between climate action and inequality; 2) the social and economic benefits framework of acting on climate change, and how such actions can contribute to creating prosperity, jobs and improved air quality; 3) the emerging research on consumption-based carbon measurement[6], to which city networks could contribute to by broadening the scope of such initiatives, and; 4) the way to better communicate the need for change and climate actions in order to trigger a behavioural change within cities that is more conducive to achieving the Paris Agreement - this may therefore require city networks to work closely with local governments to make the sustainable option the most attractive way forward for cities to develop.

Finally, an increasingly important challenge that cities and local governments are already faced with and will increasingly be in the future is the need for city networks to help them better understand the full impacts of climate migrations.

The way forward: some recommendations

As identified on multiple occasions and through many sessions during the CitiesIPCC conference, there is an increasing need for the co-creation of knowledge, and a systemic approach to knowledge generation[7], so that researcher, practitioners and policy-makers can jointly identify the research needs for cities in light of climate change. As such, city-networks can play a crucial role as they can act as facilitators and translators in this conversation between city staff and the scientific community so that a genuine two-way conversation can take place at the local level.

For such dialogues to occur on an ongoing basis, more fora will have to be created so that the scientific, policy, and practitioner communities have increasing opportunities to better work together and learn to speak one another's language on issues pertaining to cities and climate change - something also highlighted by Bai et al[8]. In the immediate future, the Cities and Regions Talanoa dialogues supported by ICLEI could certainly help keep the momentum created at the CitiesIPCC conference and offer a fertile ground for the various communities of practice to pursue what has been started in Edmonton.

Ultimately, in order for the interactions between researchers, practitioners and policy-maker to bear fruit on climate action, city networks must be seen as living laboratories that foster innovative peer-learning actions that accelerate actions in cities. Similarly, research networks could function in an analogous way. However, for that innovation to truly occur, it is essential to take risks and therefore to accept failures, something that cities may be averse to. Science could help cities and local governments to reduce that risk by providing an objective eye to add value from the failures of their innovative endeavours.

6 http://www.c40.org/researches/consumption-based-emissions

7 Defining and advancing a systems approach for sustainable cities - COSUST, Vol. 23, December 2016 - https://www.sciencedirect.com/science/article/pii/S1877343516300896

8 Six research priorities for cities and climate change - Nature, Vol. 555, March 1 2018 - https://www.nature.com/articles/d41586-018-02409-z

SESSION TITLE: **MAPPING THE GREENHOUSE GAS DATA LANDSCAPE** - MONDAY MARCH 5TH

Session Chair:
Michael Steinhoff (ICLEI-USA)

Session Speakers:
Jennifer Ewing-Thiel (City of Bellevue, Washington, USA), **Ookie Ma** (US Department of Energy, USA - Not present), **Felix R. Vogel** (Climate Research Division, Environment and Climate Change Canada, Canada), **Oksana Tarasova** (Atmospheric Environment Research Division, WMO, Switzerland), **Phil deCola** (University of Maryland, USA), **Lucy Hutyra** (Boston University, USA), **Marc Chiappero** (ARIA do Brasil, Brazil), **James Whetstone** (NIST, USA - Not present)

Parallel session summary

Session Aims and Format

As interest in the emissions profile of cities has grown, so has the range of stakeholders and use-cases for the data included in a community-scale GHG inventory. In many cases inventories are built around "best available" activity data rather than data tailored for a particular purpose. As multi-year data from cities emerges, limitations of certain data for understanding overall and sector-specific progress and performance management are coming into sharper focus. Meanwhile novel approaches for direct measurement of gases emanating from cities are maturing and offer insight into these challenges.

Ultimately the success of local authorities to make effective decisions and the field's ability to chart progress relies on being able to provide the best analysis of available data to the right actor with authority to take emission related decisions. The session aims to promote dialog among practitioners and researchers working in this space to advance the work of both.

The session format was brief project-focused talks with questions posed to the audience via online poll, concluding with questions from the audience posed to panelists.

State of the art of the field

Not long after the beginning of the UNFCCC did municipal officials recognize that they had the opportunity to meaningfully contribute towards reduction of greenhouse gas emissions and the first attempts at community scale inventories began in the late 1990s. In the first decade and half, this practice had no formal guide. National inventory methods provided a conceptual framework but were not tuned to city scales. Where applicable, methods developed for either corporate accounting or local air quality emissions inventories were stitched together to make the practice more relevant for local scale decision making.

By the time of the US Community Protocol in 2012, the state of the art methods had evolved in ways that were constrained by available data that could be reasonably obtained by a typical city. Very few cities can afford to create custom transportation datasets that meet all the desired attributes for an inventory. They use whatever is available instead.

As geographic methods evolved, many practitioners and researchers recognized the role of local government in affecting emissions beyond their borders and of being impacted by emissions originating outside their local domain. Both full consumption based and demand-centered hybrid life-cycle accounting were recognized as important perspectives in the US Community Protocol. These are particularly well suited to informing infrastructure decision making and community engagement strategies that are well within the sphere of influence of local government, unlike many emissions sources that are included in geographic accounting.

Recent advances in technology for atmospheric observation and modelling tools are now opening a new front in our ability to reliably estimate the emissions that come from a defined geographic area in a timely manner. Indeed, it was the power of direct atmospheric observation of increasing concentration of greenhouse gases alongside signals of a changing climate that alerted humanity to this growing threat. Direct observations can also be used to reveal the contribution of emissions sources in cities that were previously poorly understood and therefore not quantified, such as fugitive methane from natural gas distribution systems. These methods hold the potential for better cataloging the direct emissions contributed by each city to the atmosphere. As cities have a newly elevated status in the UNFCCC process, the information needs about their performance has changed. As the fundamental methods are further tailored towards addressing urban stakeholder needs, the approach remains fundamentally linked to work at regional and national scale which ensures the compatibility of information gathered at any scale.

Today we find ourselves at a point where there are now a range of stakeholders with differing research, analysis, and management questions that need to be informed by data about greenhouse gas generating activities and sources in cities. What is lacking is a forum to systematically identify which approaches are best attuned to the information needs of each stakeholder. As the more expansive view of a city's influence on distant emissions sources grows and the needs of scientific organizations to understand the specific flux of CO2 and other greenhouse gases from cities, it may be time to recognize that although activity based inventories alone provide a signal useful for evaluating whether the emissions in cities are growing, slowing, or reducing in absolute terms, augmenting that signal with atmospheric observations has excellent potential to substantially improve that signals quality. At the same time municipal officials do not manage emissions directly. They manage building codes, transportation infrastructure, waste management and so on. The information developed in activity based inventories is crucial to the formulation of policy locally, advocating action by governments on a regional basis, and informing constituents on the impact their choices have on emissions globally. Consistent monitoring of that is necessary for local government policy evaluation and further management.

All approaches have their drawbacks, such as in the temporal and spatial resolution that is available from an activity based inventory, as well as the scale-ability of techniques that both require physical hardware to be deployed across an area and advanced modeling to analyses and interpret the data. One area that holds some promise to addressing some of these limitations is to look for opportunities to combine both approaches to find the extent to which they can be complementary. One example highlight is the work in Recife Brazil where both approaches were used and illustrated that when combined to produce comparable results that they acted to reinforce confidence levels that the main sources of emissions in the city were well understood. It is likely that if this approach was taken in other instances that substantial differences would be revealed. For example, many activities based inventories provide an incomplete assessment of energy use, where utility privacy rules prevent the disclosure of the industrial sector. Atmospheric observation could provide a more reliable method. If that approach was integrated into the larger inventory framework, it would allow local governments to focus on building related energy use in the residential and commercial sectors and consistently and purposefully exclude industrial energy from data requests. This would reduce uncertainty regarding what may or may not be included in the energy use obtained from utilities and by consistently eliminating it, give local government a better signal of trends in building energy use which is more likely to be addressed with local government policy.

As many cities progress from their first inventory to subsequent performance tracking, natural questions as to the drivers of performance change from one inventory to the next arise. Answering those questions has highlighted challenges with the types of data that are commonly used in an activity based inventory. The procedures for a drivers of change analysis generally require relating the activity data to other on-the-ground observations of things that are likely to be having an impact, such as physical changes to the built environment, population, and the impact of local programs. To the extent that activity data for an inventory is downscaled from higher levels of government data or highly modeled, it is impossible to say whether the apparent change in performance is an artifact of the estimation method or actually related to the changes happening on the ground. Recognizing these kinds of limitations further demonstrates the potential of direct atmospheric observations to provide an important additional source of data that would capture local dynamics in a more reliable way.

Much of the above discussion has been focused on the context of the global north where there is a reasonable amount of institutional capacity to develop data for an activity based inventory. A topic that was highlighted in the overall conference proceedings was the role of informality and the difficulty in understanding activities in the informal economy as well as attempting to manage them. The emission estimates based on atmospheric observation may provide an opportunity to monitor in real time the emissions from the fastest growing regions of the world.

Towards a Research Agenda

The following unknowns in the field were identified through this session.

- Diversity of the information needs of the user community in urban environments is not systematically documented.
- Development of socio-economic and physical typologies for cities.
- Continued development inventory methods that support policy actions and demonstrate their effectiveness and move more cities away from Tier 1 methods.
- Collection and linking together diverse observations on urban scale (current limitations in low-cost sensor technologies, ease of use of measurement and modeling tools).
- Improved understanding of the complexity and best practices of atmospheric modeling of urban emissions and ways to communicate that understanding to diverse audiences.
- Identification of pathways that are scalable and can be deployed broadly in cities of differing types and levels of resources.

While atmospheric measurement networks have been established in several cities and are yielding new insights, many more case studies are urgently needed. Establishing monitoring programs now will record baseline emissions which can be used to demonstrate progress towards emissions reductions goals over time. Also, investment in monitoring efforts will yield insight into cost-effective mitigation actions that are tailored to particular cities with unique combinations of sources.

More work comparing community scale GHG inventories being constructed by urban policy makers and inventories constructed by scientific investigators is needed. Several different methodologies and frameworks exist for constructing community scale GHG inventories and these should be evaluated for robustness and reproducibility using applied research methods and will lead to a better understanding of emission sources and sectors in cities. Communication and collaboration between inventory and atmospheric science communities should be developed to reinforce each other. Initiatives that require greenhouse gas inventories should encourage experimentation with methods when there are opportunities to advance the state of practice and accommodate new approaches that can demonstrate alignment with accepted GHG inventory accounting principles.

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SESSION TITLE: **URBAN CLIMATE INFORMATION TO SUPPORT DECISION MAKING: FROM LOCAL TO GLOBAL -** MONDAY MARCH 5TH

Session Conveners:
Nigel Tapper and **Rafiq Hamdi**

Student Rapporteur:
Giovanni Di Lullo

Presenters/Panellists:
Valéry Masson, Adriaan Perrels, Maja Zuvela-Aloise, Xuemei Bai, Chao Ren, Jamie Voogt.

Parallel session summary

Authors:
Rafiq Hamdi, Nigel Tapper, Jeffrey Raven, Helen Cleugh and **Giovanni Di Lullo**

Session Aims and Format

To maintain or improve the quality of living in cities and to assess the efficacy of climate adaptation and mitigation approaches, urban planners, managers and policymakers need detailed information on future urban climates at a residential to city scale, but most of the global climate models and observations do not adequately account for the urban environment. In fact, cities affect the local weather by perturbing the wind, temperature, moisture, turbulence, and surface energy budgets. The foundation of urban-scale climate information is our current high-resolution urban downscaling expertise, combined with local-impact models, and ensemble dynamical and statistical downscaling. This combination enables the propagation of climate change and uncertainty from global to the city scale. The first part of this session will address critical knowledge gaps around downscaling to city-scales and how to assess and reduce uncertainties; this will be critical input to the forthcoming IPCC scientific assessments. Complementing this focus on models, the second part of session will shift focus to observations. The Global Climate Observing System Terrestrial Observation Panel for Climate (GCOS-TOPC) is responsible for identifying and facilitating the monitoring of Essential Climate Variables[9] (ECVs) that feed into IPCC/UNFCCC climate assessments. GCOS-TOPC is responsible for several critical ECVs including global surface albedo, land cover change and soil moisture, and as a matter of priority is currently considering one or more ECVs that might represent evolving human adaptation to climate change in critical terrestrial realms, including cities. Through a facilitated panel and audience interaction, the second part of this session aims to make important progress on the identification of such ECVs and how they may be efficiently measured/monitored. Such variables representing urban adaptation might be bio-physical (e.g. changed urban characteristics from satellite observation), or socio-economic (e.g. direct funding invested in adaptation response). Development of appropriate city-related ECVs will be a lasting legacy of this Cities IPCC Conference.

State of the Science

City-scale climate simulations

Regional Climate Models (RCMs) are widely used to understand meso-scale processes as well as to downscale climate change projections from global climate models (GCMs) to the regional scale required for impact studies. The World Climate Research Program (WCRP) launched a coordinated exercise of regional climate simulations: CORDEX (www.cordex.org). These are downscaling experiments of regional climate models on 14 domains, covering terrestrial continents or regions. These simulations are typically done at spatial resolutions ranging from 50km down to 12.5km, and forced by several global climate models and emission scenarios. These modelled simulation data are available for the scientific community. However, the production of country-scale high-resolution (i.e. less than 10 km) climate projections is a prerequisite to evaluate impacts of future climate change on human societies and their urban environment and to formulate adequate adaptation measures (IPCC AR5; WG2, Chapter 8).

In order to take into account the interaction between the city and the atmosphere in these high-resolution climate models, specific surface-atmosphere exchange schemes, dedicated to urban areas, have to be implemented. Such schemes were developed in the 2000s (Masson 2000, Martilli et al., 2002, Hamdi and Masson 2008). They represent the cities with a simplified geometry (urban canyon) that, even if it simplifies the reality of the building arrangements, is able to capture the major part of the physical processes that influence the radiative and energy fluxes in such a complex 3D environment. For instance, the Town Energy Balance (TEB) scheme that is included in a full surface scheme called SURFEX (Masson et al 2013), that represents also water and vegetation surfaces, is now open source and could be used widely. The coverage of these surfaces is known through the global ECOCLIMAP database (Faroux et al., 2013).

The researches challenge should now be to go beyond what is classically done in regional climate modeling, and to improve dynamical/statistical downscaling techniques so that they are

[9] Essential Climate Variables (ECVs) – the minimum set of variables, observed at global scale, to describe the Earth's climate system. Observation of ECVs is administered by the Global Climate Observing System (GCOS).

valid down to the city scale. The diversity of results that arises from natural climate variability, the use of different models (global, regional, impact models) and emission? scenarios (land use, greenhouse gases) is identified as uncertainty. The ambition is also to advance significantly the development (or delivery?) of Urban Climate Services employing high spatial resolution atmospheric and land surface models. This will require high resolution climate modeling (~1km of spatial resolution). Usually such simulations are done for a specific city and for separate months or seasons (e.g. July, or Summer, for several years), or for a couple of years. Very rare long (more than 10 years) modeling climate studies exist at this scale: Hamdi et al. (2014, 2015, 2016) explored for the Brussels Capital Region and the Grand Paris Region changes in the Urban Heat Island and urban heat waves under the IPCC A1B scenario for the 2050s. However, a systematic dynamical downscaling with all available global and regional models is impossible, mostly due to the huge computational costs. To resolve this issue, an intelligent methodological design should be developed. For example, under the URCLIM ongoing project (Masson et al., 2018), the authors are working on the development of a new methodology based on the concept of "urban signature", in order to be able to do very long runs at urban scale using stand-alone land surface models only.

Essential Climate Variable(s) to represent human adaptation to climate change in cities

There are currently no ECVs to represent human adaptation to climate change in cities, therefore progress in this regard is ground-breaking. Co-Convenor Tapper began the Sub-Session by describing the important role of GCOS and its identified ECVs in providing critical input about the climate system and progress on mitigation (and potentially adaptation) to the work of the UNFCCC and IPCC. He suggested that one or more new ECVs could be bio-physical (e.g. changes in % green canopy observed by remote sensing) or socio-economic (e.g. direct funding invested in adaptation response), or some other identifiable response. Four other participants provided critical input to the Sub-Session. In his opening remarks Jeffrey Raven referred to the Urban Planning and Design chapter of the new Climate Change and Cities 2nd Assessment Report (Rosensweig et al., 2018) where a number of city adaptations to climate change had been identified that could be potential ECVs. These include modifying form and layout of buildings and districts, adoption of heat resistant construction materials and reflective coatings (to increase urban albedo), and increased vegetation cover.

First panelist Xuemei Bai emphasized that ECVs would be essential and useful to capture and evaluate adaption at a range of scales and locations. She suggested caution in identifying ECVs that can represent the diversity of global cities and in ensuring that there is a causative link between the chosen ECV and the adaptation action identified. Second panelist Chao Ren focused on the case of design strategies for Hong Kong to overcome effects of excessive heat that may now be sufficiently mainstreamed to be possible ECVs. She identified albedo manipulation (cool building materials), vegetation enhancement, shade manipulation (building and street geometry and trees) and ventilation. The final panelist James Voogt made a strong case for an appropriate city adaptation ECV to be drawn from among various urban surface cover and structural parameters on the basis of their known controls on near-surface urban climate and hydrology (see for example Oke et al., 2017). Vegetation fraction, impervious fraction, complete surface fraction and albedo were all potential adaptation ECVs that could be readily provided by remote sensing. Urban surface and air temperatures (or an ECV derived from these) were also discussed, but issues of representativeness are a challenge to be overcome.

The identification and subsequent monitoring of one or more city ECVs is highly innovative – such information has to our knowledge never been tracked before. The chosen ECVs are likely to represent the complexities of climate adaptation implementation in cities. For example, the tracking of implementation of green infrastructure would represent a linkage between the bio-physical representation of the adaptation response and the commitment of financial resources for the purpose. It would also represent a trade-off of the demands for city space (building v's green space).

Towards a Research Agenda: Key Knowledge Gaps and Next Steps

Urban Climate Modeling

Research needs and priorities

- The need to urbanize, through appropriate urban parameterization, atmospheric models that are used to downscale global climate information to the city scale taking into account all pertinent processes that impact the urban environment, including physical, biochemical, sociological, and socio-economic systems/processes. This will require multidisciplinary research initiatives.
- The need to coordinate an inter-comparison exercise using different Regional Climate Models run at the urban scale with different urban parameterizations.
- To fulfil the need of urban planners and city stakeholders, these models should be run at kilometre/hectometre resolutions but at the same time be able to provide an estimate on the associated uncertainties.
- The need for fine scale urban data of many types: architectural information on buildings, human behaviour,

energy consumption and meteorological monitoring network for cities and especially in Africa and Asia. These data should be open and widely available for urban climate models and services.

- Emphasis should be put on simulating near-term future climate change impacts; i.e. the next 30 years of so. This is the time scale on which stakeholders are interested and also in order to fill the gap in the literature for this time horizon. It is also a time horizon that is less affected by the emission scenario.
- As global climate change and city expansion evolve on similar time-scales, it is important to simulate both – this will then take into account demographic evolution in and towards cities.
- Fill the scientific knowledge gap (in the published, peer-reviewed literature) about the effect of 1.5°C versus 2°C global warming on the urban climate of cities for different time horizons.
- Better understand and model sea level rise in coastal cities and its associated uncertainties.
- The need for dynamical and/or statistical methods to propagate the uncertainties from global, regional, to local impact models at the city scale.
- Stimulate and foster the interaction between urban climate researchers/modellers with urban planners, architects, and sociologists; especially when the interaction with the atmospheric models and the impact of mitigation/adaptation strategies are concerned.
- WUDAPT and the architectural typologies: Understand and quantify local impacts in the context with Regional impacts (e.g. while urban density increases UHI, regional urban sprawl results in a hotter region).
- The need for urban climate-based Design Guidelines in addition to downscaling methods of dynamical and statistical techniques.

Links with stakeholders

- Develop climate service tools for climate adaptation and climate resilient planning of urban infrastructure.
- Improve collaboration and communication between scientific communities, technical developers/industry and decision makers/communities/government.
- Integrate climate information into (urban) planning processes and embedding climate resilient design principles in infrastructural projects.
- Clarify value proposition to analyse/evaluate/prioritize ECV's: Overlapping adaptation and mitigation.
- The diversity of results yields uncertainty. Given the urgency for climate action by city stakeholders, is the focus on "perfect" the enemy of the good? Focus should be on a catalog of digital tools with "best practice" design guidelines together.

ECVs to represent urban adaptation

Research needs and priorities

This sub-session strongly supported the need for one or more ECVs to be identified that can represent human adaptation to climate change in cities. The session identified the critical need to monitor progress on climate change adaptation in the urban space in order to reduce risk and increase resilience in the face of climate change.

A number of possible ECVs were identified in the session, mainly related to bio-physical characteristics of the urban environment. Particular issues will be accommodating the diversity of global cities and identifying causality between adaptation action and the particular indicator.

Data acquisition and monitoring are key to the success of development of ECVs to track climate adaptation in cities. Steps required are:

a. Move quickly to confirm a relevant bio-physical indicator that is widely applicable among diverse cities, choosing from (probably) vegetation fraction, albedo, impervious fraction (1 to 3-month time-frame).

b. Present proposal to GCOS Terrestrial Observation Panel on Climate to confirm need for an urban adaptation ECV and to ratify the suitable choice (12-month time-frame).

c. Work through the logistics of implementing the monitoring program for the bio-physical ECV across as many diverse cities as possible (12 month to 24-month time-frame).

d. In the longer-term, if possible identify an appropriate socio-economic ECV choosing from (as possible examples) city investment in adaptation response, electric car sales/registration, greenhouse gas emissions reductions. It will need to be clear that such an ECV represents both adaptation and mitigation.

Links with stakeholders

The provision of robust bio-physical and/or socio-economic ECVs/indicators will feed directly into local and global climate change policy (e.g. through monitoring urban environmental change/adaptation progress through time and possibly against targets). While the identification and monitoring of suggested bio-physical ECVs can largely be achieved by engaging the relevant science (e.g. remote sensing) providers and urban managers, the development of one or more socio-economic ECVs would require the assistance/advice of relevant stakeholders outside of science and urban management (e.g. the finance/insurance industry, etc.).

Plenary Summaries · Parallel sessions summaries · Conference Posters · References · Annexes

SESSION TITLE: **COASTAL COMMUNITIES AND CLIMATE SUSTAINABILITY: THE CHALLENGES, THE OPPORTUNITIES, AND WAY FORWARD** - TUESDAY MARCH 6TH

Valentine K. Ochanda (Technical University of Mombasa, Department of Environment Sciences, Kenya), **Daniel K. Irurah** (University of The Witwatersand, School of Architecture and Planning, Johannesburg, SA), **Tom M. Logan** (University of Michigan, Department of Industrial and Operations Engineering, Ann Arbor, MI, USA), **Felipe C. Mandarino** (Instituto Pereira Passos, Rio de Janeiro City Government, Rio de Janeiro/RJ, Brazil), **Victor S. Indasi** (Climate Systems Analysis Group, University of Cape Town, SA), **Andyan Diwangkari** (Georgia Institute of Technology, School of City and Regional Planning, Atlanta, USA)

The main aims of the session were the analysis of Coastal Risks and Vulnerability. In the face of a changing climate and the presenters were selected from academia, city and regional practitioners and climate change practitioners in urban planners, engineers and social scientists under theme two on urban emissions, impacts, and vulnerabilities (Science and practice of cities)

Introduction

Coastal cities and islands, especially in the developing world, are vulnerable to extreme climate events according to the Intergovernmental Panel for Climate Change's (IPCC) climate projections[10]-[11]. Utilizing current and most complete Coordinated Regional Downscaling Experiment (CORDEX) – Africa[12] model ensemble, consisting of 25 simulations under Representative Concentration Pathway (RCP) 8.5; researchers from South Africa analyzed the response to rainfall & temperature extremes over five African Coastal city regions – Cape Town, Durban, Dar es Salaam, Maputo & Mombasa, when projected global temperatures reach 1.5°C and 2.0°C. RCP 8.5 comprises the largest ensemble and is considered the most realistic business-as-usual scenario given the current trajectory of greenhouse gases emissions[13 14]. These and other climate change related impacts provide significant and urgent impetus to adapt our communities and infrastructure to cope and thrive in the long term. To achieve this, we require substantial engagement between policy-makers and researchers, to co-develop relevant knowledge and inform and guide the implementation of resilient and adaptive measures which truly reduces our future coastal cities vulnerabilities.

A fundamental aspect of defending our coastal communities is understanding their risks. The risks span all sectors of our society, economy, and environment and we urgently need to improve how we analyze and communicate them. For example, future models need to incorporate dynamic feedbacks between potential adaptive actions, the hazard, and human behavior to understand the temporal evolution of risk[15]. Failure to capture these aspects can lead to maladaptation and overreliance on engineered structures[16 17], leading to increased vulnerability. It should also be noted that the population's vulnerability to climate change is also influenced by the urban form in which the population is living. Amidst the vast pace urbanization, urban sprawl, which features low-density land use, low land-use mix, low connectivity, and high automobile dependence, is considered as non-climatic factors that affect the three key determinants of vulnerability to climate change defined by the IPCC[18]. Failure in capturing the effect of different urban forms on vulnerability would lead to ineffective policies and adaptation strategies.

If nothing else, climate change is increasing our uncertainty and decreasing our knowledge of the state of the hazards. Adequately capturing this in our estimations and communications of risk is essential[19]. Climate change is also increasing the likelihood of unexpected events, referred to as "black swans"[20] by the risk community. These unexpected events present a serious threat to our community and the hard-adaptive measures so far taken to defend against natural events[21]. Decision support and decision-making techniques

10 Shiferaw, B. et al. (2014) Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. Weather & Climate Extremes 3, 67-79.

11 World Bank, (2010). Report on the status of Disaster Risk Reduction in Sub-Saharan Africa.

12 Giorgi, F., Jones, C. and Asrar, G.R., (2009). Addressing climate information needs at the regional level: the CORDEX framework. World Meteorological Organization (WMO) Bulletin, 58(3), p.175.

13 McSweeney C F, Jones R G, Lee R W and Rowell D P (2015). Selecting CMIP5 GCMs for downscaling over multiple regions Clim. Dyn. 44 3237–3260 doi:10.1007/s00382-014-2418-8

14 Taylor K E, Stouffer R J, and Meehl G A., (2012). An overview of CMIP5 and the experiment design Bulletin of the American Meteorological Society 93(4) pp485-498

15 Logan, Guikema, and Bricker (submitted). Engineered climate adaptations can increase vulnerability to natural hazards.

16 Burby, R. J. Hurricane Katrina and the Paradoxes of Government Disaster Policy: Bringing About Wise Governmental Decisions for Hazardous Areas. Ann. Am. Acad. Pol. Soc. Sci. 604, 171–191 (2006).

17 Magnan, A. K. et al. Addressing the risk of maladaptation to climate change. WIREs Clim Chang. 7, 646–665 (2016).

18 Congedo, L. & Macchi, S. (2015). The demographic dimension of climate change vulnerability: exploring the relationship between population growth and urban sprawl in Dar es Salaam. Current Opinion in Environmental Sustainability, 13, p. 1-10

19 Aven, Terje. 2014. Risk, Surprises, and Black Swans: Fundamental Ideas and Concepts in Risk Assessment and Risk Management. Routledge.

20 Ibid

21 Ibid 12

which incorporate this irredeemable (aka deep) uncertainty are necessary to further develop and integrate into current planning practice[22 23].

In Rio de Janeiro, Brazil, for example, the City Government's Instituto Pereira Passos has a decade of experience studying and mapping vulnerability to sea level rise in the municipality. This experience, with one report published in 2008[24], and the second one in 2011[25], brought significative experience and knowledge on the research gaps existing at the local scale. Among the gaps identified were: first a lack of locally relevant sea level rise projections; including poor tide gauge availability and consequent lack of data on current mean sea level and sea level rise rates. The third gap identified was a lack of an integrated vertical reference for 3D modeling of the coastal zone and a less detailed inland elevation data. These gaps again have bedeviled the city of Mombasa sea level analysis and other developing countries[26]. Several actions need to be taken, including building partnerships with local and international institutions to create data centers or access data among others to tackle data shortcomings in these areas.

The most important of them for Brazil was the partnership the City has built with the National Aeronautics and Space Administration (NASA) to anticipate natural hazards better and become more resilient to environmental pollution and climate impacts. In this context, local sea level rise projections were built according to a four-component methodology[27], which included local and global factors. Also, to monitor current sea level rise rates, the data from satellite altimetry missions (JASON, TOPEXPoseidon) is currently in use. Facing other gaps identified, the City has acquired LiDAR elevation data to build more accurate 3D models. However, there isn't yet an integrated model for the coastal zone that would allow modeling of wave impacts, coastal flooding, and other methodologies. In this scenario, vulnerability to sea level rise was mapped with the static approach, with projections as 10-year average centered around the decade of 2080. The results show how there is a strong link with social vulnerability, with informal settlements/slums being identified as some of the most vulnerable areas to sea level rise in Rio de Janeiro[28].

Currently, 48% and 71% of the infrastructure for Mombasa and Lamu islands In Kenya respectively falls within the Low Elevation Coastal Zones (LECZ. Which are less than 10m thus highlighting their extreme vulnerability under the pessimistic sea-level-rise (SLR) scenario[29] In Rio de Janeiro, for example, an analysis on the city vulnerability by the 2080s indicates that almost 7.7% of the city area is highly vulnerable to impacts of climate change. The case is not very different from Buenos Aires where more than 90% of the population is living in urban agglomerations, with a temperature increase on 100C posing a threat to the highly urbanized city hence heightening the delicate balance and importance of climate change adaptation in cities. Populations living in these cities exacerbate the challenges in cities to impacts of climate change. The simulation findings for Mombasa city indicate that exposure level to the 1:100 storm surge at 4m elevation falls between 433,300 and 2.5 million people and over US$9.1 billion in assets exposed by 2090. Under RCP 8.5 (business as usual-scenario) for Lamu Island[30], the exposure level of between 37,200 and 480,400 people and over US$ 648 million in infrastructure/assets exposed by 2090. The threat to the city, therefore, means that the planning of cities and its development control are key in climate change adaptation, mitigation as well as protecting infrastructure from these cities from impacts of climate change.

What we currently know

The main aim of the Paris agreement is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels. As well as pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius where financial flows, technological adaptation, and capacity building are key to the achievement of this goal, these systems, however, are still fragmented and financial burden especially from developing countries is a prohibitive factor. The session agreed that the coastal cities are facing an unprecedented threat from the effects of climate change and a changing climate. Some of these cities are predicted to face severe consequences that include flooding increased tsunamis in coastal areas. For example, the CORDEX Africa model

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22 Shortridge, Julie, Terje Aven, and Seth Guikema. 2017/3. "Risk Assessment under Deep Uncertainty: A Methodological Comparison." Reliability Engineering & System Safety 159. Elsevier: 12–23.

23 Stults & Larsen (accepted) Tackling Uncertainty in U.S. Local Climate Adaptation Planning.

24 Gusmão, P.P; Carmo, P.S.; Vianna, S.B. 2008. Rio Próximos 100 anos. IPP/SMU, Rio de Janeiro.

25 Silva, L. R. A.; Mandarino, F. C., (2011): Impactos Sobre o Meio Físico: Elevação do Nível do Mar e Redefinição da Linha de Costa na Região Metropolitana do Rio De Janeiro. In: INPE. Megacidades, Vulnerabilidades e Mudanças Climáticas: Região Metropolitana do Rio de Janeiro. Rio de Janeiro: Inpe, 2011. Cap. 2. p. 109-122.

26 Ochanda, V.K., and Irurah, D.K., (2017) Shoreline integrated SLR impact prediction in Mombasa and Lamu Islands in Kenya. Clivar exchanges no 71 pp32-35.

27 Ibid 22

28 Horton, R., Little, C., Gornitz, V., Bader, D. and Oppenheimer, M. (2015), New York City Panel on Climate Change 2015 Report Chapter 2: Sea Level Rise and Coastal Storms. Ann. N.Y. Acad. Sci., 1336: 36–44. doi:10.1111/nyas.12593

29 Ibid 23

30 Ibid

projections show that Cape Town, Durban, Maputo, Dar es Salaam and Mombasa city regions warm faster than the global mean, up to more than 1oC under the 1.5oC. The warming is more than 1.5oC under 2oC global warming. The Multi-model ensemble means of the projected changes in precipitation and temperature at annual and seasonal timescales under 1.5°C and 2.0°C global warming for RCP 8.5 show that the studied city regions warm faster than the global mean. Which is up to more than 1˚C under the 1.5˚C and over 1.5 ˚C under 2 ˚C global warming compared to the present climate. This warming will most likely lead to an increase in the length and frequency of extreme weather events including droughts, flash floods and heat waves tending towards the Paris agreement is not being achieved[31 32].

The temperature increases and effects of climate changes are becoming a challenge especially because the coastal communities have many investments regarding hotels with limited resources directed at adaptation and mitigation of the impacts, therefore seriously exposing coastal cities to threats that might bring tourism-based economies to their knees. Most communities that live in coastal areas as seen in the presentation had their adaptive measures and indigenous knowledge that they relied on for survival during challenging times. However, coastal systems have seriously changed especially with the tourism demand and supply, and some of these systems have been neglected in the search for business opportunities.

Summary and research gaps

How to achieve climate resilience remains highly uncertain. Adaptation and resilience are complicated by competing interests and varying levels of understanding and interpreting the risks. Research gaps exist in understanding the effect of and the dynamics between adaptation alternatives. The complex interdynamics can result in seemingly intuitive infrastructure solutions resulting in maladaptation. There are research gaps compounded by knowledge gaps such as the lack of integrated height vertical references between land and sea for coastal zone 3D models. The complexity of coastal systems and islands impedes the development of several derived studies, like wave impact modeling and coastal flooding. Increasing understanding of these aspects will improve modeling of adaptive strategies and their effect on communities.

Integrating this understanding with social research is another essential element. In some cases, the interaction between adaptive measures and subsequent human behavior can result in unintended consequences. Additionally, the impacts of sea level rise and other consequences are distributed unequally across the cities' populations, often concentrated in regions with existing social vulnerability, for example, Mombasa, Jakarta, and Rio de Janeiro. The sprawling and unplanned neighborhoods are more vulnerable than compact neighborhoods. Therefore, city planning and influence of development control is key in understanding the challenges of coastal cities adaptation and resilience to climate change. In the same breath, some of the areas that need reinforcement include ascertaining whether the temperature increases in Africa will offset any benefit from increased rainfall and propose robust, evidence-based and resilient adaptive strategies for the coastal cities and especially with regards to city form and character to help alleviate the impacts of global warming.

Indigenous based knowledge and the functioning of basic engineering as well as ecological adaptation techniques are key in understanding coastal systems challenges and how to minimize the negative impacts. The analysis of urban texture, form the planning laws and regulations that influence the development of cities and urban areas and. The role of development control in enhancing blue economy is important in helping come up with adaptation and mitigation that can be replicated in developing as well as developed economies in the quest to understand the best ways cities and coastal communities can protect themselves from the impact of climate change.

Results and discussions

There are still major gaps in data inputs needed for more detailed research on the local impacts of sea level rise in coastal cities globally. Therefore, there are still relevant knowledge gaps on the impacts of sea level rise in those areas. The kind of research required to close these gaps should be interdisciplinary and trans-sectoral, as shown in this paper by the partnership between the City of Rio de Janeiro, Mombasa, Cape town with stakeholders for example NASA. Working with local universities is highly important for City Governments, and this should happen permanently, outside the limited (and still dominant) scope of Governments hiring expert reports.

By creating bridges between urban and climate change stakeholders the research developed by Instituto Pereira Passos has advanced in co-producing knowledge and identifying further data and knowledge gaps in the research of sea level rise local impacts. As IPCC moves forward to address the city scale, having the Cities IPCC Cities and Climate

[31] Dosio A (2017): Projection of temperature and heat waves for Africa with an ensemble of CORDEX Regional

Climate Models. Climate Dynamics 49(1–2), 493–519.

[32] Russo S, Marchese A F, Sillmann J and Immé G 2016 When will unusual heat waves become normal in a

warming Africa? Environmental Research Letters, 11(5) pp54016

Change Science Conference was the catalyst in factoring on coastal cities which is an important step. The next frontier of research on cities and climate change and the work presented brings light to the challenge of scaling down IPCC scenarios and others currently faced by climate adaptation planning and research happening inside city administrations.

Cape Town, for example, is experiencing its worst drought on record. Projections show a statistically significant reduction in rainfall and increase in temperature, suggesting the possibility of frequent drought events in the future. Projections in Durban, Maputo, Dar es Salaam and Mombasa show a statistically significant increase in temperature but with an insignificant reduction in rainfall. Further studies required to ascertain whether the temperature increases will offset any benefit from increased rainfall.

Figure 1: Coasts risks and vulnerability Session participants (from left Tom, Dr. Ochanda, Felipe, Andyann, Ines, and Indasi)

SESSION TITLE: GUIDE FOR INTEGRATED URBAN WEATHER, ENVIRONMENT AND CLIMATE SERVICES (IUWECS) AND HOW IT CAN BEST MEET THE NEEDS OF RESEARCHERS AND STAKEHOLDERS - TUESDAY MARCH 6TH

Session Conveners:
Alexander Baklanov, James Voogt

Session Participants:
Valéry Masson, Tanya Müller, Luisa Molina, Chao Ren, Felix Vogel
Session Shepherd: Boram Lee

Parallel session summary

Authors:
Baklanov, A., Voogt, J.A., Lee, B., Masson, V., Molina, L., Müller, T., Ren, C., Vogel, F., Nielsen, C.

Session Aims and Format

The Integrated Urban Weather, Environment and Climate Services (IUWECS) is a new initiative from the World Meteorological Organization (WMO) that seeks to provide science-based integrated urban services supporting safe, healthy and resilient cities. As part of that initiative, a Guide for IUWECS is being developed. The current version of the Guide is available for comments on: https://www.wmo.int/pages/prog/arep/gaw/documents/GuideIUWECSPart1.pdf (comments to be sent to: wmo.cities@gmail.com). The intent of the session is to present the draft IUWECS Guide and to receive feedback from attendees on the guide recognizing that attendees at CitiesIPCC will represent the range of groups expected to be involved in future IUWECS.

The intent of the IUWECS Guide is to document the best available knowledge, technologies and practices for producing and providing the relevant services that cities require to respond to the hazards posed by climate change. Such services include a combination of dense observation networks, high-resolution forecasts, multi-hazard early warning systems, and climate services. These services should assist cities in setting and implementing mitigation and adaptation strategies, which will enable the building of resilient and thriving cities that promote the Sustainable Development Goals (SDGs). The Guide also includes a multidisciplinary approach to better serve the social-economic needs of urban areas and identify the required partnerships to establish and sustain urban services, including research, city governments, international organizations, and private sector stakeholders.

The session presentations provided an overview of the Guide and case city presentations (on examples of Hong Kong, Mexico City, Paris and Toronto) illustrating the best available knowledge/technologies and practices. Feedback were solicited from participants on desired services, products and requirements for developing effective multidisciplinary partnerships among urban/city governments with meteorological and other key agencies with a view to building operational IUWECS for cities that will help them achieve SDGs.

State-of-Knowledge Summary

Recommendations from the IUWECS Guide:

- IUWECS are needed and it is important not to wait for a disaster to act. There are examples of well-functioning IUWECS which can be used.
- Encourage NMHSs to contribute in the promotion, development and coordination of integrated urban services, including knowledge transfer.
- Ensure that legal and institutional frameworks are in place in partner cities that clearly define government agency interactions and responsibilities to enable creation and maintenance of integrated services.
- Engage with relevant stakeholders from the beginning including raising awareness and getting feedback.
- Further research, including multidisciplinary cross cutting studies, is needed to develop IUWECS capabilities.
- Encourage NHMS to facilitate wider accessibility of data via influencing ownership issues and technical support.
- Encourage WMO members to showcase demonstration projects on urban services.

Question on / Recommendations to the Guide:

- The key is to ensure that the newly developed Guide would contribute to improve the current operation to provide useful services for cities. Integration of physical and social aspects, based on fundamental knowledge of what individual city needs, should be incorporated into the development of a Guide.

- A continuing challenge is to ensure close linkage between a short-term focused operation and a long-term adaptation strategy, especially in a local scale. Well-tailored models (adapted to city-scale needs) can be used to establish such a linkage, which must be supported by standardized data available for a sufficiently long term, not only for physical environmental parameters but also for societal parameters reflecting the urban environments and user implications. Scientific deliberation should be tailored respectively to different stakeholders' needs.

- Recognizing the critical importance of the integration, participants raised a question on monitoring and evaluation of an integrated system, particularly on data; i.e. monitoring and evaluating the source and availability of data, as well as analysing the demand for different datasets.

Recommended recently published peer reviewed papers:

Baklanov A, CSB Grimmond, D Carlson, D Terblanche, X Tang, V Bouchet, B Lee, G Langendijk, RK Kolli, A Hovsepyan, 2018: From Urban Meteorology, Climate and Environment Research to Integrated City Services. Urban Climate, 23: 330-341, https://doi.org/10.1016/j.uclim.2017.05.004

Aerial view of flooding caused by Hurricane, Harvey_Houston, Texas © Shutterstock

SESSION TITLE: **HOW DATA AGGREGATION CAN SUPPORT SUBNATIONAL ACTORS IN FRAMING CLIMATE POLICY** - TUESDAY MARCH 6TH

Session Participants:
Tiffany Hodgson, Dr. Kevin Gurney, Dr. Cathy Nangin, Dr. Shobhakar Dhakal, Dr. Eric Lindquist, Alex Kovac, Dr. Shannon McDaniel

Parallel session summary

Session Aim

The aim of this session is to assess the impact of city and local government efforts to advance the Paris Agreement, while also identifying areas where cities need input through collaboration and with support from other levels of government, research and the private sector.

The session is linked to three main themes of the IPCC Conference: (i) Enabling transformative climate action in cities; (ii) Cities & climate change and (iii) Urban emissions, impacts and vulnerabilities.

Session Format and Working Methods

This is a science-practice-policy session where current work from scientists and urban practitioners will be presented followed by a panel discussion moderated by a city network and encouraging an high level of engagement with the audience.

Participants

Tiffany Hodgson, United Nations Framework Convention on Climate Change
Dr. Kevin Gurney, School of Life Sciences, Global Institute of Sustainability, Arizona State University, Tempe, AZ, USA
Dr. Cathy Nangini, + Data Scientist and Visualization Specialist, Laboratoire des Sciences du Climat et de l'Environnement, France
Dr. Shobhakar Dhakal, Associate Professor, Department Head, Department of Energy, Environment & Climate Change, Thailand
Dr. Eric Lindquist, School of Public Service, Boise State University, Idaho, USA
Alex Kovac, Research Analyst, World Resources Institute
Dr. Shannon McDaniel, Director of Data Strategy, Global Covenant of Mayors for Climate and Energy

Session Description

Opening and welcome address, **Shannon McDaniel** (3 min): perspectives from the city on the importance to make the case for climate action through better understanding and measurement of the multiple impacts of climate actions.

- **First presentation, Tiffany Hodgson** (10 min): Overview of the work of the UNFCCC and the role as convener of climate action data at both the national level and the city level with NAZCA and why this matters for cities in support of the Paris Agreement.
- **Second presentation, Kevin Gurney** (10 min): Results from two large scientific efforts to generate high space/time resolution CO_2 emissions inventories in the US, both part of larger scientific efforts that combine the Vulcan/Hestia results to atmospheric monitoring to create a unified system with both emissions estimation and atmospheric verification.
- **Third presentation, Cathy Nangini and Shobhakar Dhakal** (10 min): Present a global CO2 emissions dataset for cities that disclose their emissions to the Carbon Disclosure Project (www.cdp.net) complemented by ancillary variables related to emission drivers in each city, e.g. transportation and socio-economic indicators.
- **Fifth presentation, Eric Lindquist** (10 min): Present on the convergence of climate science and big data from a public policy perspective and articulate the opportunities and challenges presented by this situation.
- **Sixth presentation, Alex Kovac** (10 min): Present on the methodology of data aggregation used in the KNN model employed, highlighting data that is present from cities and where more information is needed.
- **Seventh presentation, Honorable Mayor Upadhyay from the city of Rajkot, India** (10 min): Insights and experiences from a city perspective, thoughts around knowledge gaps for cities in reporting efforts.
- **Q&A and open discussion / Moderated panel discussion (led by Shannon McDaniel) with the audience (26 min)**

The session and the findings presented by the three research directly address some of the key barriers for the integration of wider impacts and benefits into sector-level planning in cities. The work represents a first step in an effort to make these impacts and benefits, and the tools for their evaluation, more understandable and accessible to decision makers and researchers. The audience is encouraged to engage in, criticize and further build upon the methodologies and results, and to make use of the content where possible as a tool for moving towards more holistic and participatory planning for sustainable development in cities.

Key findings from the panel

Each session should produce a summary of relevant key knowledge and a set of recommendations which will be the foundation for a new, jointly created, global research agenda on cities and climate change. Where applicable, please provide a link (to a maximum of one per research gap or recommendation) to a relevant publication, peer reviewed or from grey literature.

SESSION TITLE: **HUMAN HEALTH IMPLICATIONS OF CLIMATE CHANGE** - TUESDAY MARCH 6TH

Session Convener/Shepherd:
Dr. Megan Melamed (IGAC, University of Colorado, USA)

Session Participants:
Dr. Benedicte Dousset (Hawai'i Institute of Geophysics & Planetology, University of **Hawai'i at Manoa,** USA), **Dr. Nigel Tapper** (Monash University, Australia), Dr. Patrick **L. Kinney** (Boston University School of Public Health, USA), **Ms. Rachel Huxley** (C40 Climate Leadership Group, UK)

Student Scientist:
Maya Reshef (RN, University of Alberta, Canada)

Parallel session summary

Description and Aims

Cities around the world consume 78% of the world's energy and produce 60% of all carbon dioxide. They are home to hundreds of millions of people, and yet, they remain highly vulnerable to the impacts of climate change. As the climate warms, a range of human health issues are being exacerbated, ranging from heat exposure, to insect and waterborne diseases, to respiratory and cardiovascular diseases. However, it is difficult to both quantify the costs associated with climate change impacting human health and, at the same time, the benefits to human health resulting from climate change mitigation options. The aims of this session were to explore the human health implications of climate change, how these impacts affect different socio-economic categories, methods to incorporate the costs associated with human heath into climate change impacts, quantifying the human health benefits and impacts of climate change mitigation options, and case studies of cities which are acting against climate change and result in human health benefits.

State of the Science

Climate change and the human health implications associated with it share many similar root causes; anthropogenic heat production, urbanization, excessive use of motorized vehicles, limited green space, etc. Responding to these issues requires cities to establish both mitigation and adaptation strategies. Mitigation strategies aim to reduce the causes of climate change, such as greenhouse gas (GHG) emissions, whereas adaptation strategies aim to reduce the effects of climate change, such as vulnerability of humans and systems. Some research has already been done at the global scale to help cities develop these types of strategies. For example, a global analysis of extreme heat events (EHEs) based on papers published between 1980 and 2014, was conducted to identify the location, timing, and climatic conditions associated with human death. The researchers found that EHEs were mostly reported for cities in mid-latitudes zone, yet deadly heat conditions also occur in other climatic regions and currently the risk could be underestimated. This is a critical gap, as deadly heat exposure has significant effects on global land-use and human population health. They also found that countries worldwide face varying levels of risk according to latitude. For example, cities in a temperate zone will undergo more warming than those in a tropical zone, however the latter will be exposed to more days with deadly climatic conditions because of the year-round effect of combined warm temperatures and high humidity (Mora et., al 2017).

Some of these researchers have also analyzed the 2003 EHE in Paris, and the related risks of heat exposure, vulnerability, and mortality. The findings informed health risk anticipation, management, and resilience strategies. This study indicated that compared to rural areas EHEs are deadlier within cities due to the heat island effect that delays night time cooling, and that elderly people were the most affected (Dousset et al., 2011; Laaidi et al., 2012). Global level research is fundamental in understanding the broad health implications of climate change, and efforts to link it with urban research are important to build an understanding around climate change and health within cities.

Many local level endeavours are already underway and are starting to map out human health implications of climate change within individual cities. One study conducted in Melbourne, Australia in response to their millennium drought, an event lasting from 1996 to 2010, found mortality drastically increased by as much as 20% during days that reached an average daily temperature above 28-30° Celsius (Nicholls et al., 2008). They also found that even a small reduction in daily average temperatures has the potential to save many lives (Tapper et al., 2014). This finding was the basis for a dedicated research program on heat mitigation strategies, particularly those associated with irrigated and un-irrigated green infrastructure. Strategies, including better heat warning systems and emergency services preparedness appear to have reduced excess deaths during EHEs by at least 50% between 2009 and 2014 (Nicholls, Loughnan and Tapper, 2016).

Important findings that arose from this group's work are: 1) exposure, vulnerability, and adaptive capacity are all important in determining heat-health; 2) ensuring local emergency services were better prepared to deal with EHEs is crucial to success; and 3) use of science and technology (remote sensing, digital maps, observations, modelling and other sources of data) enabled the researchers were to produce approaches, tools, models, and fact sheets to aid in mitigation of current and future EHEs (Loughnan, Nicholls and Tapper, 2012; Coutts et al., 2013; Loughnan et al., 2014; Tapper et al., 2014; Coutts et al., 2015; Coutts, et al., 2016; Thom et al., 2016; Broadbent et al., 2017; Nice, Coutts and Tapper, 2018; and references therein). Sharing and understanding research such as this allows cities to learn from one another, and further provides an opportunity for city leadership to adapt the findings to fit their own unique contexts.

Like any national or international community, cities make decisions based on competing priorities. Sometimes these priorities are immediately obvious to urban decision makers, while other times they are not. Climate priorities are not always immediately obvious, but city leadership must take them into consideration when making decisions about the future of cities (Jack and Kinney, 2010). Also, it is important for cities to recognize that not all climate-related decisions take an "all or nothing" approach. There are many useful co-benefits for cities that align climate action, human health, and city priorities. Co-benefits are present in many different areas of city planning, for example, city leadership can promote other modes of transportation (like bicycles), which promote health and reduce emissions, or they can increase the amounts of spaces for leisure and recreation with benefits for health and well-being. In Australia, citizens are encouraged to harvest storm water to reduce water scarcity, and this water can be used in a variety of ways (Coutts et al., 2012). Climate smart cities can introduce adaptation and mitigation strategies in several ways, and can simultaneously improve the health of their populations while doing so.

Cities are faced with unique challenges and opportunities regarding climate change mitigation and adaptation that differ from the global level. When it comes to cities, there are two types of climate change effects that are worth noting: 1) The direct effects of climate change, which are easy to record and understand (increased temperatures, occurrence of extreme events, heat waves, floods, etc.); and 2) the indirect effects, which are more challenging to measure (air quality, water quality, land use change, ecological change, etc.) (Watts et al., 2015). Although cities are lacking data linking these indirect climate outcomes to the health of their populations, some do exist and are continuously being developed. For example, it is known that each year in New York City there are around 320 deaths and 870 hospital visits due to the high levels of transportation emissions (Kheirbek et al., 2016). Information such as this is critical for the academic, practitioner, and urban policy-making communities as it helps develop an understanding around the relationship between climate change, the urban setting, and human health.

Initiatives aiming to help cities connect with one another, develop adaptation and mitigation strategies, and improve the health of populations are already emerging. For example, the C40 benefits research programme has started working with cities to drive urban action against climate change. C40 works with cities to help make them more efficient and climate conscious, and utilizes an approach built to be effective and efficient in measuring a wide variety of climate and health co-benefits. This group works with the understanding that cities do not have an abundance of resources available to them for big scale projects. Instead, they offer cities a methodology to use across a range of resources. Through their partnerships, they work with cities to prioritize desired actions and impacts, and they also collect data on the cities throughout the process. Due to the lack of climate change data at the city level, their guiding methodology acts with the best-available data, but the group uses the data collected to help develop urban climate knowledge.

Collecting urban data is critical for climate change mitigation and adaptation worldwide. Technology plays an important role in this, and some cities are already developing and utilizing tools dedicated to local data collection. One such example is the Long-Range Energy Alternative Planning Systems with Integrated Benefits Calculator, which is new to the urban setting and potentially useful when given to local decision makers. It does not require expertise to use, and it can help derive emission inventories and assess changes in emissions and impacts on: health, crop yield, climate from greenhouse gas abatement, air pollution mitigation, and energy planning (Climate and Clean Air Coalition, 2018). However, this tool, as well as many others, are not readily available to all cities worldwide, and those which lack access must also be considered if we wish to keep global warming below 2°C.

Towards a Research Agenda: Key Knowledge Gaps and Next Steps

The largest knowledge gap that needs to be addressed with regards to cities, climate change, and human health implications is the lack of data. Although data collection is progressing, city leaders must act urgently to adapt to, and mitigate climate change. Without all the information and tools necessary to make crucial decisions regarding climate strategies, they should be able to adjust their decisions according to the best available data. Cities around the world must work independently and together towards documenting and quantifying the impacts of climate change on human health, which will require new ways to measure both the direct and indirect effects of climate change. A second gap that needs to be addressed is the integration of co-benefits into urban planning. Health and climate co-benefits exist, and cities can benefit from identifying which ones are present within their own borders. Health and equity benefits are important for city level decision makers to understand, and although they may differ among cities, decision makers can start incorporating them into their urban planning strategies immediately.

Some mitigation and adaptation strategies can enhance human health and promote the safety and well-being of the population while contributing to urban cooling. Examples of such mitigation strategies comprise reducing the use of heat-releasing systems, such as air-conditioning units, increasing surface vegetation, advancing low carbon innovations in transportation and industries, reducing heat/energy consumption, and finally, integrating local climate and human health data into urban planning and decision making.

For adaptation strategies, cities would benefit from collecting local data to anticipate the impact of future climate-related events, reduce uncertainties, and secure urban resilience at the local and regional scale. For example, it is important to determine temperature patterns, delimit day/night risk areas, develop public health surveillance, alert systems, and emergency services, set up preventative measures, paying closer attention to vulnerable populations, and increasing communication and awareness (Dousset et al., 2011; Laaidi et al., 2012). Without mitigating GHG emissions, by the end of the century almost half the global land and two thirds of the human population could be exposed to deadly heat conditions (Mora et al., 2017). Hence, drastic mitigation strategies are imperative to minimize the impacts of climate change on human health, meanwhile adaptation strategies are vital to advance urban resilience.


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SESSION TITLE: MAINSTREAMING URBAN GOVERNANCE AND FOOD, ENERGY AND WATER (FEW) SYSTEMS TOWARDS CLIMATIC RISK REDUCTION - TUESDAY MARCH 6TH

Session Conveners:
Patricia Romero Lankao (National Centre for Atmospheric Research, USA), **Delali B. K. Dovie** (University of Ghana, Ghana), **Debra Davidson** (University of Alberta, Canada), **Ama Essel** (UNFCCC African Group of Negotiators (AGN), Ghana)

Session Speakers:
Semu Moges (Addis Ababa University, Ethiopia), **Patricia Romero Lankao** (National Centre for Atmospheric Research, USA), **Debra Davidson** (University of Alberta, Canada), **Kwadwo Ohene Sarfoh** (Prime-Stat SVC, Ghana), **Raymond Kasei** (University for Development Studies, Ghana), **Shuaib Lwasa** (Department of Geography Makerere University, Uganda)

Session Shepherd:
Anne-Hélène Prieur-Richard (Future Earth)

Student Scientist:
Sarah Thacker

Parallel session summary

Session aims and format

Urbanization and climate change pose both unprecedented risks to populations' and FEW systems' securities, and opportunities to create more sustainable and fair futures. With climate change already amplifying risks, scholars and practitioners have underscored the need to understand the hazards these cities face, how hazards unequally affect the FEW security of populations, and how we can mainstream urban governance to better adapt to and mitigate climate risks. The session included case studies, perspectives and lessons-learned, an analysis of how inequalities in risks are framed, and what are cities doing to incorporate equity considerations into urban adaptation and risk mitigation. Session Format and Working Methods: The session included (8-minutes) talks and an open dialogue.

State-of-the art of the field

Because this was a blended session, the presentations touched on what we know and recent research directions on several topics, for instance on methodologies, on governance, flood risk and adaptation, and on challenges and options to build city-wide resilience. Other topics include the cities understanding and managing of the links between inequality in climate change risks to the security of people and FEW systems. Below is a brief description.

Governance, Adaptation and Flood Risk

Disruptive events, such as floods and socio-political turmoil, threaten the sustainable availability and use of land, housing, food, energy and water resources and services. Speakers presented examples of risks posed by floods in different cities. Accra (Ghana) is illustrative of governance and infrastructural arrangements that can fail because of poor sanitation combined with population growth and inadequate warning systems. While annual rainfall has not changed in last 60 years in the basin, the duration of rain season has shrunk, and the intensity of rain has increased. Rainfall comes from outside the city, within the watershed, and enters city canal. So people do not necessarily see the water levels rising until it's too late. Functional flood early warning system are a way of warning people in vulnerable communities. Take home message: even if cities are well managed, factors outside the city will affect its resiliency. Therefore, policy makers and government need to put in perspective all these connections

Boulder, Colorado USA illustrates the risks to people and places posed by the 2013 flood, a low probability, high impact extreme event. The intense precipitation that brought on the Boulder flood appears as a harbinger of more frequent extreme events under a changing climate. The flood triggered impacts in the transportation, energy, and water sectors that generated negative cascading effects. The results could be felt across the diverse sectors and livelihoods, and interests that were intricately woven into the social fabric itself, affecting everything from the mountains to the plains, from communication to emergency response -profoundly changing the experience of everyday life. Interestingly, while actions and responses by different sectors and jurisdictions were effective and helped to minimize the negative cascading impacts, risk mitigation actions were not enough to counteract the negative impacts of infrastructural interdependencies.

Climate Adaptation at scale

There are currently few comprehensive examples of climate change adaptations at a scale that builds resilience of city systems, the consequence of which creates risks undermining years of development achievements. This clearly creates an urgent need to identify scalable adaptations, to enable exchange of good ideas, practices and skills as well as practical action for local authorities to adapt to climate change. It is also known that what happens at a micro-level affects the macro-level while macro-level linkages to micro-level impacts are discerned as feedbacks of climate change. Cities in the global south like Kampala face many challenges compounded by climate change related impacts of flooding, pollution and health issues. Evidence from early initiatives indicates that dealing with such problems and challenges requires working on solutions that have cascading effects across spatial scales.

Inequality in risk to people and FEW systems in adaptation plans of 43 cities

Differences in climate risk and vulnerability and in capacity to mitigate and adapt to climate disruptions result from inequality. Climate change is a risk and vulnerability amplifier often more greatly affecting the poorer and more marginalized populations within and across cities. Among the resources and options that vary with inequality to create urban vulnerability, access to food, energy, and water are so essential that they can serve as indicators of an uneven distribution of many resources conditioning vulnerability. This study analyzed the way local governments 43 (C40) cities are currently understanding and managing inequality in climate change risks to the security of people and FEW systems in cities. In an increasingly unequal world, equity took the back seat in the adaptation strategies of these cities. Tensions at play in the adaptation plans, reflect a disconnect between inequality in climate risk, and the overall development trends and goals city officials care about. With a few exceptions, actions frequently focused on infrastructural interventions to enhance resilience, low-carbon utilities and buildings, promoting a circular economy, and risk as a source of investment opportunity. Thus, most cities have been unable to link their adaptation policies to their other local development goals let alone equity priorities.

Methodologies

Two main methods to assess urban vulnerability assessment/ sustainability were discussed using urban agriculture as an example. The first, a criteria and indicator approach, offers an efficient, systematic template for application across big sample size but it can only capture a snapshot in time. It compartmentalizes variables and hence misses intersectionality. It does not capture agency (people living in city, power, and relationships). An alternative Social Process (or Practice) Approach focuses on a particular process that contributes to vulnerability by determining inputs, outputs, and actors. While this approach is time intensive, it is better suited for smaller sample size. Because it includes agency and intersectionality, it can reveal hidden vulnerability sources. The Process Based Approach is a good compliment to existing methods. Excluding it may overlook important adaptive processes.

University Stakeholder engagement

The experience through a project entitled 'URADAPT' (http://uradapt.iwmi.org/) shows that it is possible to create and maintain a long-term university-City government - stakeholders' engagement. The platform consisted of the city experts, the stakeholders including vulnerable communities (such as the women association, the slum dwellers, upstream-downstream rural communities), the researchers and policy makers, and regularly meets for various research related issues. The platform was called Demand Driven Action Research (DDAR). How do we conduct our business? i) The platform members sit in a meeting and provide narration of the main problems and challenges. ii) In the meeting, they convert the narrations into research questions and researchable topics, refined and formulated properly in the University and assigned to PhD and MSc students. iii) They then discuss data requirements, data collection and any preliminary results. iv) They present the results and interpretation and engage in a campaign for developing a policy briefing. In this process, sustaining the platform beyond the policy briefing to the policy action phase had become a challenge.

Engaging different sectors

The climate compatible development (CCD) approach developed by the Climate Development and Knowledge Network in the UK has emerged to bring coherence between different sectors, including outcomes of their intersections by mainstreaming the roles of the science, policy and practice communities. The approach promotes local co-creation and coevolution of knowledge from higher to lower policy scales and informed citizenry responsibility and participation to understand the synergies and tradeoffs between development and mitigation, development and adaptation, and mitigation and adaptation at the nexus of FEW systems.

Towards a research agenda

Climate change and urbanization present a two-way feedback loop. Knowledge is needed on how flooding, a major climate change risk, interacts with urbanization and governance to impact people and places unequally. Equally important is to better design and implement early warning systems that can help reach vulnerable populations effectively. It is also important to note that flooding begins upstream and affects those living downstream. The interconnectedness of places (for example, upstream and downstream) should be taken into account in the adaptation action.

We lack comprehensive examples of climate change adaptations at a scale that builds resilience of city systems, the consequence of which creates risks of undermining years of development achievements. This clearly creates an urgent need to identify scalable adaptations, to enable exchange of good ideas, practices and skills as well as practical action for local authorities to adapt to climate change. The next research agenda should address a mix of strategies for bridging local to citywide linkages of adaptation measures. These could be plot-level interventions that have a cumulative effect on city-wide scale reduction of climate change risks to spatially cascaded and nesting possibilities.

Including equity in the climate discussion is key. Climate change affects groups in society unequally, with people in lower income situations being the most vulnerable. Equity should be as important as the environment and economy. We need to address the three pillars of sustainability if we are to reach sustainable development goals, but we do not know how. While participants liked the inclusion of social aspect and agency in the session talks, they also felt that these topics were missing in the plenary sessions.

The Social Process/Practice Approach can compliment existing methods to assess vulnerability and does a good job of capturing agency. Excluding this approach could lead to overlooking important adaptive processes.

Our understanding of the political economy of resilience planning needs work. There are gaps in our knowledge of the global-national-city-community level interface of climate issues.

Data is of key importance for our ability to scale up integrated solutions. We should identify data gaps and continue collecting data and designing tools to appropriately analyze the data. With this, monitoring is very important.

Creating a long-term research platform between research universities, the city government and key stakeholders is essential for shared understanding of climate science, adaptation and mitigation processes at cities. It facilitates distributed data generation. However, there are issues in communicating science from academia and researchers to policy makers and vulnerable people.

While city officials often embed adaptation in a larger development vision for the city, little research focuses on how different interpretations of these concepts play out in existing adaptation plans. For instance, we can address this gap by analyzing how development, sustainability, resilience and risk relate with, balance, or contradict each other within adaptation plans.

Thailand floods, Natural Disaster © Shutterstock

SESSION TITLE: **PROMISE OF GREEN INFRASTRUCTURE TO COMBAT CLIMATE CHANGE IN CITIES** - TUESDAY MARCH 6TH

Session Conveners:
Claire Walsh (Newcastle University), Harriet Bulkeley (Durham University), **Camilo Ordóñez Barona** (University of Melbourne)

Session Speakers:
David Hetherington (ARUP), **Shuaib Lwasa** (Makerere University), **Laszlo Pinter** (Central European University), Bettina Wanschura (Ramboll)

Session Shepherd:
Richard Dawson

Session Student Scientist:
Jinhan Xie

Parallel session summary

Authors:
Claire Walsh, Harriet Bulkeley, Camilo Ordóñez Barona, David Hetherington, Shuaib Lwasa, Laszlo Pinter, Bettina Wanschura.

Session Aims and Format

Green infrastructure and nature-based solutions can provide a transformative solution for cities to adapt to the impacts of climate change e.g. providing flood protection, as well as contribute to climate change mitigation, e.g. sequester carbon. Green infrastructure also has a wider array of economic, social and environmental benefits which can improve the urban form in general and enhance the effectiveness or reduce demand on other infrastructure sectors. Knowledge gaps exist in how to evaluate, manage, fund, and deliver green infrastructure. However, across the globe new methods and approaches are emerging, as well as examples of best practice.

This session brings together researchers and practitioners to consider the use and challenges of designing, implementing, managing, and financing green infrastructure in a range of urban contexts from across the globe. The outcome of an interactive workshop will be will identification of research gaps and priorities, data daps and needs, and ways to improve the interface between research, policy and practice as well as an emerging evidence database of green infrastructure solutions that can successfully contribute to transformative climate action in cities, enabling learning and knowledge exchange.

State-of-knowledge Summary

In IPCC AR5, the function and services provided by green infrastructure are recognised as being vulnerable under climate change e.g. coastal wetlands being inundated by sea level rise (Section 8.2.4.5 'Green Infrastructure and Ecosystem Services'). Its value towards adaptation in urban areas, peri-urban and rural areas with respect to the opportunities for management, conservation and restoration to enhance services and increase resilience to extremes is discussed in Section 8.3.3.7 'Green Infrastructure and Ecosystem Services with Urban Adaptation' and draws upon examples of its use in e.g. flood management, moderating temperature, creating open spaces and providing habitats from a range of urban areas. Many of the challenges outlined in AR5 e.g. balancing competing needs for space, financing and selection of the appropriate plants for particular functions remain.

Extent of Green Infrastructure and Nature Based Solutions
The use of green infrastructure/NBS (GI/NBS) as a form of urban development could be regarded as an 'emerging issue' in terms of being a trend that seems to be increasing over the past decade and concerning which the evidence base is still relatively limited. Our session documented that innovation with GI/NBS in European cities is now quite widespread (Urban Nature Atlas, https://naturvation.eu/atlas) – covering many different domains and urban contexts, from more prosperous to more marginal urban conditions – yet our understanding of the drivers of this phenomenon and its implications for addressing climate change remain relatively limited. There is also much less evidence concerning the extent to which such approaches are being adopted outside of European cities, though the evidence presented by both the academic and practitioner communities suggests that there are a range of different ways in which the capacities of nature are being harnessed to address urban sustainability agendas in cities in Australia, Asia, sub-Saharan Africa (informal settlements) and the Americas.

Figure 2: Promise of Green Infrastructure to combat Climate Change in Cities Session participants

Other emerging issues that have a bearing on the uptake and mainstreaming of GI/NBS relate to the following dynamics:

a) New terrains of climate responses in cities – GI/NBS are one of a number of 'solutions' competing for space in the city. Many such solutions are implemented in urban 'terrains' that are traditionally under-used or under-valued, such as roofs, pavements, verges, marginal land and so on. At the same time, such terrains are increasingly being valued as the sites for the implementation of different technologies – such as solar panels or measures to 'cool' the city. How these dynamics of competing for the space to make cities sustainable will play out, and indeed which is the most appropriate combination of responses in any one city, is a key research gap if we are to support city-based action.

b) Climate finance – the potential opportunities and challenges of leveraging investment at the urban level to address climate change is a particularly important issue in relation to GI/NBS, which may require different investment vehicles and business models capable of recognising their contribution to the 'commons' as well as specific flows of benefit to particular sectors/industries/neighbourhoods/actors. Any discussion of appropriate forms/means and agents of climate finance needs also to consider the extent to which it is fit for purpose for investment of this kind, while research on green infrastructure/NBS needs to engage with the wider debate on the nature and potential of financing responses to climate change at the urban level.

c) While GI/NBS are effective at helping cities adapt to climate change, by lowering ambient temperatures or controlling water run-off, among other benefits, their capacity to adapt to changing climatic patterns has been largely overlooked. This may require different planning, design, and investment mechanisms that off-the-shelf or business-as-usual practices may not be able to provide.

Challenges for GI/NBS at the city-scale

Spatial Scale – to date most research evidence has focused on medium/large cities. There is comparatively little research done in general on small cities/urban settlements, and in this case green infrastructure/NBS is no exception, and where mega-cities are concerned the potential of these kinds of solutions can seem to be dwarfed by the size of the challenges, perhaps with the exception of experiments being conducted in Chinese mega-cities. Another key scale challenge is that many such solutions are implemented at the building, street or neighbourhood scale and we currently lack the evidence base and modelling approaches capable of assessing their (combined) impact at the 'urban' scale, although research models to assess discreet benefits e.g. flood risk (CityCAT: http://www.ncl.ac.uk/ceser/research/integrated-systems/cities/citycat/) and urban heat (UrbClim: https://www.urban-climate.be/c/urbclimDescription/) are emerging.

Temporal scale – to date, most GI/NBS research takes a cross-sectional and pattern-assessment approach that is frozen in time, which is not useful to explore the dynamics of climatic change, which operate and accrue over long-time periods. Multi-seasonal, multi-yearly, and other type of long-term studies that assess GI/NBS efficacy and performance are much needed to understand the interplay between their benefits and their capacity to adapt to changing climatic patterns.

Urban settings – there is growing evidence that the urban setting in which GI/NBS are implemented is crucial for their impacts, effectiveness and consequences. In particular, there is growing evidence where we can say with some confidence that such interventions can lead to urban gentrification and the widening of social inequalities if not implemented with sensitivity to these potential impacts. However, the evidence base of the ecological, economic and social impacts of green infrastructure/NBS has to date been derived from relatively few urban contexts (with the Global South particularly poorly represented) and our understanding of the *institutional, governance and financial* urban settings within which GI/NBS can be developed and implemented remains less developed than our knowledge of their potential ecological and economic benefits.

Related to these challenges are the following external factors which need to be addressed:

Multilevel governance – the conditions under which green infrastructure/NBS are developed and implemented are reliant not only the specific governance arrangements and processes in place in any one urban context. This includes strategic guidance, policy requirements, regulatory codes, norms regarding risk/return calculations, incentives and the availability of different forms of expertise, capacity and resources.

Rural-urban linkages – the influence of ecological and social patterns operate non-linearly across an urban-rural scale. Changing vegetation, wildlife, infrastructure, and socio-demographic dynamics will all operate across the rural-urban border under a changing climate, and municipalities with defined jurisdictional boundaries may struggle to address this cross-boundary socio-ecological issues.

Research gaps and priorities

Solutions for the transition to low carbon and climate resilient cities (Science and practice for cities): while there is a growing body of evidence on the contribution that green infrastructure and nature-based solutions can make to addressing climate change at the urban level, our understanding of their potential is limited in three key ways. First, research has tended to focus on a relatively narrow range of urban contexts (primarily in the Global North) and a small number of indicators of the value of green infrastructure/NBS, limiting our understanding of their utility. Even where research evidence is strong, there is limited knowledge/confidence concerning the multiple/confounding impacts that such solutions can provide and how these benefits and risks are distributed across diverse communities as well as in time and space. Second, we lack the evidence base and methods through which to calculate the combined effect of multiple green infrastructure/NBS interventions across different scales. Third, partly reflecting the novelty of these forms of response to climate change, their long-term contribution is under-researched. It is particularly important to understand how green infrastructure/NBS might be affected by changing climatic conditions over the long-term in order to be able to create cost-effective and resilient solutions. Equally vital is the need to develop approaches which are able to demonstrate the full range of the value of green infrastructure/NBS in order to demonstrate the potential for different forms of public and private investment.

Enabling transformative climate action in cities (advancing science and advancing cities). Our session takes some first steps in systematically documenting the ways in which green infrastructure/NBS is being realised at the urban scale and the modes of governance required for its implementation. However, our understanding of: (a) the actors and institutions involved in the development of NBS/green infrastructure; (b) the governance processes and instruments required to support their implementation; (c) the forms of innovation (technical, social and in relation to business models) emerging and the mechanisms through which they could be mainstreamed; and (d) the ways in which stakeholders and communities are engaging with the development and use of green infrastructure/NBS remains limited. In particular, we have yet to identify whether using 'nature' as a means of responding to climate change raises additional/different governance, performance and investment challenges than where more traditional 'brown' or 'grey' infrastructure is involved, which in turn may require different points of leverage and coalitions of actors in order to enable urban transformation.

Integrating science, policy and practice

Different research, policy and practitioner communities currently operate multiple approaches and techniques for assessing the value of GI/NBS. Bringing these into dialogue, and recognising the ways in which different audiences/stakeholders value the different contributions that GI/NBS can make, can provide the basis for a more robust approach to the assessment and valuation of GI/NBS. Valuation is intrinsically linked to how to finance and fund GI/NBS. Long term full scale demonstrations such as the UK's National Green Infrastructure Facility will begin to provide the evidence on the performance, cost, management and maintenance of GI/NBS over the long term.

Research agenda

The session identified with workshop participants the following priorities around the sub-topics of research gaps and data needs:

Research gaps, challenges and priorities

- Develop methods and approaches that monetise the benefits and services that GI and NBS provide in order to convince cities/businesses to invest in them.
- Related to the above: how can non-monetised values e.g. social, cultural, psychological be incorporated into the evaluation of GI and NBS.
- Evidence from full-scale demonstrations of GI technologies and long-term monitoring of features.
- Develop outcome-orientated performance indicators of GI and NBS.
- Understanding the specific health benefits of GI and NBS.
- Examples of successful financing and funding portfolios for GI and NBS
- What tools (policy, etc.) exist to compare the relative benefit of conserving existing GI and nature instead of implementing new projects?
- How can different needs be balanced e.g. urban agriculture/ GI/ NBS that may compete for space?
- Understanding and evaluating social justice when implementing GI and NBS projects.
- Incorporate evidence into a systemic assessment in cities to test solutions and to identify synergies and trade-offs e.g. link with Urban Integrated Assessment Frameworks that incorporate climate change, demographic change and land use change.
- Investigate remote sensing techniques to monitor state and performance of GI/NBS.
- More research need from a Global South perspective.

Data needs:

- Long-time monitoring of the performance of GI and NBS for all function and service types.
- Collate cross-spatial and cross-temporal datasets.
- Aspiration towards combined social, ecological, institutional, economic, and engineering databases.
- Understand to what extent data and evidence collected on the performance of GI and NBS can be transferred between climatic regions.

- Can existing data be used to run scenarios and make projections of where to locate GI and NBS?
- Demonstrate how data can provide the evidence needed to highlight the multiple benefits of GI and NBS, and the appropriate financial and governance arrangements.

Bridging the gap between the three communities:

- Ensure all evidence and knowledge from research is in the public domain.
- Design and implementation of GI and NBS is iterative. Practitioners have vast knowledge that needs to be captured.
- Build a meaningful interface e.g. develop guidebooks and strategies fed by scientific evidence, practical lessons and appropriate governance and policy.
- There is a challenge of working at different timescales, policy and practice – short term; research – longer-timescales. However, the SDGs are setting a time target of 2030 and encourages all to work towards a common goal.
- Embed researchers in the Municipalities to identify needs from both perspective in the partnership – gathering appropriate data and building skills.
- Funders could force researchers to ensure research agendas are co-developed with policy makers and practitioners; could they be paid to be involved in delivering projects?
- A strategic approach to develop links between practitioners and students/education e.g. internships, secondments, research partnerships; an underused opportunity.

Furthermore, suitable vehicles for communicating evidence gathered from the three communities were suggested:

- Study tours as a form of tangible peer to peer learning
- Embedded PhD students in policy and practice e.g. Municipalities
- City-based institutes who have a key role as knowledge brokers
- Link evidence to how GI/NBS can contribute to other issues
- Make use of city networks e.g. C40 network
- Key role in citizen science in being involved in collecting and collating evidence (helps build trust between scientists and communities) and emergence of crowdfunding to implement GI/NBS.

SESSION TITLE: SMART CITIES AND THEIR PROMISE FOR ADDRESSING CLIMATE CHANGE IN CITIES - TUESDAY MARCH 6TH

Session participants (convener, chair, speakers, discussants, etc.):
R. Keivani, F.H. Abanda, M. Archibald, D.P. de Leon Barido, H. Rahmat, M. Patel, L.F. Cabeza, V. Vilarino

Parallel session summary

Session Aims and Format

This session presents several approaches to solving the complex problem of decreasing urban greenhouse gas (GHG) emissions. Each speaker discussed a technology, method, or program that has demonstrated potential to increase urban energy efficiency or effect behavioral change. The approaches presented in the session aimed to contribute to an overall scalable shift in the way urban infrastructure is designed, built, and managed with a goal of reducing the impact cities have on climate change. Topics in this session include the: use of Building Information Management (BIM) for building energy efficiency, use of sensors and user-designed information communication technology (ICT) to provide high-resolution data that incentivizes energy efficient behaviours in low-middle income neighbourhoods in Managua, Nicaragua, implications of the use of open online platforms and collaborative urban governance for urban climate actions and the efforts by a public-private sector collaborative research vehicle in Alberta for bringing resources together and better identifying industry focused requirements for more targeted applied research.

BIM for building energy efficiency

The performance of the building sector vis-à-vis energy efficiency has not significantly improved despite global increase in sustainability awareness. According to a report by EIA (EIA, 2018), the global energy consumption in the residential sector is around 30-40%. Most commercial buildings waste 25% of their energy. Salehi ***et al.*** (2015) found that building consume 60% more energy than original expectations. The attainment of the Paris Accord target of 1.5°C by 2100 will require the adoption of aggressive strategies to improve the performance of buildings. This is particularly important given that optimizing energy efficiency in buildings can close 20% to 55% of the gap between current emissions trends and 2030 abatement targets. Optimising building energy efficiency requires continuous monitoring of energy consumption and the complete understanding of the key factors impacting the buildings (Allouhi et al., 2015). BIM - an innovative and collaborative way of working that is underpinned by digital technologies which support more efficient methods of designing, creating and maintaining the built environment provides an opportunity to better manage information for the improvement of building energy efficiency. Compared to traditional optimization systems, BIM provides greater energy savings through a combination of accurate energy monitoring, real-time decision support systems, and actuators and identification of consumption patterns. Through BIM, enhanced supervision of energy flows and use in buildings can be conducted and new partnerships between energy managers, energy distributors, energy equipment suppliers, and technology (including smart software tools), can inform the optimal management on the evolution of energy use in buildings, and result in quantifiable energy consumption reduction better than traditional optimisation systems. Lastly, emerging technologies (CCTV, IoT, Big Data, Apps, and Sensors etc.) common today with smart cities can be integrated with BIM for urban energy efficiency management – not easily done with traditional optimisation systems.

A review of the literature revealed three main findings. Firstly, the integration of BIM with other emerging smart cities information technologies such as Big Data, Sensors, Smart devices is still very limited. Secondly, most BIM systems contain rich data for managing standardised projects in the global North with limitations with the same for the global South, given the large scale of informality of its construction sector. Thirdly, research findings from the literature used in the building chapters of the First, Second, Third, Fourth and Fifth assessment are based on traditional optimization techniques.

To address the aforementioned gaps, three main research paths will need to be pursued. A further investigation into efficient ways of integration and interoperability of BIM and other emerging technologies will need to be conducted. Secondly, an investigation of the adaptation of BIM for information management of projects in the global South is imperative. Lastly, it is also important for authors to consider BIM-based optimization research in the next and future IPCC reports.

The incentivization of energy efficient behavior using sensors and user-designed ICT for high-resolution data in low-middle income neighborhoods in Managua, Nicaragua

High-resolution data for energy consumption across important cities of the global South is scarce. While there have been recent advances in remote sensing to develop estimates of global consumption using nightlights data, there have yet to be major developments in infrastructure to provide open and reliable high-resolution data streams of energy consumption. These data are crucial, as they are elemental to designing and implementing sustainable energy solutions across entire regions of the global South (Revi et al., 2014). Without reliable data, it is difficult to develop reliable effective energy efficiency implementations, sustainable energy solutions, or provide reliable access to basic services in cities. One of the main gaps for the community to move forward is on the development of cost-effective solutions that can create data for cities, while providing immediate benefits to users. While remote sensing can create superficial estimates of energy demand, for example, it is not obvious how that data will translate to immediate benefits for users. With available and mature wireless sensor network technology, emerging economies have the opportunity to develop and implement solutions that both collect data and that provide benefits to users. Rigorous, reliable data monitoring consumption of energy and other basic urban resources is crucial to making progress towards city and global climate change goals.

The case study presented in Nicaragua was the first pilot in Latin America to use wireless sensor networks for the monitoring and control of household level energy consumption and appliances (de Leon Barido et al., 2017). With Nicaragua being a regional leader in the deployment of renewable energy (60% of its electricity generation comes from non-hydropower renewable energy), it was an ideal country for a novel sensing and control implementation, as the country needs to develop cost-effective solutions that will move it towards realizing the benefits of a smart grid (Nicaragua is also the second poorest country in the Western Hemisphere).

The Nicaragua case study demonstrated that wireless sensor networks are a mature technology that can be used to create data from scratch, and be implemented in a way that can immediately benefit users and cities. The goal of the project was to enable behavioural energy efficiency through real time feedback, and control of appliances to reduce grid peak prices and better integrate wind energy through the control of appliances and the use of wireless sensor networks. Users saved 9% of their energy consumption per month through a novel feedback and monitoring system, but they also contributed to reducing grid costs and emissions by reducing the energy consumption of their appliances through automation of their electrical appliances. At this scale, and if only one third of the capital city participated in the implemented solution, it would save the city $US 50 million per year, for a relatively small investment.

One of the key challenges for moving forward is for low, low-middle income countries to avoid copying and repeating mistakes that the United States and Europe did in the development of their urban smart grid infrastructure. Instead of hundreds of millions of dollars, and decades of roll outs of smart meters, the global South has an incredible opportunity to harness the benefits of wireless sensor networks, to create solutions that are locally beneficial to communities and cities. The benefits of sensor networks for creating energy data allows for small pilots to be deployed at first, investigate co-benefits and address issues, and then cost-effectively deploy at scale with solutions that work for urban dwellers and city services.

Open Online Platforms and Collaborative Urban Governance for urban climate actions

This presentation discussed the opportunities for utilising social media platforms to enhance collaboration in addressing climate change. As pointed out in the literature (Innes and Booher, 2010; 2016), the conventional modern planning and hierarchical control have failed to address complex and shifting problems that are recently dominated by environmental degradation and limited resources and infrastructures due to rapid urbanisation. It is suggested that collaborative dialogue and action drawing on multifaceted information represent an effective strategy for tackling such complex problems (Innes and Booher 2016). Facilitating not only multi-directional dialogues between the grassroots, government and public officials but also the spread of information and innovative practices, social media enable the collaboration of many and diverse participants and have the potential to bring together dynamic populations. By amplifying collaboration between citizens, civic leaders, experts, public and private organisations, digital communication technologies offer new opportunities to operate participatory dynamics to tackle climate change as a complex and shifting problem that involves many players and interdependent interests.

The use of social media data can be employed in identifying and supporting climate adaptation initiatives. Social media data represents varying degrees of availability depending on the property rights of public or private actors (Severo et al., 2016). As compared with traditional methods such as survey and interviews, social media data collection is much simpler, cheaper, and faster and allows us to map the constantly shifting landscape of citizens' needs, interests, and innovations in regard to climate change. In the case example of Twitter conversations around climate change, it has been demonstrated how user-generated data can be employed to improve understanding of collaboration between involved participants. To achieve this, however, data mining techniques are required to create narratives, foster storytelling, and amplify citizens' participation in climate adaptation efforts. Understanding the social dynamics of collaboration as they appear on social media, has implications for policy and practice to develop effective creativity strategies in tackling climate change in cities.

Limitations of social media data such as potential biases, and privacy issues have been identified. As for the directions of future research, an investigation into the development of a mechanism for collaborative urban governance and civic engagement in urban climate actions that uses open and online platforms is imperative.

Efforts by a provincial alliance to promote smart city technologies and a specific polytechnic applied research initiative aimed to help the industry

Climate change threats and independent advances in digital technologies are driving innovation agendas within cities. Climate change is influencing government policy linked to the emission of Greenhouse Gases. New emissions targets are in turn influencing innovation activity in various industries where traditional methods generate large emission loads, including electricity generation (Pursley & Wiseman, 2011).

In parallel, advances in electronics and software engineering are generating low cost technologies that can be applied to a multitude of social and economic problems. These advances are enabling the potential for radical reinvention of transportation through both the electrification of vehicles and introduction of autonomous control. Sensing and control innovations offer the promise of much more efficient building energy management. In spite of the availability of highly capable technologies, there are significant gaps in understanding how best to deploy technologies to deliver the most effective and manageable solutions that will provide meaningful and durable climate change mitigation or adaptation (Weijermars et al., 2012).

Faced with emission reduction targets, various industries are taking steps to develop and deploy innovations designed to reduce GHG emissions. The problems are complex with deep interdependencies that require open collaboration and interdisciplinary knowledge (Lund et al., 2017). Efforts to advance commercial solutions tend to be isolated within corporate structures prioritized by consideration of economic value and competitive advantage while simultaneously acknowledging the social and environmental gravity of the challenge. Reaching Paris Agreement goals may be achievable, but only with an aggressively accelerated research and commercialization agenda. One path forward is to take advantage of the deep practical knowledge available in polytechnic institutes, combined with outputs from fundamental research in universities and make this ecosystem of innovation available to industry. Given that we, as a species, are operating in uncharted territory without the benefit of a guaranteed path to resolution, an innovation model that supports experimental evaluation and validation of technologies guided by multidisciplinary expertise offers a tenable path forward.

Technical research has great potential to deliver solutions that provide commercially viable and socially acceptable innovations (Broto & Bulkeley, 2013). These innovations must deliver effective low or no-carbon electricity reliably and in sufficient quantity to meet future demand growth. Many candidate solutions need to be evaluated, validated, and scaled for commercial deployment. No single technology can deliver value, scalability, and meaningful mitigation or adaptation across all economies, geographies, or societies. Higher-level research in economics, policy, and system management that aggregates technical development outcomes can broadly inform government and intergovernmental policy (Pittock, 202). A well communicated, coordinated, and outcome driven research agenda informed by validated understanding of technical and social issues should be effective at delivering an effective plan in response to climate change threats.

Based on the preceding sections, four main research questions will need to be addressed in order to mainstream emerging ICT into climate change mitigations and adaptations.

- How do we integrate data and information for from emerging technologies such as BIM, smart metering and sensory application and social media to enhance lifecycle collaborative planning/decision-making energy conservation and improvement of environmental performance of buildings?

- How do we adapt emerging ICT to the building sector in relation to integrating indigenous knowledge, quality and relevance of data and information for delivering smart cities of the global South?

- Related to above how do we address barriers and challenges relating to intellectual property rights and conflicts in private stakeholder business interests and public data sharing, privatisation of public data, incentivising stakeholder participation and capacity building particularly in informal and low income areas of global South and instituting complementary methods to reductionist data mining and technical methods for more comprehensive understanding of wider influence impacting on energy use/demand, behaviours and decision making?

- How do we enable better public-private collaboration for instituting applied and industry focused research through creation of special university-industry research institutions?

SESSION TITLE: **INTERACTIONS OF CLIMATE MITIGATION AND ADAPTATION IN CITIES: SYNERGIES AND TRADE-OFFS -** TUESDAY MARCH 6TH

Session Conveners:
Stelios Grafakos and **Jen Heemann** (Institute for Housing and Urban Development Studies, Erasmus University Rotterdam, Netherlands), Urban Climate Change Research Network (UCCRN) and **Nicola Tollin** (University of South Denmark, Denmark)

Session Participants:
Moderator:
Minal Pathak (Ahmedabad University, India)
Speakers:
Steve Winkelman (Green Resilience Strategies, USA),
Sean O'Donoghue (eThekwini Municipality, South Africa),
Stelios Grafakos, (Institute for Housing and Urban Development Studies (IHS), Erasmus University Rotterdam, Netherlands)

Session Shepherd:
Richard Dawson (Newcastle University, UK)

Student scientist:
Andres Felipe Cañavera Herrera (University of Alberta, Canada)

Parallel session summary

Session Aims and Format

Currently, an increasing number of cities (Reckien et al., 2015, Grafakos et al., 2018) are moving towards addressing climate change adaptation and mitigation (Ad-Mit) in an integrated manner. Local governments urgently seek support and guidance, but the interrelationships (synergies and conflicts) between climate Ad-Mit in cities is a relatively recent topic in research, policy and practise. This session stimulates discussions between policy-makers, practitioners and academics in order to elucidate current understanding and define the most pressing urban Ad-Mit interrelationships' topics to be addressed in future research.

The session started with three short presentations on: i) Practitioner's perspective, with a focus on methods and tools to identify, implement and measure Ad-Mit interactions ii) Policy-maker's perspective, on integrating adaptation and mitigation in policy and planning within the constraints and realities of a medium-sized developing city in Durban and iii) Researcher's perspective, on the synergies and trade-offs of Ad-Mit across key urban sectors based on a recent comprehensive study of 102 European urban climate change action plans that integrate adaptation and mitigation. Then the participants were split into groups for breakout interactive sessions. Each group choose to address one of the main questions of the session:

Which are the main *opportunities* and *challenges* of *integrating* urban Ad-Mit in policy and planning? What kind of support researchers can provide to policy-makers regarding *Ad/Mit integration?*

Which are the main types of *interrelationships (synergies and conflicts) of Ad-Mit in cities* and which urban **sectors** cut across by providing real examples?

Which are the main available *methods and tools* to measure Ad-Mit interrelationships in cities? What important aspects newly developed tools and methods need to address and consider?

State of the Art of the Field

The 5th Assessment report of the IPCC states that mitigation alone is not sufficient to respond to climate-related risks and adaptation plays a crucial role when creating alternative development pathways. Furthermore, joint consideration of outcomes of adaptation and mitigation has been limited and needs further investigation (IPCC, 2014). Against this background, the session aimed to discuss the interactions of climate adaptation and mitigation in cities along with their potential for integration into planning and implementation.

Question 1: Which are the main opportunities and challenges of integrating urban Ad-Mit in policy and planning? What kind of support researchers can provide to policy-makers regarding Ad/Mit integration?

Stelios Grafakos, based on an extensive review of urban Climate Change Action Plans (CCAPs) in Europe, highlighted that 17% of CCAPs in Europe integrate adaptation and mitigation. Regarding *opportunities for integrating* Ad-Mit from a practitioner's perspective, Steve Winkelman highlighted the following aspects: i) saving time and resources; ii) achieving multiple co-benefits; iii) expanding funding sources; iv) increasing return on investments, and v) accelerating implementation and scaling up. From a policy perspective, Sean O'Donoghue argued that Ad-Mit integration saves financial resources for the local government, helps to align research initiatives with the policies and recommends investments to the city council.

During the discussion in groups, the participants highlighted the following *opportunities*:

Resources
- Sharing resources
- Better use of financial resources
- Packaging projects with multiple benefits for multiple investors and funders

Planning

- Avoiding conflicts and pitfalls between Ad-Mit
- Streamlining Planning processes
- Detailed integrated climate change plans may motivate people to act
- Integrating communities in the planning process with focus on
  - Fostering dialogue on services

Capacity and learning

- Enhancing capacity building and resources to support finance and implementation of Ad-Mit measures
- Sharing real-world examples of Ad-Mit solutions with clear documentation of multiple benefits and compelling visual communication
  - Sharing examples and peer learning

On the other hand, the groups also identified related *challenges*. According to the participants, the main constraints of integrating Ad-Mit are categorised as follows:

Understanding

- Adaptation and mitigation have been addressed separately for a long time
  - Separate scientific community and disciplines
- Normally municipalities have a better understanding of climate mitigation than climate adaptation

Assessment

- Adaptation and mitigation are measured differently
  - There is a common "currency" for measuring mitigation (MtCO2)
  - Adaptation benefits are typically localized and may represent avoided losses or improved recovery times after disruptions
  - While adaptation seems to be integrated into many sectors and aspects (with obvious co-benefits), mitigation is focused on specific areas related to energy
  - Targets are quantified for mitigation, but not for adaptation

Planning and decision making

- Lack of integration among plans: infrastructure, land use, transport, energy, climate change mitigation, climate change adaptation and disaster risk reduction.
- Isolated decision-making, such as for capital budgeting and operations & maintenance preventing a total cost of ownership perspective and lifecycle asset management approaches.

Stakeholders involvement

- Adaptation and mitigation have often different audiences and actors
- Adaptation plans often require high engagement cost considering the complexities of local vulnerability and potential adaptation options

Organisational/ institutional

- Framework legislation often singularly targeted to A or M, but not both
- Institutional structure support is challenging due to distributed authorities and competencies
- Lack of support from the organization and high levels of governments

Furthermore, the participants of the groups stated that researchers could provide *support* to policy-makers by developing integrated methodologies to assess and evaluate Ad-Mit measures and their integration. Researchers can further help with economic evaluation, quantification of mitigation and adaptation targets, impacts, as well as the assessment of joint benefits in Cost-Benefit analysis and project valuation. Furthermore, researchers can support policymakers by helping them to understand the opportunities, drivers, challenges and barriers to integration of Ad/Mit in planning.

Question 2: Which are the main types of interrelationships (synergies and conflicts) of Ad-Mit in cities and which urban sectors cut across by providing real examples?

During the session, a few examples of measures that address both mitigation and adaptation were shared by the speakers and the participants. Steve Winkelman highlighted Adaptation and Mitigation synergy opportunities around distributed and integrated energy systems (e.g., microgrids) that can include renewable energy, storage (thermal and electric), energy efficiency and demand management that can both reduce GHGs and enhance energy system resilience. He noted how targeted and scaled-up green infrastructure solutions can reduce building energy use, help mitigate urban flooding and ameliorate urban heat island effects. Protecting low-carbon transport systems, such as shading pedestrian facilities and preventing subways from flooding bring both Adaptation and Mitigation benefits. Providing diverse, low-carbon transportation choices (public transport, walking, cycling) can enhance multi-modal accessibility, and increase network redundancy advancing system resilience pre-, during and post-disasters. Using Vancouver as a case, the practitioner also recommended holistic strategies for neighbourhoods, packed within multiple policies and offering multiple benefits.

Sean O'Donoghue presented the example implemented by the city of Durban, which developed a community ecosystemic space, called Community Ecosystem-based Adaptation.

The space integrates job creation (a national top priority) with ecosystem services and ecosystem management and received support from political actors. Urban greening, in this case through urban forestry, offered a good example of synergy of Ad/Mit considering also other local sustainability benefits.

According to the results of the comprehensive review of 102 European CCAPs that integrate adaptation and mitigation, the main sectors where Ad-Mit interactions occur are urban greening (37%), construction and buildings (23%), education and communication (17%) and energy generation (10%).

The breakout groups highlighted the following sectors, where Ad/Mit synergies occur:

1. Green Roofs
   a. Adaptation: reduced water runoff, cooling
   b. Mitigation: cooling benefits and energy savings
2. Food Roofs
   a. Co-benefits on socio-economic development
      i. Job creation
      ii. Poverty reduction
3. Blue carbon – mangroves
   a. Carbon sequestration
   b. Avoided costs from storm surge
   c. Sediment retention services
4. Mobile apps – Kenyan agricultural group
   a. Climate insurance; market data
5. Community Mapping
   a. Primary adaptation knowledge
   b. Incorporate mitigation response, e.g. insulation
6. Transport – planning
   a. Saved emissions

Question 3: Which are the main available methods and tools to measure Ad-Mit interrelationships in cities? What important aspects newly developed tools and methods need to address and consider?

From the practitioner perspective, Steve Winkelman highlighted the importance of asking "the climate question", which is: how will policies and investments affect GHGs and Climate Resilience? He suggested the use of the Green Resilience Matrix to identify synergistic opportunities and proposed development of an A+M toolkit to evaluate Ad-Mit opportunities by type of measure and sector and assesses synergies, co-benefits, conflicts, trade-offs and costs. The toolkit would accelerate Ad-Mit action by recommending implementation strategies and funding sources. Regarding monitoring and evaluation, he emphasized the importance of practical metrics that measure what people care about and need, such as cost savings, time savings, access to critical infrastructure and government services and business continuity.

Sean O'Donoghue presented Durban's experience on integrating adaptation and mitigation strategies, from a policy perspective. Sean argued that adaptation and mitigation must address the city's specific needs for a successful implementation. An example is the Integrated Adaptation and Mitigation strategy of Durban that emphasises job creation - one of the city's objectives. Furthermore, the strategy is aligned with national and regional South African policies, which resulted in broad support from different levels of government.

The working groups discussed the importance of measuring Ad-Mit interrelationships and development of tools in the urban context. The participants highlighted the experience of developing methodologies in the framework of the Clean Development Mechanism (CDM) to measure carbon emissions reductions, as a potential learning outcome for developing methodologies for both adaptation and mitigation project impacts.

From the scientific perspective, Stelios Grafakos presented a collaborative study of about 17 researchers from 9 research institutes in Europe, which assesses the level of Ad-Mit integration in 152 urban integrated Climate Change Action Plans (CCAPs) in Europe.

He argues there is an increasing number of cities with an integrated approach, which is crucial to understand potential Ad-Mit synergies and trade-offs. However, so far there is lack of understanding on how different sectors interact including interactions of adaptation and mitigation policies and associated sectors. Considering the lack of an evaluation framework of Ad-Mit integration, he presented a systematic operationalization of the planning cycle for analyzing and evaluating the level of integration of Ad-Mit policies in CCAPs.

From the preliminary findings of the study, Stelios highlighted that almost half of the plans include both a GHG emissions and Vulnerability profile, whereas a high percentage (70%) of the CCAPs considers local sustainability co-benefits of climate action. The 40% of the CCAPs that analyzed have identified clear Ad-Mit interrelationships. In addition, and based on the overall evaluation of the level of Ad/Mit integration, 18% of the total sample can be classified as "advanced integrators", which means they achieve a good level of integration. On the other hand, it means that the majority of the plans do not fully integrate adaptation and mitigation strategies. Furthermore, national policy frameworks can help local governments to integrate adaptation and mitigation (e.g. national governments mandating local governments to develop a combined climate adaptation/ mitigation plans).

In conclusion, there is a growing, but still limited, number of climate change action plans that advances Ad-Mit synergies. We still need an integrated framework approach to study the synergies and conflicts of Ad-Mit interrelationships and advance their implementation. Synergies between adaptation and mitigation go beyond climate change, covering other sectors and aspects such economic, health, quality of life and biodiversity.

Towards a research agenda

Among the *important gaps in knowledge* highlighted during the session, participants agreed there is a need for methodologies and tools (such as nexus, co-benefits, cost-benefit and multi-criteria studies) to identify, assess, monitor, and evaluate synergies and trade-offs between climate change adaptation and mitigation measures. The identification could include Ad-Mit opportunities by type of measure and sector, while the assessment could address synergies, co-benefits, conflicts, trade-offs, and costs. The monitoring and evaluation could cover "actionable" indicators for intermediate outcomes (e.g., pavement permeability), and outcomes that are practical and meaningful to policy-makers and the public (cost savings, economic benefits, time savings, business continuity, etc.). Furthermore, it is essential to better understand the interactions across critical infrastructure systems (e.g., energy, transport, telecommunications, water) and cross-jurisdictional coordination (e.g., for land use and infrastructure planning and watershed management).

In order to advance the research agenda, the *science, policy, and practice communities can collaborate* by sharing knowledge and experience (e.g. through case studies and peer learning), to define best practices on planning, implementing, and financing Ad-Mit measures that present mutual benefits in mitigating and adapting to climate change. The communities could work together on developing simple, meaningful, and actionable metrics of Ad-Mit interactions. Also, there is a need to build and share knowledge on the socio-economic aspects (e.g. job creation and money saving), strategies to get political support, ecosystem services' gains, as well as additional local sustainability benefits of integrated adaptation-mitigation projects.

In practical terms, this collaboration can be developed through coordinated applied research in the field of Ad-Mit interactions, where universities and knowledge-based institutes provide technical assistance and support to cities in identifying opportunities to maximize adaptation-mitigation synergies and designing policies to implement them. Furthermore, through peer learning programmes and activities, cities can learn from each other how to successfully develop and implement Ad-Mit measures.

Comprehensive reviews still need to be undertaken to even larger number of CCAPs and similar analysis and evaluation frameworks could be applied in other regions to get more insights on how and to which extend cities integrate adaptation and mitigation in their CCAPs and their implementation. Also, there is a gap of knowledge on the drivers/barriers of integrating Ad-Mit, and further understanding the correlation between the level of integration and other variables. Quantitative and qualitative analysis studies could address the afore mentioned research issues.

SESSION TITLE: **TRANSFORMING THE BUILT ENVIRONMENT, RESEARCH & EXPERIENCE** - TUESDAY MARCH 6TH

Session Conveners:
Rob Bernhardt (CEO Passive House Canada)

Session Panellists:
Sean Pander (Green Building Manager, City of Vancouver), **John Lee** (Deputy Director for Green Buildings & Energy Efficiency, New York City Mayor's Office), **Dr. Adam Rysanek** (Associate Prof. UBC School of Architecture & Landscape Architecture, Vancouver, BC), **Souran Chatterjee** (doctoral researcher at Central European University, Budapest, Hungary)

Student Scientist:
Thomas Lippiatt (University of Alberta, Canada)

Panel moderator, Rob Bernhardt opened the session by stating the solutions for achieving the required reductions in emissions from buildings are both known and tested. High performance buildings, capable of having their energy needs met by renewable sources, have been built in large numbers around the world. To ensure effective transformation of the built environment, it is critical to be mindful of the nexus between that research & experience and effective policy. To be effective, public policy must be science and fact based, with clearly defined outcomes and performance metrics. As the panelists will frequently refer to Passive House levels of performance, the session opened with a short description of Passive House buildings.

Presentation 1: Introduction to Passive House High Performance Buildings, Rob Bernhardt

The Passive House high performance building standard arose from an EU funded academic research project seeking to identify how efficient buildings should be. The cost and performance data from numerous projects identified a cost-effective level of efficiency based on fundamental building physics. That level represents up to a 90% reduction in heating or cooling loads relative to existing buildings, and a substantial reduction in all other energy uses within buildings. Achieving that level of efficiency enables building mechanical systems to be simplified and reduced in size. Furthermore, achieving that level of performance required the architectural design of the building to be inherently efficient, reducing mechanical run lengths and reducing or eliminating the need for certain services. Creating efficient building architecture creates more compact, simpler, building forms, leading to a reduced envelope area and fewer corners to detail, generating significant cost savings during construction. In this way, the incremental cost of more insulation, high performance windows and ventilation systems are largely offset, leaving owners with a small incremental construction cost and life-long operational savings.

Passive House is a tool, centred around an energy model, enabling designers to create a building that reliably performs as modelled, essentially eliminating the usual gap between modelled and actual performance. The methodology is not prescriptive - different buildings in different locations will not use the same materials or designs, but all achieve a common performance level.

A fundamental attribute of achieving Passive House levels of energy efficiency are the multiple benefits experienced by building occupants. Thermal comfort, air quality, and hygiene requirements are included in the metrics such buildings are required to achieve. A Passive House in a warm climate will look different from one in a cold climate, but both will deliver superior quality of life in terms of affordability, thermal comfort, indoor air quality, durability and health. The design focus in a hot climate is to reduce cooling loads while maintaining the co-benefits, whereas a cold climate building design will focus on limiting the heating loads.

A project in Esquimalt, BC, Canada illustrates the combined impact of using wood construction and Passive House design in a 12-storey 83-unit condominium building. This wood-framed building is significantly carbon negative after completion because of the sequestered carbon in the wood. With a low carbon electrical grid and Passive House levels of operating efficiency, a life cycle analysis of that building reveals it remains carbon positive throughout its first hundred years of operation. Such buildings are possible today, and being built at scale.

The climate change imperative is driving regulators towards Passive House levels of efficiency. However, it will take more than the climate change imperative to overcome industry and consumer inertia. The buildings of tomorrow must be better than those of today, offering the multiple benefits Passive House buildings are known for. To achieve market transformation, both public policy and consumer demand for better buildings must be engaged. Such better buildings offer the opportunity to achieve the UN Sustainable Development Goals relating to buildings. Those goals encompass not only energy efficiency, but the co-benefits described above.

The scientists on the panel will address the importance, and economic value, of the co-benefits of high performance buildings and how those benefits can be used to support the adoption of policies requiring such performance. The representatives of New York City and Vancouver will describe how they target such performance levels and are successfully transforming their built environments.

Presentation 2: Measuring productivity impact of energy efficiency measures, Souran Chatterjee, Central European University

Energy efficiency improvement actions do more than reduce CO2 emissions. Recent studies have shown that such measures yield a wider set of impacts for the economy and society. Ideally, a decision on energy-related investment or policy should be taken based on potential full cost and benefits (both anticipated and unanticipated) associated with the policy or investment, however this practically never takes place due to the absence of a mature quantification methodology of these multiple impacts. There are two key rationales behind not including all the benefits:

1. Most of the indirect benefits arise from a sustainable energy policy and thus are ignored unknowingly.
2. Not all indirect benefits can be or have been quantified and hence are usually not included in a decision-making process.

The exclusion of the multiple impacts of energy efficiency underestimates the benefits of energy efficiency. Productivity impact is one such crucial impact which has not yet been clearly defined as a multiple impact. Also, the linkages between different energy efficiency actions and productivity impacts are not clearly described in the literature. As a result, there is no standard metric to quantify different aspects of productivity resulting from the improved energy efficiency actions. Thus, the research being undertaken by the presenter defines three main aspects of labour productivity resulting from building-related energy efficiency improvement actions:

1. **The amount of active time available** for productive work. This can be affected, for instance, by being sick - more precisely absenteeism and presentism, which reduces the amount of active time available.
2. **Workforce performance within a certain time frame.** Indoor air quality and thermal comfort of tertiary buildings can improve the mental wellbeing of the entire workforce and this can result in more productive time for work.
3. **Earning ability/value added per unit of time worked.** This can be affected, for instance, parental and child health problems negatively impact the child's education and long-term earnings.

This study takes one improved energy efficiency action, namely HVAC system (Heating ventilation and air conditioning system) with airtight building envelope to show the effects on different aspects of labour productivity.

This study proposes a systematic methodological framework which can quantify these three metrics of productivity gains rigorously by assessing the difference between the two COMBI[33] scenarios (reference and efficiency scenario).

The authors[34] have calculated the productivity impacts of two energy efficiency actions (HVAC system with airtight building envelope and modal shift towards active transportation) for each EU 28-member state. The results show that in Europe, on an average 4.5 active days/person per annum can be gained by having more deeply retrofitted buildings, passive houses, and nearly zero energy buildings. In addition, by improving the mental well-being on an average a European country can gain around 15.7 million euro/year. Moreover, on an average 1961 healthy life years per million population per annum can be gained by avoiding indoor exposure.

In addition, results-related other multiple impacts[35] of building energy efficiency measures such as GDP growth, employment and excess winter death avoided are also presented.

Presentation 3: Beyond Efficiency. Developments in evaluating the impact of climate change on the future city, Dr. Adam Rysanek, University of British Columbia

Dr. Rysanek's academic work has focused on City Energy Modeling with recent conversations on this subject focusing on Urban Planning issues rather than the national scale questions. His research is now centred on the effects of increased atmospheric CO_2 concentrations on indoor environmental quality (IEQ). The Singapore ETH Centre has been studying the effects of increased atmospheric CO_2 on indoor environmental quality (IEQ).

In a ground-breaking study (Allen et al) CO_2 was shown to directly correlate to cognitive functioning. Cognitive tests related to CO_2 levels demonstrated a 900 ppm increase in indoor CO_2 concentrations reduce cognitive function by 50%. As CO2 levels are directly related to outdoor levels, and building ventilation rates correlate to building energy demand, is it possible the economic risk of higher indoor CO_2 is similar to the direct cost of climate change on future building energy use? Preliminary results (unreviewed) indicate the annual cost of climate change from lost productivity exceeds the

[33] The COMBI project quantifies the multiple non-energy benefits of energy efficiency in the EU-28 area. It gathers existing approaches and evidence from the EU area and develops modelling approaches for impacts. COMBI is financed by the EU-Horizon 2020 research programme (call EE-12). For more information, please see COMBI website: https://combi-project.eu/

[34] Souran Chatterjee and Diana Ürge-Vorsat

[35] Results related to macro-economic impacts and avoided winter death are measured in project COMBI (https://combi-project.eu/) by Copenhagen Economics and University of Manchester.

cost of the increased cooling energy used to maintain indoor thermal comfort. In addition, the cost of increased ventilation rates required to maintain indoor CO_2 levels below 1100ppm is similar to the cost of increased energy use to maintain indoor thermal comfort through air conditioning.

Presentation 4: A Market Transformation Approach to Public Policy for Zero Emissions Buildings, Sean Pander, City of Vancouver

The City of Vancouver has two bold visions: (1) Reduce all GHG emissions from buildings by 20% by 2020. This was achieved in 2015, so a more ambitious strategy was required. (2) All newly permitted buildings must have no operation GHG emissions by 2030 or earlier.

Vancouver is initially focussing on new construction. Although new construction only accounts for 1-2% of total floor area per year the cumulative effect of this new construction combined with the demolition of older buildings means that more than 50% of the built area expected in Vancouver by 2050 is yet to be constructed. In addition, new construction is where a city has the most regulatory authority and is the point in a building's lifecycle where money is being made. Most importantly, it's where there are the fewest technical and societal barriers to high performance. By tackling new buildings, the retrofit problem of the future becomes much smaller, and industry develops the skills and components to tackle retrofits, which tend to be more challenging.

Vancouver's Zero Emissions Building Plan has 3 elements: absolute limits on heat loss and GHG emissions stepping down to zero emissions by or before 2030; demonstrate early leadership by requiring city buildings and incenting private developers to build to near zero emissions today; and build industry capacity by investing in knowledge sharing, barrier removal, and compliance tools. Vancouver requires innovation and low carbon leadership as a condition for allowing additional density or a change in use (rezoning). The 2016 Green Building Policy for Rezoning reduced GHG emissions 70% relative to the building code & had strong development industry support. Staff are now recommending those policy requirements become the regulatory minimum requirement in 2021.

In the past, reliance on the ASHRAE 90.1 standard lead to complex mechanical solutions that failed to deliver the required results. A different regulatory structure was therefore required. Targeting specific building performance outcomes, with a clear focus on envelope based solutions and simple mechanical systems to provide reliable results and robust buildings. Iin addition, it yields multiple other benefits such as improved indoor air quality, occupant comfort, and maximizes related local economic development.

The rapid evolution of building codes requires development of near zero emissions buildings today, driving design & construction innovation, resolving regulatory barriers, catalyzing the supply chain and lowering costs. New City facilities must now be built to Passive House or alternate near zero emissions standard with 9 City facilities starting design or construction to Passive House in 2018. At the end of 2015 Vancouver had one single family Passive House building completed. Only 18-24 months later, 20% of the city's large-scale development applications were for certified Passive House projects, representing over 110,000 sq. m. of floor space.

To support industry capacity building, the city has also established the Zero Emission Building Centre of Excellence to facilitate workshops, dialogues, courses, peer-to-peer knowledge sharing, curated research library of best practices and identifying trends.

Vancouver has worked to identify science based principles and adopted policies incorporating the metrics and indicators building science and experience demonstrate are required to achieve the desired outcomes. By implementing policies grounded in that way our city has succeeded in achieving interim emission reduction targets and anticipates meeting longer term targets. Importantly, a perceptible shift towards a culture of high performance in the design and construction sector is taking place, laying the foundation for future innovation and excellence.

With this transition underway, the importance of embodied emissions is rapidly increasing. With the implementation of the first steps of the Zero Emissions Building Plan, the embodied emissions of new concrete buildings will be equivalent to 60 years of operational emissions. Significant additional research and data is required on embodied emissions, low emission materials, and different approaches to construction if regulations are to be developed to address these emissions soon.

Presentation 5: Concrete Jungle Where Dreams are Made, John Lee, New York City Mayors Office

New York City (NYC) has been studying and tracking GHGs for the last 10 years. The main thrust of GHG emissions in NYC is through the 80% reduction by 2050 or "80 X 50" project.

The majority of NYC's emissions come from buildings and 40% of building emissions come from grid electricity, largely generated with natural gas.

Unlike the City of Vancouver, in 2050 90% of the built form will still consist of buildings that are already standing today, making NYC's problem largely a retrofitting problem. The majority of building GHG Emissions (by end use) are from space heating a water heating, leading to a focus on envelope performance. The hot, humid summers in NYC and the cold winters make efficiency in both heating and cooling important. Since Hurricane Sandy struck the city in 2012, resiliency has been an important consideration to ensure residents are able to remain in buildings without an energy supply. Highly energy efficient buildings maintain a more comfortable indoor environment during grid service interuptions.

NYC has taken a leadership role to reduce building emissions by adopting specific policies and initiatives. As with the City of Vancouver, NYC has looked for science based methodologies proven to have achieved the desired results. By 2018 City-owned new buildings must be designed to very-low energy standard such as Passive House and by 2025 private-sector new buildings must be designed to that very-low energy standard. NYC established a Centre of Excellence (BEEx) to connect the city's real estate and design communities to energy and lighting efficiency solutions through education, exhibitions, technology demonstrations and research.

Given the dominance of existing buildings in NYC, large scale retrofits of the existing built form are necessary to achieve GHG targets. We know reductions of 40-60% in energy use are possible using existing technologies and strategies. Deep energy retrofits are more challenging than high performance new buildings, but the design and construction community is showing the way with early projects.

The collective impact of the policies adopted in NYC has been to shift the conversation, with large and small Passive House high performance buildings, both new and existing, coming forward in increasing volume. Integral to the process of improving buildings in NYC is ensuring the city continues to thrive, has an inclusive, equitable economy with opportunities for residents to live with dignity and security. Through this process, and capitalizing on the multiple benefits of high performance buildings, NYC plans to become the most sustainable big city in the world, a global leader against climate change and ready to withstand and emerge stronger from the impacts of climate change and other 21st century threats.

Flooded area in Pathanamthitta,Kerala, India © Shutterstock

SESSION TITLE: CLIMATE CHANGE AND EQUITY IN THE CONTEXT OF SDGS - TUESDAY MARCH 6TH

Session Convener:
Swati Janu

Session Participants:
Darshini Mahadevia, Laura Flórez, Karim Elgendy, Roger Cremades, Swati Janu

Session Shepherd:
Caterina Sarfatti

Student Scientist:
Ashley Roszko

Parallel session summary

Session Aims and Format

The session brought together academics and practitioners from Latin America, Asia, Europe and the Arab region to discuss inclusive and sustainable approaches to mitigate as well as to adapt to climate change. In a panel format of individual presentations followed by a discussion, the presentations discussed the unique environmental, economic and social conditions of their respective regions, the development needs of developing economies and approaches to building resilience of vulnerable communities.

With its focus on the built environment and urban planning through the interdisciplinary lens of science and on-the-ground work and research, the session aimed to influence policy on housing, land use and urban development. Every presentation offered a solution or a new approach for the future through new planning tools, climate smart urban forms, climate responsive frameworks and innovative approaches to inclusive low carbon development pathways. The Question and Answer session began with the presenters providing responses regarding the link between climate action, equity and the United Nations Sustainable Development Goals (SDGs) by discussing the challenges in their spheres of work with relevance to the theme. The discussion with the audience touched on the need to work on non-standardized approaches to contextualized challenges and distinct urban scenarios.

State-of-the-art of the field

The session looked at how cities could be transformed to mitigate and adapt to climate change and related risks while taking into account socio-economic inequalities and the needs of vulnerable urban communities. It explored the intersection between strategies for urban sustainability and resilience by looking at the role of urban and environmental planning in climate change adaptation and mitigation measures. The session built on how to bring about large-scale adaptation and mitigation models with practitioner led case studies from informally built urban settlements. Even though the selected presentations varied widely in their themes, a common thread was found in terms of their focus on the built environment, the use of urban planning and proposals of innovative approaches.

Darshini Mahadevia's presentation on 'Mainstreaming climate change mitigation in equitable urban transformations: Insights from Indian cities,' discussed the challenges faced by Indian cities in addressing the New Urban Agenda of development deficits, Paris Agreement and the SDGs together. Mahadevia highlighted a variety of trade-offs and synergies between urban planning actions and the SDGs, from the point of view of socio-economic inequities. For example, when mitigation pathways are pursued, this has sometimes led to evictions of the urban poor in Indian cities. She presented an integrated framework that could be embedded in urban planning to make planning more holistic and aligned with the SDGs.

Roger Cremades' presentation on 'Computing complex climate-smart urban forms' explored how to overcome the knowledge gap expressed in the words "little understanding of how different aspects of urban form interact and affect emissions" by Seto et al. (2014) in the 5th Assessment Report of the IPCC. This was done with the help of a mathematical model that demonstrated how urban growth and transformation can be planned in order to achieve low emissions from transportation while considering climate-related risks. However, to implement this in practice, traditional city planning frameworks would need to be altered. Cremades highlighted how different cities can be sustainably planned with co-benefits between mitigation of emissions and adaptation to climate risks.

Laura Flórez's presentation on 'To tree or not to tree: Urban heat island vs. air pollution mitigation strategies in a tropical mountain city (Colombia),' discussed how urban design could lead to reduced emissions through a low-carbon transportation plan. Her study was based in Medellin, a city that has undergone several efforts for inclusive urban planning and climate mitigation responses. Medellin has a well-integrated public transit system with one of its highlights beings the linking of the favelas on the hills and bringing about inclusive mitigation efforts. Flórez demonstrated the dilemma of how urban planning interventions, that could lead to lowered emissions and also bring about economic equity, could be at odds with the motivations of environmentalists and citizens. She highlighted the need for education and engagement of citizens, leaders and policymakers for equitable solutions to achieve SDGs.

Karim Elgendy's presentation on 'Urban resilience as a transformative tool for sustainable cities in the Arab region' highlighted how planning for resilience can be leveraged to also make cities more sustainable. Elgendy mentioned that standard urban resilience models in the Arab region, which usually focus on recovering and restore the functionality of regional cities following shocks and stresses, might restore them to an unsustainable state. He also pointed out how steady-state notions of urban sustainability are unrealistic in a region susceptible to socio-economic and environmental stresses (e.g. refugee migration, extreme weather events, and military conflicts). He called for bespoke strategies to build resilient urban systems for the cities of the Arab region that could also jump start their transition to higher sustainability (e.g. diversification energy generation systems can include sustainable systems).

Swati Janu's presentation on 'Building resilience of informal settlements' discussed the need to identify informal settlements as self-built affordable housing which needs to be facilitated instead of razed, especially in an emerging economy like India which faces a huge affordable housing deficit today. Janu called for more equitable planning approaches in the Indian government's policies and response to climate change. Her presentation demonstrated how the sustainability of large scale, high rise social housing projects by the government ranked much lower than other possible models with compact urban forms and walkable, mixed land use neighbourhoods drawing from the socio-urban fabric of informal settlements. She discussed the urgent need to build resilience of ongoing, incrementally built housing through top-down policy measures or bottom-up innovative approaches that could incorporate ICTs.

A common theme underlying all the presentations was how conventional urban planning approaches need to be transformed to meet the needs of cities with marginalized populations through sustainable practices, as well as adaptation and mitigation efforts.

The presenters discussed how they could better align with SDGs (Mahadevia), issues of equity (Mahadevia & Janu), and lead to smarter city forms for more sustainable, mitigative and potentially adaptive practices (Cremades & Janu). The presentations also brought out the inherent conflicts preventing the adoption of sustainable and resilient measures. In particular, Flórez's presentation showed the complexities of urban planning and development of mitigation and adaptation strategies, with their collision with public perception and environmentally driven civic movements. Similarly, Mahadevia and Janu presented the conflict between the needs of the marginalized communities in Indian cities and the government's planning and policy responses which often inflict violence on the poor in the form of forced evictions.

It is important to note that the topic of inequity is ignored by Revi et al. (2014) in the 5th Assessment Report of the IPCC in the table of contents and the topics of poverty and inequality are not mentioned in the chapters enough. Only Box 8-1 on Recent Literature on Urban Adaptation in Low- and Middle-Income Nations captures some of the authors' reflections on the difficulties of urban planning in the global South, but there is not any clear message on how to better address the difficulties of inequity in urban planning. Seto et al. (2014) similarly overlook topics on inequality in the table of contents, however it mentions that "it is in developing and least developed country cities where opportunities for integrated infrastructure and land-use planning may be most effective at shaping development and emissions trajectories" (see box 12.7 in: Seto et al., 2014). Thus, the relevance of the topic, although not fully addressed, is indeed highlighted. The discussion towards the end of the session brought to light that urban informality may no longer be a phenomenon of the global South or emerging economies, with newer forms of informality also originating in the cities of global North with growing inequalities and refugee influx which need to be noted as well.

Planning for urban growth and transformation that could minimize energy consumption for housing and transportation is key for climate goals. However, there is no consensus on how deep the urban transformation should be. Added to this in the lack of consolidated and uniform data sets on cities, especially on the role played by informal settlements in terms of their emissions. Janu's presentation postulated that these self-built settlements are least responsible for climate change due to their low carbon emission lifestyles while they are the most vulnerable due to their weaker socio-economic backgrounds and lack of safety nets. Other challenges facing cities are resource scarcity in the face of rapid in-migration (rural-urban/ international) and influx of refugees. Elgendy highlighted the challenges of managing urban transformation in conflict-ridden security environments on one hand and impending environmental challenges such as desertification, on the other.

The session discussed the need to identify key actions cities need to take to be able to distribute benefits of climate action in a more equitable way, with a focus on SDG 11: Making cities inclusive, safe, resilient and sustainable. New planning frameworks and tools were put forward by Mahadevia, Elgendy and Cremades while Janu discussed possible bottom up civic initiatives and successful policy approaches. Flórez further highlighted the need for dialogue with citizens and need for participatory processes in urban planning. To address SDGs in the context of equity, it needs to be noted that while looking at solutions for clean, sustainable energy - policies also need to look at access to participatory processes, access to information, access to energy, access to sustainable transport, access to energy efficient and affordable housing.

Towards a research agenda

A variety of policy and research gaps were identified through the session which pointed out the need for further research on the role of urban planning in transforming cities to be more sustainable and adaptive without an unequal distribution of climate risks and benefits.

- Research on evidence of inter-relationships between urban planning, SDGs and climate change adaptation and mitigation within the context of high levels of informality in global South needs to be further built on. Understanding informal urban systems is extremely difficult through the conventional lens of formal regulatory frameworks, and requires a more bottom-up, innovative approach to monitor and support informal settlements.

- Further case studies of cities in the global South are necessary to document synergies of climate actions and their wider sustainable development benefits and a documentation of trade-offs including lock-ins, costs and conflict with SDGs.

- Data shortages and very diverse data sets at the city level act as a major barrier to the science community in understanding issues of urban sustainability and urban resilience.

- The science, research and practitioners' communities can benefit from their collaborations to develop easy-to-use methodologies and frameworks to assess and measure the distribution of the wider impacts of climate action in cities. The Urban Climate Actions Impact Framework, developed by C40 Cities and Ramboll, in partnership with 10+ international organizations offers one way ahead.

- There is a need, especially in emerging economies, to have spatially explicit data of riverine and coastal flood risks along with calculations of projected sea level rise for different climate scenarios.

- A better understanding of resource flows into and from cities (critical to urban resilience and sustainability) can be achieved through modelling of energy, water, material and waste flows.

- Use of technology, especially phone based ICTs, can be especially efficient to disseminate information and empower, while cutting down delivery costs of solutions.

- A stronger understanding of what increasing access to climate action means in cities and how improved access benefits distribution is needed.

- Peer-to peer learning and knowledge sharing should be integral to the kind of platform provided by IPCC. A partnership based platform can be up-scaled to both large cities and as a tool for comparing multiple cities. The experience of the many city networks around the world are testament to the integration of policy and practice and to peer-to-peer communication. Models showing benefits between environmental and economic aspects of cities could trigger major transformative action.

SESSION TITLE: **ENERGY SYSTEMS AND BUILDINGS** - TUESDAY MARCH 6TH

Session Participants:
Ian McVey, Project Manager (Ontario Climate Consortium Secretariat, and co-director of the Community Energy Knowledge Action Partnership), **Kang Kang (KK) Tong** (Humphrey School of Public Affairs, University of Minnesota, USA), **Mohit Arora** (Singapore University of Technology and Design), **Peter Cox** (President of ISCES+CC, NSCES+CC) ICOMOS International), **Dr. Catherine Bale** (School of Chemical and Process Engineering and School of Earth and Environment, University of Leeds, UK), **Dr. Radhika Khosla** (Centre for Policy Research, New Delhi; University of Oxford, UK), **Nafisa Mahbub** (PhD Candidate, Sustainable energy Laboratory, Mechanical Engineering, University of Alberta, Canada)

Session discussants:
Aisa Tobing (Jakarta Research Council), **Paolo Bertoldi** (Senior Expert, Energy Efficiency and Renewables, Joint Research Centre), **Peter Love** (Chair, Ontario Climate Consortium), **Hassan Shahrukh** (Energy Management Analyst, Office of energy Management, City of Edmonton)

Parallel session summary

Authors:
McVey, Ian - Ontario Climate Consortium Secretariat, and co-director of the Community Energy Knowledge Action Partnership

Session Aims and Format

While cost-effective technologies are available to transform the buildings sector to be efficient and low-carbon, a wide range of barriers related to market, behaviors, and political institutions create a complex and difficult context to adopt these technologies. In addition, buildings and their energy supply are embedded in wider urban systems. Overcoming lock-in of existing infrastructure should consider this interdependency with other subsystems, which makes the transformation even more challenging. Thus, integrative city-scale solutions are needed to address the motivations of multiple levels of government, and mobilize a diverse range of stakeholders within the city. This calls for a new role for local governments to integrate both vertically with higher orders of government, as well as horizontally with key private and institutional building stakeholders within the city. This session featured a panel presentation that highlighted barriers hindering progress in the buildings sector, and explored the potential roles for local government working in cross-sectoral partnerships to mobilize innovative governance solutions across scales to help stimulate accelerated uptake of low carbon technologies and behaviors.

State-of-the art of the field

According to the IPCC AR5, buildings are responsible for a ⅓ of total global final energy use, and of energy-related GHG emissions. This energy use and related emissions may double or potentially even triple by mid-century due to several key trends, including population growth, migration to cities, household size changes, and increasing levels of wealth and lifestyle changes.[36] Cost-effective technology and best practices exist that can reduce future global final energy demand to be constant with, or even below, today's levels.[37] Strong barriers hinder the market uptake of cost-effective opportunities, including market barriers, behavioral barriers, and political institutional barriers.

Understanding how to overcome these strong barriers first requires an appreciation of buildings as part of complex urban energy systems that are both social and technical in nature. As complex systems, it is important to think of urban energy systems as comprising agents and networks at different scales of governance, from national to local. They are dynamic systems that have capacity for co-evolution between social and technical aspects, as well as for learning and adaptation.[38] A common framework for understanding urban energy systems can help to understand the scope and boundary of the urban energy system, and help represent interdependencies which might help in avoiding unintended consequences from policy interventions. Furthermore, such a framework can help stakeholders visualize the system, which can help in participatory engagement with cross-sectoral stakeholders to identify opportunities for positive lock-in of low carbon attributes. Participatory visioning – enabled through agent-based modelling techniques that bring in a diverse range of local urban actors to co-create solution pathways can be an effective way of overcoming socio-political and market barriers/inertia in complex urban energy systems.

Early and continued stakeholder engagement in model development can help to build legitimacy and trust, as well as validate assumptions that underpin the model. Participatory modelling (such as Companion Modelling with agent-based models) enabled participants to envisage system-wide interdependencies and possible holistic policy solutions, leading to options for action towards climate change mitigation.[39]

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36 Lucon O., D. Ürge-Vorsatz, et al. 2014: Buildings. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Section 9.1.

37 ibid. Section 9.2 & 9.3.

38 BALE, C. S. E., VARGA, L. & FOXON, T. J. 2015. Energy and complexity: New ways forward. Applied Energy, 138, 150-159. http://dx.doi.org/10.1016/j.apenergy.2014.10.057

39 VOINOV, A. & BOUSQUET, F. 2010. Modelling with stakeholders. Environmental Modelling & Software, 25, 1268-1281.

On the building energy supply side, the conventional approach of buildings as sites of consumption from a centralized grid source is shifting to include more localized infrastructure supply opportunities, such as district thermal energy, electricity microgrids with distributed generation and storage, and smart energy systems[40]. This shift opens up more opportunities for city scale energy systems to have more local stakeholder participation, as well as opportunities to deploy technologies that can reduce city GHG emissions[41],[42],[43], and build energy system resilience to extreme weather events[44]. Although these localized energy systems can play a significant role in deep-decarbonization[45], how to change these existing heating or cooling infrastructure is a key challenge to capture the potential climate mitigation and adaptation benefits. The localized energy systems are one type of sociotechnical systems, and different theoretical frameworks examined the dynamics of sociotechnical system transitions[46],[47]. These frameworks were built upon past and present experiences[48],[49] with less emphasize on how to facilitate future changes in urban infrastructure.

Research on district energy system transitions in the United State took a future development perspective to understand the ongoing and future transitions of district energy systems. Furthermore, this research implemented a co-evolutionary framework[50] in analyzing what factors can support or create barriers for future changes. Data of this research are 14 semi-structured interviews with professionals working in district energy system in the United State. It is found that DES systems in the US is slowly moving towards hot water distribution with low- or zero-carbon energy sources, with buildings having high energy efficiency. Cities and universities, who realized the carbon reduction and resilience benefit of DES, are leading the transitions in the US. From co-evolutionary perspective, DES operators should make strategies on building close relationship with customers and closely monitor new technology development. Furthermore, low-carbon transitions of DES need resources and support from multiscale governments. At the local level, policies encourage dense development and low-carbon heating/cooling means will contribute to the DES's development. At the state or federal level, technical support program can help cities re-examining their energy systems for better choices. Financially, more projects, to reduce the up-front cost for capital investment in energy development, will support the transition significantly, because the economic equation of low-carbon DES is more capital investment upfront and less maintenance and operational cost. Generally, DES is a localized energy infrastructure, while the enabling factors for the transition are embedded at multiple scale policies.

On the demand-side, this session presented state-of-the art knowledge of residential energy services and energy behaviors emerging from cities in India. We learned about the emerging energy challenge in India due to urban migration and development needs, which have lock-in implications that are both national and global in scope.[51] [52] We currently lack sufficient data to understand the nature and scale of this challenge (i.e. future residential energy use and emissions trajectories), or the impact that well-designed policy interventions can have on this trajectory. This study presented provided new information on how the spectrum of residential energy users, from social housing to the wealthiest parts of the country, are demanding energy services, and the policy implications of targeted interventions on the basis of this information, particularly for cooling.[53] We also learnt that in spite of the trends of energy services use in households, there is immense granularity in energy use behaviors across homes which stems from energy use

40 Lund, H. (2018). "Renewable Heating Strategies and their Consequences for Storage and Grid Infrastructures Comparing a Smart Grid to a Smart Energy Systems Approach." Energy.

41 Ramaswami, A., Tong, K., Fang, A., Lal, R., Nagpure, A., Li, Y., Yu, Y., Jiang, D., Shen, H., Russell, A.G., Shi, L., Chertow, M., Wang, Y., Wang, S., 2017. Urban Cross-Sector Actions for Carbon Mitigation with Local Health Co-Benefits in China. Nature Clim. Change 7(10), 736-742.

42 Connolly, D., Lund, H., Mathiesen, B.V., Werner, S., Möller, B., Persson, U., Boermans, T., Trier, D., Østergaard, P.A., Nielsen, S., 2014. Heat Roadmap Europe: Combining district heating with heat savings to decarbonise the EU energy system. Energy Policy 65, 475-489.

43 Tong, K., Andrew, F., Huajun, Y., Yang, L., Lei, S., Yangjun, W., Shuxiao, W., Anu, R., 2017. Estimating the potential for industrial waste heat reutilization in urban district energy systems: method development and implementation in two Chinese provinces. Environmental Research Letters 12(12), 125008.

44 UNEP, 2015. District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy. United Nations Environment Programme, Kenya.

45 Ramaswami, A., Tong, K., Fang, A., Lal, R., Nagpure, A., Li, Y., Yu, Y., Jiang, D., Shen, H., Russell, A.G., Shi, L., Chertow, M., Wang, Y., Wang, S., 2017. Urban Cross-Sector Actions for Carbon Mitigation with Local Health Co-Benefits in China. Nature Clim. Change 7(10), 736-742.

46 Geels, F.W., Sovacool, B.K., Schwanen, T., Sorrell, S., 2017. Sociotechnical transitions for deep decarbonization. Science 357(6357), 1242.

47 Loorbach, D., Niki Frantzeskaki, Avelino, F., 2017. Sustainability Transitions Research: Transforming Science and Practice for Societal Change. Annual Review of Environment and Resources 42(1), null.

48 Geels, F. W., et al. (2016). "Bridging analytical approaches for low-carbon transitions." Nature Clim. Change 6(6): 576-583.

49 Turnheim, B., et al. (2015). "Evaluating sustainability transitions pathways: Bridging analytical approaches to address governance challenges." Global Environmental Change 35: 239-253.

50 Foxon, T.J., 2011. A coevolutionary framework for analysing a transition to a sustainable low carbon economy. Ecological Economics 70(12), 2258-2267.

51 Seto, K. C. et al. 2016. Ann. Rev. Environ. Res. Vol. 41, pp 425–452.

52 Ürge-Vorsatz, D. et al. 2018. "Locking in positive climate responses in cities" Nature Climate Change Vol 8, pp 174–177.

53 Radhika Khosla and Aditya Chunekar (Eds.) (2017). Plugging In: A Collection of Insights on Electricity Use in Indian Homes. Research Report. Centre for Policy Research, New Delhi and Prayas (Energy Group), Pune.

patterns and lifestyles.[54] We understand that demand-side interventions can have a significant impact on household decisions and uptake of low carbon technologies, but the window to accomplish this is small, as the bulk of investment in infrastructures and subsequent behaviors will take place in the next two decades.[55]

This session also looked at the demand-side of energy systems from a technical perspective, addressing the challenge of retrofitting existing (heritage) buildings. In the session we learned that present schemes for retrofitting existing heritage buildings are not delivering significant energy performance improvements and in fact some of the interventions being installed will cause serious damage to our older, historic and traditional buildings. Heritage building retrofit packages recommended by incentive schemes are not based on actual knowledge on the building typologies or real-world modelling of retrofit performance. There are now efforts underway to gather data on real-world performance of energy retrofits to heritage buildings, and understand the potential to achieve net zero or near zero energy performance in this segment of the building sector around the globe.

Finally, this session included a presentation that explored building demolition and materials re-use in the Singaporean context. Building materials themselves represent a significant amount of embodied energy and carbon, up to 20% of the total lifecycle building energy consumption. Current building practices in Singapore and elsewhere around the world are leading to premature demolition of buildings (i.e. before the useful life of the structure is complete). Reducing premature demolition, and ensuring beneficial re-use of building materials when demolition happens, are two important objectives of city-scale climate policy. We need a better understanding of the role that local governments can play in the context of multi-level governance frameworks to enable a change in building construction practices to address this issue. We need to educate the industry and in particular planners on the important embedded energy within the existing built heritage and where adaptation, reuse and re-purposing existing buildings is essential in cutting the worlds carbon footprint.

Session participants agreed that local governments have a critical role to play in enabling low carbon and climate resilient transitions in the urban building energy systems sector. Particularly important is the role of local government in creating or leading cross-sectoral partnerships with building sector stakeholders - on both the demand and supply side - to mobilize and motivate transformative action. Rather than being a government-led initiative, strategic partnerships can lead to more robust outcomes from both a technical and social perspective.

Towards a research agenda

What are strategic roles for local governments in the context of vertical (multi-level) governance, and horizontal (intra-city/regional) governance contexts? How can local government enable participatory models of engagement that bring public, private and institutional stakeholders together to empower them to co-create and implement transformative action frameworks in the building sector?

Research is needed to understand how to design and implement end-use/demand-side energy interventions to lock-in efficient low carbon consumption trajectories. What impact can such end-use interventions have? How can that impact be optimized?

We need enhanced understanding of buildings as key nodes within city energy systems – the interaction between buildings and wider energy infrastructure systems – and how policy, governance institutions, novel business model, and technological interventions can best be combined to enable low carbon (socio-technical) transitions.

How can we best design and utilize data/analytical tools to enable effective city-scale decision-making, accountability, and stakeholder engagement (participatory visioning?) around transformative action?

The issue is not data/analytical tools themselves, but how they are embedded into decision-making tools. There is a need to co-create tools with user-groups so that they have more trust in the outputs of models and analytical exercises. Related to this, there needs to be transparency around assumptions with modelling - implicit assumptions that aren't stated can reduce trust. Involve communities in developing the assumptions that go into modelling exercises.

Lack of building obsolescence data at city scale, though most of the cities have such data but it is never publicly available. If city authority could provide such data, scale of secondary resources availability could directly be linked with resources demand to support suburban-rural population which can help realize multiple SDG's. Annual resources consumption data for building sector can also help achieve better forecast.

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54 Felix Creutzig, Blanca Fernandez, Helmut Haber, Radhika Khosla, Yacob Mulugetta and Karen C. Seto. 2016. "Beyond technology: Demand-side Solutions to Climate Change Mitigation." Annual Review of Environment and Resources Vol. 41, pp 173-198.

55 Radhika Khosla, Ambuj Sagar and Ajay Mathur. 2017. "Multilevel Climate Governance and Technology Deployment: A View from India's Buildings Sector," Environmental Policy and Governance Vol. 27, Issue 2, pp 149-162.

Online and in-person professional development/training courses for municipal practitioners that translate academic research into practical training modules for city planners and program implementers

Open-source analytical tools (e.g. spatial, energy economy modelling), with accompanying guidance and peer support to enable usage by municipal practitioners. Customizable to local city contexts.

Facilitated partnerships between local governments and local academic institutions (i.e. in the same geography) to create internship opportunities (for students) and fellowship opportunities (for practitioners) in order to build capacity for implementation and innovation

Grant programs specifically designed to enable applied research at the science-policy-practice interface. Grant programs to enable embedded academic expertise within local governments.

Increased use in academia of participatory modelling methods to increase and share knowledge of systems and identify solutions, incorporating stakeholder knowledge and preferences to improve legitimacy of models and policy interventions, and develop a common understanding.

Flooded Flooded water on street -Vietnam © Shutterstock

SESSION TITLE: GOVERNING CLIMATE CHANGE IN COMPLEX URBAN SETTINGS: RESILIENCE THROUGH SOCIAL INNOVATION - TUESDAY MARCH 6TH

Session Convener:
Anna Taylor (University of Cape Town, SA)

Session Participants:
Thomas Heyd (University of Victoria); **Joanne Douwes** (eThekwini Municipality, Durban); **Leslie Mabon** (Robert Gordon University); **Thomas Bowman** (Bowman Change Inc.); **Emily Prestwood** (University of the West of England)

Session Shepherd:
William Solecki

Session Student Scientist:
Shingirai Mandizadza

Parallel session summary

SESSION:
Governing Climate Change in Complex Urban Settings: Resilience through Social Innovation

Authors:
Anna Taylor, Thomas Heyd, Joanne Douwes, Leslie Mabon, Thomas Bowman, Emily Prestwood and Shingirai Mandizadza

Session Aims and Format

The session aimed to explore the kinds of engagements, relationships and social innovations needed to understand and strengthen climate resilience and transformative change in cities, especially those grappling with inequality and marginalization. Drawing on research undertaken in the cities of Aberdeen, Bristol, Cape Town, Durban, Harare, Iwaki, Long Beach, Lusaka, São Paulo, Victoria, Windhoek and Yubari, the session aimed to identify research challenges and gaps related to communicating, engaging and acting across organizations, sectors and social groupings, i.e. boundary spanning, to address complex urban climate change problems in innovative and transformative ways.

The format of the session was in 3 parts. The first was a round of 5-minute inputs from each of the speakers (strictly adhered to by all presenting 20 slides set to auto-advance every 15 seconds). The second part was a panel discussion addressing the following four questions: (1) What constitutes the boundaries that need to be spanned?; (2) What is innovative about how knowledge and action is being connected in the contexts you are working in, and what do you see as the leading edge where new or more innovation will be needed to progress the work?; (3) How does power and politics feature in your work and in what ways are marginalized constituencies empowered to have a greater stake in decisions at the city scale?; (4) If it takes collective action and partnerships to transform cities, what does it take to be a transformative partner? The third part invited inputs, questions and comments from the audience.

State-of-Knowledge Summary

Introduction

The session was premised on the need for shared knowledge and sustained action between multiple actors to bring about urban transformations to urgently address climate change, while recognizing significant inequalities in the power and capabilities of these actors. The session dealt with issues of: transformative partnerships; marginalization; conflicting values and rationalities; positionality; knowledge co-production; innovation and collective action in building urban climate resilience and carbon neutrality. The concept and practices of boundary spanning - building relations, interconnections and interdependencies across sectors and margins – was explored as a means of building and linking knowledge and action to address complex climate change challenges in a number of urban contexts.

Presentations

Heyd spoke of the resilience being built in marginalized communities through initiatives built on values of solidarity and inclusivity (Gutberlet et al., 2013). The key to resilience is general adaptability to a diversity of foreseeable, as well as to surprising or unforeseen, disturbances. While financial and physical resources are crucial to ensure this adaptability, social and cultural capital, deeply ingrained in the values and beliefs of a community, can be a source of resilience. One example of this is informal waste-picking organizations in urban Brazil that pioneer inclusive forms of organizing, managing and governing waste collection, separation and commercialization, benefitting marginalized communities through empowerment, greater economic inclusion, building environmental awareness and lowering environmental impacts, including Greenhouse Gas emissions (Gutberlet and Heyd, forthcoming; King and Gutberlet, 2013). A second example is how the traditional indigenous knowledge and identity-giving values of the T'Sou-ke First Nation are being harnessed to envision and transform their communities into sustainable living spaces, including the largest solar photovoltaic installation in British Columbia (approx. 550 solar panels with a capacity of 75 kilowatts) and greenhouse gardens that supply their community with fresh vegetables.

Douwes challenged notions of transformation, interrogating climate adaptation work undertaken in the city of Durban, South Africa, to explore: what constitutes transformation in environmental governance; what 'metrics' might be used to assess whether action is transformative; and what facilitates and inhibits transformation. Her findings are that transformation entails completely altering a system to address underlying causes of risk and deliver outcomes that are sustainable, equitable and just. To completely alter a system to be more sustainable, equitable and just requires being intentional about working with and for those currently marginalized and requires working across numerous scales: spatial; governance (from local communities to international arenas) and temporal scales.

Lessons from Durban show that to work in such intentional and cross-scalar ways requires navigating complexity, making meaningful connections, understanding context, (re) framing agendas, fostering partnerships, creating and utilizing windows of opportunity, critical reflection and tolerance of discomfort. Both initial leaders and supporting champions are needed, who are brave, connected and skilled. Spaces and networks – both formal and informal – for creativity, innovation, experimentation, collaboration, sharing and learning are essential. Transformation requires spanning and often breaking down existing boundaries (for example between government agencies and universities), as well as establishing new boundaries (for example between politics and fossil fuel intensive, environmentally destructive industries). However, these transformative qualities are often not those of local governments with their hierarchies, siloes and rules that constrain collaboration, flexibility and innovation. Consequently, strategic intermediaries with the skills to bridge between organizations, groups, sectors, disciplines and programmes are needed, as are the time and resources to build relationships and connect up complex structures and processes.

Mabon addressed the significance of boundary spanning in the context of building consensus around potentially sensitive or ethically challenging decisions which may need to be taken to address climate change at the urban scale. He did so in the context of cities economically reliant on carbon-intensive activity, where national transitions to low-carbon energy and production systems may have knock-on negative effects for urban environments and living, specifically in the case of Yubari, Japan. The competences of municipal government planners, practitioner-academics and third sector organizations in facilitating cross-sector dialogue were seen as critical in ensuring Yubari recovered from bankruptcy following the decline of the coal industry in a way that primarily benefited the city's most vulnerable residents, ensuring that workers who have contributed to development of places reliant on carbon-intensive activity are not left behind in a low-carbon transition (Mabon and Shih, 2018). Specifically, ability of planners and academics to work across municipal government, academic, private and civil society sectors was assessed as being critical to building agreement on how necessary but unpopular decisions (e.g. managed abandonment/ decline) could be steered in order to return immediate benefit to the local community through, for example, better living quality or more efficient service provision.

Taylor presented arrangements and practices of embedded research as one approach to co-producing robust and actionable knowledge, thereby strengthening the governance of climate change in cities, with a focus on African cities. Embedded research, as practiced in the Mistra Urban Futures and Future Resilience for African Cities and Lands projects, is an arrangement between research and host organizations that establishes a joint research agenda and has researchers working in the host organization (notably a city government) for a sustained period, effectively as a seconded staff member (Patel et al., 2015; Taylor et al, 2016). During that time, they work with colleagues in the host organization to translate existing knowledge from research into policy and practice and vice versa, and to develop new knowledge around shared questions in such a way that it has clear relevance to and use in policy and/or practice (Taylor, in press).

There is a need for embedded research because tackling climate change in cities involves a wide array of coordinated and sustained actions across a range of sectors and scales, requiring collaboration and shared knowledge. Yet, policy-makers, practitioners and researchers struggle to work well together because they frame the issues differently, prioritize the problems and solutions differently, and work to different timeframes. So new ways of working are needed that forge connections, collaborations, knowledge integration and innovations. Embedded research enables inductive theorizing of urban climate action, especially in the global South, and evidence-informed policies and practices.

Bowman addressed the gap between climate science, education, social science and communications, drawing on the case of Long Beach, California. Having politically committed to doing a GHG inventory and Climate Action Plan, the city government commissioned an assessment of climate risks. The resulting assessment highlighted familiar data gaps and challenges of downscaling climate models to city scales, and provided valuable guidance. But, the reports were too technical for policymakers, business people and city residents and so had very low uptake. To address this a companion set of action guides was developed to present the key conclusions and recommended 'best practice' actions – for example relating to water security, coastal inundation and differential vulnerability – in concise, clear, contextually relevant ways. Effective actions for businesses and residents to take, organized around the 5 risks identified in the assessment, are presented to highlight their benefits, first showing free and low-cost steps first and then moderate to larger investments that deliver bigger returns. Critically, drafts of the companion were tested with consumers representing the city's ethnic and economic diversity. The work has shown that these types of publications address the chasm between expert knowledge and public and private choices, supporting civic deliberation, planning and activism.

Prestwood spoke of the partnership approach being taken to transition Bristol, in the UK, to carbon neutrality by 2050. Enduring and transformative partnerships are required to design, implement and evaluate sustainable development plans, including climate mitigation and adaptation, in cities in ways that are equitable and just. Such partnerships need to challenge and overcome the business-as-usual approaches that inhibit innovation and urban transformation, while enabling residents to flourish.

The Bristol Urban Living Partnership, with member organizations from across the private, public, voluntary and third sectors, made it possible to develop a novel, transdisciplinary integrated diagnostics framework and methods to address several key urban challenges. The framework has been applied to diagnose where and how Bristol struggles to optimize collaborative social practices, as well as how these can be improved to foster equitable urban sustainability, by bringing together multiple viewpoints from across the Bristol urban area and the wider region. One of the key components of this work was developing a common or shared language around carbon neutrality. The work of the partnership in Bristol highlighted challenges associated with diversity, specifically the participation of marginal groups, engaging politically, avoiding the formation of silos, securing sufficient funding and taking sustained action. These are the basis for a set of metrics being developed to assess partnership networks in any city.

Panel discussion

Ensuing discussion between the panelists confirmed that many boundaries and silos exist and are a serious constraint to transforming cities to be low/zero carbon, climate resilient, equitable and sustainable. These include professional, disciplinary, territorial/spatial, political, cultural and knowledge boundaries. These boundaries are evident in language or terminology, social networks and the distribution of roles and responsibilities.

Overcoming these boundaries requires trusted intermediaries and intermediation, with associated skills and capabilities that are currently rare, requiring investment and strengthening. No one sector, actor or organization can transform cities. Partnerships are essential. Making meaningful connections and building trust takes time and intentional investment. Drawing partners in early in a project or process is crucial so that they walk the journey from beginning. Mature and enduring relationships are required to take risks, try new things, make mistakes, be challenged and navigate differing values, perspectives and priorities that give rise to competing visions and pathways for transformation.

Boundary spanning to share knowledge and act collaboratively is very difficult but essential. Power and politics are always at play. Spaces to challenge hierarchies and rules, experiment with new ideas, try out different practices and learn together need to be created and maintained in an equitable manner. Government agencies struggle to do this themselves, but if they recognize the value then can work with others to support such processes. The knowledge and practices of marginal and informal groups are an essential part of governing sustainable urban transformations, but often have little visibility and voice. Integrating indigenous and experiential knowledge with scientific research in assessment frameworks and platforms is an important part of redressing such power imbalances. Crisis, whether financial austerity / bankruptcy or water scarcity, is often a catalyst for bringing people together and shifting power dynamics.

Audience engagement

Engagement with the audience highlighted that it is not possible to map the path that urban transformation is to take, it is too complex and contested. Instead we need to collectively work on creating conditions in which people can intentionally take steps, experiment, innovate, learn, share and collaboratively work through challenges and create opportunities. There is a need to recognize the existence of complexity and diversity without being overwhelmed and paralyzed by it. Unequal and unknown ramifications of policies, actions and interventions, often manifesting beyond the spatial boundaries of the city, need to be attended to through ongoing research, learning, adjustment, capacity building and restitution through formal and informal networks that span various spatial scales. Trust and trust building is key, but we are seeing growing mistrust between governments, communities, business and science in many cities. Tackling this has to be contextually specific, especially culturally specific. This is where trusted intermediaries are important, but who those are will be different in each city.

Knowledge frontiers

Key questions raised within the session to take forward are:

- How can city governments become effective agents of transformation within the required timeframes required to deliver the international sustainable development goals?

- What does it take to be a transformative partner within inter-city, intra-city and multi-scalar networks?

- How can the vision and goals of climate resilient, sustainable and equitable urban transformation be established in different contexts?

- Under what conditions do marginalized groups develop and practice social innovations that increase climate resilience and decrease carbon emissions of cities? What role do values and beliefs play in this?

- How can researchers, regional, national and international bodies make the innovations and practices of marginal groups more viable, visible and widespread?

- What urban governance arrangements are required to navigate low-carbon urban transitions that are just and equitable, especially in fossil fuel based resource cities (e.g. Yubari, Japan)?

- How effective is embedded research as an approach to generating the kind of knowledge and action needed to transform cities and address climate change?

- What are the ethical considerations of doing embedded research on issues of cities and climate change?

- How can embedded research and comparative urbanism be combined to generate knowledge and action on addressing climate change in cities?

- How can scientific experts and communications experts collaborate more effectively to produce assessments and guidance that readily translate into policies and action in the public, business and civic spheres?

- Can metrics to assess city partnership networks be used to facilitate learning, strengthen and extend networks and foster the transformation of cities towards meeting local and international sustainable development goals?

SESSION TITLE: **IS SHORT TRAVELED QUALITY THE ANSWER FOR TRANSFORMATION? - URBAN MOBILITY AND CLIMATE CHANGE**
- TUESDAY MARCH 6TH

Session Convener:
Astrid Arnslett (senior communication adviser, CICERO center for international climate change (Norway))

Session Participants:
Edgar Sandoval (professor at TESCI (Tecnológico de Estudios Superiores de Cuautitlán Izcalli, Mexico), **Indrika Rajapaksha** (Department of Architecture, Sri Lanka), **Sohail Ahmad** (PhD, Technische Universität Berlin (TUB), Germany, and Mercator Research Institute on Global Commons and Climate Change (MCC)), **Jago Dodson** (RMIT of Melbourne, Australia), **Monicah Karangi** (Urban Planning Consultant -The World Bank, Kenya), **Hege Westskog** (research director at CICEO –center for international climate research, Norway) and the attendees of the session itself

Session Shepherd:
Gian Delgado

Parallel session summary

Authors:
- Astrid Arnslett
- Based on the excellent minutes from Brian (student)

Session Aims and Format

Is short traveled knowledge the answer for transformation? - Come join us for input on the theories behind transformation of local societies and get great examples of urban mobility challenges. You will also get the chance to contribute with your own knowledge and experience in our world café where you can discuss about themes like: What knowledge do we have concerning urban mobility that we can build on – practice and scientifically? Where are the major knowledge gaps in the scientific literature/data in urban mobility? What are the major challenges for the future urban mobility? In what aspects of urban mobility do we need more co-designed and co-produced knowledge leading to effective and inclusive urban practices? How can we better achieve a cross-country/ cross-region understanding of urban mobility? Where in the process from idea/technical development to implementation are the main obstacles for developing future urban mobility?

State-of-Knowledge Summary

a. Transformation to a low-emission society: Role of Municipalities

We need not only to look at technology change, but also behaviour change and system changes. (IPCC 2012). Climate change can be regarded as a wicked problem. Due to its complexity it is difficult to manage within existing institutions and management strategies. Transition can also imply negative short-term consequences because of conflicting objectives. Stricter land use practice can e.g. give priority to the development of local hubs and city centers and cause a conflict between the need for densification on the one hand and securing urban qualities on the other hand. Transition to a low emission society is therefore closely linked to a process of reframing and change of mind-set.

In particular, it is essential to discuss how municipalities can develop solutions that reduce the need for total demand for energy and resources. This means that direct as well as indirect emissions should be includes also in local and regional transition processes. Otherwise reduced direct emission might be compensated by and even larger increased emissions related to external travel, imported goods etc.

Most municipalities cannot afford to develop separate “low-emission solution” without seeing this as an integrated approach regarding municipal services, land use planning and various investment programs. This implies a need for all kinds of local projects, activities and services to integrate several perspectives and objectives

The concept “short travelled quality” reflects a unifying strategy for the transition process. The efforts to reduce greenhouse gas emissions can thus be linked to the focus on local resources, and how environmental, social and cultural qualities can form a sustainable basis for a totally far more efficient and locally based circulation economy. It is recommended to work in parallel with change processes on three levels. These levels can be termed efficiency, development and transition. Efficiency (level I) means measures which improve the functioning of different systems (e.g. a building or a car) without changing the system or the underlying concepts. Development (level II) implies change in systems or concepts in areas such as housing and infrastructure and can be directed at a change from use of private cars to bike or train.

There is probably a significant potential for climate efficiency through more coordinated approach in when it comes to different investments in different infrastructure. This can also imply developing more integrated financial schemes for stimulating low carbon regional, urban or area development. Transition (level III) involves developing housing, work, recreation, food, services, etc. in ways which reduce need for energy and resource use in the first place.

An example is urban development based on short distances between residential, work and recreational areas.

Transition is not only about framing the transition challenge and to make decisions about what to do, but also about how processes are organized and the quality of participation processes. A key will probably be to involve citizens, civil society, businesses and other important stakeholders in open and co-creating processes. Transition to a low emission society does not primarily require new knowledge, new regulation or improved technology. Most important for local and regional authorities are to use the legitimacy as democratic actors to stimulate climate innovation processes. Municipalities should therefore primarily take the role as facilitator in order to strengthen collaboration across established sectors, administrative levels and relevant stakeholder groups. Thus, municipalities can be a catalyst for change and transition.

b. Reducing energy intensity through disruptive technology.
Deep Decarbonization Pathways Project conclusion: It is quite possible to pull this off:

- Energy efficiency
- Decarbonizing energy and fuels
- Switching top end-uses low-carbon supplies

Energy Efficiency alone has reduced the energy efficiency gap by 65% on average

In all decarbonizing pathways, electricity becomes nearly carbon-free by 2050 through slow introduction of no-carbon energy (including nuclear, CCS, and biofuels).

End-use switch example: Use EVs and electric heaters, displacing the demand for oil and coal.

c. Assessing socioeconomic dimensions of transport
Sector radiative forcing data: Yes, power is a huge contributor, but so is on-road bits (i.e. once you root out net-negative effects of power (i.e. soot cooling), power is less of a concern than on-road transport!).

Vulnerability Index for Petroleum Expenses and Risks:

-Australian cities: Wealthy urban families are less vulnerable to higher fuel prices than suburban or rural areas with lower socioeconomic status. Not everyone is equally impacted by fuel costs.

If we propose high-efficiency vehicles as a way to solve this, who can afford to own such vehicles? These overlap with the wealthy, inner-urban areas, and thus this group's per-trip costs are lower than the more car-dependent suburban regions, leading to a feedback loop that perpetuates the inequality.

Similarly, the ratio of transport: household spending is higher in the outer suburbs. (Leaps through most related stats – i.e. engine size, efficiency change, etc. – through many Australian cities.) HOWEVER: If the outer-suburb families could invest in high-efficiency vehciles, the impact on cost savings would be significantly higher.

These dimensions are vital to anyone aiming to craft policy about shaping behaviour by making carbon more expensive, i.e. through fuel prices.

d. Climate-compatible development in African cities.
Development> Mitigation, and Adaptation strategies intersect in pro-climate areas.

Africa is urbanizing faster than anywhere else, yet, land-use planning isn't taken seriously, especially transport. With climate-specific planning on transport, projected savings of $70bn in African cities.

Example of land-use planning intersection with transport: Density guidelines on building expanding city regions. Compact cities have obvious benefits for reducing transportation costs. So why are cities sprawling? Example: Nairobi. High land prices in dense cores drive people outside of the city, which is far cheaper, and thus bought in larger plots.

Problems emerge: 60% of people in Nairobi commute by walking. If the city expands, it excludes the people who walk.African cities are being made for cars. With the right policies (this section is rushed), denser cities with more affordable transport can exist, which don't preclude large chunks of the population.

e. Exploring the urban built form, atmospheric pollution and exposure assessment: case of developing Asian megacities in Sri Lanka.
By the year 2030, seventy percent of global population will concentrate in the cities of Asia and Africa. Thus, the tropical

urbanization is significant. Air pollution is rising in many cities of the world's poorest cities and causes 1 in 9 deaths of which 87% are low and middle-income countries. Urban health is an emerging dilemma.

The Health Map of Barton and Grant (2006) informed integrations between people and cities at all levels from neighbourhoods to region. Current cities and its urban planning represent less interactions and built environment enhances missing links between people and environment. The case study city of Colombo, Sri Lanka is an evidence for present urbanization issues of a developing Asian mega city in tropics.

The centralized urban planning strategy of Colombo as the commercial capital represents a highly densed city with 20187 residents per Km^2. The metropolitan area is with 5.6 Million inhabitants and daily commuting population is 1.5 Million of which 50% is for employment. Thus, transport system dominated by fossil fuel based transport mode is a major issue which will worsen the air quality in cities and has a negative impact on building designs. Active built forms with air-conditioning dominates the office building stock and average Building Energy Index of the urban offices is high as 220 kWh/m2/annum.

Energy obsolete building stock without proper regulatory measures to control energy demand of old and future building stock will emit more GHGs in future with the present megapolis development trends of the city. Moreover, the location of schools facing major traffic routes in the city of Colombo has an immense impact on air quality of naturally ventilated school buildings. Pedestrian exposure to ultrafine particles in the second largest city of Kandy with the streets of highest number of pedestrians is in average 46% higher than the Europe mean roadside particle number concentrations. Thus, the lack of potential policies to control transport demand with less prioritization of public transport modes and less interest on implementing energy codes will become barriers and the rapid urbanization will originate challenges to accomplish nationally Determined contributions of Paris agreement by the year 2030.

f. Influence of Urbanization on Commuting Emission in India

Urban case studies on GHG emissions are inconsistent, not taking into account geography.

Comparison on urban and rural commuters: In Rural, fewer total commutes, but most commutes in both regions are short (under 2km). A 1% increase in urbanization -> A +2% increase of commute emissions. +10% density = -1.3% emissions, and +10% GDP/capita = +5.1% increase in emissions. However, these changes do not spread evenly: generally speaking, they're concentrated in areas of the cities, rather than the rural areas. Mitigation strategies therefore need to be spatially variable, taking into account the changes in impact (cost and benefit) in different regions. A solution fit for a city will not work in the country.

Towards a research agenda

Where in the process from Idea / Technical Development to Implementation are the main obstacles for developing future urban mobility?

Table 1: Urban Mobility and Climate Change Session, Main obstacles for developing future urban mobility

Stakeholders – Who Drives the Urban Mobility Agenda	Government	Knowledge / Data:	Science – Implementation
Car Companies – Expand mobility options that are car-based. • Regulations – Car technology, pricing/equity policies, incentives for electric/hybrid, • Engaging private developers / private sector • Business Sense for sustainable urban mobility • Public pressure for reee, high-quality public transportation: Urban mobility as a public good	• Establish no-car zones (park&ride) • Ad-hoc: Funding, investments • How much power do municipalities have in making urban mobility decisions? • Consider decentralization: create regional networks as a resource • Capacity/Expertise: Funding for science, promote regional science for policy • Integrating land use / transport / housing using systems thinking.	• No sufficient data on city-level. • Travel patterns in cities. • Freight transport • Land-use – specifically pedestrian design • Data gaps create a challenge in calculating emissions, etc. • Obsolete data. (not keeping up with land use or technology innovation) • Health impact of transportation modes • Climate-proof infrastructure options: Incorporate current and future risks. • IF you don't have data, you can't develop policy.	• Local capacity / expense for undertaking climate science • Build capacity of city governance to understand data • Access to data. • Executable data: What is the appropriate scale? • Lack of desegregated data • Localized solutions – i.e. driverless cars, light rail

How can we better achieve a cross-country / cross-region deployment of urban mobility?

Table 2: Urban Mobility and Climate Change Session, Solutions for better cross-country urban mobility

Why are urban transport solutions not spreading to new regions?	How could research solve this problem?	What obstacles are there to implementing these solutions?
• Political will varies • Policy is not uniform – bureaucratic obstacles to motivated actors • No one-size-fits-all solutions • Vested interests • Lack of integration	• Lack of collaboration, academic compartmentalization gets in the way • Measure Cross-regional differences in availability of resources • Sister-city experiments • Sharing case studies	• Lack of planning – "silos" • No mechanism to implement legislation • Ability of government to upgrade (I believe she meant "alter") knowledge and attitudes

Table 3: Urban Mobility and Climate Change, Major challenges and knowledge gaps in Urban Mobility

What are the major challenges for the future of urban mobilty?	What are the major knowledge gaps in scientific literature or data in urban mobilty?
• Utility and Interest. • Electrification, demand, scale of electrical grid • Congestion • Transportation as a BUSINESS rather than a SERVICE, and corruption that follows • Governance and Autonomy issues • Land-use • Renewable technology is harder to deploy for mobility • Contextual urban mobilty infrastructure • New trends of auto industry will lead to future interest. • Exclusion in mobility solutions (implied to be inequitable distribution of solutions) • Big Data and Automation • Ignorance of walkability	• Influence of car companies • Land use planning and transit infrastructure • Collect reliable information especially in poor areas • Using Big Data for policy assessment – the ethical implications of using such data • Impact of autonomous vehicles • Conversion factors for active transportation • Health impact data for active transportation • Individual preferencesof spending • Health impact data for passive transporation, especially on long commutes • Primary data on trucks in cities • Impact of ride-hailing • Why is public transportation not the first option of people (i.e. is it a cultural attitude rather than a numeric answer such as rider numbers) • What is happening with car-sharing programs or car-pooling systems • Open data for immediate public use • Lack of data to achieving goals • Potential issues relating to data usability

In what aspects of urban mobility do we need more co-designed and co-produced knowledge leading to effective and inclusive urban practices?

Table 4: Urban Mobility and Climate Change, Needs for more co-designed and co-produced knowledge

Future of not including people = installation of infrastructure not possible.	Resilience	Walkability	Participatory processes:
• Ex: Construction of a bus lane. • Co-design in the stage of planning. • Involve a TEAM of actors, not only one group. Need to bring the most VULNERABLE to the table. • (Discussions only involving car owners leads to over-representation of people who use one specific solution.) • Use co-design/production to find out what problem we are going to solve. • Multi-modal transport planning also includes walking.	• Acknowledge power relationships and constraints. • Make sure everyone has incentive to get involved. • Example: Edmonton's bike lanes. • Cycling organization / support network used to gather data used by the city to implement bike lanes, solving problems for both groups • Developed by a partnership between city and NGO – not so much division of POWER as division of RESPONSIBILITY • Necessarily involves a certain minimum number of people before this can happe • -Make sure the most vulnerable are involved: may involve partnership with NGOs already working with these groups	• Walking trips make up 65% of world trips • Need to make it SAFER, EFFICIENT, and ENJOYABLE. • Design of facilities • Co-production: Business interests & planning	• Expert-based + users of infrastructure • Example: Google Maps mapping bike lanes by involving bikers • Different stakeholders to involve: Population, Government, Industry, Science • Translating from the language of science to the language of social actors • Co-design of policy • Planning • Design densification processes BEFORE construction starts • Solve by having a third party be a condition to operate to hand over data. • Need to be led by a trusted party, i.e. Government

What knowledge do we have concerning urban mobility that we can build on – in practice and scientifically?

Table 5: Urban Mobility and Climate Change, Scientific and practical knowledge on urban mobility

• A lot of knowledge but not geographically sensitive • African cities following carbon-intensive transport that is road-based as a "leap frog"? • Informality is a key factor in African cities – cites a poster on transport in Nairobi • Distributional issues: More likely to die from accidents if you're poor. • Governance and it's institutional design is a key factor, as planning and finance is too centralized. • Land-use and transport needs to be integrated. • Link between congestion and health • Integrated planning practices • What innovative interventions will work and at what level of development? • Disincentivise private car use (ie low-accompany lanes) • Reinforce emerging signals against car use, i.e. current attitudes among millenials	• We know a lot about how to move people sustainable. But we aren't focusing on low-cost transport (i.e light rail corridors stuck in traffic). Urban freight is a major sector that is often overlooked. • Land-use coordination at local scale (i.e. garbage disposal) rather than building level. • Active transport relative to air pollution. • Mobility acts as a distribuional issue • Robust methodology for transport research,especially in developing countries • New data collection and sources • Co-benefits assessment for transport interventions • Urban planning to support active travel. • Political questions about space allocation in transport. • Ensuring provision for active transport in a new transport intervention.	• A lot of data is available from smartphones, currently used only by tech companies. • Smart-card transit data, data from private transport providers (i.e. Uber) available? • Issues of private delivery of transport services, and service quality • Improving coordination and connection of transit services • Integration of mobility options • Movement of goods during disasters – ways to improve? • Informal transport systems and safety • Resilience of tansport in disasters for evac and relief • Design for superhighways that meets needs of all users including pedestrians and bikes, and relative quality of service by alternatives • Inappropriate adoption of developed world transport "solutions" in the developing world • Optimal modal mix for developing cities (Public / Private / Active) and trade-offs.

SESSION TITLE: INNOVATIVE APPROACHES FOR STRUCTURAL TRANSFORMATION IN/OF URBAN AND PERI-URBAN AREAS - WEDNESDAY MARCH 7TH

Session Participants:
Chair:
David Dodman

Speakers:
Muhammad Mumtaz, Susan Mason, Barbara Norman, Kevin Sieck

Parallel session summary

Authors:
Barbara Norman, David Dodman, Ankit Gupta, Susan Mason, Kevin Sieck, Muhammad Mumtaz,

Description of session

This panel examined the interactions, legislations, new ways of coordinating and mobilizing resources, and new frameworks and technical capacities for decision making through a survey of implementation practices and opportunities that span cities and their peri-urban areas. Particular attention was paid to the opportunities and challenges for moving beyond 'assessments' and towards the actual implementation of local actions in support of climate resilient urban development.

The operating and implementation systems included environmental, political and social boundaries and opportunities for climate change action. The panel examined a framework for processes in planning decisions for environmentally sustainable and climate-adapted futures. Additionally, we explored multiple key challenges and hurdles for effective climate governance in the cities in Peshawar Valley of Khyber Pakhtunkhwa (KPK), Pakistan with a focus on the adaptation initiatives taken in the Valley. Attention was also given to the development of community-based urban resilience and climate action plans.

The panel related a range of innovative practices, experiments, and ideas from around the globe – such as regionalism in California, planning within planetary boundaries, transnational networks across Asia and Europe, community-based strategies in Denmark and Indonesia, a toolkit to support urban adaptation processes in Germany – that are leading to the emergence of new urban actors, spaces, and political dynamics enabling structural transformations towards low carbon and climate resilient cities.

Key points in the session

The session was an eclectic set of papers brought together under the theme of 'urban – rural with a focus on innovative approaches to transformation. The key points raised in the session included:

- An increasing awareness of the need to plan for climate change but hampered by continuing lack of clarity over who is responsible for funding and actions particularly in uncertain areas like urban – rural boundaries.
- Engagement of all levels of government in the innovation process critical particularly local knowledge who understand local conditions, for example lands liable to flooding (Netherlands).
- There needs to be an appreciation that smaller settlements may require more assistance and targeted support than the large cities as there appears to be less action on climate change in country towns maybe because of less resources and relative isolation (USA).
- Following on the above there is a need to adapt solutions to scale and the response may vary accordingly, that is from major (capital cities) to small and incremental (villages in India).
- An integrated approach to planning for climate change was a cross cutting theme in all the presentations which is not surprising given the urban- rural theme.
- An integrated regional approach with a clear vision and targets can facilitate urban rural coordination necessary to implement action on climate change (water, energy, transport); example of the New York Regional Plan Association.
- A changing urban- rural landscape with climate change requires processes for incorporating science into land use decisions on a regular basis.

The discussions in this session highlight a gap in the IPCC reports to date that have yet to adequately address the urban –rural boundaries in the context of climate change. Furthermore, there is an identified need to more fully appreciate the implications of the 'scale' or size of urban/rural settlements and a more nuanced approach across the urban hierarchy from global cities to towns to villages.

Common threads were the continuing need for co-ordination of actors including rural urban interaction. Incremental change needs to be linked to the wider strategies on a regional scale.

Citizen engagement is critical but citizens must see project as meaningful and successful in making change. The role of education to affect change remains central and the need for finance in capacity building for climate action.

Gaps identified included interlinking urban and rural and co-ordination methodologies. Overall it was considered by the audience that there is insufficient attention given to rural integration, local capacity, food security and river sustainability, regional resource management, rural sustainability, urban and rural linkages and opportunity for polycentric regional development. National land use mapping to see change over time remains a large gap.

Towards a research agenda

Based on the above panel session and presentations, the following research agenda is identified:

1. Identify the particular needs of communities that straddle the urban-rural boundaries through selected case studies on climate adaptation. More localised climate information may be needed to better support urban and rural adaptation processes.

2. Examine leading practice in integrated regional planning for climate action (mitigation and adaptation).

3. Explore the role of civil society organizations/networks for implementation of climate policies in urban regions.

4. Urban climate change finance can be diverse but often the options city and regional governments have available to them are inadequate. Greater attention to financial innovations could be an important contribution to knowledge on urban and regional climate change governance.

5. Explore innovations to scale up new and emerging institutional forums for stakeholder and citizen participation in the process of urban climate change governance to get greater effectiveness in urban and regional climate change governance.

6. Vertical intergovernmental arrangements matter for success. In particular the need to be able to account for a range of condition, local priorities and political contexts. Finding ways that these relations can be structured to maintain consistency and provide direction while also being flexible to provide space for local priorities could be instrumental to advancing climate change action in cities.

7. Building trust among all different actors/sectors involved in integrated urban and regional planning. This is key for a successful co-development of climate-adapted solutions. *Time* could be the main investment in this case.

SESSION TITLE: INFORMAL SETTLEMENTS AND ECONOMIES: MEANS FOR TRANSFORMATIVE CLIMATE ACTION - WEDNESDAY MARCH 7TH

Session Convener:
Cities Alliance / UN-Habitat

Session Participants:
Moderator:
Dr. Debra Roberts (Co-chair, IPCC Working Group II | Head of Sustainable and Resilient City Initiatives Unit, eThekwini Municipality, Durban, SA)
Speakers:
Mr. Michael Uwemedino (Director, The Human City Project and C-MAP initiative, Nigeria), **Hon Gale Tracy Christian Rigobert** (Minister of Education, Innovation, Gender Relations and Sustainable Development) **Filiep Decorte** (Deputy Director New York Office, United Nations Human Settlements Programme (UN-Habitat)), **Mr. William Cobbett** (Director, Cities Alliance), **Mr. Kabir Arora** (Coordinator, Alliance of Indian Waste Pickers), **Mr. Jean-Pierre Elong Mbassi** (Secretary General, United Cities and Local Governments-Africa), **Mr. Trevion Manning** (Director for Planning, St. James Municipal Council, Jamaica), **Ms. Sheela Patel** (Director of SPARC & chair of SDI)

Session Shepherd:
Julie Greenwalt (Cities Alliance)

Session Student Scientist:
Shingirai Mandizadza

Parallel session summary

Authors:
Jo Douwes, Julie Greenwalt, Marcus Mayr, and Osnat Wine

Session Aims and Format

With 90% of urban population growth until 2050 projected in Asia and Africa, many cities and much of future urban growth is and will continue to be characterised by informal settlement, unplanned urban expansion, incremental development and livelihoods reliant on the informal economy.

As both climate change and urban growth accelerate in the Global South, discussions on the transformative action required to address these dual challenges while still advancing the achievement of all Sustainable Development Goals (SDGs) are an increasingly urgent priority.

The session will address Conference Theme 4 on "Transformative Action for climate change" by sharing innovative practices and technological solutions from the informal sector. The session will also provide examples of how transformative climate action rooted in the informal sector is critical for addressing poverty and inequality, and how residents of informal settlements and participating in the informal economy can re-shape the power relations to create the new vision for what a climate-compatible, equitable, resilient and inclusive city needs and should look like.

Objective: This session will feature the perspective of researchers, policymakers and practitioners with experience in informal settlements and economies examining the implications, and proposing strategies and recommendations for scaling up climate change mitigation and adaptation in and for informal communities.

This session will offer concrete recommendations for the research, policy and action needed for:

- Transformative climate action at the interface between climate change and the informal sector,
- Enabling integrated and inclusive city-wide development for low-carbon & climate resilient cities.
- Setting research, policy and action agendas that prioritise better quality of life in cities; especially secondary cities and rapidly expanding cities in the Global South –

Through this, session will address all 17 Sustainable Development Goals (SDGs) and the interconnection among and other global sustainability agreements such as the New Urban Agenda, the Sendai Framework for Disaster Risk Reduction and the Paris Agreement on Climate Change.

State-of-Knowledge Summary

Please refer to the background paper specifically commissioned for the CitiesIPCC conference on this exact topic:

Responding to climate change in cities and in their informal settlements and economies, available at:
https://citiesipcc.org/wp-content/uploads/2018/03/Informality-background-paper-for-IPCC-Cities.pdf

SESSION TITLE: THE IMPORTANCE OF MONITORING AND REPORTING (M&R) FOR THE AGGREGATED IMPACT OF LOCAL CLIMATE ACTION AND THE ASSESSMENT OF COVENANT OF MAYORS INITIATIVE - WEDNESDAY MARCH 7TH

Session Convener:
Paolo Bertoldi (European Commission JRC, Italy), **Stelios Grafakos** (Erasmus University Rotterdam, Netherlands)

Session Participants:
Amanda Eichel (Global Covenant of Mayors Secretariat, Belgium), **Paolo Bertoldi** (European Commission JRC, Italy), **Maryke van Staden** (ICLEI, Germany), **Jen Heemann** (Erasmus University Rotterdam, Netherlands), **Edoardo Croci** (Universita Bocconi, Italy), **Anthony Bigio** (George Washington University, USA), **Lauren Ross** (American Council for an Energy Efficient-Economy (ACEEE), USA)

Session Shepherd:
Claire Markgraf (C40)

Session Student Scientist:
Ranon Soans (University of Alberta, CA)

Parallel session summary

Session Aims and Format

Through city networks and M&R platforms such as the Covenant of Mayors and the Carbon Climate Registry, cities all over the world are reporting their GHG emissions and reduction targets. This session aimed at i) presenting recent research outcomes based on the data provided by cities through M&R platforms, ii) identifying data challenges to scientific research related to the aggregate emission impact of urban areas, and iii) proposing solutions for data gaps and research. Particular attention was given to the importance of M&R according to recognized protocols and how collaborative research by academia, practitioners, and policymakers can guide policy making and practice. The session also addressed the results achieved by the Covenant of Mayors' signatories at the projected GHG emissions reduction by 2030, and the new Global Covenant of Mayors for Climate and Energy as well its preliminary aggregation results up to 2050.

These topics were addressed by seven speakers representing academia, M&R platforms, and city networks. Following each speaker, a poll was taken asking the audience to identify the key research gaps identified in the presentation. This data was collected using Mentimeter online software; results were displayed live on screen in word cloud form and collected. A question period was held following the final presentation.

State of the Art of the Field

The first three presenters discussed M&R actions by globally networked climate action organizations – the Global Covenant of Mayors (GCoM), the Covenant of Mayors (CoM) in Europe, and ICLEI. The next three presenters were academic researchers who discussed the use of these forms of M&R data in their research. The final presenter represented a bottom-up example of M&R created in USA. Each perspective is summarized in this section, followed by their respective research gaps.

Global Covenant of Mayors(GCoM)

Cities involved in the GCoM commit to measuring and tracking GHG emissions and climate risk and vulnerability and reporting progress on a regular basis. Work to aggregate the efforts of all GCoM partners (including the Compact of Mayors and EU Covenant) started in 2016 and by 2017, the network had grown to into a cohesive global alliance of 7500 cities, with a potential aggregate emissions reduction impact of 1.3 $GtCO_2e$/Year as of 2030. This has helped data reporting from cities improve in quality, quantity, and become standardized at the global level. These data improvements provide an increased evidence base for increased investment in urban low carbon infrastructure.

As a global network, merging methodologies to develop an international standard by which cities can report GHG emissions is critical. Such a standardization will hopefully be available publicly by the end of 2018.

A gap identified by the GCoM is that many cities find it difficult to complete this intensive data collection and reporting. It is suggested that there should be opportunities to automate some of this on behalf of cities, so that they have the ability to focus on reaching their targets.

Europe – Covenant of MayorsCoM

The European section of the CoM, represents 7750 cities and 255 million citizens. The CoM strategy involves helping cities to i.) gather data on emissions, ii.) create a plan to reduce emissions, and iii.) create targets. Throughout the process, emissions are monitored to look at the current impact, and monitor how far cities are from reaching their targets. Efforts have also expanded beyond mitigation to include considerations of adaptation and access to energy. The commitment by these cities is to reduce emissions by 20% by 2020 and 40% by 2030. Even at the overall target of 20%, many of these cities committed to much higher targets. Collectively, these European cities by 2020 have committed to a reduction of 27%, equivalent to 1/3 of the EU 2020 GHG reductions – about 300 million tons.

About 700 monitoring reports have now been received. And already, in 2014, reporting cities had reduced emissions by 23%, already surpassing their targets. Cities that have a 2050 target are projected to go from 5.5 tons/capita to 2 tons/capita. Moreover, cities that have already monitored and reported GHG and carry on with the same pace of emission reduction will lower their emissions to under 1ton/capita/year.

cCR – ICLEI

The carbonn Climate Registry (cCR) by ICLEI was created as a global reporting platform for local and regional platforms, focusing on data aggregation and tracking impacts and trying to connect local actions with NDCs. There are more 1000 cities towns and regions reporting in the system, mostly equal between the global south and global north. ICLEI developed a voluntary integrated MRV (Measurable, Reportable, Verifiable) reporting system to ensure different levels of government are connected effectively and to build a better understanding of trends. This can provide a wealth of information, including impacts on economics, social issues, and vulnerable communities, that can assist national governments in tracking subnational climate change impacts. It is critical to understand how the quality of this data can be improved; all data is checked for completeness, but ICLE does not have the resources to check every single data point for quality.

Over 7000 actions have been reported and a 5.6 gigaton CO_2 emissions reduction (equivalent of over 1 billion cars off the road) by 2020 is expected, based on reported data, not extrapolations. A 26.8 gigaton reduction is expected by 2050. They are capturing targets, activities, performance in GHG reduction trends, risk and vulnerability tends.

Because reporting is difficult for cities to undertake, for cities doing great reporting, ICLEI has created incentives such as an improved online profile, providing connections with initiatives such as the GCoM for them to gain visibility, and other supports. Often, the teams working on reporting are small with limited capacity, so it is essential that universities and agencies assist cities in getting quality reporting.

Major gaps for the cCR involve improving connections between localities and higher levels of governance, and the limited capacity of cities to track data.

Academic Use of M&R Data

Research discussed by Jen Heemann, from Erasmus University Rotterdam, compares GHG emissions data informed by local governments through the Covenant of Mayors (CoM) and the Carbonn Climate Registry (cCR) platforms. Mainly, the speaker highlighted data gaps and challenges that currently constrain an aggregate assessment of cities' emissions and, therefore, compromise the scientific understanding about the extent cities are reducing emissions and achieving their mitigation targets. The study included 76 cities with a population over 250,000 inhabitants, with sufficient information in the platforms. Eight cities in Europe published emission inventories in both cCR and CoM platforms. A simple comparison of the data available in both platforms showed major data differences, namely:

- Different emissions in the same reporting year
- Different reduction target percentage in the same target year

For example, the city of Paris informed different emissions for the baseline year 2004 in the platforms, resulting in an emission difference of 44% for the same year. The reliability of data was questioned, as there were inconsistencies in emissions reported. It is suggested that cities need to provide more information on the methods and scopes applied to account emissions, and the sectors covered. Other research gaps mentioned by the presenter include the assessment of the extent to which cities are implementing climate action plans and which factors influence the implementation of urban climate-related actions.

City emissions over time have been increasing and literature shows many drivers of GHG per capita emissions. Research of Edoardo Croci at Bocconi University using CoM data contributed to this literature, analyzing the 124 European cities over 100,000 people which delivered a sustainable energy action plan by Feb 2014. It was found that buildings, particularly residential, represent the majority of emissions. Transportation is the second factor, followed by industry, then power and public lighting. A regression was performed searching for correlation between drivers and urban emissions per sector. Population densities, climate conditions, local EEFs, and GDP are positively correlated, while urban density is negatively correlated. Increase in population size shows a less than proportional increase of total emissions, so there is a sub-linear relationship which shows that there are agglomeration economies. This means that the more heavily populated the city, the more efficient the city is in emissions. This is not a conclusive and complete model, but the ability to use standardized global data – as provided by Covenant of Mayors sample, has made data much easier to collect for research.

Research by Anthony Bigio out of George Washington University leans on data from the Covenant of Mayors. This work posits that compact urban form – universally endorsed as the way forward and solution – is insufficiently practiced as a strategy to mitigate urban GHG, not even in Europe. Literature confirms that properly done urban density and compact urban form can deliver major emissions reductions.

For instance, North American cities, with lower levels of density, have very high energy consumption, while European cities are rather low. Turning to the CoM, there is an endorsement of land use planning as a policy instrument across the whole database, yet sprawl is pervasive through much of Europe. The work shows 6-8% of emissions reductions coming from urban planning matters, however, that number goes down to 3.4% in larger urban agglomerations As a case study, Stockholm is rapidly moving towards zero carbon emissions by 2050. This research argues, with support from data, that achieving these results would be impossible without pursuing compact urban form policies in the last 30 years. Part of advocating for stronger adoption of compact form can involve using M&R data and urban form forecasting to help model and prefigure the urban future. A model of future urban growth in California, adding 10 million people between 2010 and 2050, compared the business-as-usual sprawl vs. a smart growth scenario. The smart growth alternative required only 1/3 of land consumption and ½ the household costs for transportation and utilities, while only 1/3 of GHG emissions would be generated.

American Council for an Energy Efficient Economy

The American Council for an Energy Efficient Economy (ACEEE) is a US-based research organization focusing on advancing energy efficiency policies and programs. Lauren Ross, senior manager of ACEEE's local policy program, presented on their qualitative tool that is a bottom-up look at what cities are doing at the ground-level with an emphasis on policy (i.e., no modelling involved). Their City Energy Efficiency Scorecard is a tool that tracks progress of the implementation of energy efficiency policies and programs among large US cities. The scorecard is a report released every two years, benchmarking 51 large US cities. The first report was released in 2013. The overarching goal of the Scorecard is to compare large US cities exclusively on their energy efficiency efforts, creating friendly competition among cities, and to focus on policies to highlight important actions cities can take to improve their energy efficiency. The scorecard is broken up into 5 policy areas: local government operations, community-wide initiatives, buildings policies, energy and water utilities, and transportation policies. These metrics are based on nuanced qualitative information for each sector. ACEEE researchers are working to move beyond policy adoption to begin also tracking policy performance (i.e., progress towards climate and energy savings goals). Hopefully with time, more performance metrics can be included. Overall, researchers have concluded that most US cities are not on track to meet their climate and energy consumption goals, and this may be linked to a lacking availability of energy data. More standardized and transparent data is needed, as it can provide important feedback into local policy and planning.

Towards a research agenda

What are the key knowledge gaps in the field that have been identified by the session?

The main knowledge gaps identified are:

- Lack of harmonized standard for reporting city GHG emission;
- Data differences and inconsistencies in different M&R platforms that currently constrain an aggregate assessment of cities' emissions;
- Lack of verification, validation and quality checks in data reported by cities;
- Mechanisms to avoid double counting between local, regional and national emission reports;
- which is the extent of urban climate actions' implementation;
- Tools for the assessment and evaluation of local polices and measures to attribute GHG emission reduction to policies (in order to assess which policy are more successful);
- Lack of data on costs of policies to access the cost effectiveness of policies;

In addition, the following points were identified as important:

Much work is still needed to track policy and program implementation and progress towards climate and energy savings goals. This relies on good bottom-up analysis as well as more standardized and transparent local energy and emissions data.

More applied research is required in simulating alternative urban growth scenarios as urban climate action policies. Urban density and form are invisible in urban emissions inventories, and are thus often unaddressed. Compact urban form can greatly contribute to mitigation.

SESSION TITLE: FROM SCIENCE TO ACTION: MAKING ESTIMATES OF THE MULTIPLE BENEFITS OF URBAN CLIMATE ACTION ACCESSIBLE FOR DECISION MAKERS - WEDNESDAY MARCH 7TH

Session Convener:
Thomas Day (founding partner of NewClimate Institute)

Session Participants:
Thomas Day (founding partner of NewClimate Institute), **Thomas Bailey** (Head of Research and Innovation, C40 Cities Climate Leadership Group), **Prof Dr. Andy Gouldson** (Professor of Environmental Policy, ESRC Centre for Climate Change Economics and Policy, University of Leeds. Leeds, UK. Chair of the Leeds Climate Commission Economics Workstream Lead, Coalition for Urban Transitions - a New Climate Economy Special Initiative on Cities. London, UK), **Prof Kristie Ebi** (Professor in the Department of Global Health, University of Washington), **Dr Aspásia Camargo** (Special Advisor of Innovation and Sustainability at the Mayor's Office, City of Rio de Janeiro, Brazil)

Session Shepherd:
Megan L. Melamed (PhD, IGAC Executive Officer, University of Colorado/CIRES)

Parallel session summary

Session Aim

To stimulate a dialogue and to foster cooperation that contributes to reframing climate action by investigating systemic linkages, synergies and trade-offs between urban systems, climate change and the various developmental goals. Evidences from new researches and assessment frameworks demonstrate climate actions are aligned with economic and social goals.

The session is linked to three main priorities of the IPCC Conference: (i) Enabling transformative climate action in cities; (ii) Cities & climate change and (iii) Transition to low carbon, resource efficient, and climate resilient cities.

Session Format

This is a science-practice-policy session where evidences from ground-breaking research in Global South and Global North regions will be presented by scientists and urban practitioners followed by a panel discussion moderated by a policymaker and opened to engagement with the audience.

SESSION TITLE: CLIMATE ADAPTATION FINANCE: URBAN PERSPECTIVES - WEDNESDAY MARCH 7TH

Session Convener/Author:
Jesse M. Keenan (Harvard University)

Session Speakers:
Jesse M. Keenan (Harvard University); Kweku Koranteng (Stellenbosch University); **Justice Musah-Surugu** (University of Ghana); **Dumisani Chirambo** (Seeds of Opportunity); **Eric Chu** (University of Birmingham)

Session Abstract

This panel provides a contemporary survey of the spectrum of financial products and delivery models that are shaping the emerging climate adaptation finance discourse. Collectively, the presentations represent two distinct challenges. One challenge is defined by the mainstreaming of adaptation considerations into known units of risk-adjusted financial products. Whether it is through strategic leverage or the modification of underwriting criteria, mature financial service delivery models themselves are challenged to advance institutional adaptation that accounts for not only the uncertainty of climate change but also the opportunities. The second challenge and corresponding sub-theme reflects the desire to co-align financial and social capital at local scales that are arguably more appropriate for addressing local vulnerability and local determination as to the forms and timing of future adaptations. Through an exploration of empirical knowledge of ongoing adaptation in agriculture, energy and financial services, this sub-theme offers insight into not only alternative delivery models but a range of alternative criteria for underwriting the "upside" or "returns" of financial investments. Both sub-themes are united in advancing practices that identify trade-offs and substitutes that reflect an accounting of co-benefits or conflicts that may arise from such investments. This panel provides a critical evaluation of the challenges facing urban adaptation finance.

This section serves as a memorialization of the proceeding of the "Climate Adaptation Finance: Urban Perspectives" session (the "Session"), as well as observations of the general adaptation finance discourse advanced at the IPCC Cities conference (the "Conference"). In summary, the disciplinary foundation advancing adaptation finance is primarily based in international development studies and conventional finance specializations, including public finance, infrastructure finance and real estate finance. This represents a significant challenge in terms of bridging a common set of conceptual and analytical frames. The international development studies cohort primarily focused on administrative capacity deficits, distributive economic benefits and capital pooling strategies. The finance cohorts largely focused on innovation in underwriting methodologies, creditworthiness and capital market implications. The distinctions in language, methods and scales of inquiry operated to cloud more advanced discussions during the Conference. The discourse during the Session and the Conference can be categorized into three primary areas: (i) institutional adaptive capacity; (ii) project finance; and, (iii) capital markets.

Institutional Adaptive Capacity

The majority of the Session participants focused on institutional adaptive capacity. Eric Chu presented work in a municipality in India that highlighted the political challenges associated with implementing adaptation and disaster risk mitigation projects. Chu's field work highlighted a variety of conditions associated with intra-governmental transfers, the recognition of co-benefits, and the financial management of entities of varying degrees of institutional capacity. Chu highlighted the necessity to examine path dependencies of associated public actors and argued for the necessity of said entities to change logics along the way in light of changing social and environmental contexts. Justice Seguru's presentation focused on Ghana's shift from central dependency to local capacity in advancing adaptation. In particular, Seguru focused on the scramble for resources and local determination in the face of national steering influences.

Much of the work highlighted the lack of 'bankable' projects and the various explanations for such deficits, including corruption, non-liquid capital accumulations in households, and the existing inadequacy to adapt credit standards for untested consumers. Seguru concluded with the proposition for alternative non-public entities that could serve as a financial conduit for local actors that otherwise bypasses corrupt and ineffective local governments.

Consistent with the challenge of household access to finance, Kweku Koranteng presented work that highlighted the utilization of savings groups to finance capital improvements for solar energy facilities. This work was reinforced by other examples and ideas at the conference that focused on the capacity for crowd funding and cooperative structures. This theme was reinforced by Dumasani Chirambo's citation of the utilization of diaspora funding groups. However, Koranteng's central critique centered on the extent to which deep state subsidies were sustainable and the extent to which such subsidies were subsidizing consumption over and above capital improvements. This critique highlighted a significant challenge for assessing the trade-offs between adaptation and mitigation and that extent to which payees and beneficiaries are further disaggregated by market finance.

Finally, Dumasani Chirambo presented work in Zimbabwe that focused on the aggregate demands of adaptation finance across Africa, as well as the extent to which rapid urbanization is driving such costs. Chirambo's work highlights the value of aggregating adaptation costs and benefits for urban processes that have historically been conceptualized to be independent of environmental change, including the interrelationships between housing, mass transportation, public health and sector-specific economic productivity. This line of research is critical for measuring and quantifying co-benefits that may either be internalities or externalities to adaptation investments.

In summary, the institutional adaptive capacity issues fall into one of the following lines of inquiry. First, there is a general agreement on the lack of institutional administrative capacity in both the global south and north. This is partially attributable to a lack of clarity, if not synchronicity, between the scale of investments, which are often regional, and corresponding jurisdictions, which are often highly localized. This raises the proposition for greater education and training in not only basic conventions of finance, accounting and underwriting, but also the mathematics of uncertainty in light of the shift in a post-Stern landscape away from simple net present value (NPV) calculations that are conceptualized to be too limited in their inherent stationarity.

The broader challenge for intra-government coordination also raises the proposition for the desire to develop alternative borrower entities, as eluded to by Chirambo and Keenan among many other session participants. Part of the challenge of redesigning the architecture of intra-governmental relationships relates to a rebooking of the concept of equity within specific projects. This is less relevant for transfer than it is for more complex capital stacks which require varying degrees of contributions. For instance, contributing planning resources and other resources from non-sponsoring agencies could be viewed as part of the public borrower's overall equity contributions. Overall, future inquiries examining the relationship between institutional adaptive capacity and project level finance are likely to yield productive insights into alternative delivery models in light of current credit and administrative challenges.

Project Finance

Beyond institutional adaptive capacity, the second scale or category of focus within the Session and the Conference related to inquires within the domain of project finance. Jesse M. Keenan highlighted ongoing research regarding the development of various trust conduits, the mechanism of leveraging alternative revenue sources, and asset impairment methodologies. Keenan also highlighted the necessity for analytical clarity between mitigation, resilience and adaptation. In particular, Keenan highlighted the necessity to draw necessary analytical distinctions between categorical variants of resilience (i.e., engineering, ecological, socioecological, disaster, urban and community). The current conflation of resilience and adaptation has been argued to be highly problematic, especially in light of the tremendous sophistication of ongoing research in civil engineering, architecture and urban planning that respects these categorical divisions, as well as the associated conflicts and synergies. In particular, the elastic properties to the reversion to the status quo consistent with engineering and disaster resilience frames is often inconsistent with transformative adaptation in economic terms. For example, elevating housing structures is often maladaptive to households over the long-run because it delays relocation, accelerates building system depreciation and rarely ever yields a positive net present value within the remaining useful life of the asset.

A proper analytical utilization of these concepts is critical for identifying and measuring conflicts and synergies between multiple—and often conflicting—stakeholders, systems and investments. This analytical discipline is critical for diversifying cost-benefit models in favor of robust decision making and other such models that seek alternative assessments of adaptation investment strategies. As previously eluded to, there exists an emerging body of literature that highlights the economic maladaptation of various resilience investments by virtue of a misalignment of interests across scales of time, space and actor-orientation.

Specific to urban scales and systems, there are multiple ongoing and future research challenges. First, the degree and rate of impact of climate change on infrastructure systems is not well understood in terms of operations and maintenance, as well as a general account of the asset impairment assessments of these infrastructure systems. Current research is advancing life cycle analysis of buildings and infrastructure in terms of informing the economic decision-making resilience and adaptation investments. This is particularly important because yield attainment in many infrastructure assets is highly sensitive to the performance of the asset towards the end of the useful life of the asset. Understanding the range of impacts and performance is critical for underwriting financial investments and managing collateral asset risk. For instance, a desalinization plant that serves as an adaptation to decline potable water sources today may underperform in the future in energy generation and transmission capacities are not contemporaneously maintained. By this measure, understanding path dependencies for economic allocations and strategies is also central to managing risk and maintaining the public institutional adaptive capacity referenced by Chu.

For instance, if a municipal borrower draws too heavily on its bonding capacity in order to invest in hazard mitigation for a limited hazard, such as nuisance flooding from rainfall, it may not have the bonding capacity in the future to address impacts related to sea level rise—even though both hazards are seemingly related in their underlying mechanisms of impact.

Additional inquires for project level adaptation finance include the necessity to rethink procurement and environmental laws and regulations. For instance, in the realm of procurement there are opportunities to impose climate mitigation requirements and to develop protocols for training and utilizing local labor. In addition, the stationarity of environmental regulations is being challenged by the dynamic nature of climate change. It is increasingly recognized that in order to advance an adaptation finance market, there must be the development of a pipeline of projects that can be utilized in an experimental fashion to measure resilience and adaptive capacity performance. Cumbersome regulations is frequently cited as challenges to developing such a pipeline.

Aside from modifying environmental regulation, governments play a key role in facilitating adaptation financing. First, governments are tasked with designating and modifying land use classifications that help steer the efficient delivery of insurance services and mortgage availability. One related potential avenue of research relates to the economic utilities of adaptive land use modifications over other steering mechanisms, such as building codes. Second, governments are challenged to develop a tracking system for publishing and authenticating government data that can be relied upon for making investment and design decisions. For instance, architects and engineers are increasingly bearing greater risks for taking on climate change considerations into their design. Currently, the inconsistent utilization of global, national and regional data is serving as a limitation to managing those risks through proper mechanisms, such as professional liability insurance. The same standardization of may also help create efficiencies in capital markets that may serve to bring down the overall weighted average cost of capital. The current framing coming out of the Conference was that governments could develop a block-chain system for data authentication that could be relied upon by market actors.

Finally, governments are challenged to impose procedures for incorporating equity considerations into decision making. Both the aforementioned exposure classification and data authentication processes may be highly susceptible to degrees of arbitrariness and exploitation that lock-in existing inequities. In fact, these resilience of certain financial processes, may serve to be maladaptive to various communities and sectors within cities. As referenced by Keenan, current research in the

U.S. is being undertaken by both banking regulators and state governments on how community development investment processes, as well as mortgage finance processes, may utilizing an equity "lens" for underwriting. Finally, government oversight over the public good is also being advanced in dialogues about the utilization of value capture instruments, such as tax increment financing districts and impact fees. There is some emerging research that highlights the potential viability, as well as the limitations, of such instruments.

Capital Markets

The final scale of focus highlighted at the Session and the Conference related to Capital Markets. While some participants focused on innovation in instruments, the counter position is that markets are already highly adaptive to developing instruments. The more immediate challenge is to leverage novel sources of revenue and then utilizing that revenue in a manner that promotes some parity between the revenue source and the levered investment of that revenue. For instance, Keenan highlighted the utilization of the resilience trust fund that was levered based on revenues from a surcharge on property and casualty insurance lines. In this case, the trust fund would invest in resilience functionality and hazard mitigation in the built environment that would maintain the insurability and viability of existing insurance markets. As a general proposition, future research is tasked with understanding the relationship between hazard mitigation and/or resilience investments in the built environment and the benefits that may be accrued from premium and/or deductible reductions.

Additional research inquires relate to disclosures in both the corporate equity and municipal bond markets. In particular, securities regulations are likely to accelerate great sophistication in bond disclosures. Likewise, credit rating agencies are increasingly utilizing climate assessment in their rating. As such, local public borrowers are challenged to develop adaptation, resilience and hazard mitigation strategies that can stay ahead of the coarser assessments being advanced by the credit rating agencies. As climate exposure becomes a greater reality for cities, the methodological advancement of path dependency analysis of existing or emerging adaptation strategies is critical.

This increased climate exposure is likely to have wide ranging impacts on a variety of sub-national actors. For instance, it could be argued that institutional adaptive capacity deficits and associated adaptation pathways may be expanded and limited respectively by virtue of a declining financial capacity of cities. As such, strategic economic adaptation strategies must also be informed by greater transparency as to the nature of exposure, vulnerability and risk. To advance this analysis and ongoing intelligence, research must be advanced so as to account for various asset impairment calculations, discounting methodologies, reserve accounting protocols, and public accounting regulations.

As Keenan highlighted, it is difficult for cities to develop adaptation strategies for allocation of resources without fully understanding the wide spectrum of liability, exposure and financial capacity. As previously reference, without adequate reserve accounting for operations and maintenance the accelerated depreciation of capital assets may prove to be major unanticipated burden. This challenge also highlights a general proposition for adaptation finance. The empirical research suggests that adaptation projects are not advanced independent of existing demands. Rather conventional projects are developed with resilience functionality and adaptive capacities. As such, adaptation finance is more fundamentally about financing the marginal utilizes associated with these resilience and adaptive functionalities. In this regard, adaptation finance operates as both a stand-alone proposition and also as a financing facility as part of a complex capital stack. Overall, the Session and Conference provided valuable insight into the range of future research inquires shaping urban adaptation finance.

SESSION TITLE: INITIATING CLIMATE AWARENESS IN URBAN PLANNING PRACTICES THROUGH PARTICIPATORY ACTION RESEARCH - WEDNESDAY MARCH 7TH

Session Convener:
Julia Hidalgo (National Centre of Scientific Research, Laboratoire Interdisciplinaire Solidarités, Sociétés, Territoires, Toulouse)

Session Participants:
Jihene Ghiloufi (Urban Agency of Greater Tunis), Tereza Moura (Laboratorio de Conforto Ambiental da Universidade Federal da Bahia), Genevieve Bretagne (Urban Planning Agency of Toulouse), Zahra Mhedhbi (National Centre of Scientific Research, Laboratoire Interdisciplinaire Solidarités, Sociétés, Territoires, Toulouse), Sinda HaouesJouve (Toulouse University, Laboratoire Interdisciplinaire Solidarités, Sociétés, Territoires), Hans van Ammers (Municipality of Arnhem), Edward Ng (The Chinese University of Hong Kong), Kevin KaLun Lau (The Chinese University of Hong Kong)

Session Shepherd:
David Dodman (International Institute for Environment and Development)

Student Support Scientist:
Carolina Montenegro (University of Alberta, Department of Psychology)

Parallel session summary

Session Aims and Format

The current session aimed to explore the historical processes of climate issues integration in the planning policies of five cities from the North and the South. The selected cities, Arnhem in The Netherlands, Hong Kong in China, Salvador in Brazil, Toulouse in France and Tunis in Tunisia, have in common that they are using or would use urban climate maps (UCmaps) as a tool to communicate, to raise awareness and to integrate local and regional climate information into operational urban planning tools. Putting into perspective those five cases, the session aimed to draw lessons about methods and tools used in environmental or human and social sciences that can be mobilized to initiate climatic awareness in urban policies. For each city case, a 10' oral presentation held by a researcher and/or a practitioner focused on the local historical process of climate issues integration in urban planning policies and explored the following research questions:

- Tunis, how to integrate this new theme in the particular context of a LDR city?
- Salvador, how to disseminate and transform urban climate knowledge into real actions? Toulouse, the interservice dissemination challenges within a municipality services and agencies.
- Arnhem, how to really start the implementation of needed measures: turn to more compulsory regulation?
- Hong Kong, a successful case of application for high-density cities.

A discussion time with conference attendees on how to initiate climatic awareness in urban planning practices was dedicated at the end of the oral presentations.

State of the art of the field

Over the last few decades, climate science applied to urban areas has made significant progress in linking the properties of the urban surface cover, including its extreme spatial heterogeneity, to changes in the overlying atmosphere. Significant gaps in our understanding of processes remain but it is generally acknowledged that the outstanding issue is the need to transfer knowledge into urban decision-making (Hebbert and Mackillop, 2013). Cartographic tools are a good support for a sciencepolicypractice partnership based discussion and cartographic techniques for mapping thermal distributions, cold air lakes and flows, wind patterns, pollution concentration, etc. combining meteorological and climate information, land use data, and terrain information have the advantage to fit both urban planning practices and urban planning tools needs. Fine-grained spatial mapping started in Germany in the 1970s. The German methodology has been used and adapted in Europe, Asia, and South America. Urban Climate Maps has become a reference tool to resolve scientific climatic knowledge into guidelines and planning recommendations (Ng and Ren, 2015).

In applied climate studies at the local scale, the specificity of the research findings for each individual terrain of study makes difficult comparison of results and the rise in genericity. Urban climate research in general and UCmaps studies in particular need to transcend local case studies and develop standardisation methods. This session fits in the Theme 4 of the conference "Enabling transformative climate action in cities" and aimed to discuss the processes and tools (as the UCmaps) by which climate awareness can be initiated in urban planning practices through participatory action research. In the context of this session participatory action research makes reference to the coproduction of research knowledge and methods with urban practitioners.

Urban planning tools matter in the context of climate change because they allow tackling both mitigation and adaptation objectives. Classical applications are energy consumption reduction (that is highly dependent on weather conditions for building heating and cooling), urban heatisland mitigation, wind, rain and snow management and for effective use of green space to enhance air quality and human comfort. Once the local climate priorities are established, climate change dimension can be introduced through long-term climate evolution and extreme hazard impacts analysis.

Here are some key lessons from the presentations and discussion:

- All the successful examples around the world of climate management at the local scale implicate two key ingredients: the presence of a research team and a long and close process of collaboration and acculturation between researchers and practitioners. The coproduction process that allows site-specific policy and regulatory application, stabilization and institutionalization over time is most of the times a bottom up phenomenon. This allows us to identify participatory action research through mobilization of climate knowledge at the local and regional scales as a key to succeed in integrating climate into local policies.

- However, these two ingredients alone do not guarantee success. A topdown setting of targets by national government for local governments could increase the possibilities of developing and implementing environmental and climate codes at the local level by local politicians and practitioners. This could benefit cities such as Salvador, which faced strong difficulties to move from urban climate knowledge to real actions, in spite of the local climate research team efforts. Through Arnhem case it was discussed about more compulsory regulation regarding climate issues (moreover heat stress) and how this can easier be achieved linking the implementation of needed measures with the Quality of life and Health framework and the Energy Agenda.

- Even if local and national dynamics are favourable, most of the times climate issues are not enough to initiate awareness. In these cases, it can be related to other urban policies in function of local context as for example a thematic Environmental GIS platform relevant for urban environmental studies in Tunis or a Smart city project in Toulouse. It is important to understand the reality in which the study is integrated at all levels from national to local, for that reason production of knowledge in adjacent domains which falls within the human and social sciences, such as the analysis of the regulatory frameworks, the governance systems and the social representation of climate change by stakeholders, not only can booster the integration process, but also bring to light levers and brakes to this integration.

- Toulouse and Tunis cases introduced the discussion of city empowerment concerning climate issues leadership. Through Toulouse case the challenges and difficulties concerning the internalization and dissemination of climatic awareness within the municipality administration was discussed. It was for example pointed out the key role of boundary workers as the urban planning agency for their capacity of dissemination linked with its high technicality, its ability to act on its own initiative and its distance with political level. Tunis addressed the strong differences on urban planning priorities between less developed and more developed region cities and how an urbanism 'a posteriori' is a huge impediment to climate integration in urban planning.

- All the city cases and in particular the Hong Kong case, showed that success to initiate climate awareness in urban planning practices rests in:

  - interdisciplinary knowledge production applied to climate studies: a climatic profile of long term regional climate evolution, local climate knowledge based in observations and/or numerical modelling, impact and vulnerability studies combining physical and social dimensions. Also, experts on regulatory frameworks and the governance systems must be implicated.

  - efforts on weather and climate knowledge communication with easier concepts for the population to grasp and relate to health and risks: for example, publishing a booklet to disseminate climate concepts related to urban areas and consequences of climate change and how cities can act at all scales with the possibility of mitigation/adaptation of urban spaces by means of a more climateconscious design of cities, neighbourhoods and buildings.

  - short and long-term work and coproduction of knowledge, methods and tools with local practitioners is also imperative.

This session aimed to discuss the processes by which climate awareness can be initiated in urban planning practices trough participatory action research mobilizing urban climate knowledge at the local and regional scales and in our opinion can feed the « Institutional, financial, and governance structures that enable governance for climate resilient and sustainable settlements, cities and key infrastructure » focus of analysis proposed on the chapter 6 outlines of the working group II contribution to the next IPCC sixth assessment report (AR6, http://www.ipcc.ch/scripts/_session_template.php?page=_46ipcc.htm).

Towards a research agenda

Research has shown that urban climate maps work successfully in the academic, practitioner, and urban policy communities but some important gaps concerning the knowledge production and the research strategy to achieve this knowledge still remains:

- National and international research strategies must encourage works on climate and environmental issues at the urban scale. With a high interdisciplinary character and through participatory action research, to work with urban practitioners, in cities, closer to the municipalities' expectations.

- The scientific part of UCMap has been well studied but the translation into local policy is often less effective. Future research should focus on how UCMaps and associated planning tools can be integrated into the transformation process of the city into a more sustainable and climate sensitive future. Nonetheless, UCMap has proven a useful methodological tool for incorporating urban climate knowledge into planning. Learning from practices in cities where the integration did work and did not work or has not worked yet. Research that facilitates favourable legislative evolution that clearly identifies energy and climate themes as important issues for urban planning and encourage implementation from national to local scales.

- More specific and systematic research needs to be developed in the context of developing cities for which planning with the climate is difficult, simply because urban planning is sometimes an effort out of reach: informal urbanization, massive poverty, priority of other issues, etc. Even if the experience capitalized by northern cities can be useful in this perspective, there can be no question of simple transfers of solutions to developing cities.

- When assessing climatic information, the key words for planners are 'prevailing' and 'critical'; these translate to 'how often' and 'how important', respectively. The 'how often' aspect of information is normally well presented in tables and diagrams; unfortunately, the 'how important' aspect of the information is typically missing (Ng, 2012). Scientific literature regarding impact studies in urban environments has proliferated in the past decade, but for now no common thought has been given to the methodology and expected results concerning analysis methods and impact indicators.

Two technical breaks related to the big data production and availability on urban structure and atmospheric/climatic conditions can be pointed (Hidalgo et al. 2018).

- Concerning urban data production, it is pointed out the difficulty to obtain coherent and consistent urban databases suited to urban climate studies. These databases must contain information on both urban form (land-cover, materials and building dimensions) and function (occupation patterns). Recent initiatives are the Global Human Settlement Layer, the second generation of Ecoclimap database and the World Urban Database and Access Portal Tools (WUDAPT) initiative (Ching et al., 2017).

- Concerning the atmospheric knowledge production, it is indicated the predominant disconnection between the national meteorological services that produce atmospheric data and analysis and the territorial planning professions. In urban areas, the complexity of the urban atmosphere needs high-density observations, but the high cost of standardized atmospheric measurements made observational networks dependent of national meteorological services. The shift from physical measurements to numerical models reinforce the centralized character of the atmospheric knowledge. The applied climatology field must be structured in a similar fashion to meteorological organization network worldwide, including the necessary financial means and a general focus in including urban climate knowledge at all education levels.

SESSION TITLE: **CLIMATE CHANGE ADAPTATION IN CITIES: INSIGHTS ON ACTORS, INSTITUTIONS, AND AGENDAS** - WEDNESDAY MARCH 7TH

Session Convener:
Chandni Singh

Session Participants:
Speakers:
Amy Davison, Kathleen Diga, Garima Jain, Chandni Singh
Session Chairs/Discussants:
Bruce Currie-Alder, Allan Lavell

Session Shepherd:
Gian Delgado

Student Support Scientist:
Carolina Montenegro (University of Alberta, Department of Psychology)

Parallel session summary

Authors:
Chandni Singh, Allan Lavell, Amy Davison, Bruce Currie-Alder, Garima Jain, Kathleen Diga

Session Aims and Format

Cities and urban areas across the world face significant risks from climate change and are increasingly taking an active role in formulating, implementing and financing climate change adaptation (Revi et al. 2014). In rapidly growing economies in the global South, urban adaptation action is inextricably linked with goals of ensuring sustainable development and mitigating disaster risk (Revi, 2016). Given the nature of this adaptation-development spectrum (Singh, Gajjar, & Deshpande, 2016), in practice, adaptation actions are undertaken by multiple actors, at different scales; mediated by diverse institutional arrangements; and reflect different agendas and visions of what effective adaptation and sustainable urban development mean.

The session will have four speakers' present cases on diverse imaginations and practices of urban adaptation from cities of the global south: Chennai (India), Cape Town (South Africa), Durban (South Africa), and the larger region of and around Bangalore (India). Rooted in robust empirical evidence, the cases highlight how adaptation across cities is mediated by different actors with multiple and often competing agendas, and varied formal and informal institutional arrangements. The proposed cases are:

1. Migration as adaptation: insights from a rural-urban continuum in South India (Chandni Singh, Indian Institute for Human Settlements, India)

2. Climate Change Planning in Cape Town - long term adaptation planning vs. short term crisis management during Cape Town's 2015 - 2017 drought (Amy Davison, City of Cape Town)

3. Assessing poverty and climate action in Durban through local actors, institutions and agendas (Kathleen Diga, University of Western Cape, South Africa)

4. Relocation as adaptation: examining post-disaster relocation within the larger development agenda in the Chennai metropolis (Garima Jain, Indian Institute for Human Settlements, India)

Drawing on the empirical richness of the cases, two invited guest speakers (Allan Lavell, FLASCO and Bruce Currie-Alder, IDRC), spanning the science-policy spectrum will comment on how fore fronting different agendas and actor-institution combinations result in differential adaptation outcomes. The panellists will also reflect on how imperatives of sustainable development, climate change, and disaster risk reduction necessitate a reframing of urban adaptation.

The insights from the discussion will help (1) collate lessons for effective urban and territorial adaptation in the global South, and (2) identify spaces for policy intervention for mainstreaming adaptation practice.

State-of-Knowledge Summary

- How science-policy-practice interactions are currently contributing or could contribute

- Potential frontiers of knowledge required to address your session topic:

  - Need to **identify entry points to enable urban adaptation,** especially in fast developing economies where imperatives of poverty reduction compete with investing in climate adaptation.

  - **Incentivising long-term, forward-looking, flexible planning** is necessary to avoid lock-ins and potential maladaptation - the evidence on this is weak and can be strengthened in AR6, and through the Cities Special Report in AR7.

  - Strengthen pilot attempts at using **envisioning exercises** that co-produce different visions for the future through multi-stakeholder engagement.

- Relevant published literature based on the cases:

  - Gajjar SP, Jain G, Michael K and Singh C. Entrenched vulnerabilities: Evaluating climate justice across development and adaptation responses in Southern India *in* K.K. Bhavnani, J. Foran, P.A. Kurian & D. Munshi (Eds.), Climate Futures: Re-imagining Global Climate Justice. Berkeley, CA: University of California Press. (Forthcoming)
  - Jain, G, Singh C, Coehlo K, and Malladi T (2017) Long-term implications of humanitarian responses: The case of Chennai. IIED Working Paper, London UK. http://pubs.iied.org/pdfs/10840IIED.pdf
  - Jain, G, Singh C and Malladi T (2017) Rethinking Post-disaster Relocation in Urban India. IIED Policy Brief, London UK. http://pubs.iied.org/17430IIED/
  - Singh C, Michael K and Bazaz A (2017). Barriers and enablers to climate adaptation: evidence from rural and urban areas in India. ASSAR Information Brief, ASSAR, South Africa. https://goo.gl/mxm2ZO
  - Michael K, Singh C and Bazaz A (2017). Dimensions of Vulnerability in Rural and Urban Areas: A case of migrants in Karnataka. ASSAR Information Brief, ASSAR, South Africa. https://goo.gl/cBPi9m
  - Jain, G., C. Johnson, A. Lavell, S. Lwasa, A. Oliver-Smith and E. Wilkinson (2017). Risk-related resettlement and relocation in urban areas. London, Climate and Development Knowledge Network. CDKN ESSENTIALS. https://cdkn.org/wp-content/uploads/2017/07/Risk-related-resettlement-CDKN.pdf
  - Bazaz, A., S. Ramoji and G. Jain (2016). Exploring Relocation Risk Assessment Methodologies and Findings. London, University College London. https://doi.org/10.24943/cirf5.2016
  - Jain, G., A. Bazaz, R. Jigyasu, T. Malladi, A. Balasubramanian and S. Ramoji (2016). Risk-related Resettlement and Relocation in Urban Areas: A Diagnostic for India. London, University College London. https://doi.org/10.24943/cirf.2016
  - Jain, G. (2016). Risk-related Resettlement and Relocation in Urban Areas: Research Framework and Summary of Findings. Site Report I. London, University College London. https://doi.org/10.24943/cirf1.2016
  - Malladi, T., G. Jain, S. Kraleti, S. Ramoji, A. Balasubramanian and G. Hegde (2016). Risk-related Resettlement and Relocation in Urban Areas: Detailed Site Case Studies. Site Report II. London, University College London. https://doi.org/10.24943/cirf2.2016
  - Jain, G. (2016). Risk-related Resettlement and Relocation in Urban Areas: Data from Primary Work. Site Report III. London, University College London. https://doi.org/10.24943/cirf3.2016

SESSION TITLE: **CITIES AND THE CHALLENGE OF 1.5C: ASSESSING MODES, MECHANISMS AND MANIFESTATIONS OF COORDINATION IN GLOBAL URBAN CLIMATE GOVERNANCE**
- WEDNESDAY MARCH 7TH

Session Convener/Chair:
David Gordon

Session Participants:
Pakamas Thinphanga, Sander Chan, Patricia Romero Lankao, Fee Stehle, Emma Lecavalier,
Co-Convenors:
Angel Hsu, Craig Johnson

Session Shepherd:
William Solecki

Parallel session summary

Session Aims and Format

The transformative potential of cities in pursuing a global target of limiting mean temperature rise to 1.5C represents a source of much hope and optimism. City-networks are working to foster transnational city coordination; meta-networks like the Global Covenant of Mayors for Energy and Climate have been forged to link cities together in a more comprehensive manner; smaller initiatives like the Climate Neutral Cities Alliance are working to stimulate holistic sustainability transitions in, and across, a select number of urban settings, and; global initiatives have emerged in the form of the New Urban Agenda and the urban SDGs.

Cities are, in other words, more ambitious and more globally engaged than they have ever been. Yet it remains unclear whether, how, and with what effects they can coordinate their actions to achieve such meaningful collective and global impact. Our panel session aimed to bring together three distinct bodies of research related to the impact and potential of networked urban climate governance in an effort to identify key research questions and develop the outlines of a shared research agenda of interest to scholarly, practitioner, and policy communities. The session drew together a diverse mix of participants from academic and policy-oriented communities and asked them to reflect on their prior experience and ongoing activities (research and program/policy-oriented) in an effort to think holistically across the intersections of global, local and regional scales of transformational climate governance. The panel session was organized around brief interventions from the six (6) panelists, followed by an extended moderated discussion between the panelists and audience members. The session produced a lively discussion around the challenges of thinking across scales, the need for critical attention regarding questions of participation, representation, and inclusion, and the challenge of pursuing the global coordination of cities in the face of a diversity of urban contexts and capacities

State-of-Knowledge Summary

The study of city-networks and global climate governance has matured and advanced in important and exciting ways (Acuto & Rayer 2016). This work is linked to, and informed by broader shifts in the architecture of global climate governance characterized by a transition from top-down, state-driven efforts towards a bottom-up process of aggregation that is broadly inclusive of the voluntary efforts and activities of a diverse constellation of sub- and non-state entities, such as states, provinces, private corporations, and cities (Hoffmann 2011; Bulkeley et al 2014). Exemplified by the Paris Agreement, this bottom-up approach to global climate governance positions cities, and city-networks, as key players and meaningful contributors to the goal of limiting global temperature increases to 1.5C and remaining within the stated global carbon budget (Hale 2016). This has contributed to shifting cities, and city networks, from the margins towards the middle of the global conversation, and has directed considerable attention towards efforts to assess the ability of cities to live up to ambitious objectives related to emissions reduction and systemic transformation (C40-Arup 2016; UNEP 2015, 2016).

Our reading of these efforts – grounded in our collective experience participating in these scholarly communities – is that they are divided into three distinct, although largely disconnected, camps.

A first aims to assess and understand the outward orientation of cities engaged beyond their borders, undertaking efforts to coordinate their actions through city-networks and facilitate their collective capacity to open up pathways to meaningful systemic change. City-networks face a pressing need to demonstrate their collective impact and importance, as a means of legitimating their relevance on a global scale and formal inclusion in the global climate regime and underwriting efforts to secure access to sources of public and private investment and capital (Gordon & Acuto 2015, PwC 2014) and to demonstrate a positive return on investments made by funding partners whose contributions have enabled the expansion of city-network activities. Research has as a result been directed towards identifying and quantifying the impact of city-networks at a global scale in a variety of ways: adding up city targets related to emissions reductions (C40 & Arup 2015), modelling the potential impact of city actions (Hsu et al 2015), cataloguing the number of policy actions undertaken or planned (C40 & Arup 2014), and tracing the link between objectives and action (Chan et al 2018) or outcomes (Kona et al 2016). A portion of this work has focused on questions of accountability – whether cities and city-networks can be accountable to the global regime, to one another, and to financial markets and institutions from which they seek financial support (Gordon 2016, Widerberg & Pattberg 2017). While efforts are ongoing to address the challenges inherent to the task (see Widerberg & Stripple 2016, Bansard et al 2017 for example) the underlying premise here is that the global impact of city efforts is a function of coordination within city-networks, convergence around common standards of measurement (i.e. the Global Greenhouse gas Protocol for Cities), and the scaling up/expansion of citynetworks to allow for the transmission of policy ideas (Lee & van de Meene 2012), the creation of linked urban markets, and the possibility of enhanced city agency.

A second line of research directs its attention towards the local dynamics of urban climate governance, and aims to assess the ways in which climate change is being/can be governed in and by cities – through the use of particular policy instruments, investments, and technologies. This research is oriented towards identifying the local dynamics that shape urban responses to climate change, whether these be institutional, cultural, geographic, or historical (Hughes 2016; Krause 2011). Research here has focused on the practical interventions undertaken in specific cities, the implications that these have for urban communities and citizens, and the inequalities that often operate at urban scales as a result of factors such as corruption, marginalization, exclusion, and a lack of capacity.

Considerable attention has been paid to the local political trade-offs of pursuing mitigation targets at the expense of other more immediate adaptation needs and priorities, highlighting the importance of recognizing and addressing co-benefits, distributional equity and environmental justice (Castan Broto, 2017; Chu et al., 2017; Shi et al., 2016). A related issue concerns the political and administrative challenge of financing transformative climate actions through local taxation, decentralization, private investment and municipal debt. By sharing best practices, disseminating standards and leveraging investment, city-networks have been shown to provide an important means of building urban capacity (e.g. Gordon and Johnson, 2017), but the factors affecting city engagement in transnational city-networks remain poorly understood.

Questions have also been raised about the agency of cities and communities within cities (e.g. municipal leaders, local stakeholders, civil society) to engage in truly transformative processes (Castan Broto, 2017). Observations have been made that local efforts to reduce emissions and vulnerability are themselves embedded in a context of structural inequality that potentially undermines the ability of poor and politically marginal populations (e.g. slum dwellers, migrant labour) to engage in climate policy processes and decisions, raising questions about what constitutes a just and equitable transformation (Chu et al., 2015; Wachsmuth et al., 2016; Castan Broto, 2017; Shi et al., 2017).

A third, if less developed, line of research situates cities within their broader regional and national contexts and explores the multi-level interactions that shape, condition, and constrain the capacity of the "city" to engage in climate governance (Bulkeley & Schroeder 2011). Here we see an effort to establish a via media between presumptions of city subordination to domestic political institutions (Brutsch 2013) and the notion that they operate autonomously from these institutional contexts and represent a zero-sum transfer of power and authority away from the state. Oriented instead around the notion of a reconfiguration of authority (Hickmann 2016) this work picks up on themes of multilevel governance prevalent in early scholarship on city-networks (Betsill & Bulkeley 2013; Bulkeley & Kern 2009) and calls for increased sensitivity to the impact of institutional, political, and sociocultural context on the capacity for city-networks to contribute to opening up, supporting, and expanding transformative pathways (Fuhr et al 2018).

Empirical observations have been made that cities and city-networks can play an "entrepreneurial" role in fostering urban climate policy experiments, potentially breaking the mold of maladaptive development pathways and envisioning new and alternative policy scenarios (Bulkeley et al., 2015; Anderton and Setzer, 2017; Castan Broto, 2017). However, questions have been raised about the extent to which innovating and experimenting with untested policy approaches is dependent upon the availability of wealth, resources and capital that tend to coalesce around affluent, knowledge based urban economies (Hodson and Marvin, 2010; Bulkeley et al., 2015; Florida, 2017; Hodson et al., 2017).

A related concern is that the "hard" infrastructural plans and policies that are being used by national governments, international donors, multinational corporations and transnational networks to integrate regional economies are rooted in a particular understanding of risk and vulnerability that fails to understand or address the "hidden" vulnerabilities of slum dwellers, the homeless and other marginal populations whose interests and living conditions are often overlooked in official risk assessments (Chu et al., 2017; Romero Lankao et al., 2016; Satterthwaite and Bartlett, 2017; Shi et al., 2016; Sovacool et al., 2011; 2015).

Towards a research agenda

What we see is a pressing need for research that brings together these three camps and thinks holistically across them. We believe that doing so can help develop a clearer understanding of the transformative potential of collective urban responses to climate change, and a more accurate assessment of the viability, durability, scalability, and transformative potential of these efforts. We argue for putting aside the presumption of win-win solutions, apolitical policy pragmatism, and technology driven synergy and instead addressing the tensions that invariably arise between competing imperatives (responding to and satisfying global as opposed to local audiences and interests) and interests that operate within, between, and across urban contexts. We highlight the need for research into the institutional arrangements capable of managing the tensions and trade-offs between the reality of urban diversity (within and across cities) and the objective of urban coordination, convergence, and collective effect (see for example Bulkeley et al 2016 on the factors shaping variations in urban autonomy).

This research agenda stands to make two important contributions. The first is to contribute to advancing ongoing efforts at measuring the impact and effect of urban interventions and network initiatives. This implies developing means of assessing the collective impact of networked city efforts beyond those most readily quantified (city targets, actions, and policy outputs) so as to take seriously the challenge of linking positive ex post effects of urban climate actions (C40 & LSE 2018) to processes that allow for participation, voice, and inclusion in generating plans, targets, and policy interventions in cities. It suggests the need to build upon, and extend, recent efforts at identifying indirect or non-linear (rather than incremental) pathways to transformative change (van der Ven et al 2017) and the potential effects of disruption created by governance experiments implemented at the urban scale (Bulkeley & Castan Broto 2011).

In each of these cases there is an opportunity to develop more widely accepted means of translating the transformative potential of urban interventions into a language that is legible to both global audiences interested in assessing the potential (and evaluating the related risk proposition) of investing capital, underwriting debt, or providing financial support required by cities (Colenbrander et al 2018) and to local communities and citizens whose voices and interests are often under-represented in these conversations.

The second contribution this research agenda stands to make is to re-politicize the central – if often contested – goal of urban transformation. Building on the notion that transformation is both an experiential phenomenon (manifest in the unplanned or rapid transformation of urban space and livelihood) and a governance objective that entails the disruption and reorganization of urban fabric, form, and function, a research agenda that engages global, urban, and regional dimensions of networked urban climate governance can help draw attention to the contested way in which transformation is understood, the objectives or endpoints towards which it is oriented, and the implications of competing trajectories for marginalized individuals, communities, and cities (Bulkeley et al 2015).

Offering a meta-framework that integrates existing knowledge and ongoing research initiatives, this research agenda speaks to the need to more fully integrate considerations of the political into instances of global urban climate governance; to excavate the power relations that shape how climate governance is defined, operationalized, and oriented (Johnson 2018), and how this process is complicated by the fact that it operates across the global/national/urban interface. This research will require engagement with practitioners and policy-makers in cities, city-networks, and upper levels of government in a variety of different contexts in order to co-produce knowledge required to better understand how ideas, interests, and imperatives are translated from the global down to the local, and vice versa. And given the competing imperatives at play, it will require focused interaction between scholars, practitioners, and citizens in order to build awareness and support for urban policy interventions and investments.

SESSION TITLE: **RAISING AND STEERING FINANCE FOR CLIMATE ACTION IN CITIES** - WEDNESDAY MARCH 7TH

Session Participants:
Ani Dasgupta (Global, World resources Institute Ross Center for Sustainable Cities), **Sarah Colenbrander** (Global Global Programme Lead, Coalition for Urban Transitions; Senior Researcher; International Institute for Environment and Development), **Günter Meinert** (Head of Department, Urban and Municipal Development, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)), **Manisha Gulati** (Programme Manager, C40 Cities Finance Facility, C40 Climate Leadership Group), **Andrew Sudmant** (Research Fellow, Centre for Climate Change Economics and Policy, University of Leeds), **David Jackson** (Director of Local Development Finance, UN Capital Development Fund)

Parallel session summary

Authors:
Sarah Colenbrander, Sam Ezebunandu, Ani Dasgupta

Session Aims and Format

This session aimed to introduce the concept of urban finance readiness as a framework to understand how governments at different levels can raise and steer resources towards low-carbon, climate-resilient forms of urban development. It additionally aimed to invite expert comment and input on this framework, in order to guide future research on financing climate action in cities.

This session opened with a keynote presentation by Ani Dasgupta, the Global Director of the WRI Ross Center for Sustainable Cities. Sarah Colenbrander, Global Programme Lead for the Coalition for Urban Transitions, then convened a panel discussion on the feasibility of the urban finance readiness framework and priorities for future research on financing urban climate action. The session concluded with questions and comments from the audience.

State-of-the art of the field

This session makes three key intellectual contributions, which collectively establish a research agenda for financing low-carbon, climate-resilient cities.

First, this session demonstrates that neither domestic nor international public finance are sufficient to meet the global financing gap. Global investment in infrastructure falls short by more than US$1 trillion every year. The investment gap is especially acute in cities of the global South, where both populations and economies are growing rapidly. With a few exceptions such as China, neither government budgets nor international aid can meet this shortfall. The finance deficit prevents cities from responding effectively to development needs, let alone doing so in a way that is compatible with the Paris Agreement.

The scale of the financing gap suggests that there is a need for more research to demonstrate what 'transformative' urban climate projects might look like and to strengthen the economic and financial case for these projects. A detailed economic and financial case can change the political economies of decision making and galvanise a range of critical actors, including national ministries, development banks, commercial banks and investment companies.

Second, this session demonstrates that private capital has the potential to fill the urban infrastructure financing gap. There are sufficient resources disbursed across commercial banks, investment companies, pension funds, sovereign wealth funds and insurance companies. There also a range of financing instruments with substantial potential to unlock this finance, including debt financing, land value capture, public-private partnerships and pricing, regulation and standards.

Private investors have been largely unwilling to invest in urban infrastructure at scale – particularly in low- and middle-income countries – due to high risks, low returns and imperfect information. Additionally, there are higher costs associated with private capital. There are therefore both supply- and demand-side constraints in mobilising private finance for climate-compatible infrastructure.

Academic research on climate finance has largely concentrated narrowly on public resources, particularly climate-specific expenditure by multilateral development agencies and climate funds. This session highlighted that there is a need for much greater attention to private finance, and how it can be systematically mobilised and steered towards sustainable urban infrastructure at scale. This does not mean that public finance is not important; there is widespread consensus that public finance must play a catalytic role in creating an enabling environment, building critical capacities, supporting early market entrants and crowding in private investment for low-carbon projects. But there is a need for more research on the conditions for and contingencies around private low-carbon investment, particularly in low and lower-middle income cities.

Third, this session introduced the concept of 'urban finance readiness'. Urban finance readiness is an important determinant of a country's ability to raise and steer finance towards climate-compatible urban development. It is a function of both of levels of economic development and the coherence and effectiveness of public institutions. In other words, public agencies vary in their capacity to collect own-source revenue, deploy financing mechanisms and structure infrastructure projects to secure investment. They similarly vary in their capacity to effectively mainstream climate considerations into fiscal and financial systems. The concept of urban finance readiness offers opportunities to systematically address climate change in all aspects of financial decision-making.

This highlighted two key areas for future research. First, there is a need to evaluate the effectiveness of activities or reforms intended to enhance the financial readiness of key urban departments and agencies. This can inform the design of policies and projects to build key capabilities. Second, there is a need to assess the different ways that climate goals can be mainstreamed into urban finance systems on both the supply and demand side. Increasing levels of urban finance is no guarantee that cities will transition to lower-carbon or more climate-resilient paths. Rather, it may just accelerate 'lock in' to high-carbon systems. Institutional, policy and regulatory reforms will be required to break organisational lock-in and steer investment towards climate-compatible options.

Towards a research agenda

1. **Strengthening the economic and financial case for climate-compatible urban development from the perspective of a range of different actors (including diverse investors).** A detailed economic and financial case for low-carbon, climate-resilient cities can change the political economies of decision making and galvanise a range of critical actors. The limitations and gaps in the existing evidence base are clearly documented, and most pronounced in cities of the global South.[56] In particular, there is a paucity of research or even financial data on smaller cities in low- and lower-middle income countries. Where possible, research should identify synergies between climate action and local priorities (such as air quality, congestion or job creation) in order to build political and public buy-in.

2. **Identifying the components of urban finance readiness, and activities or reforms that can enhance the readiness of different departments and agencies.** One of the primary barriers to climate action in many cities is lack of finance. There is therefore a need to address fundamental weaknesses in urban finance systems. A comprehensive collection of comparative and longitudinal studies focused on demand-side institutions (rather than project finance) could inform the development of integrated, extensive investment programmes that systematically mobilise and direct finance.

3. **Assessing the different ways that climate goals can be mainstreamed into urban finance systems on both the supply and demand side.** Researchers can generate the locally-specific evidence necessary for national and local governments to design urban climate frameworks that take advantage of synergetic effects and improve policy coherence; avoid blind spots, inefficient duplication and redundancy; overcome poor sequencing; enhance social learning; and escape institutional inertia and enable innovation.[57] Nor will not be sufficient to merely improve financial returns through – for example – carbon pricing. Policies must be designed to tackle non-financial obstacles to climate-positive investment, such as capacity deficits or split incentives.

4. **Evaluating the best actors and mechanisms to best support learning, replication and scaling on both the supply and demand side.** A huge range of low-carbon and climate-resilient urban projects have been financed successfully, but have not achieved scale. There is therefore a need for horizontal replication (the reproduction of proven approaches through multiple, small initiatives) and/or vertical mainstreaming (integrating proven approaches into dominant institutional policy and practice). Future research could usefully evaluate how learning can be disseminated among and within both supply- and demand-side institutions.

[56] Gouldson, A, Sudmant, A, Khreis, H and Papargyropoulou, E (2018) The Economic and Social Benefits of Low Carbon Cities: A Systematic Review of the Evidence. Coalition for Urban Transitions. London and Washington DC.

[57] Rode, P, Heeckt, C, Ahrend, R, Huerta Melchor, O, Robert, A, Badstuber, N, Hoolachan, A and Kwami, C (2017) Integrating national policies to deliver compact, connected cities: an overview of transport and housing. Coalition for Urban Transitions, London and Washington, DC.

SESSION TITLE: **INTERCONNECTIVITIES AND RESILIENCE: THE PRACTITIONER RESPONSE TO BUILD SOLUTIONS** - MONDAY MARCH 5TH

Session Convenors and Sponsors:
David Viner and **Anne Kerr** (Mott MacDonald); **Candice Howarth** (University of Surrey); and **Dru Crawley** (Bentley Systems)

Student Scientist:
Kaelin Koufogiannakis

**(Note: this was incorrectly identified in the Programme as: Embedding Practitioner Evidence in the IPCC Process)*

Key Points

It is essential that the Practitioner community in its widest sense is included in the research agenda. The practitioner community has an enormous wealth of embedded research, data and experience that can be used to contribute to designing the practical solutions to delivering mitigation, adaptation and resilience solutions to climate change.

Cities are complex constructions that in themselves are polycentric and multi-sectoral. The scientific agenda needs to be constructed in a manner that does not revert back to silo-based research or this risks failure to capture the full range of processes and interactions that occur within cities and the responses made at that scale as a result of climate change. The integrative nature of the city environment requires integrative solutions, many of which may transgress city boundaries and link cities together.

- ***What emerging issue(s) could be incorporated and integrated into the research agenda on cities and climate change that are relevant to your session topic (e.g., informal settlements, electrification and automation of transportation, etc.)?***
  Improved analysis of informal settlements: improved means of data collection; better representation of interests and needs at city level; construction of models; and stakeholder engagement.

- ***What challenges are present, as they relate to your session, working at the city scale (small, medium, large, mega city) and within the context of different urban settings (e.g. city governance structures, local government political cycles, decision making processes etc)?***

  – Scale and resolution issues across the city space: this relates to climate model projection as well as governance structures
  – Data for smaller cities is often not available due to resource constraints of data collection and analysis
  – Imbalance between too little and too much regulation
  – Lack of finance for supporting development of robust resilience to climate change in cities
  – Conflicting decision-making processes when different practitioners are not considered

- ***What key external factors outside cities need to be considered to fully address the topic of your session (e.g., rural urban linkages, food productions, telecommunications, agricultural productions, CO2 emissions, transboundary issues, etc.)?***
  Cities are huge sinks of resources, requiring the wider environment and peri-urban region for support. One key issue that is rapidly emerging is that of the use of plastics and its impacts on the global environment. Poorly resourced cities with limited waste management systems are a key source of plastic pollution. Tackling plastics and requires reduction in their use and identification of alternatives for the production of the key platform chemicals. It is anticipated that much of this will be sourced from biomass, thus raising issues around land-use, food production and marine sources. The UK Research Councils have commissioned a workshop on plastics to address the research priorities in this area.

- ***What questions or challenges related to the topic of your session could be better addressed by integrating the science, policy, and practice communities?***
  Understanding the needs, resources, capacities and challenges faced by the range of actors that operate within a city and whose processes and resources (e.g. energy, food, water, environment) may be impacted and at risk from climate change.

  There is still a fundamental issue around financing resilience and adaptation.

  – Funders agencies including the multilateral development agencies and private banks do not always understand the benefits of investment in adaptation and resilience, they cannot see the benefits when they have returns on investment that are short-term compared with the lifetime of say, a given infrastructure project. The World bank have developed guidance on how to assess climate resilience in all its future Hydropower schemes.
  – Finding different ways of capturing the value of RI and making infrastructure interdependent
  – For example, a tunnel as both roadway and water access in flooding
  – Capturing value of duality of infrastructure

- It is difficult to convey in a practical and realistic manner the cost benefits of non-economic issues. Greater understanding is needed for the social and environmental benefits of resilience and adaptation measures. For example, local communities may implement resilient infrastructure to both be resilient and build local community needs like parks and gardens - use what is of value to them to encourage resilient infrastructure

- ***Identify what data, monitoring, modelling, and/or data architecture could contribute to addressing the priority research gaps you identified on cities and climate change. Describe how they could facilitate scientific research to help inform evidence-based policy development.***

  - Presently, based upon extensive practitioner evidence there is little monitoring and evaluation undertaken of resilience and adaptation measures, for example: how do schemes perform; what adverse consequences are there; are schemes performing in an economic sense; is flexible adaptation a sensible development?
  - Cities comprise of complex systems, there is limited research of the nature of interdependencies within a system and between systems. Understanding the risks to polycentric systems, connectivity within and across cities and interdependencies.

- ***Identify knowledge needs across the science, policy, and practice communities relevant to your session that could help to better address city scale issues in scientific research, the policy process, and translating research into action.***
  What are the processes that are currently available and what need to be constructed to incorporate non-scientifically published evidence within the research agenda and IPCC process? For example, how best to access the evidence within reports produced the practitioner community that are comprehensively reviewed, yet may be commercially confident? There is a need therefore, to establish a formal process for this established upon a robust evidence base to incorporate diverse evidence and examples within the future research agenda.

- ***Identify elements and/or functionalities of a science-policy-practice partnership-based platform that could integrate knowledge, expertise, etc., to address questions/challenges related to your session. Discuss if you think these elements could be leveraged to be used on different topics, be upscaled either to larger cities or multiple cities, and be mainstreamed to address cities and climate change at all scales.***
  There are cultural tensions between academic and practitioner communities that have to be overcome so that the full range of evidence and research can be brought to bear on this issue.
  For example, different perceptions of time, peer review confidentiality, the recognition that a great deal of the practical solutions are not delivered and understood by the academic community alone.
  If practitioners can appreciate that their work will have 100-year implications, maybe they will see more value in long-term academic research.
  Consult fields of science studies, Science/Technology/Society, and anthropology to address this gap
  Can initial collaboration (ex. Cross-reviewing each other's work) start to break down tensions?
  Importance of intermediaries, that can cross the practitioner – academic communities.

- ***Thinking more broadly than just your session, identify elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between cities and climate change.***
  Communication of results through realistic visual modelling work.

SESSION TITLE: **IDOC WORKSHOP: SPECULATING ON FUTURE ENERGY SYSTEMS** - MONDAY 5TH MARCH 2018

Session Conveners:
Mary Elizabeth Luka, Sheena Wilson

Session Participants:
Natalie Loveless, Sourayan Mookerjea, Charles Stubblefield

Session Shepherd:
Gregory Reppucci, Cynthia Rosenzweig

Priority research gaps on the following topics:

- ***What are the top one to two research priorities highlighted in your session? Please relate them to at least one of the conference themes.***

  - Our interactive workshop invited participants to respond to provocations and possibilities offered by the University of Alberta's Future Energy Systems scientists and social scientists, as well as policy makers, and activists. The assemblies of videos used in the workshop and the responses to them demonstrated a range of divergent and convergent ideas that articulated the limits and promises of "disruptive technologies and innovations [for] urban infrastructure and design, [imagining the] political, technical, social, policy and institutional leadership and behaviour changes required" (theme 3). The top two research priorities highlighted in our session therefore addressed:

    i. Social science and humanities research on democratizing communication platforms for deliberation and decision making regarding climate change resilience capacity building.

    ii. Social science and humanities research on dismantling patriarchal and continuing colonial power asymmetries structuring major communication platforms.

- ***What emerging issue(s) could be incorporated and integrated into the research agenda on cities and climate change that are relevant to your session topic (e.g., informal settlements, electrification and automation of transportation, etc.)?***

  - Resilience depends ultimately on social cooperation.

  - Resilience is something we do with and for each other

  - Resilience cannot be commodified without undermining itself.

  - Resilience is fundamentally a common. (Federici, Silvia. nd. "Feminism and the Politics of the Commons." The Commoner.org.; Mookerjea, Sourayan. 2013. "Paths Through the Utopian Forest: Athabasca Tar Sands Development, the Politics of Community and the Common". Canadian Journal of Sociology. Special Issue on Tar Sands Development in Northern Alberta. Summer, (38) 2: 233-254.)

  - All technologies, including energy technologies, are social and political artefacts. They shape how urban spaces are embedded in ecosystems, especially how urban spaces depend on rural agricultural settlements and hinterlands.

  - Undemocratic control of technologies (resulting from corporate ownership and colonial legal orders) place severe limits on resilience capacity building by cities in so far as technologies tend to be designed to: promote the economic and political interests of their proprietors; ignore the needs of women and other marginalized groups; reproduce political, economic and knowledge dependencies and, in the form of consumer goods especially, increase material throughput and toxic waste. (Haraway, Donna. 1991. Simians, Cyborgs and Women: The Reinvention of Nature. New York: Routledge.)

- ***What challenges are present, as they relate to your session, working at the city scale (small, medium, large, mega city) and within the context of different urban settings (e.g. city governance structures, local government political cycles, decision making processes etc)?***

  - One of the issues for discussion in our session was that the science already tells us that responses to climate change is social and political, and that people need to better understand how a changing climate is going to change the routines and norms of their everyday lives and is already throwing many lives into severe crisis, especially of the powerless and poor, especially in the global South. Consequently, communities (as local hubs of economic, social, cultural and political activity) are the ideal sites to enable change. However, the lack of legal and political frameworks ensuring equitable access to energy and mitigation/adaptation capacities -- provide obstacles to locally effective yet universally inclusive responses.

- Globalized capital markets and resulting pressures on local labour markets interact to undermine the transparency and accountability capacities of formal democratic processes on which the effectiveness of city scale capacity building responses depend.

- Speculative investment in real estate creates planning volatility and contributes to deepening social and political inequalities.

- Communication strategies tend to be reduced to information only, with all nuances and complexity minimalized.

- Despite evidence of their effectiveness, independent media and community-based arts sectors are ignored both as citizen participants and potential facilitators of socially just imagined futures and enablers of transparency and accountability mechanisms for city governance.

- Inequitable climate resilience is highly problematic, costing lives and resources, and will inevitably face resistance from those whom it excludes.

• ***What key external factors outside cities need to be considered to fully address the topic of your session (e.g., rural urban linkages, food productions, telecommunications, agricultural productions, CO2 emissions, transboundary issues, etc.)?***

  - The global financial architecture wherein a vast surplus of privatized wealth wields an autarkic power able to undermine any and all climate justice based capacity building efforts because this wealth remains beyond the reach of democratic controls. (Y. Varoufakis, 2011. The Global Minotaur. Zed Press: London).

  - The interlocked dependencies of labour in worldwide and exponentially growing "free zones" (Easterling, 2014), and the massive, concentrated investments in broadband monopolies and the "Big Four" (Google, Amazon, Facebook, Apple) software, information and digital consumer systems (Easterling, 2014; Galloway, 2017) link together to undermine other forms of socio-cultural and political infrastructures. (K. Easterling, 2014. The Power of Infrastructure Space. Brooklyn: Verso. S. Galloway, 2017. The Four. New York: Portfolio/Penguin.)

  - The marginalization of local, indigenous and feminist knowledge systems based on historically sustainable ways of adapting to ecosystems before their colonial-patriarchal enclosure into a global scale extractive and growth oriented social order predicated on the accumulation of capital. (Mies, Maria. 1998. Patriarchy and accumulation on a world scale: Women in the international division of labour. Palgrave MacMillan.)

• ***What questions or challenges related to the topic of your session could be better addressed by integrating the science, policy, and practice communities?***

  - Likewise, our session focused on the changes to social life that will result from a change in energy systems. As social institutions, new energy systems will reshape political institutions, economic systems, and the rituals and rhythms of everyday life. This is particularly true, where it is necessary, for geographic or socio-ecological reasons to radically reduce energy consumption not only in households but especially in industry. Scientist-respondents in our session were concerned with the over focus on scientific questions at the IPCC and the relative neglect of discussions and research on the political economic constraints shaping the direction of scientific research. They identified the need for more research on political, social and cultural dimensions of climate change resilience and mitigation and wanted more discussion on these issues.

  - Furthermore, some respondents from the global south came into the conversation assuming energy inequality in the global north was a non-issue. They were interested to learn about the conditions of Indigenous communities and the ways that energy and climate change are having gendered and classed impacts (not only in the global south, but also) in the global north.

  - Respondents commented on the fact that climate change responses and new energy systems needed to be sustainable, not for 50 years or a 100 year, but for 500 or 1000 years. They were debating and discussing different definitions of sustainability. Many participants agreed that the sustainability and resilience of cities must be for the long term, not simply for one or two generations.

  - Respondents agreed that a first necessary response to climate change is energy transition. Why? 1) because energy transition is a first critical response to decarbonize the environment. Energy transition will be different based on local conditions: geography, cultural context, socio-economic realities etc. Therefore, energy systems need to be designed by communities for their communities. In so doing, new energy systems and the ways they are integrated, can also be organized so as to ensure energy justice and reconstitute socioeconomic relationships in more equitable ways (Wilson et al, 2017 "On Petrocultures, or Why We Need to Understand Oil to Understand Everything." Petrocultures: Oil, Politics, Culture. McGill UP.; and Wilson 2018 "Energy Imaginaries: Feminist and Decolonial Futures" Materialism and the Critique of Energy. MCM Prime. Forthcoming.) Respondents were very interested in this approach and wanted to discuss more about the variable needs of different communities: rural, indigenous, urban. Furthermore, they were very interested in data we presented on how urban-centric and classist many green standards are (at least in the global north).

1 recommendation on the following topics:

- ***Identify what data, monitoring, modelling, and/or data architecture could contribute to addressing the priority research gaps you identified on cities and climate change. Describe how they could facilitate scientific research to help inform evidence-based policy development.***
  - Qualitative data obtained through sociological, feminist, and decolonial methods of historical research and qualitative interviews; so as to gain access to oppressed local knowledges, standpoints, and practices which are more sustainable and which can inform social, political, and technological developments. (Turner, Terisa E., and Leigh S. Brownhill. 2004. "Why Women are at War with Chevron: Nigerian Subsistence Struggles Against the International Oil Industry." Journal of Asian and African Studies, vol. 39.1 pp. 63-93.)
- ***Identify knowledge needs across the science, policy, and practice communities relevant to your session that could help to better address city scale issues in scientific research, the policy process, and translating research into action.***
  - Scientific, political, and practice communities generally lack engagement with, and thus access the knowledges of, local populations, particularly that of the most vulnerable and oppressed populations. And, it is often these populations which have some of the most valuable insights on the sustainability of cities. (Vinyeta Kirsten, Kyle Powys Whyte, and Kathy Lynn. 2015. "Climate Change Through an Intersectional Lens: Gendered Vulnerability and Resilience in Indigenous Communities in the United States". Portland: Department of Agriculture, Forest Service, Pacific Northwest Research Station.)
- ***Identify elements and/or functionalities of a science-policy-practice partnership-based platform that could integrate knowledge, expertise, etc., to address questions/challenges related to your session. Discuss if you think these elements could be leveraged to be used on different topics, be upscaled either to larger cities or multiple cities, and be mainstreamed to address cities and climate change at all scales.***
  - The science-policy-practice partnership-based platform would greatly benefit from a broad integration of social science, humanities, communities, particularly that of indigenous communities, and women's knowledges into its decision-making processes. Such an integration would enable cities and leaders both to conceptualize and grapple with the social and political consequences of their actions, and to make more equitable and sustainable decisions. (Wilson, Sheena. et al. Eds 2017. Petrocultures: Oil, Politics, Culture. Montreal: McGillQueens University Press.)
- ***Thinking more broadly than just your session, identify elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between cities and climate change.***
  - Any comprehensive and practicable assessment of the linkages between cities, environments, and climate change would need to be qualitative as well as quantitative. Such an assessment would examine the impact cities have on the biodiversity and functioning of the ecosystems adjacent to a city as well as at a distance: assessing the impact cities have on the environments of other nations, cities, and hinterlands where resources that are used within a city are extracted, shipped, and stored. Furthermore, such an assessment would necessitate an examination of the social and political practices of cities, including relations of trade, production, and transportation that link cities to their regions and to other cities. To this end, assessment frameworks that include critical reflection and interrogation of systemic values and ideologies is crucially important. (Moore, Jason. 2015. Capitalism in the Web of Life: Ecology and the Accumulation of Capital. Verso: London.)

SESSION TITLE: **CO-BENEFITS FOR EMERGING ECONOMIES: PRACTICAL EXPERIENCES AND POLICY IMPERATIVES** - MONDAY MARCH 5TH

Session Convener:
Dr Mahendra Sethi

Session Participants:
Jose A. Puppim de Oliveira, Getulio Vargas Foundation (FGV, Brazil), **Geng Yong** (School of Environmental Science and Engineering, Shanghai Jiao Tong University, China), **Osman Balaban** (Middle East Technical University - METU, Turkey), **Fee Stehle** (University of Potsdam, Germany), **Jyoti Parikh** (IRADE, India)

Session Shepherd:
Lykke leonardson and **Aliyau Barau** (Shepherds)

Priority research gaps on the following topics:

- ***What are the top one to two research priorities highlighted in your session? Please relate them to at least one of the conference themes.***
  Cities in developing countries till recently had a limited research on climate response, that too pre-occupied with adaptation agenda. As many of these developing countries are harbouring fast growing economies, these would have to simultaneously respond to local development pressures, environmental issues and the test of global climate change. Thus, cities in emerging economies are in the right position to effectively assess multiple challenges and their trade-offs associated with rapid growth, sustainable development, mitigating excessive emissions and adapting to climate change (Sethi & Puppim de Oliveira, 2018). At the same time, there are several gaps in estimating and applying co-benefits in urban settlements. These include conceptual gaps, methodological gaps, empirical gaps and policy-governance gaps (Sethi 2018). Thorough identification of climate co-benefits in urban development projects and greater use of assessment tools to evaluate these is the most important aspect. This is directly relevant to imperatives for action (theme 1 of the conference).

- ***What emerging issue(s) could be incorporated and integrated into the research agenda on cities and climate change that are relevant to your session topic (e.g., informal settlements, electrification and automation of transportation, etc.)?***
  Emerging economies and other developing nations have a huge potential to adopt climate mitigation (IPCC 2014a). Most of the new infrastructure, industries, housing, etc. that is going to be created in this century would be in the urban settlements of these countries (IPCC 2014b). This can have immense development related climate co-benefits.
  There are several emerging issues that could be incorporated and integrated into the research agenda on cities and climate change that include promotion of clean energy generation and use (rooftop solar), public transport typically mass-transit, light-transit (as applicable), non-motorized transport, electric vehicles, energy efficient buildings or green habitats and waste to energy technologies. Another major issue is climate responsible urban planning, mainstreaming climate agenda/ actions in urban plans, smart city plans and building capacities of local governments to implement these. In addition, it is vital to prioritize climate policies that bring co-benefits, as they improve public health (Doll and Puppim de Oliveira, 2016) and can mostly benefit the poorest, such as those in informal settlements (Ahmad and Puppim de Oliveira, 2016)

- ***What challenges are present, as they relate to your session, working at the city scale (small, medium, large, mega city) and within the context of different urban settings (e.g. city governance structures, local government political cycles, decision making processes etc)?***
  Among the major factors that limit urban climate action in developing countries are the institutional and financial weaknesses of local governments, and the lack of policy pressures from upper levels of governance as well as the community. At the same time, while no one in the public-sector questions the imperative of co-benefits, their awareness and willingness to seriously pursue them is limited, particularly because many potential co-benefits involve multi-functional and multi-level cooperation between different governments, that could further pose challenges political and financial decision making with their limited capacities.

- ***What key external factors outside cities need to be considered to fully address the topic of your session (e.g., rural urban linkages, food productions, telecommunications, agricultural productions, CO2 emissions, transboundary issues, etc.)?***
  There are several external factors while considering mitigation co-benefits, for instance using hinterland as carbon sinks, sourcing energy from thermal plants located in rural areas, or importing raw materials from outside the cities for building infrastructure, housing, etc. Similarly, urban agriculture can be used as a co-benefits policy response in cities of developing countries for adaptation of informal settlements to climate change. In order to internalize these external factors, there is a pressing need to have integrated methodological models or tools that

could exhaustively and precisely evaluate and simulate energy/ carbon offsets, co-benefits (monetary and non-monetary) across different geographical and administrative sub-national units.

- ***What questions or challenges related to the topic of your session could be better addressed by integrating the science, policy, and practice communities?*** A fundamental question for science, policy and practice community is how to maximize co-benefits at the intersection of global climate change, national environmental goals and local development. Focusing on local, regional, or national climate initiatives in an isolated manner leads to blind spots and runs into the danger of overlooking challenges arising from the multi-scalar nature of climate change

  There are several challenges pertaining to how to design, re-design low-carbon and climate resilient cities and manage the existing ones. In fact, there is hardly any policy tool that helps to evaluate and compare benefits of green field and brown field development. Similarly, there is a need to identify and revise norms and standards that lock-in more emissions in local transport, energy sector, commercial and residential buildings, etc. Bringing the science, policy, and practice communities together can help reduce research and policy gaps in this area (as highlighted in point no. 1 above) and ensure a timely realization of co-benefits in climate mitigation and adaptation.

1 recommendation on the following topics:

- ***Identify what data, monitoring, modelling, and/or data architecture could contribute to addressing the priority research gaps you identified on cities and climate change. Describe how they could facilitate scientific research to help inform evidence-based policy development.*** The successful application of co-benefits in urban settlements of emerging economies hinges on wider use of scientific assessment tools by decision makers. There is an urgent need to have integrated tool that could methodically and clearly evaluate and simulate energy/ carbon offsets, monetary and non-monetary co-benefits. The tool would require building of a robust database of cities, multi-sectoral modelling and its methodology should consider the following aspects:

  - It takes into account risks, vulnerabilities and hazards on cities and also contributions of city based GHG emissions to various mitigation sectors.

  - Utilize available national/ regional datasets and indicators. Downscales national scenarios on urbanization, GHG emissions, climate variability, etc. as regional level inputs, and at the same time upscale local urban data, user and their behavioural data collected through surveys at locality to city scale.

  - The tool should also be able to quantify co-benefits based on simulation of different factors particularly user choices, spatial planning, density, type of built-form and their energy needs, city structure, land use mix and transportation/ mobility choice.

  - The tool ought to perform evaluation of scenarios, apply spatial-temporal and real-time analysis for simulations and periodic monitoring for policy guidance, decision making, regulations and mid-term course corrections.

- ***Identify knowledge needs across the science, policy, and practice communities relevant to your session that could help to better address city scale issues in scientific research, the policy process, and translating research into action.*** There is insufficient knowledge on climate co-benefits in scientific, policy and practice communities, especially in developing countries. For instance:

  - There is a need to develop future climate and energy scenarios till 2080 at the city level. Currently available projections are at broad regional scale which have limitations in their applicability at local/city scale.

  - There is a need to conduct studies and develop methodologies for comparative assessment of co-benefits of various technologies used – across different sectors

  There should be national level stakeholder workshops organized on co-benefits to enhance awareness and cooperation of these diverse groups along with the citizenry. There is a major requirement of having information dossiers for politicians, public representatives, administrators/ bureaucrats, civil society, etc. The scientific community/ academia should be trained and provided with basic funds to do more studies and demonstration projects to evaluate policy imperatives. Joint labs could be setup in established urban and engineering institutions with support from multilateral agencies, local or state governments, etc. where researchers could learn, collaborate and co-generate action based projects. These labs could further instil climate co-benefits in environmental and development policies of national and sub-national governments. In addition, cities ought to be devolved special funds and technical assistance (through UN agencies and national governments) to prepare local level co-benefit plans. Most importantly, practitioners working on master plans should be exposed to capacity building programmes, where they could be trained to use planning tools on co-benefits. Tools could further be introduced in academic curriculum of urban planning and management schools.

- ***Identify elements and/or functionalities of a science-policy-practice partnership-based platform that could integrate knowledge, expertise, etc., to address questions/challenges related to your session. Discuss if you think these elements could be leveraged to be used on different topics, be upscaled either to larger cities or multiple cities, and be mainstreamed to address cities and climate change at all scales.***
  Experience on co-benefits suggests the following:

  - Urban climate co-benefits can be initially achieved with simple technologies already available, there is no need of "rocket science" (Puppim de Oliveira, 2013)

  - Support bottom-up initiatives through public policies and international mechanisms in order to scale up results and disseminate innovations (Doll and Puppim de Oliveira, 2017; ESCAP, UNU, UNEP and IGES, 2016)

Established and functional channels of intergovernmental coordination and cooperation should be utilized in the vertical dimension between the international, national, regional, and local spheres, and horizontally in networks between cities in the national and transnational context, both within and across sectors In order to widen the application of co-benefits in policies and practice, there has to be knowledge based advisory platform that guides practitioners and decision makers about which tools would serve what specific purpose. As discussed above, setting up of urban climate labs in larger cities would be crucial to bridge the gap between multi-level governments, the private sector, international agencies, professionals, academia and the people. In addition, cooperation and comparative research between similar cities followed by handholding of smaller cities would help mainstream climate action on ground.

- ***Thinking more broadly than just your session, identify elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between cities and climate change.***
  The co-benefits approach is perhaps the only assessment framework that proactively considers systemic linkages, synergies and trade-offs between cities and climate change. While there is a debate about how economic cost-benefit analysis seems to miss some of the ancillary benefits, it is important to highlight that it is a necessary evil. Decision makers in cities of developing countries usually prioritize a strong financial or economic benefit in climate change policies. Future research should focus on developing new and sound methodologies, inclusive of benchmarks, unit values, etc., to translate the non-economic benefits of climate change policies into monetary terms, which may in turn raise the awareness of decision makers on real value of co-benefits policies (refer Rashid et al 2017)

  There are also arguments on how projects on climate action and co-benefits should be executed- in project mode setting up new organizations/ SPV (World Bank style) or should they be housed in existing institutions? It is felt that for an effective climate policy environment where wider co-benefits are likely to occur, institutional reform and organizational change should be in place. The true success of climate policy in future, especially in developing countries, depends on decentralization of governance systems and empowerment of local governments, through greater scientific/ technical assistance.

SESSION TITLE: GUIDE FOR INTEGRATED URBAN WEATHER, ENVIRONMENT AND CLIMATE SERVICES (IUWECS) AND HOW IT CAN BEST MEET THE NEEDS OF RESEARCHERS AND STAKEHOLDERS - TUESDAY MARCH 6TH

Session Conveners:
Alexander Baklanov, James Voogt

Session Participants:
Valéry Masson, Tanya Müller, Luisa Molina, Chao Ren, Felix Vogel

Session Shepherd:
Boram Lee

Priority research gaps on the following topics:

- ***What are the top one to two research priorities highlighted in your session? Please relate them to at least one of the conference themes.***
  - We highlight the need to build integrated services on weather, environment, and climate, to support safe, healthy, and resilient cities. A guide is essential to help translate the science to improve these urban services and has been established by the WMO: Integrated Urban Weather, Water, Environment and Climate Services (IUWECS, see the Guide: https://www.wmo.int/pages/prog/arep/gaw/documents/GuideIUWECSPart1.pdf) to help cities be resilient to climate change impacts. Chapter 5 of the draft guidelines for IUWECS identifies 11 major science and knowledge gaps. The session will help prioritizing the list. Two that are highlighted here are: urban atmosphere scales requirements – what scales are really required for useful forecasts for urban applications? And how can the integrated services offered by IUWECS be evaluated to help demonstrate their benefits and costs. Such evaluation will require multidisciplinary cross-cutting studies. This research priority relates to Theme 2: Urban emissions, impacts and vulnerabilities (Science and practice of cities) for it will help in urban forecasting and risk management.
- ***What emerging issue(s) could be incorporated and integrated into the research agenda on cities and climate change that are relevant to your session topic (e.g., informal settlements, electrification and automation of transportation, etc.)?***
  - IUWECS will help address many emerging issues of climate change, due to problems of water contamination due to sea-level rising or flooding, and breakdown of infrastructure and compromise to human health due to extreme weather events (e.g., wind, heat waves, heavy rainfall). About 90% of disasters for urban areas are of hydrometeorological nature and they have increased due to climate change. But 70% of GHG emissions are generated by cities. Therefore, the problem has a strong feedback and these two phases of the problem should not be considered separately. Besides, through a domino effect, a single extreme event can lead to new hazards and to a broad breakdown of a city's infrastructure. There is a critical need to consider the problem in a complex manner with interactions of climate change and disaster risk reduction for urban areas Integrated services are the solution. IUWECS recognizes the following emerging issues that city faces from climate change:
  - the risks associated with cascading effects from extreme events in cities and linkages between disaster risk reduction and climate change in cities;
  - the multitemporal dimensions of weather and climate information needed by cities that are relevant to the mitigation and adaptation actions they need to take;
  - Integrated services are key for city responses to climate change.
- ***What challenges are present, as they relate to your session, working at the city scale (small, medium, large, mega city) and within the context of different urban settings (e.g. city governance structures, local government political cycles, decision making processes etc)?***
  - This session identified many challenges to establishing IUWECS, primarily on collaboration, scales, and resources. Collaboration of the research community with various agencies at different levels of government and private sector are needed to effectively develop and deliver the services. This is driven by societal needs due to continued migration to cities creating densely populated environments and associated infrastructures, which result in ever increasing vulnerabilities and risk to natural and anthropogenic hazards. Variations in how National Meteorological and Hydrological Services (NMHSs) relate to urban-scale end-users and the level of understanding by city-partners to engage in IUWECS. Financial and additional resources of observations and

modelling systems that can contribute to urban scale end-users that may not be implemented in NMHS (i.e. mobilize equipment form different divisions) will need to be contributed for implementation.

- ***What key external factors outside cities need to be considered to fully address the topic of your session (e.g., rural urban linkages, food productions, telecommunications, agricultural productions, CO2 emissions, transboundary issues, etc.)?***

  – Key external factors that need to be considered include geophysical and atmospheric hazards, infrastructure, telecommunications, and transboundary issues. Major geophysical hazards (e.g. earthquakes, volcanic eruptions, space weather, coastal inundation, wild fires) and atmospheric hazards (e.g. hurricanes, typhoons, smoke from large fires, sand and dust storms) interact with meteorology and environment, having social and environmental consequences (e.g. on transport systems, housing, food/water supply, disease). Building/infrastructure standards may be contradictory for the different hazards. Telecommunications will be important in terms of providing communication and management of risk to end-users and in providing the types of services, advice and warmings needed by cities. Transboundary issues may arise due to inequality of cross-border resources with other jurisdictions.

- ***What questions or challenges related to the topic of your session could be better addressed by integrating the science, policy, and practice communities?***

  – The IUWECS fundamentally recognizes the importance of integration – as reflected in the title of the Guide. Successful IUWECS, presented by the demonstration cities, support integration of science, policy and practice communities. The premise of the IUWECS Guide is that an integrated approach will be of significant benefit to cities in enabling them to achieve their sustainability and resiliency goals. At the most basic level, integration of the science, policy and practice communities should help promote the adoption of IUWECS. Identifying the needs of end-users is one. More specifically, several of the science and knowledge gaps identified in the Guide (Chapter 5) will require multidisciplinary approach, for example on evaluation of integrated services.

1 recommendation on the following topics:

- ***Identify what data, monitoring, modelling, and/or data architecture could contribute to addressing the priority research gaps you identified on cities and climate change. Describe how they could facilitate scientific research to help inform evidence-based policy development.***

  – Data/monitoring: Urban scale monitoring of variables is often not routinely made by NMHSs. Implementation of routine and real-time monitoring of the physical and chemical characteristics of the urban atmosphere are needed, at relevant space and time scales for urban applications. Data from new technologies (e.g., crowd-sourced data) should be considered for applications.

  Modelling: Urban scale modelling is an important resource for urban applications. These systems will need to consider the availability of data to characterize the urban surface (built and vegetated) – e.g., see WUDAPT initiative, the assimilation of observations for model initialization and assimilation. Such systems exist but need to consider how they can be implemented to serve the users.

  Data architecture: Cities need to consider common formats to enable exchange amongst partners in the IUWECS. See Chapter 4 of the IUWECS Guide for details.

- ***Identify knowledge needs across the science, policy, and practice communities relevant to your session that could help to better address city scale issues in scientific research, the policy process, and translating research into action.***

  – We relate this to what the IUWECS Guide describes as 'Capacity Development'. The knowledge needs differ depending on the partner involved. It will require NHMSs to better develop urban scale observation, modelling and forecast skills and for end-users to understand the potential available data. Those with a focused meteorological or hydrological background will need broader training in earth systems science as well as the human impacts in urban areas. Both groups will need strategies for working to develop, evaluate, and improve services. In support of obtaining these knowledge needs we identify a range of learning solutions.

For knowledge gaps the answer would be linked to elements in Section 5.3. I might emphasize here:

i. Better understanding of how to make use of urban scale observations for services and/or research.
ii. Better understanding of urban atmosphere scales requirements.
iii. Better understanding of the impact of cities and changes to cities on the climate/weather and environment.
iv. Better understanding of the critical limit values of weather, climate and environmental information with respect to human health and environmental protection.

- ***Identify elements and/or functionalities of a science-policy-practice partnership-based platform that could integrate knowledge, expertise, etc., to address questions/challenges related to your session. Discuss if you think these elements could be leveraged to be used on different topics, be upscaled either to larger cities or multiple cities, and be mainstreamed to address cities and climate change at all scales.***

  – Integrated Urban Weather, Environment and Climate Services (IUWECS) directly addresses the challenge in its conceptualization. The intent of the session is to help improve the guidance being provided to both cities and national meteorological and hydrological agencies that can lead to a more widespread adoption of the IUWECS framework that can be used in cities worldwide. The experience of IUWECS in selected cities has shown that the utility of the approach can be broadened from just select meteorological applications to include climate and more generally environmental services.

The key elements from past experiences that should apply to all sectors of IUWECS and all cities:

i. Initiation of IUWECS is often opportunistic.
ii. Success requires engaging relevant stakeholders from the outset.
iii. Importance to establish/understand regulatory and institutional frameworks underlying the creation and maintenance of integrated services.
iv. Cross-sector technology transfer mechanisms and cross-sector service provisions are needed for operational implementation.

- ***Thinking more broadly than just your session, identify elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between cities and climate change.***

  – IUWECS is intentionally designed as a framework to provide an element of assessment that links different partners (e.g., scientists, national environmental agencies, urban-scale end users) within the assessment of service integration and provision. IUWECS calls for interactive evaluation with users. A challenge here is to provide assessments of the impact of an IUWECS – where before-after comparisons are one possible approach for selecting case cities.

  The so-called "urban test-beds" may also provide another element of a novel assessment framework. Test-bed cities are characterized by provision of high spatial resolution (in 3D) of atmospheric and surface parameters relevant to a particular application. Identification and continued support of selected test-beds cities that provide a sampling of climate zones and types of services required could be generally applicable to better understanding the interactions of cities and climate change.

SESSION TITLE: **HOW DATA AGGREGATION CAN SUPPORT SUBNATIONAL ACTORS IN FRAMING CLIMATE POLICY** - TUESDAY MARCH 6TH

Session Participants:
Tiffany Hodgson, Dr. Kevin Gurney, Dr. Cathy Nangin, Dr. Shobhakar Dhakal, Dr. Eric Lindquist, Alex Kovac, Dr. Shannon McDaniel

Priority research gaps on the following topics:

- ***What are the top one to two research priorities highlighted in your session? Please relate them to at least one of the conference themes.***

Shannon McDaniel

– The need for tracking impact and progress of GHG reductions at the city level

– Data needs to be improved, through application of standards of data that is collected, accessibility and a focus on developing countries where generating data is technically challenging.

To address climate change in city boundaries, and to demonstrate their critical role in accelerating the nationally determined contributions of their respective national governments, both environmental data and the impact of climate actions need to be rigorously evaluated. Cities are inundated with more data than ever before, but this means little if they do not know the quality of the data and how to manage and analyse it. Relating to theme 1, enabling transformative climate action in cities, this session focused on the need for improved tracking of impact and progress of GHG reductions. In order to effectively utilize data to evaluate both city emissions as well as the impact of climate actions on these emissions, there is a large data gap that must be addressed prior to analyses. This session highlighted the need for the application of global data standards around how emissions data is collected, but also extending to climate actions themselves and their analyses. Further, this session emphasized that data from cities should be fully transparent and accessible. Finally, the need to focus research on developing countries, where generating robust data is technically challenging, was underscored.

- ***What emerging issue(s) could be incorporated and integrated into the research agenda on cities and climate change that are relevant to your session topic (e.g., informal settlements, electrification and automation of transportation, etc.)?***

Shobhakar Dhakal / Cathy Nangini

– Our session highlighted the data bias towards cities in developed regions, whereas data from cities with smaller incomes are difficult to find and/or obtain. Inventory repository managers have a crucial role to play in establishing collaborations with cities around the world to encourage data collection and transparency. Researchers would also benefit from collaboration with researchers in other parts of the world where data is e.g. likely to be reported in the local language or where technology has not yet been adopted for reporting emissions. Understanding some sectors, such as the informal sector, would be impossible without such collaborations, yet for many cities this sector plays a vital role in both the current and future development of a city's ecosystem.

- ***What challenges are present, as they relate to your session, working at the city scale (small, medium, large, mega city) and within the context of different urban settings (e.g. city governance structures, local government political cycles, decision making processes etc)?***

Alex Kovac

– The biggest challenge in aggregating and projecting emissions data across a large number of cities is about **data consistency.** This includes diversity of available data (e.g. some include only ***scope 1*** while others may include both ***scope 1*** and ***scope 2*** data), inconsistent definitions and boundaries of data, and unclear uncertainty thresholds. The second major issue is concerning the **methodologies for projection of future emission scenarios.** Due to diversity of cities and data availability, it is difficult to apply a single methodology to project the future emission scenarios across all cities that are reflective of real situations and likely economic, population, and technology changes. The third challenge is about **how to link the aggregation data to facilitate action.** This will require more detailed analysis of sectoral emissions data and the related policies and actions from all cities.

- ***What key external factors outside cities need to be considered to fully address the topic of your session (e.g., rural urban linkages, food productions, telecommunications, agricultural productions, CO2 emissions, transboundary issues, etc.)?***

  Kevin Gurney

  – In order to move from scope 1 CO_2 (and GHG) emissions accounting to scope 2 (electricity) and scope 3 (consumption), a large amount of data is required. For scope 2, the power production mix that serves a given city must be known. That is achievable in many developed countries but perhaps less so in developing countries. In simple cases, the estimation is obvious (one power plant supplying a city) but in the case of a grid with multiple facilities and buying/selling this becomes more complicated. For moving to scope 3, the amount of data becomes quite unmanageable quickly. This is one of the reasons that scope 1 and 2 are considered the more common reporting framework. First would be the upstream elements of the energy supply (refineries, wells). Next would be permanent consumables and finally for and services.

- ***What questions or challenges related to the topic of your session could be better addressed by integrating the science, policy, and practice communities?***

  Eric Lindquist

1 recommendation on the following topics:

- ***Identify what data, monitoring, modelling, and/or data architecture could contribute to addressing the priority research gaps you identified on cities and climate change. Describe how they could facilitate scientific research to help inform evidence-based policy development.***

  Alex Kovac

  – To address the data consistency issues, it is important to develop a **common GHG accounting standard and data reporting framework** for all cities. The reporting requirements should allow flexibilities for application in different countries and regions with different data availability and capacity. The GHG accounting standard and reporting framework should be constructed to also satisfy the needs of the research community in supporting their understanding of the universe of cities. It should also improve **data granularity,** such as sectoral and sub-sectoral data, to allow more detailed and meaningful analysis of reported data. Cities should also **regularly update and report their data** to ensure reflective of latest progress in implementing climate actions. Finally, all cities and reporting platform should ensure **transparency** of the report data. If reported data are transparent and publicly available, the policy and scientific communities could better integrate it into collaborative research for more meaningful analysis to facilitate more effective climate action. For **future research,** it is useful to complement the abovementioned bottom-up data (city generated and reported from local activity data) with sensing/monitoring and macro-scale models to improve data accuracy and actions.

- ***Identify knowledge needs across the science, policy, and practice communities relevant to your session that could help to better address city scale issues in scientific research, the policy process, and translating research into action.***

  Shobhakar Dhakal / Cathy Nangini

  – As discussed, the need for a "gold standard" for reporting city emissions is paramount. Current protocols should be unified, or at least it needs to be understood how to transform from one to the other. Also, city emissions can be derived from many different approaches and their combinations—inventories, remote sensing, physical gas species measurements—and comparative analyses are necessary for quality-control to best understand their limitations, strengths and biases. There is good work in progress but it is only a start. But the city emissions themselves are only part of the story. Understanding city emissions has a lot to do with understanding the fundamental characteristics of a city itself. This includes "basic" physical properties such as population or area size, as well as socio-economic characteristics. Here, the data gap is very wide. First, it is not always straightforward to obtain such data, and second, a set of "necessary and sufficient" characteristics for understanding (and therefore predicting) city emissions has yet to be determined. Some progress has been made towards understanding the typology of cities on the basis of e.g. their energy use, and similar analyses for city emissions would be valuable, not only for a city's current emissions, but to assess their likely future emissions as a function of changes in these parameters (effected by, for example, policy initiatives). In terms of translating research into action, here again the gap is wide. It was suggested in the plenary talks that a city should have not only a "Science Officer" but also a "Social Science Officer" to help build the trust that is necessary for the community to get on board with climate change initiatives. At our session, this trust gap was clearly highlighted by Eric Lindquist, who gave several real-world examples of failures of trust in different public scenarios. Such officers would be an ideal combination for obtaining, validating and interpreting the data, and then translating it into quantifiable action by understanding how to identify and subsequently overcome barriers in public support.

- ***Identify elements and/or functionalities of a science-policy-practice partnership-based platform that could integrate knowledge, expertise, etc., to address questions/challenges related to your session. Discuss if you think these elements could be leveraged to be used on different topics, be upscaled either to larger cities or multiple cities, and be mainstreamed to address cities and climate change at all scales.***

Eric Lindquist

- ***Thinking more broadly than just your session, identify elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between cities and climate change.***

Kevin Gurney

– I think a more comprehensive assessment framework for cities would include resilience, adaptation, mitigation as a way to gather a more holistic view of how a particular city will intersect the climate change problem. This appreciates the varying emphases that an individual city can place on these different responses – varying with development level, resources, anticipated impact, socio-economic and socio-political conditions, geography and so on.

Distributing water to plants in fields © Shutterstock

SESSION TITLE: **CLIMATE CHANGE AND THE END OF CONSUMER SOCIETY** - TUESDAY MARCH 6TH

Session Conveners:
Maurie J. Cohen (New Jersey Institute of Technology, USA)

Session Participants:
William Rees (University of British Columbia, Canada), **Halina Brown** (Clark University, USA), **Philip Vergragt** (Tellus Institute, USA), **Manu V. Mathai** (Azim Premji University, India)

Session Shepherd:
Jason Jabbour

Priority research gaps on the following topics:

- ***What are the top one to two research priorities highlighted in your session? Please relate them to at least one of the conference themes?***

    i. Research on how to effectively communicate the concept of consumption as a lifestyle choice as well as a system of cultural understandings, institutions, economic well-being, power, and so forth. This is necessary in order to conceive of consumption as a purposefully engineered social system for ensuring high levels of energy and materials throughput, and not, as mostly viewed as a set of disaggregated social practices—eating, recreating, shopping. More extensive research is required on successful small-scale initiatives that effectively reduce resource utilization among mainstream communities, particularly as measured in terms of GHG emissions per capita.

    ii. How vulnerable are modern consumer cities to climate change, particularly the breakdown in global and regional transportation that might come from an energy crunch, related food/resource shortages, and the geopolitical strife that is likely to result from millions of climate refugees (or the political refugees fleeing local resource wars)? How might cities respond to unprecedented heat-waves, deep-freezes, storm-surges, and geopolitical chaos and climate refugees.

    iii. Research is further required on how to implement social change toward low-impact lifestyles in cities. What are the drivers of high-impact lifestyles and how to ameliorate their adverse impacts. What are emerging trends that could be reinforced and amplified (for instance millennials in cities aspiring to less material-intensive lifestyles?) What is the role of stakeholders including businesses, civil society organizations, and local governments in facilitating and managing those changes?

    iv. Research is required on how cities in currently less affluent countries could maintain prevailing low per capita consumption levels and avoid overconsumption and emulating the problematic patterns in the global North. How to leapfrog toward maintain sustainable consumption patterns while assuring a dignified life for a majority of citizens.

- ***What emerging issue(s) could be incorporated and integrated into the research agenda on cities and climate change that are relevant to your session topic?***

    i. We require more finely grained analyses of the relationship between income and GHG emissions in urban households, especially work that is stratified by cultural/lifestyle subgroups. There is a need for data-based studies of how different ways of organizing community life – both the physical form and social relations – affect consumption as measured by GHG emissions.

    ii. How we avoid gentrification while upgrading and densifying cities. This is essentially a question of how to encourage and enable lifestyles that are characterized by small ecological footprints while simultaneously raising the quality of urban life.

- ***What challenges are present, as they relate to your session, working at the city scale (small, medium, large, mega city) and within the context of different urban settings?***

    i. There is currently an unambiguous lack of recognition that consumption patterns constitute viable issues for intervention and policy making. Prevailing silos of activities (both policy and activism) are related to affordable housing, social justice, energy conservation, environmental protection, and so forth but resource throughput at different scales—from the household to the metropolitan area—is not a recognized frame of analysis and understanding. Moreover, the environmental/climate communities do not see consumption as an environmental issue and do not get involved, either in research, activism, or policy making (there are, of course, some notable exceptions and we aim to highlight these examples in our session)

- ***What key external factors outside cities need to be considered to fully address the topic of your session?***

  i. Economic growth as an overarching policy priority; Governments at different geographic and political scales will need to refocus on well-being for all rather than the singular and exclusive promotion of economic growth as impelled by increasing consumption.

  ii. National governments need to focus on livelihoods for all rather than promoting full employment. Work-time reduction could be beneficial to promote sustainable lifestyles in cities and the role of new digital automation technologies (e.g., artificial intelligence, robotics, autonomous vehicles) will need to receive careful consideration.

- ***What questions or challenges related to the topic of your session could be better addressed by integrating the science, policy, and practice communities?***

  All issues addressed in our session need close integration of research and practice; and co-production of knowledge and policies.

- ***Identify what data, monitoring, modelling, and/or data architecture could contribute to addressing the priority research gaps you identified on cities and climate change. Describe how they could facilitate scientific research to help inform evidence-based policy development.***
  Consumption-based GHG emission data for each sub-national unit of governance (city, state/province), following the model established in the state of Oregon.

- ***Identify knowledge needs across the science, policy, and practice communities relevant to your session that could help to better address city scale issues in scientific research, the policy process, and translating research into action.***
  See above

- ***Identify elements and/or functionalities of a science-policy-practice partnership-based platform that could integrate knowledge, expertise, etc., to address questions/challenges related to your session. Discuss if you think these elements could be leveraged to be used on different topics, be upscaled either to larger cities or multiple cities, and be mainstreamed to address cities and climate change at all scales.***

  Such platforms should function outside of formal governance structures but can be usefully supported by local governments, local business, and local civil society. They should be conceptualized as loci for higher order learning among stakeholders and participants, focused on reframing the issues in ways to which all parties can relate.

- ***Thinking more broadly than just your session, identify elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between cities and climate change.***
  See above

SESSION TITLE: **GOVERNING CLIMATE CHANGE IN COMPLEX URBAN SETTINGS: RESILIENCE THROUGH SOCIAL INNOVATION -** TUESDAY MARCH 6TH

Session Convener:
Anna Taylor (University of Cape Town, SA)

Session Participants:
Thomas Heyd (University of Victoria); **Joanne Douwes** (eThekwini Municipality, Durban); **Leslie Mabon** (Robert Gordon University); **Thomas Bowman** (Bowman Change Inc.); **Emily Prestwood** (University of the West of England)

Session Shepherd:
William Solecki

Session Student Scientist:
Shingirai Mandizadza

5. ***What are the top one to two research priorities highlighted in your session?***

   How do the groups, communities, organisations and sectors that constitute and shape cities become more intentional and collaborative in fostering transformative climate change adaptation and mitigation (Bos et al., 2015)? This requires critical consideration of: (a) what constitutes transformative actions and outcomes; (b) how to work with and through dissensus regarding desired outcomes and the means of achieving change; (c) who the key agents and inhibitors of transformation are; (d) what kinds of collaboration are needed across agents/actors to move processes forward, and (d) what skills are needed (e.g. trans-disciplinary facilitation) to foster such collaborations and enable processes of transformative change. There is a need to understand what is an ecology of institutions within and between cities that has the collective capacity to appreciate and deliver transformative climate change action, with mechanisms (i.e. time, space, will and skills) for regular evaluation and course correction. Furthermore, in which ways can and do marginalised populations address their resilience needs and how can researchers support their efforts? This calls for participatory research approaches and opportunities for marginalised groups to critically reflect on, showcase and enhance their approaches to addressing climate risks and building resilience (Ziervogel et al., 2016).

6. ***What emerging issue(s) could be incorporated and integrated into the research agenda on cities and climate change that are relevant to your session topic (e.g., informal settlements, electrification and automation of transportation, etc.)?***

   Our session had a focus on process, particularly processes of engagement, collaboration, co-production (of knowledge) and transformative change, so the core issues to be integrated into the research agenda are inclusion, (dis)empowerment and deliberative decision-making. The related second order issues that came out strongly in our discussions are those of trust, neutral spaces (i.e. creating neutral spaces to flatten power relations), shared meaning (i.e. finding concepts and terms that build bridges and understanding between communities / sectors / disciplines) and skills (particularly facilitation, translation, networking and mediation skills). These process-based issues pertain to many, if not most, substantive issues (like decarbonizing electricity or reducing flood risk in informal settlements) involved in addressing climate change in cities.

7. ***What challenges are present, as they relate to your session, working at the city scale (small, medium, large, mega city) and within the context of different urban settings (e.g. city governance structures, local government political cycles, decision making processes etc.)?***

   Fostering and sustaining the kinds of partnerships and governance arrangements needed to bring about urban transformation is a significant challenge (Termeer et al., 2016). Political cycles, techno-managerialism, hierarchical and siloed organizational structures (especially in city governments), competition over funding, social fragmentation, epistemic violence and distrust all contribute to undermining transformative partnerships. The importance of local partnership organizations is not sufficiently well recognized, given their role in longer term planning and transformation, and their ability to act as a counter-weight to political cycles. Significant and enduring relational work needs to be done to give meaning to SDG17 (i.e. partnerships for the goals) at a localized level, building networks and coalitions of action and learning within and between cities. Importantly, local organizations to partner with include those that have arisen endogenously among economically marginalized groups, such as waste-pickers cooperatives for example.

   Another related challenge is how to meaningfully and effectively scale up, down or out successful approaches, initiatives and measures when city contexts vary significantly and therefore one cannot assume that what works in one city will be transferable. How do we take transformation models and their broad aspirations and goals, and relate, and transfer or replicate these to the neighborhood level to change lifestyles and behaviors of local citizens and SMEs. At the same time, how do we take successful schemes, initiatives or business models with support at the local/neighborhood level and replicate them more widely, in a new context, and without intensive support such as public subsidy? This is where intra-city and inter-city learning partnerships are key.

8. ***What key external factors outside cities need to be considered to fully address the topic of your session (e.g., rural urban linkages, food productions, telecommunications, agricultural productions, CO2 emissions, transboundary issues, etc.)?***
Ensuring that countries/regions have clear and enabling national policies on climate change and on urbanization / urban development (that are grounded in local realities and inputs, particularly including socially and economically marginalized groups) is a critical factor in providing a strong framework for urban climate action, and in facilitating relevant partnerships and financial and funding flows for this work (Cartwright et al., 2018).

    In terms of climate change mitigation, there needs to be greater integration of consumption and production at the city level to account for global flows of carbon, so that responsibility for and accounting of carbon emissions is not exported from consumption-based economies to producer economies. The same can be said for water and for food from a climate adaptation perspective, recognizing that cities are integrally linked to rural areas and other cities within and beyond their national territories. Cities need to see themselves as part of a global ecosystem and also need to consider mitigation and adaptation actions in harmony.

9. ***What questions or challenges related to the topic of your session could be better addressed by integrating the science, policy, and practice communities?***

    Elaborating the processes, capabilities and skill sets required to integrate the science, policy, and practice communities was one of the key objectives of the session. As such, the questions from our session relating to integration of these communities that need to be addressed are: clarity on what constitutes boundaries within and between these 'communities' and why they exist; understanding where and what innovation is required to facilitate this integration and how it can be fostered; clarifying the power relations that exist within and between different communities and ensuring one or more groups are not marginalized and/or overly dominant; and elaborating the qualities required for different community members to be truly 'transformative' partners.

Recommendation on the following topics

- ***Identify what data, monitoring, modelling, and/or data architecture could contribute to addressing the priority research gaps you identified on cities and climate change. Describe how they could facilitate scientific research to help inform evidence-based policy development.***

  Collecting social network data on the quality and quantity of relations between actors in the science, policy and practitioner communities (including the public, private and third sectors) within and between cities is key. There is also a need for more open data in cities on climate change impacts and multiple associated impacts such as air quality, health and inclusion, alongside activity data (e.g. energy consumption) with integrated reporting, that allows the city to track behavior changes and the impact (or not) of policies.

- ***Identify knowledge needs across the science, policy, and practice communities relevant to your session that could help to better address city scale issues in scientific research, the policy process, and translating research into action.***

  A knowledge need arising from the diverse presentations in the sessions is the need for a schematic/typology of competences and skill sets which individuals and organizations need to be able to develop in order to effectively conduct work across boundaries. These may include, for example, ability to understand different organizational cultures, ability to bear in mind ethical and normative issues, ability to translate between different knowledge schemes and language sets. In instances where organizations do not have the required skills sets for such work, knowledge is needed on what avenues/approaches exist to help facilitate stronger partnerships with entities that do have the required skills and what organizations can do to build and/or attract the necessary skills for trans-boundary, collaborative work? There is need for a heuristic or organizational maturity model as a means to identify and share beneficial partnership practices, to speed up social and business model innovation processes, and have transformative impact.

- ***Identify elements and/or functionalities of a science-policy-practice partnership-based platform that could integrate knowledge, expertise, etc., to address questions/challenges related to your session. Discuss if you think these elements could be leveraged to be used on different topics, be upscaled either to larger cities or multiple cities, and be mainstreamed to address cities and climate change at all scales.***

  The platform needs to invest in intermediaries, boundary agents and partnership organisations that can connect and build shared meaning and actions across organisations, sectors, issues, places and scales. Embedded researchers could be one such modality. Funding arrangements are needed that support relationship strengthening, skills development, listening and reflective learning in combination with action and implementation. A partnership platform needs to be able to identify the existing skills present in local groups, communities, organisations and businesses and the gap between those present and those needed to mobilise sustainable transformations. Then the platform can determine what incentives, long-term planning and support are needed to create a transformative operating environment. Local businesses need to be provided with a fuller picture of the social, environmental and economic value of transformation. This may come from engaging with the values of traditional, indigenous and marginalized communities, in addition to policy makers, customers, shareholders and the research community.

- ***Thinking more broadly than just your session, identify elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between cities and climate change.***

  One element of a 'novel assessment framework' is explicit consideration - from the outset - of how the production and utilisation of scientific knowledge is itself a social process. That is, assessment of what the climate change issues are - and what the range of potential/acceptable outcomes are - in a specific city context ought to include consideration of which sectors and people are included in decision-making processes, and the competences of decision-makers to connect different knowledge systems to reach outcomes that are both scientifically appropriate yet also equitable and acceptable across society. Any novel assessment framework should integrate boundary spanning and systems thinking approaches in combination with co-production, collaborative/participative approaches to generate knowledge (Miszczak and Patel, 2017). This is required to successfully identify the opportunities, challenges and barriers for cities and their citizens and organizations to take transformative climate change action. For example, the systems thinking, co-production, embedded research and learning journeys piloted in the Bristol Urban ID and FRACTAL projects are essential methods for research into managing complex urban climate issues. Any framework needs to help organizations at all scales and with all backgrounds, as well as citizens in whatever capacity, to understand the value of changing aspirations, behaviors and practices. Developing a shared language is also important in conveying meaning, for example around carbon neutrality and embedded carbon.

SESSION TITLE: **INFORMAL SETTLEMENTS AND ECONOMIES: MEANS FOR TRANSFORMATIVE CLIMATE ACTION** - WEDNESDAY MARCH 7TH

Session Convener:
Cities Alliance / UN-Habitat

Session Participants:
Moderator:
Dr. Debra Roberts (Co-chair, IPCC Working Group II | Head of Sustainable and Resilient City Initiatives Unit, eThekwini Municipality, Durban, SA)
Speakers:
Mr. Michael Uwemedino (Director, The Human City Project and C-MAP initiative, Nigeria), **Hon Gale Tracy Christian Rigobert** (Minister of Education, Innovation, Gender Relations and Sustainable Development) **Filiep Decorte** (Deputy Director New York Office, United Nations Human Settlements Programme (UN-Habitat)), **Mr. William Cobbett** (Director, Cities Alliance), **Mr. Kabir Arora** (Coordinator, Alliance of Indian Waste Pickers), **Mr. Jean-Pierre Elong Mbassi** (Secretary General, United Cities and Local Governments-Africa), **Mr. Trevion Manning** (Director for Planning, St. James Municipal Council, Jamaica), **Ms. Sheela Patel** (Director of SPARC & chair of SDI)

Session Shepherd:
Julie Greenwalt (Cities Alliance)

Session Student Scientist:
Shingirai Mandizadza

Priority research gaps on the following topics:

- ***What are the top one to two research priorities highlighted in your session? Please relate them to at least one of the conference themes.***

  i. **Low-carbon development opportunities in informal settlements,** for the informal economy (mitigation): One area that clearly necessitates future research is the low-carbon transformation of informal settlements, economies and communities. The question is how can low-carbon and climate-friendly interventions help transform informal communities, assisting mitigation, or rather avoiding future emissions. Traditional development models and current practices of informal community 'upgrading' involves the gradual transition to carbon-intense development pathways associated with a general transformation to middle-class and more formal urban lifestyles. These classic trajectories lock-in carbon intensities for decades. How can low-carbon investments help avoid those 'lock ins'.

  ii. **Integrating and correlating development and climate change priorities:** Somewhat connected to the above (I) is the better understanding of the trade-offs and correlations between sustainable development and climate change. How can climate action support wider sustainable development interventions in informal communities and economies and vice versa, how can 'traditional' development interventions (i.e. basic service provision, safety nets, community empowerment) support climate change mitigation and adaptation actions to achieve transformative change for the close to 1 billion people living at the edge of poverty and oftentimes live in the most climate vulnerable places. A specific element of that wider research question was discussed quite at length during the session:

  What changes are needed in the space of (outdated) planning approaches to transform to include informality as part of urban planning?

  iii. **Community-driven Climate Action:** Participatory, community-based approaches in informal settlements are a long-studied and practiced subject, and many positive development outcomes were realized through community based interventions. In the field of climate change –perhaps because this is a field with different actors – this subject of community based climate action is not yet fully understood or arrived at centre stage, albeit it should be centre stage due to the large portion of people living in informal settlements that are vulnerable to climate change, and the necessity to build (primarily) endemic climate-resilience within communities. A specific question, the policy-making community raised during our session was:

  How can scientists contribute to identifying and then building on examples of inherent community resilience and innovation?

- ***What emerging issue(s) could be incorporated and integrated into the research agenda on cities and climate change that are relevant to your session topic?***

  i. **Informal settlements:** The reality of present and future urbanization outside of G20 countries is characterized by a certain degree of informality, with varying degrees of severity. Existing informal settlements combined with increase climate change impacts as well as continued inefficient and unplanned expansion cities in developing countries leading to a proliferation of informal settlements in critical ecosystems. The associated vulnerabilities necessitate that this subject is moved to

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the centre of attention, at least for climate adaptation, but also increasingly for low-carbon development.

ii. **Circular economy and the informal economy / resource efficiency in informal settlements:** much of the discussion on informality focuses on the issues of adaptation and building resilience, however the carbon footprint and inefficiencies of the informal economy and informal settlement development needs to be considered. Increased knowledge and understanding of improving resource efficiency and better integrating the informal economy into a circular economy that reduces waste and consumption.

- ***What challenges are present, as they relate to your session, working at the city scale (small, medium, large, mega city) and within the context of different urban settings?***

i. **Governance & policy:** Informal settlements, and the lack of many of the amenities of the 'formal city', are not by choice, but by the lack (or failure) of urban policy and governance. Local governments need to address informal settlements multi-dimensionally, as an integral part of city-wide planning, management and development. One main message from our session was:

Cities are changing and this requires a revolution in how we see cities. This involves acknowledging the centrality of informality, planning our cities in new and more thoughtful ways that make people matter and that engage them directly in the co-production of knowledge, data and human settlement design.

ii. **Weighting of options and prioritisation:** Traditional slum upgrading approaches intent to transform informal towards more traditional middle-class lifestyles and neighbourhoods. By this the per-capita emissions would rise significantly and so does, usually the adaptive capacity. Are there options to raise adaptive Capacity but decrease carbon intensity? As one participant put it:

Informal settlements can provide spaces for opportunity and innovation and there is a need to build on this in the context of climate change.

- ***What key external factors outside cities need to be considered to fully address the topic of your session***

i. **Migration patterns:** Informal Settlements are oftentimes the point of entry into the 'urban system' by the large and steady migratory flow of people from rural areas, secondary cities and towns, or neighbouring countries.

ii. **Inequality:** Informal settlements are not informal 'by choice' but rather due to a range of political, economic and social factors that manifest themselves in inequality. Climate action needs to be carefully planned and targeted to help reduce those inequalities, or at the minimum, do not add to their increase.

- ***What questions or challenges related to the topic of your session could be better addressed by integrating the science, policy, and practice communities?***

i. **Using local knowledge effectively in formal science:** data and knowledge is being generated at the local level by local communities and local urban practitioners, however the uptake of this knowledge by the policy and scientific communities have been limited. There is a need to evaluate how knowledge generated in informal contexts can be reflected in literature and science;

ii. **Connecting practitioners and scientific communities:** To date there has been minimal connection on the topic of informality between urban practitioners and the (climate focused) scientific community so collaboration on more effective research that increases understanding of the intersection between informal settlements/ economies and both mitigation and adaptation is necessary;

iii. **Policy dimension:** Ultimately while improving scientific and practitioner knowledge is useful to inform better policy, the lack of effective and concrete urban policies and inclusive city development has created the situation in which people are forced to live and work in the informal settlement in order to survive in many cities. This needs to be addressed at a policy level and incorporates effective strategies for low-carbon development and increasing climate resilience based on scientific and practitioner knowledge. Session participants (and the audience) called for:
There is a need to 're-humanise' the city – from a technological, policy to a human focus to restore dignity. The informal city is the one that is rising.

- ***Identify what data, monitoring, modelling, and/or data architecture could contribute to addressing the priority***

research gaps you identified on cities and climate change. Describe how they could facilitate scientific research to help inform evidence-based policy development.

i. **Co-production of knowledge** as the means for data collection on climate change / environment in informal settlements is critical to address this topic in a way that addresses the development priorities of local communities, their experience and knowledge, combined with relevant research at the local level. There is a need to reference informally generated knowledge in formal literature and science.

- ***Identify knowledge needs across the science, policy, and practice communities relevant to your session that could help to better address city scale issues in scientific research, the policy process, and translating research into action.***

i. **Understanding Urban Policy and governance:** Informal Settlements, ultimately, are the result of failed urban policy and governance. In order to support climate action in informal settlements and communities, one needs to understand where and why those policy/governance failures occurred and what strategies exist to address urban governance. Potentially this is a wider political context than purely climate change related, but it has to be understood how climate action can help address these broader questions.

- ***Identify elements and/or functionalities of a science-policy-practice partnership-based platform that could integrate knowledge, expertise, etc., to address questions/challenges related to your session. Discuss if you think these elements could be leveraged to be used on different topics, be upscaled either to larger cities or multiple cities, and be mainstreamed to address cities and climate change at all scales.***

i. As stated above, the **science, practice, policy on the topic of informality and climate change is largely non-existent,** so the greatest contribution to integrating knowledge and a partnership-based approach would be to establish a methodology which creates this partnership at the city/local level that can be adopted to different cities (across regions, secondary cities, etc). This methodology would determine how to effectively create these linkages to bring it to scale in multiple cities with low capacity to address these issues. One contribution in our session explained:

Cities are changing and this requires a revolution in how we see cities. This involves acknowledging the centrality of informality, planning our cities in new and more thoughtful ways that make people matter and that engage them directly in the co-production of knowledge, data and human settlement design.

- ***Thinking more broadly than just your session, identify elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between cities and climate change.***

A novel assessment framework that could support transformative climate action in informal settlements must take into account:

i. the distinct (unique) downscaled **spatial and socio-economically correlated climate vulnerabilities** of informal settlements and communities;

ii. **understand the trade-offs and correlations** between individual, community-wide and city-wide development and climate action; and

iii. understand and address the **power relationship, policy and governance** issues in order to actually address and implement climate action in informal communities and settlements

SESSION TITLE: **FROM SCIENCE TO ACTION: MAKING ESTIMATES OF THE MULTIPLE BENEFITS OF URBAN**

CLIMATE ACTION ACCESSIBLE FOR DECISION MAKERS - WEDNESDAY MARCH 7TH

Session Convener:
Thomas Day (founding partner of NewClimate Institute)

Session Participants:
Thomas Day (founding partner of NewClimate Institute), **Thomas Bailey** (Head of Research and Innovation, C40 Cities Climate Leadership Group), **Prof Dr. Andy Gouldson** (Professor of Environmental Policy, ESRC Centre for Climate Change Economics and Policy, University of Leeds. Leeds, UK. Chair of the Leeds Climate Commission Economics Workstream Lead, Coalition for Urban Transitions - a New Climate Economy Special Initiative on Cities. London, UK), **Prof Kristie Ebi** (Professor in the Department of Global Health, University of Washington), **Dr Aspásia Camargo** (Special Advisor of Innovation and Sustainability at the Mayor's Office, City of Rio de Janeiro, Brazil)

Session Shepherd:
Megan L. Melamed (PhD, IGAC Executive Officer, University of Colorado/CIRES)

Priority research gaps on the following topics:

- ***What are the top one to two research priorities highlighted in your session? Please relate them to at least one of the conference themes?***

  i. The importance to address inclusive action: the lack of data, and therefore understanding, about the distribution of benefits is a particular issue. Understanding the equity of the distribution of benefits from climate action is of major importance given the striking inequities that exist in cities, and given the need for climate action to reach the whole population in order to achieve the scale and scope required. Further research to enable this is urgently required, as estimates can be strongly biased if these hidden patterns of inequality are ignored.

  ii. Further research is vital to continue to build the evidence case and to make it more accessible to city-level decision makers. Priority city actions[58] and their respective wider impacts should be assessed through standardized method and approach and be assessable to all decision makers

  i. Better understanding of causal relationships: Further research on specific causal relationships could help to further improve these methodologies in the future, improving their accuracy and the breadth of the applicability. This especially true to approaches that can be generally applied to a range of circumstances with reasonable accuracy, which have an important role to play in making information on benefits accessible, alongside more precise case specific analysis approaches.

  ii. Improved data from cities for inputs and ex-poste assessment: The methodological approaches could also be significantly enhanced by improved availability of data on cities, both related to input data for activities in sectors, but also on ex-poste measurement of actually observed impacts, which can serve to validate and strengthen theoretical ex-ante methodologies. Research is further required on how to implement social change toward low-impact lifestyles in cities. What are the drivers of high-impact lifestyles and how to ameliorate their adverse impacts. What are emerging trends that could be reinforced and amplified (for instance millennials in cities aspiring to less material-intensive lifestyles?) What is the role of stakeholders including businesses, civil society organizations, and local governments in facilitating and managing those changes?

- ***What emerging issue(s) could be incorporated and integrated into the research agenda on cities and climate change that are relevant to your session topic?***

  i. Address the mutual reinforcing cycle between inequality and overconsumption. Consumption is major cause of GHG emissions.

  ii. Prioritize actions that have the largest impact to reduce GHG emissions in cities (McKinsey & C40, 2017)

  iii. What are the key actions cities need to take to be able to distribute benefits of climate action in a more equitable way: increase access? co-create policies? enhance better representation? Etc.

  iv. Correlations between reducing energy poverty and increasing clean and sustainable energy.

  v. What does increasing access of climate action mean in cities? access to energy, access to sustainable transport, access to energy efficient housing but also access to information, to participatory processes, etc. And how does access impact benefits distribution?

[58] Actions that have the greatest potential in most global cities to curb emissions and put cities on a 1.5°C pathway through 2030 (McKinsey & C40, 2017). Available at McKinsey & C40 Cities, 2017. Focused acceleration: A strategic approach to climate action in cities to 2030, Available at: http://www.c40.org/researches/mckinsey-center-for-business-and-environment.

- ***What challenges are present, as they relate to your session, working at the city scale (small, medium, large, mega city) and within the context of different urban settings?***

  i. City governance structures, local government political cycles, decision making processes, engagement with stakeholders including citizens

  ii. Need to enhance the capacity of cities to take wise and effective action amid complex, rapidly changing conditions. This involves building competencies such as knowledge, skills and abilities to perform effectively. Also essential is to develop the mental, emotional and cognitive capacities of leaders (at all organizational levels) that make these competencies possible[59].

  iii. Very different data sources, data sets and data availability

  iv. Very different approaches and methods to measure wider benefits of climate action

  v. Scientific evidence, alone, is not enough to drive change, since policy- and decision-makers process information in quite complex way (values, worldviews, competing interests and priorities). Numerous systemic barriers (local governance structures, political cycles, vested interests, etc) also reinforce this challenge. Therefore, there is a strong need to incorporate the human development and relationships to culture, values, and worldviews when addressing climate change.

- ***What key external factors outside cities need to be considered to fully address the topic of your session?***

  i. Engagement with national governments, scope 3 emissions

  ii. National policies on economic growth

  iii. Importance to address the diversity of needs and motivations, and hence responses to climate change. Individuals, in their multiple roles in the society (policy- and decision-makers at local or national levels, private sector leaders, citizens, etc) have diverse of needs and motivations. Climate change responses should be initiated addressing these singularities.

[59] JOINER, B and JOSEPHS, S. Leadership Agility. Five Levels of Mastery for Anticipating and Initiating Change. 2011.

- ***What questions or challenges related to the topic of your session could be better addressed by integrating the science, policy, and practice communities?***

  i. What are the key actions cities need to take to be able to distribute benefits of climate action in a more equitable way: increase access? co-create policies? enhance better representation? Etc.

  ii. Correlations between reducing energy poverty and increasing clean and sustainable energy.

  iii. What does increasing access of climate action mean in cities? access to energy, access to sustainable transport, access to energy efficient housing but also access to information, to participatory processes, etc. And how does access impact benefits distribution?

- ***Identify what data, monitoring, modelling, and/or data architecture could contribute to addressing the priority research gaps you identified on cities and climate change. Describe how they could facilitate scientific research to help inform evidence-based policy development.***

  C40 framework for impact in climate action and associated partnership - link

- ***Identify knowledge needs across the science, policy, and practice communities relevant to your session that could help to better address city scale issues in scientific research, the policy process, and translating research into action.***

  To incorporate the human dimension when addressing climate change. Scientific evidence, alone, is not enough to drive change, since policy- and decision-makers process information in quite complex way (values, worldviews, competing interests and priorities). Therefore, there is a strong need to incorporate the human development and relationships to culture, values, and worldviews when addressing climate change. Integral and Spiral Dynamics Frameworks described below can be used to address this gap.

- ***Identify elements and/or functionalities of a science-policy-practice partnership-based platform that could integrate knowledge, expertise, etc., to address questions/challenges related to your session. Discuss if you think these elements could be leveraged to be used on different topics, be upscaled either to larger cities or multiple cities, and be mainstreamed to address cities and climate change at all scales.***

i. A great deal of fragmented research and information relevant for these objectives exists, from research institutions, civil society organisations and information collected by city-level and national governments. Enhanced collaboration between these groups to share information and better understand estimated and observed impacts can help to accelerate the developing case for action, empowering cities to make the necessary moves towards a climate safe, healthy and prosperous future.

ii. The Urban Climate Actions Impact Framework

- ***Thinking more broadly than just your session, identify elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between cities and climate change.***

i. Spiral Dynamics Framework/ Integral Framework: framework for transformational social change. It integrates more than 40 years of scientific research in the US and 10 years of practical application in South Africa (where successful implementation guaranteed smooth political transition after the Apartheid). Resistance is a normal part of the change process, in fact, there can be no real change without some resistance. The magnitude and the scale of transformative change that is needed to address climate change explain the resistance and barriers encountered. Therefore, tools addressing change, in addition to climate, acknowledging that individuals (and cities and any other organization) have distinct capacities (levels and lines of development) are an essential element to effectively and efficiently tackle climate change.

ii. **PACT Framework:** Performance Acceleration through Capacity Building. Peer-reviewed tool assessed by the UK Climate Impact Programme (UKCIP) to assess different capacities of cities and other organizations. There is substantial evidence that very few cities currently have a sufficiently high level of capacity to achieve Paris-consistent goals. To be capable of reaching this goal in a meaningful way, cities' need for support will vary very greatly (independently of their region and culture) according to their different levels of capacity. Thus, cities' levels of capacity become a crucial variable in achieving Paris-consistent goals.

iii. **Urban Climate Action Impacts Framework:** A deep understanding of how climate actions are linked with the SDGs is a fundamental step to establish the case for climate action. It has been at the core of a recent global research effort led by C40 and Ramboll. The development of an Urban Climate Action Impacts Framework, supported by 15 C40 member cities and experts from sixteen NGOs, international governmental organisations, consultancies, and think tank organisations that are promoting sustainable and resilient urban development, illustrates how urban life is highly interconnected, where the environment, society and economy all impact each other (both positively and negatively) in complex dynamics. Report can be assessed in this link.

SESSION TITLE: **YOUTH VOICES AND CLIMATE CHANGE KNOWLEDGE: EMPOWERING YOUTH IN CONVERSATIONS ON CLIMATE IMPACT AND VULNERABILITIES** - WEDNESDAY MARCH 7TH

Session Convener:
Sarah Flynn & Terry Godwaldt

Session Participants:
Anthea Adjei Tawiah (Ghana), **David Felipe Gonzalez Galindo** (Colombia), **Fabrizio Sebastian Manuel Malpartida Melgarejo** (Peru), Keshav Sheetal Shah (USA), **Kevina Nuraini Yusuf** (Indonesia), **Jingtong "Judy" Lin** (China), **Natalia Okutoi** (Kenya), **Pedro Lomando Restum de Macedo Rocha** (Brazil), **Sofia Velez Rodriguez** (Colombia), **Suhanee Giroti** (India), **Taja Islamovic** (Slovenia), **Kambal Bloxhan** (Calgary, CA), **Ye Jin "Julia" Chung** (Edmonton, CA)

Session Shepherd:
Dr. Seth Schultz

Priority research gaps on the following topics:

- ***What are the top one to two research priorities highlighted in your session? Please relate them to at least one of the conference themes.***

  Theme: Enabling transformative climate action in cities (advancing science and advancing cities)

  At the level of international policy, education is increasingly identified by various governments, organizations, and bodies as a critical means of addressing climate change. For instance, the UN 2030 Agenda for Sustainable Development and the Paris Climate Change Agreement unanimously recognize the importance of climate change education. While International agencies such as UNESCO are driving climate change education policy by providing education policy frameworks and support for education policy development, there is further space for youth engagement in (a) climate education (curriculum, pedagogy, and school infrastructures) and (b) climate citizenship and civic participation.

- ***What emerging issue(s) could be incorporated and integrated into the research agenda on cities and climate change that are relevant to your session topic?***

  Youth identify the gaps in current climate education within their various school/civic contexts, particularly with regards to:

  - Inclusion and representation of diverse perspectives in climate education, including the perspectives of youth from various social positions and locations within a city
  - Locally informed curriculum that connects scientific climate research to local contexts, including but not limited to local governance, social issues, and climate vulnerabilities
  - Opportunities for project-based learning, where cities encourage partnerships with local universities and community organizations for contextual learning
  - Social media research and education that addresses (a) media literacy and fake news, and (b) social media as a tool for youth engagement in civic climate action.

- ***What challenges are present, as they relate to your session, working at the city scale (small, medium, large, mega city) and within the context of different urban settings?***

  Uneven distribution of resources among schools within a city provides challenges for implementation of climate change curriculum at a local level, where resource limitations impact school infrastructure, access to climate research, and ability for youth innovation and local climate projects. School resourcing intersects with the precarity of particular youth populations to further marginalize particular youth populations within the climate change conversation.

- ***What key external factors outside cities need to be considered to fully address the topic of your session?***

  While schools are located within city contexts, they are often governed at a regional or federal level, which has impacts for the provision of locally-based climate curriculum, as well as schools' community engagement and civic partnerships. Civic structures must be established to create linkages with schools where these are not already inherent to school governance in order to create more locally effective and responsive climate education.

- ***What questions or challenges related to the topic of your session could be better addressed by integrating the science, policy, and practice communities?***

  Effective education exists at the intersections of science, policy, and practice. However, many of the barriers to effective education lie in the fact that science, policy, and practice are not effectively incorporated into the school experience. There is therefore a need to engage youth in conversations at all levels through a recognition that youth are not only receptors of climate education and policy but also key contributors. Scientific research should be made accessible to youth through education that integrates schools and communities through project-based learning and community partnerships. This would provide youth with the knowledge and skills to participate more effectively in policy-making and to contribute to research agendas.

- ***Identify what data, monitoring, modelling, and/or data architecture could contribute to addressing the priority research gaps you identified on cities and climate change. Describe how they could facilitate scientific research to help inform evidence-based policy development.***

  Large-scale youth engagement via citizen science would provide data on youth experiences with climate change to inform policy developments that address their particular needs. Further, digital methods that draw from social media (i.e. Instagram, Twitter) could map the issue of climate change as expressed by youth through a primary means of youth participation, identifying the key actors, discourses, and issues in the climate conversation. This map could provide location-specific insight into what should be addressed in climate education.

- ***Identify knowledge needs across the science, policy, and practice communities relevant to your session that could help to better address city scale issues in scientific research, the policy process, and translating research into action.***

  While education is critical to connecting citizens to scientific research on climate issues and promoting climate citizenship at the civic level, there are few structural connections between civic governments and youth. While youth are highly invested in climate issues, they do not have a voice in civic policy making via electoral processes. Thus, cities need to consider means of direct youth consultation via youth councils, as well as indirect engagement via schools, in order to develop more effective policies and mobilize youth into effective and informed local action.

- ***Identify elements and/or functionalities of a science-policy-practice partnership-based platform that could integrate knowledge, expertise, etc., to address questions/challenges related to your session. Discuss if you think these elements could be leveraged to be used on different topics, be upscaled either to larger cities or multiple cities, and be mainstreamed to address cities and climate change at all scales.***

  A science-policy-practice partnership-based platform should structurally include youth engagement and representation, as youth are key stakeholders in the climate conversation and inheritors are current policy. Youth consultation could be integrated at all sites and scales, for instance via civic youth councils, as well as through representation in international policy bodies.

- ***Thinking more broadly than just your session, identify elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between cities and climate change.***

  As youth consider social media a primary platform for both consumption and expression of climate realities, research, and action, as well as a space for organizing for climate action, digital methods would provide a means of assessing youth voice on climate issues

SESSION TITLE: **CLIMATE CHANGE ADAPTATION IN CITIES: INSIGHTS ON ACTORS, INSTITUTIONS, AND AGENDAS** - WEDNESDAY MARCH 7TH

Session Convener:
Chandni Singh

Session Participants:
Speakers:
Amy Davison, Kathleen Diga, Garima Jain, Chandni Singh
Session Chairs/Discussants:
Bruce Currie-Alder, Allan Lavell

Session Shepherd:
Gian Delgado

Student Support Scientist:
Carolina Montenegro (University of Alberta, Department of Psychology)

Priority research gaps on the following topics:

- ***What are the top one to two research priorities highlighted in your session? Please relate them to at least one of the conference themes.***

  i. In practice, adaptation actions are undertaken by multiple actors, at different scales; mediated by diverse institutional arrangements; and reflect different agendas and visions of what effective adaptation and sustainable urban development mean. In our session, we aim to examine how various combinations of actors, institutions and agendas play out to have differential adaptation outcomes. We do so by presenting four cases across the global South where development and adaptation imperatives are critical.

  ii. The cases we are presenting draw from research (Chandni's case on migration in South India), policy (Amy's case on drought management and adaptation planning in Cape Town) and practice (Kathleen's case on community-based adaptation in Durban). This rich empirical evidence directly speaks to the conference priorities of building evidence on effective urban adaptation in the global South and will also discuss how adaptation policies need to be implemented alongside (but not limited to) imperatives of sustainable development and disaster risk reduction (as evidenced by Garima's case on disaster relocation in South India).

- ***What emerging issue(s) could be incorporated and integrated into the research agenda on cities and climate change that are relevant to your session topic?***

  i. The need to evaluate available choices of adaptation measures for holistic socio-economic and environmental outcomes at various temporal scales (based on the Chennai case)

  ii. The need to develop adaptation options for dealing with extreme or rare climate events that would not have been accounted for in "ordinary" adaptation planning, and to better understand whether and how these types of events may become a "new normal" (based on the Cape Town case

- ***What challenges are present, as they relate to your session, working at the city scale (small, medium, large, mega city) and within the context of different urban settings?***

  i. Case 1 (Bangalore): Challenge of thinking of urban and rural areas as discrete and overlooking the tangible and intangible flows through people, ideas, resources, finances etc. Thus, necessary to look at the rural-urban continuum as a system that faces multiple pressures (climatic, non-climatic), is dynamic and transitioning rapidly, and is embedded in different governance spaces. Few policies and actors traverse the rural-urban continuum leading to tradeoffs and competitions between the rural and urban.

  ii. Case 2 (Cape Town): Challenge of high levels of inequality and conflicting agendas in a resource constrained environment in which it is not possible to implement expensive adaptation options without limiting the ability to deliver on other key local government services, such as housing and transport. This is compounded by the challenge of uncertainty regarding the future climate of the region.

  iii. Case 4 (Chennai): Challenge of assessing development centric agendas for climate change adaptation outcomes, especially when the national and provincial government actors are the key decision-makers and local government and affected communities have limited capacities to cope as well as the power to affect change.

- ***What key external factors outside cities need to be considered to fully address the topic of your session?***

  i. rural urban linkages as discussed above

  ii. winners and losers (tradeoffs) across spatio-temporal scales

  iii. structural vulnerabilities entrenched historically in place

- ***What questions or challenges related to the topic of your session could be better addressed by integrating the science, policy, and practice communities?***

  i. Identifying solutions and communicating alternative adaptation measures that are equitable and effective to deal with climatic and non-climatic risks requires an integration of science, policy, and practice communities as well as the most vulnerable communities. In Chennai, these are informal settlements along river banks who face evictions after flooding events; in Bangalore these are migrant workers who enter informal wage labour and face socio-political marginalisation in the city.

  ii. Cross-institution knowledge sharing and incorporation of risk mitigation and adaptation measures in mainstream development objectives can be enabled by bringing science, policy and practice communities together

- ***Identify what data, monitoring, modelling, and/or data architecture could contribute to addressing the priority research gaps you identified on cities and climate change. Describe how they could facilitate scientific research to help inform evidence-based policy development.***

  Data or data modelling that helps cities better understand their local/regional climate systems in order to make rational evidence based policy, with a particular focus on understanding the role of extreme or rare events and how the frequency of these may change into the future (from the Cape Town Case)

- ***Identify knowledge needs across the science, policy, and practice communities relevant to your session that could help to better address city scale issues in scientific research, the policy process, and translating research into action.***

  – Social and Environmental Risk Assessment Tools and Information for all development practitioners

  – Monitoring and evaluation frameworks for development practices and investments incorporating measurements for climate mitigation and adaptation outcomes at spatial-temporal dimensions

  – Improved urban flood modelling incorporating crowd-sourced information on built-up areas

- ***Identify elements and/or functionalities of a science-policy-practice partnership-based platform that could integrate knowledge, expertise, etc., to address questions/challenges related to your session. Discuss if you think these elements could be leveraged to be used on different topics, be upscaled either to larger cities or multiple cities, and be mainstreamed to address cities and climate change at all scales.***

  – Building a global/cross-regional database on the quantum and different forms of displacement (migration, state-led or autonomous relocation, climate-induced displacement, etc.) This can be led by the International Displacement Monitoring Centre.

  – Building a searchable global platform/database that would allow city practitioners and academics to share successes and failures of adaptation measures.

- ***Thinking more broadly than just your session, identify elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between cities and climate change.***

  – Need more studies looking at examples of failure in urban adaptation and what one can learn from them

  – Examination of potential maladaptive outcomes of current interventions (and how these can be pre-empted and avoided)

  – More studies on smaller cities, especially in countries like India, Nigeria, China, where second-tier cities house significant populations and concentrate significant risks as they continue to grow.

SESSION TITLE: **YOUTH VOICES AND CLIMATE CHANGE KNOWLEDGE: EMPOWERING YOUTH IN CONVERSATIONS ON CLIMATE IMPACT AND VULNERABILITIES** - WEDNESDAY MARCH 7TH

Session Convener:
Sarah Flynn & Terry Godwaldt

Session Participants:
Anthea Adjei Tawiah (Ghana), **David Felipe Gonzalez Galindo** (Colombia), **Fabrizio Sebastian Manuel Malpartida Melgarejo** (Peru), **Keshav Sheetal Shah** (USA), **Kevina Nuraini Yusuf** (Indonesia), **Jingtong "Judy" Lin** (China), **Natalia Okutoi** (Kenya), **Pedro Lomando Restum de Macedo Rocha** (Brazil), **Sofia Velez Rodriguez** (Colombia), Suhanee Giroti (India), **Taja Islamovic** (Slovenia), **Kambal Bloxhan** (Calgary, CA), **Ye Jin "Julia" Chung** (Edmonton, CA)

Session Shepherd:
Dr. Seth Schultz

Parallel session summary

Authors:
Session Convener:
Sarah Flynn & **Terry Godwaldt**

Session Participants:
Anthea Adjei Tawiah (Ghana), **David Felipe Gonzalez Galindo** (Colombia), **Fabrizio Sebastian Manuel Malpartida Melgarejo** (Peru), **Keshav Sheetal Shah** (USA), **Kevina Nuraini Yusuf** (Indonesia), **Jingtong "Judy" Lin** (China), **Natalia Okutoi** (Kenya), **Pedro Lomando Restum de Macedo Rocha** (Brazil), **Sofia Velez Rodriguez** (Colombia), **Suhanee Giroti** (India), **Taja Islamovic** (Slovenia), **Kambal Bloxhan** (Calgary, CA), **Ye Jin "Julia" Chung** (Edmonton, CA)

Session Shepherd:
Dr. Seth Schultz

Session Aims and Format

The primary goal of this project was to allow students to share and discuss the impacts, lessons, and experiences of climate change in their homes, local communities, and urban centres; and then relay the ways in which they are uniquely adapting and responding to these challenges. After engaging in global conversations, the youth participants identified various risks and vulnerabilities they face, commonalities and differences, and established a framework of meaningful priorities, policies, and calls to action for systemic initiatives in addressing climate change, with a particular lens to education, educational frameworks, and the opportunities and challenges therein. As a result of this three-month, intensive partnership, an international delegation of youth from the participating cities met in Edmonton, and between February 28 - March 5, 2018, they produced a 'Whitepaper on Climate Change,' which will be presented in this conference session. Following introduction and the Whitepaper presentation, we will engage session participants in a 'World Café' to cultivate deep, rich conversations around issues that genuinely matter to a community of scholars sharing similar interest and passion.

State-of-Knowledge Summary

Students are in the process of producing the paper that will be presented at the IPCC Cities and Climate Change conference, which will draw upon weeks of international collaborations, surveys, and artistic responses to climate change. This paper will be provided once complete.

Flooding in Kalerwe, Kampala ©UN-Habitat/Nicholas Kajoba

CITIES
2018·CONFERENCE
IPCC

International Youth White Paper on Climate Change

EDUCATION AND CITIES

CGE TakingITGlobal INSPIRE INFORM INVOLVE EDMONTON PUBLIC SCHOOLS Alberta Louis Berger

INTERNATIONAL YOUTH WHITE PAPER ON CLIMATE CHANGE

Prologue

This paper is a result of work done by over 4000 students from 13 countries, in partnership with The Centre for Global Education, C40, the Government of Alberta, TakingITGlobal, Louis Berger, and the Berger Charitable Foundation. After weeks of engaging in online activities, national surveys, and climate action projects, students came together to collaborate, through the use of technology, in a Virtual Town Hall to discuss the youth's vision for Education, Cities and Climate Change . From every continent, the youth of the world exchanged ideas, debated alternatives, and ultimately created a document that represents their collective voice. The Virtual Town Hall was the culmination of months of online teamwork, 10,000 hours of student collaboration, over 500 hours of teacher facilitation, and the passion of these youth to engage in an international conversation and have their voices heard.

Student Art

Student artists from around the world submitted art expressions to a Global Gallery that reflected their thoughts on climate change. The writing team has described how art is significant to this paper not as a filler or decoration, but as a way of expressing what the students know. Among a group of people who speak various languages, students found art to be the language that everybody understands, although each piece might have different meanings for each person. In this paper, you will find different art expressions made by students all over the world that have helped the writers understand the different topics.

Participant Countries

- São Paulo, Brazil - Colégio Magno
- Edmonton, Canada - Queen Elizabeth High School
- Lima, Peru - Colegio de Ciencias
- Jakarta, Indonesia - SMA Labschool Cibubur
- New Delhi, India - The Shri Ram School
- Monterrey, Mexico - ASFM
- Greater Accra, Ghana - SOS -Hermann Gmeiner
- International College
- Nairobi, Kenya - St Austin's Academy
- Ptuj, Slovenia - Gimnazija Ptuj
- Alberta, Canada - ACLYN
- London, England - Reach Academy Feltham
- Los Altos, USA - Bullis Charter School
- Bogotá, Colombia - Gimnasio Los Caobos
- Beijing, China - Beijing National Day School

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Date: March, 2018

> **The People, the people are who have power to kill or keep the Earth alive, and we are all in this.**
>
> - Fabrizio, Peru

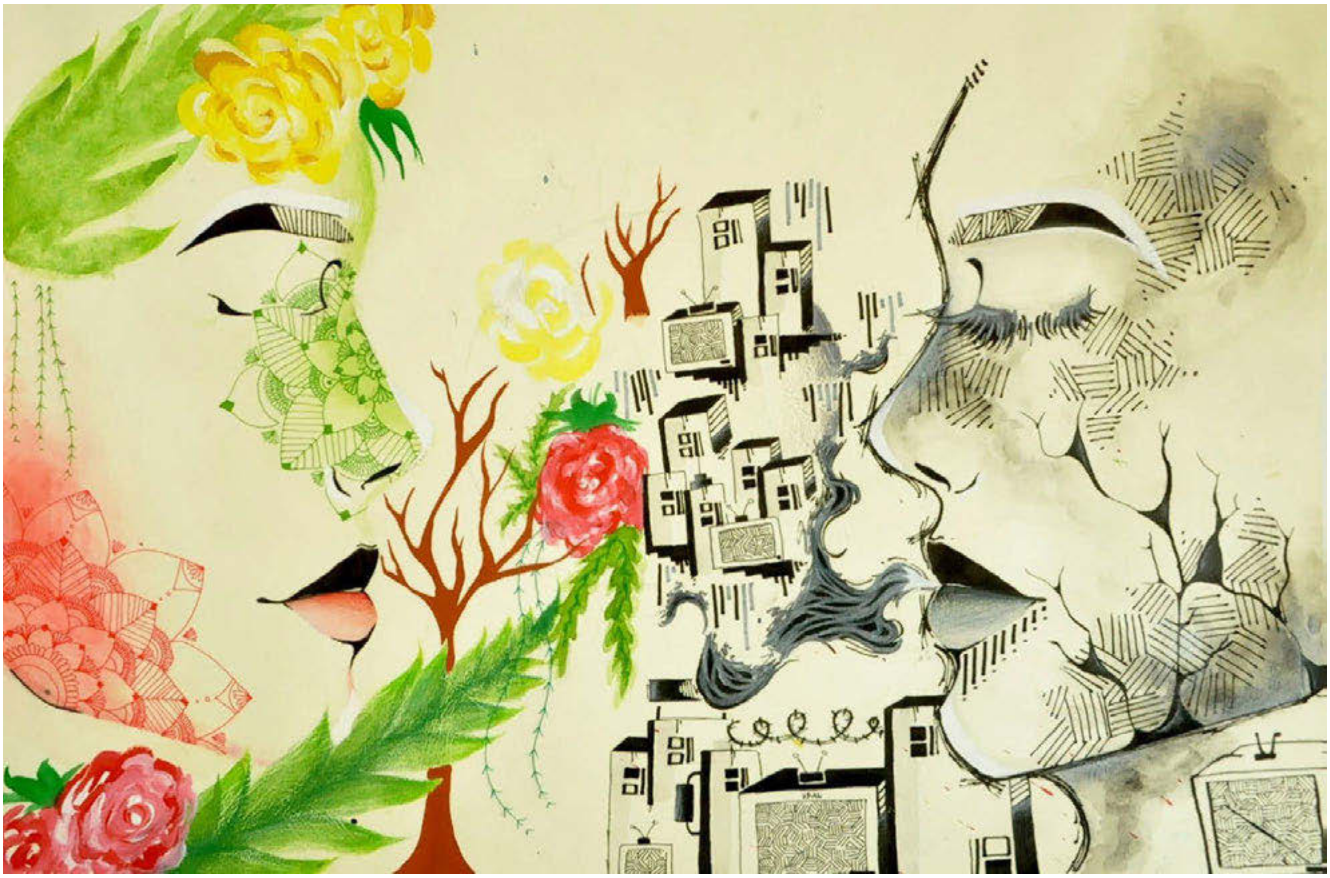
Introduction

Climate change problems did not start with the large corporations of the world and national governments. Climate change started with people whose daily choices fed their power, production, and their popularity. It is going to take those same ordinary people to mitigate climate change. We, the youth of the globe, challenge cities, governments, schools, and individuals to adopt our effective ideas to combat climate change in creative and innovative ways. Through mitigation and adaptation we have the capability to overcome climate change.

Youth will possibly play the biggest role in how the present and future societies address climate change, and so we - the youth representatives from Brazil, Canada, China, Columbia, Ghana, India, Indonesia, Kenya, Mexico, Peru, Slovenia, the United Kingdom, and the United States of America - believe that more youth should be involved in discussions surrounding climate change, and be a crucial part of finding solutions. As our surveys indicate (see Appendix), we believe that we as citizens can have an impact, but we do not see our governments taking steps to address climate issues - and we would like to see a change. While acknowledging the inherent complexities, through the themes of equity and inclusion, education and updated curriculum, infrastructure, project based learning, and social media and communication, youth have become climate action leaders both locally and globally today.

I. Equity and Inclusion

All cities around the world must recognise their place in creating and implementing an equitable response to climate change. This means that every city and government around the world is responsible for mitigating and adapting to climate change in proportion to their own impact on the climate and the contexts in which they live.



Environment - and what we are doing to it, **Jeon, Kenya**

Action points:

- Climate change conversations and action must address the barriers faced in cities and schools.
- Climate change conversations must include the opinions of all people and communities in our cities.
- Governments must meaningfully include youth in city decision-making.
- Climate change policies must benefit marginalized populations.

Climate change conversations and actions must address the barriers faced in cities and schools. In cities and schools, there are barriers that restrict how some people are represented when addressing climate issues, including gender, ethnicity, and socio-economic class. We are aware as we write that many students around the world are not able to contribute to this climate conversation, despite how they may be addressing climate issues in their contexts, and that their contributions may lead to different answers. At the city level, the voices of youth are often not heard, ignored, or not taken seriously because youth are not seen as credible participants. Compounding the issue, schools in low-income areas tend to be more vulnerable to climate change because they do not have the infrastructure to adapt to natural disasters, and are increasingly impacted as the strength and frequency of natural and climatic disasters grow. This forces some students to stay home from schools that are flooded or impacted by immense heatwaves. Even when a student may want to address climate change, they may be focused on ways for their family to survive. We believe that cities and schools must take extra steps to include these populations.

Climate change conversations must include the opinions of all people and communities in our cities. Conversations about climate change are often limited to a few privileged groups of people. Unfortunately, this means that the majority of populations do not have equitable access to information or a recognized voice regarding these issues. Some cities or towns may not have reliable and consistent internet access, limiting access to accurate and up to date data on climate change. At the same time, some of these communities might hold traditional and local knowledge that helps these people adapt to climate change in their own ways, yet may be ignored by researchers and policy makers. As examples, in Bangladesh, villagers are creating floating vegetable gardens to protect their lands from flooding, while in Vietnam, communities are helping to plant dense mangroves along the coast to diffuse tropical-storm waves. It is unfortunate and dangerous that

GLobal Warming Equity, **Lemi, India**

local knowledges and adaptations to climate change may not be recognized as valid by individuals and institutions. Therefore, we must draw these communities into global conversations on climate change.

> **To contribute, we need to act and not stay in chairs just talking about issues. We need to talk about solutions that can not only help with our own country's problems, but also solutions that can help the whole world.**
>
> - Pedro, Brazil

Governments must meaningfully include youth in city decision-making. There are multiple ways that governments can collaborate with youth. To begin, it is imperative that all levels of government establish effective youth councils with representatives that reflect the diversity of their youth populations, and publicize these councils among schools. Councils can be a platform for youth to have their voices heard by the local community along with city and national officials. To make the youth voice more credible, we support paid internships for youth in government positions, as well as government support of action projects for youth. For instance, Shauna, a student from Calgary, Canada, worked with the government to create funds for solar panels on schools. We believe that students in every city must have opportunities like this.

> **Climate change issues must be tackled in a way where all individuals are engaged to solve the problem and contribute daily. Our communities' institutions must be the ones making a change first - they must be a good model so that others can follow.**
>
> - Julia, Canada

Climate change policy development must benefit marginalized populations. If governments and schools empower and enable youth participation from all parts of the city and all types of schools, climate conversations will consist of more critical opinions and points of view. It is important to overcome inequity through collaborative actions that teach and listen with marginalized groups as equals. When all populations are included and valued, solutions are more likely to be equitable, scalable, feasible and robust, by limiting negative impacts on vulnerable populations.

Complexities

In making these recommendations, we are aware that a multitude of solutions will be required to adequately address the climate crisis. In fact, solutions for a problem in one place may inadvertently result in a negative consequence somewhere else, even within a single community. This must be taken into account when trying to resolve climate issues; every solution requires an iterative approach.

II. Education and Updated Curriculum Action points:

- Climate change must be integrated into the whole school, all grade levels, and be taught cross-curricularly.
- Schools and cities must work together to develop and use spaces for students to collaborate with other students, members of their communities and cities, and experts in the industries related to climate change, in order to find and implement viable means of addressing this issue.
- Schools must prepare students for climate disasters and involve young people in developing disaster readiness responses.

Climate change learning and action must be integrated into the whole school, at all grade levels, and be taught cross-curricularly. To engage students, climate change is a topic that must not only be integrated into science classes, but into all aspects of student learning. For example, students could explore climate change through mathematical word problems, discussing articles related to climate change in Language classes, or using Fine Arts classes to promote climate justice campaigns. We can take inspiration from Ghanaian artist Økuntakinte who creates art pieces from e-waste to reduce the volume of garbage burned up in his city, Accra. What students learn in school will allow students to address climate change through multiple angles. Moreover, older students must also learn to act as mentors to students in younger grades to offer advice and encourage them with hope. All of these unique integrations also hold opportunities for students to connect their climate learning to their cities and local communities, as we outline in more detail below.

Schools and cities must work together to develop and use spaces for students to collaborate with other students, members of their communities and cities, and experts in the industries related to climate change, in order to find and implement viable means of addressing this issue. School is not just a place of learning, but of creation, and collaboration feeds innovation. In creating a collaborative engagement space within schools, students are better able to become directly involved in actions about the issues at hand, and develop and implement real life solutions. As they develop real life solutions, students can apply them in their schools to build greener communities. Furthermore, schools must meaningfully involve individuals from diverse communities. We believe that actively including minority groups and individuals will allow students to gain a broader understanding of the impacts of climate change, thus developing their abilities to find and implement solutions that address the needs of everyone.

In between the Haze and the Sky, **Justin, Macao**

Schools must prepare students for climate disasters and involve young people in developing disaster readiness responses. Solving our climate change challenges is a relatively long process - it might take years, or even decades, as there are no universal or quick-fixes. So it is important for schools to teach students how to respond and cope with droughts, floods, and heavy rain. For instance, people living in areas such as Mumbai, where floods are common, should be taught the basic procedures to be able to survive them. Furthermore, young people must be involved in developing disaster readiness responses that make sense for them, for adapting to climate change is as equally important as solving it.

> **People are constantly looking for ideas and solutions on how to live with problems they are facing... but instead they need to learn how to fight water but how to live alongside water.**
>
> - Taja, Slovenia

Complexities

Critics of climate change education say it is a form of propaganda. Due to these widespread prejudices, there can be resistance to integrating education on climate change in schools. However, with the increasing frequency of climate tragedies like the 2015 46°C heat wave in India that killed 2,500 people, we cannot let ignorance limit us any longer. In this context, we believe that education through real life data and facts is not creating a false reality for students - it is especially necessary in the era of alternate facts. Education about climate change is not indoctrinating children, but empowering them with accurate information and data to think critically, enabling them to generate their own questions, critiques, and responses.

> **Climate change is not an ideology, but it is the reality.**
>
> -Paola, Mexico

> **Create spaces for students to talk about, create, and invent responses to climate change and the environment.**
>
> - Anthea, Ghana

III. Infrastructure

"Create spaces for students to talk about, create and invent responses to climate change and the environment"
- Anthea, Ghana

Action points:

- School infrastructure must enhance and support student learning.
- School infrastructure must become more sustainable and eco-friendly.
- Governments must offer financial aid to support and implement green school infrastructure and ensure the neighborhoods around schools support climate education and climate-friendly practices.

School infrastructure must enhance and support student learning. Teaching students about using renewable energy to run our schools or making use of public transport and cycling infrastructure are some of the first steps to linking our knowledge to real life applications. However, unless cities and schools actually make use of innovations like solar energy or offer school buses, educations falls flat. We believe that our schools must be living buildings that are net zero, with features such as moss walls, green roofs, recycled structures, and natural lighting. Such buildings can be used as learning vehicles and encourage sustainable lifestyles amongst students. For example, in Gimnasio Los Caobos school in Colombia, students carried out a project with the objective of finding a way to collect rainwater for irrigation of their school orchard. This challenge was given to tenth grade students to become aware that water is a fundamental natural resource and must be preserved. These students are providing an example for children of lower grades and are transforming the infrastructure of the school to become more sustainable.

School infrastructure must become more sustainable and eco-friendly. We believe that restructuring school infrastructure to include green spaces and natural lighting will result in improved student learning, attendance, and mental health. Fresh air from plants and the use of natural lighting will decrease stress and anxiety that arise from climate instability and raise alertness and concentration. In addition, the colors of different plants have a positive impact on student wellbeing; for example, the color green relaxes students' minds allowing for more active thinking and the development of new ideas.

Governments must offer financial aid to support and implement green school infrastructure and ensure the neighborhoods around schools support climate education and climate-friendly practices. It is the responsibility of governments to provide the necessary funds to implement green infrastructure within schools, and to ensure that the physical structure of schools support student learning. The government can provide two kinds of support: experts who work collaboratively with students to develop revised infrastructure plans, and funding to implement these plans.

Governments must also mandate school cafeterias and stores to provide climate-friendly food. In addition, cities must make sure that there are safe walking routes, bus lanes, and cycling lanes for students to use near the school; this will ensure that climate-friendly practices are incorporated into students' daily life. In these ways, schools and their surrounding neighborhoods may be used as models for other buildings and communities throughout the city. In implementing these recommendations, cities must provide for all neighborhoods and schools equitably.

Global Warming Infrastructure, **Victor, Kenya**

Day without Cars vs a Normal Day in Bogota, **Juliana, Colombia**

Complexities

We recognize that making changes to school and city infrastructure is very challenging. Adapting a city to the suggestions that we have made may come with a lot of pressure from the general public who may resist changes. For instance, while a city may desire to increase the size of their bike lanes, finding space to do so may result in reducing the size of the car lanes, which may not be received positively by the public. Furthermore, factors such as racial issues, city size, caste system, gender roles, and cultural norms may make changing the infrastructure of a city challenging. Altering infrastructure is not simply a matter of altering buildings, as neighborhoods are also shaped by histories, cultures, and social issues that make it difficult to adopt these changes. Yet we believe that cities must work to address, not run from, these issues.

Be Responsibly, **Nashita, Indonesia**

IV. Project Based Learning

We have called for our curriculum to be updated so that it includes climate change, but it is not enough to simply learn about these topics and problems. We must learn how to act on climate change and develop practical solutions that will aid our cities and communities, develop our knowledge, understanding, and skills by working on projects that will enable us to investigate, tackle, and respond over a prolonged period of time. One way we can do this is through project based learning, which gives students a chance to roll up their sleeves and do something to address climate change with the ultimate goal that student projects become a reality.

Action points

- Our education systems and curriculum must expand beyond simply imparting climate change knowledge, to developing practical skills of negotiation, creativity, critical thinking and reasoning, to empower youth to take action through project based learning.
- Cities must support opportunities for learning to expand beyond the classroom through projects that involve collaboration with other stakeholders.

Our education systems and curriculum must expand beyond simply imparting climate change knowledge, to developing practical skills of negotiation, creativity, critical thinking and reasoning, to empower youth to take action through project based learning. The outmoded method of passively learning facts is no longer sufficient to prepare students. Adapting to an complex and shifting issue such as climate change requires innovative thinking and creative approaches. Through project based learning, students go beyond the textbook to develop practical skills to mitigate current and future challenges through real world experience. In researching, discussing, analysing, planning, and doing hands-on work, students will generate their own ideas and develop critical thinking skills that will help them address real life situations. Furthermore, students will develop their own agency and collaboration and communication skills by interacting with people from other communities and schools. Having this type of connection across communities and schools can help develop skills that may not be formally developed through existing curriculum.

Similar to our curriculum recommendations, project based learning must be cross-disciplinary, directed towards all grade levels of students, with increasing complexity as students mature. First grade students, for instance, can start with small activities such as making their own recycling bins. As students advance, they can develop increasingly complex innovations that can be presented to governments or companies who can financially support their ideas, giving them resources for realisation and scaling.

Cities must support opportunities for learning to expand beyond the classroom through projects that involve collaboration with other stakeholders, such as NGOs, industry, universities, and policy makers - both locally and internationally. Working together with school and community partners will help students broaden their ideas about climate change, learn from current research, come up with contextual and effective solutions, and contribute to a community's unique assets. Furthermore, these collaborations will help students take individual and/or collective action, building bonds in their communities, and allowing them to share their ideas with the public. Cities, community partners, and schools must commit to meaningful and long-lasting collaboration, in order for projects to reach their transformative potential.

Schools are a place to practice climate citizenship bacause they are the centre of every community.

- Helena, United Kingdom

Complexities

The implementation of PBL will require commitment and participation from cities in order to address inequities in access and opportunities. PBL is resource intensive, and it requires financial support, participation, networking, and supplies, especially as youth initiate increasingly sophisticated projects that involve layers of community participation. We therefore request monetary and in-kind support from city governments, who should be motivated to invest in the future of their communities. Youth have great ideas such as designing and creating media campaigns, establishing community gardens, and installing green energy projects. However, they are not able to implement them due to the lack of financial and practical resources.

If school projects were directed towards climate change, then the effort would be so much stronger and the ideas would be so much more unique.

- Alyssa, United States

V. Social Media and Communication

Social media are online communication channels and platforms that work through global networks based on interaction and content sharing among people. They are uniquely interactive, instantaneously visible, and engaging, especially the most popular youth platforms like Instagram, Twitter, Pinterest, and Snapchat. However, schools and cities are not yet using these platforms to their full potential.

Action points:

- Schools must teach students how social media can be used to spread awareness about key issues such as climate change.
- Schools must help students understand the power of social media as a tool for organizing events and networks in support of climate action.
- Schools must acknowledge and be able to educate students to differentiate between legitimate and illegitimate information available on social media.
- Cities must use social media as a means of connecting with youth, both to spread climate awareness about what cities are doing and also to hear from youth.

Schools must teach students how social media can be used to spread awareness about key issues such as climate change. Currently, teachers do not sufficiently address the power of social media, but are instead restricting its use. With the scope of social media expanding every day, it is important that schools educate students how various platforms can be used to spread awareness about climate change. For instance, students could be encouraged to upload photographs of their environmental initiatives on Instagram, to access information about ongoing projects, and to use blogs as a way to express their opinions on climate change. Further, schools could address how social media can be used to share information about climate hazards and disasters, so that youth can immediately access support services when needed.

In the global community, you are representing a small portion of the world. Through the connections we make with other global community members, we are able to share information based on our expriences and gain a great understanding of how we are truly all connected.

- Shauna, Canada

Schools must help students understand the power of social media as a tool for organizing events and networks in support of climate action. Social media can be used as a platform that not only focuses on spreading awareness, but also acts as a platform that allows students to encourage, as well as participate in climate action. Social media enables active communication between local and international communities, including governments, organizations, schools, and companies.

Social media overcomes some language and literacy barriers that limit the impact of traditional media in many communities, allowing us to expand our networks to more diverse populations. On Instagram, for instance, people's thoughts are often expressed in the form of photographs rather than in the form of heavy text. Additionally, Instagram and Facebook provide automatic translation, allowing messages to be spread further than if they were presented in print form, within a single language.

Additionally, we can use hashtags and surveys to get people's attention and communicate with organizations to spread awareness. From campaigns and flash mobs, reforestation and waste management workshops, social media extends itself to a massive number of people.

However, to use it to its full potential, schools must teach students how to use social media effectively as a tool for social engagement and transformation.

Schools must acknowledge and be able to educate the students to differentiate between legitimate and illegitimate information available on social media. Due to the mass number of people on social media from various backgrounds, the information that appears on social media is diverse and personalized. It is necessary for educators to help students determine the validity of the information given by individuals and organizations, considering that some of it indirectly promotes their biased opinions and agendas.

Cities should use social media as a means of connecting with youth, both to spread climate awareness about what cities are doing and also to hear from youth. We are living in a digital era. Thus, cities must use social media to increase youth participation in public matters. Through this communication, the youth can also be made aware of what their cities are doing to combat climate change. Using traditional media such as printed newspapers or televised news fails to communicate with youth on their mediums, which are digital, leaving a gap between policy makers and youth.

Complexities

Schools must acknowledge the limits of social media. Not every country has the same type of social media, making it hard to have an international dialogue; China, for instance, uses Weibo and WeChat, whereas students in other places more commonly use WhatsApp, Instagram, and Twitter. Some countries also heavily censor media, preventing people from accessing certain knowledge contrary to government ideologies. Further, citizens have varying access to social media based on their access to technology, their culture, and peer group, and people of different ages use different types of social media. As a result, there is no one way to communicate with everyone, and it is difficult to create cross-generational conversations. Additionally, trends in social media are always changing, which makes keeping people engaged in addressing climate change difficult. By understanding the limits of using social media, we can learn how to use it more effectively to engage diverse communities and raise awareness about climate change.

> **We can use social media to get more people the message of being an envornmental activist - that to be one is not as difficult as they might think.**
>
> - Gimnasio Los Caobos, Colombia

Conclusion

We, the youth of the world, believe that climate change is the most critical problem we must address collectively as world citizens, leaving aside our differences.

When referring to climate change, some population are ignored and some are suffering from climate injustice. Governments have the power and responsibility to change their present situation by investing in sustainable projects, giving visible support, and spreading awareness amongst their citizens.

Additionally, our schools prepare us to be the leaders of tomorrow by teaching basic knowledge. However, they do not teach us how to adapt and to have an impact on climate change. This must be taught across each subject, involving interactive project-based activities that will assist students in developing the skills necessary to have more in-depth thinking; and therefore, more in-depth solutions. To facilitate this, schools must teach effective social media use in their curriculums, including how to promote climate change awareness and solutions in order to sensitize people around the globe. However, we must acknowledge the complexities of implementing curricular reform, such as the economic and social barriers facing many schools. Creative and collaborative opportunities involving students, communities, and local governments can and will provide meaningful solutions to diminish the obstacles that prevent us from making these proposals reality.

Climate change is not just a problem that governments must solve; it is a priority that every person must address in their daily activities to gradually address these recommendations. It is easy to talk about climate change and how to solve it, but when it comes to implementation, the challenges and lack of actions appear. So, we now call upon all the policy makers, educators, researchers, and individuals to act, to save our home, Earth.

I think that the world should not be separated each to others, and more in the issues of the planet. I think that for just one time we all should break the frontiers and do something good, something different, something disinterested, something that is going to save all that live in the Earth.

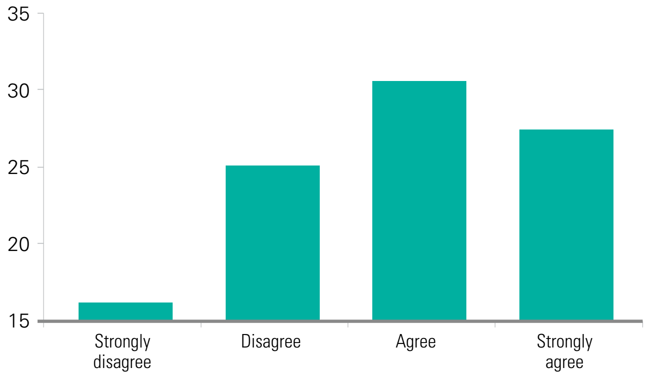
- Fabrizio, Peru

The Student Writing Team in Canada

Appendix: Survey Data

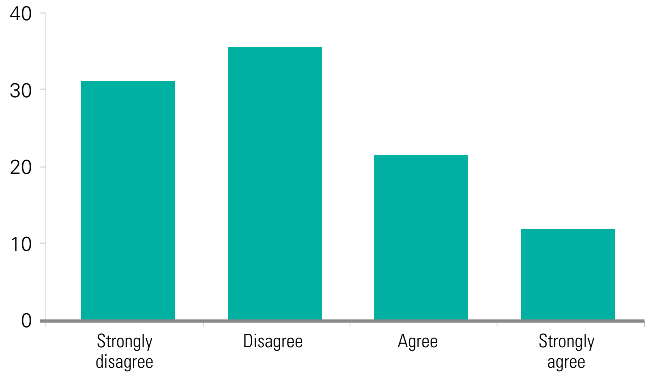
Our survey gathered data 4021 survey respondents worldwide from 12 cities.

I. My actions have an impact on the global climate.



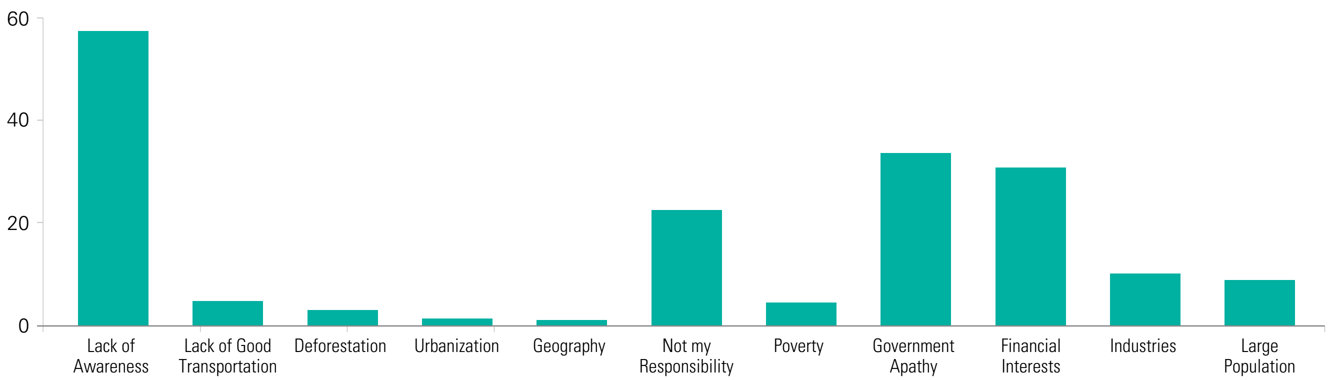
NOTE: We are uncertain whether students believe their individual actions have an impact on the global climate, or whether they perceive their actions as contributing to collective initiatives that impact the global climate. Further research is required.

II. My city is taking effective steps to prevent climate change.



* NOTE: Our survey data does not indicate whether the cities are not in actuality addressing climate change, or whether students are not aware of how their cities are taking steps to prevent climate change. Further research is required.

III. The biggest barriers to addressing climate change are:



* NOTE: Comments within the category, "financial interests," most frequently reference the dominance of corporate interests over climate issues in government policy.- Acuto, M., Rayner, S. City networks: breaking gridlocks or forging (new) lock-ins? Int'l Affairs 2016, 92(5): 1147-1166

Street lighting with solar panel energy. El Khazan street, Sharm El Sheikh. Egypt. © Shutterstock/sokolenok

Conference Posters

Poster were an essential and highly valued contribution to the IPCC Cities and Climate Change Science conference. Posters provided a view of the state of academic and practice-based knowledge related to cities and climate change. Poster presenters were also asked to provide answers to a similar set of questions as session conveners, regarding the research gaps and recommendations which have emerged during the course of their work. This input was collected by the Scientific Steering Committee and was included as important input to the development of the Research and Action Agenda. The list of questions which were answered by poster presenters can be found below. Poster presenters were asked to submit this information in advance of the conference via an online form. Presenters who were not able to access the form had the opportunity to submit their answers by email.

In order to facilitate this, each poster presenter should provide the following in advance of the conference:

- **2 research gaps** about the theme it sits under, or which are related to the following cross cutting topics: Health, Achieving 1.5 in Cities, SDGs, Systems/nexus approach or Informality.

- If appropriate considering their poster topic, poster presenters will provide 1 **(optional) recommendation** on the following topics:

  – How to integrate informal settlements in the urban agenda.

  – Better accounting for the size of cities in city agenda, especially small and medium size

  – Linkages between urban and rural areas

  – Elements of an appropriate global, regional and local monitoring systems and data architectures to facilitate scientific research and to help inform evidence-based policy development on climate change and cities

  – Elements of novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between urban systems and climate change, especially action at the local scale.

  – Elements and functionalities of partnership-based platform to systematically accumulate, assess, analyse and disseminate information on science-policy-practice linkages that enable an upscaling and mainstreaming of urban climate actions at all scales.

Note: Posters are sorted alphabeticaly according to the name of the author

Remote sensing and human perception for the integrated assessment of city parks

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Pressures on urban green:

Warming Climate **Urban Growth**

Need for city park planning based on urban green assessment

Salzburg, Austria, aerial photograph, 2014

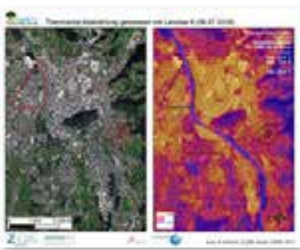
Lehener Park & neighbourhood

Preuschen Park & neighbourhood

Quantitative information from Earth Observation

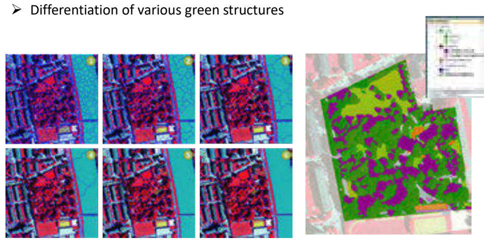
Mapping city park vicinity

- Differentiation of thermal conditions



Local mapping of city parks

- Differentiation of various green structures

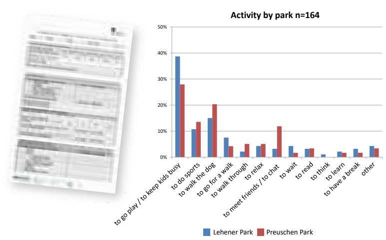


Aerial/satellite image → Multiresolution segmentation → Rule-based classification → Urban green structures

Qualitative information from in-situ collection with surveys

Capture human perception

- 164 interviews with park visitors in both study areas
- Get (1) motives for visiting, (2) attractiveness of park, (3) accessibility of park, (4) perceived importance of urban green

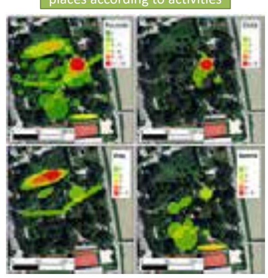


Integrated assessment of urban green

Urban green and non-green areas in the city district Lehen

Urban green in % per block of buildings in Lehen

Local hot spots of favourite places according to activities



Analysing urban green

- Perceived / actual cooling effect of urban green in parks
- Perceived / actual value of urban green in parks and in their vicinity (place of residence of park visitors)
- Localization of hotspots for action

User Workshop

The concept and the initial results were discussed in a user workshop with representatives from the Salzburg city's departments for Municipal Gardening, for Urban Planning and other stakeholders. The participants confirmed the value of the integrated approach of information collection for park planning. It allows new opportunities specifically for small cities with low experience in advanced park planning.

Discussion & Conclusion

The project grünOase (Integrated Analysis and Assessment of Green City Oases) supports sustainable planning of urban green spaces. The analysis of visitors' perception of urban green structures combined with Earth Observation based mapping indicates hotspots of urban green space attractiveness. The inclusion of citizens' perception in the planning process helps to make expert planning decisions more sustainable and more acceptable by the public.
Next to supporting the design and planning of urban green spaces, in particular of city parks, the project findings may also help in defining measures for mitigating urban heat islands.

This project is funded by the Climate and Energy Fund of the Austrian Federal Government and is carried out as part of the 8th call of the "Smart Cities Demo" programme.

Enabling transformative climate action in cities in the context of global goals

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Introduction

Since COP21, a growing movement of non-state actors has gained momentum in the global climate action agenda. Non-party stakeholders are being recognised and invited to scale up their climate actions (UNFCCC, 2016). Among them, cities – municipal authorities and commnunities- are playing a central role in the global response to climate change by reducing greenhouse gas emissions and adapting to the effects of climate change.

Given that urban centers are responsible of more than 70 percent of the world's total greenhouse gases [1] and house a large proportion of the population and the economic activities most at risk from climate change [2], they represent an unique opportunity for scaling up and accelerating a transition to an inclusive, low-carbon and equitable economy.
Significant mitigation and resilience strategies could be delivered by fundamental transformations in the energy, transport and urban infrastructure systems, combined with major behavioral shifts and social and policy change, in a relatively short time frame. Cities have unique and strong influence over several policy levers such as local governments.

To this purpose, different stakeholders coallitions are partnering to implement low-carbon, climate resilient development at subnational and cities level through a growing number of iniciatives and platforms led by cities around the world. This experiences can be a new valuable source of knowledge around cities and climate in general and on science-policy-practice linkages in particular and can enable mainstreaming of urban climate actions at all scales and sectors. Preliminary findings are described in this poster and indicate the main lines of analysis that will be developed in a paper that is in process.

[1] "Why cities?" C40 Cities, accessed January 30, 2018, c40.org.
[2] Climate Change: Implications for Cities. Rian van Staden (2014)

Goals

The aim of this study is to analyze innovative approaches to transformative climate action in cities, as a way to enable the up-scaling and mainstreaming of urban climate actions at all scales and sectors. To this end, focus is put on knowledge frameworks, collaboration schemes and institutional learning carried out by various multistakeholder city initiatives. Identifying key success factors that are common to these platforms, as well as key challenges and barriers, can contribute to increase replication. Demonstrating implementation progress is critical to achieving the climate goals altogether with all Sustainable Development Goals (SDGs).

Method

An updated analysis of the pace and scale of the global transformation at city level is being conducted, based on website information, oficial reports and documents and peer reviewed literature. A group of multistakeholder initiatives towards zero emissions and resilient cities is being analyzed in order to synthesize approaches and frameworks, success factors, barriers and drivers to scale-up. A particular set of multistakeholder initiatives were selected to deepen the analysis: Zero Emissions Cities project , Urban Infrastructure Initiative, Urban Leds, C40 and 100 Resilient Cities.

The criteria employed to select this particular group of initiatives/platforms for the assessment are based on the global scope and coverage, the multiple nature of stakeholders 'action, the ability to design and implement models that can be replicated and escalated to get cities onto a low emissions pathway and the ability to share knowledge and best practices.

These frameworks can be effective knowledge platforms for collaboration between cities officials, local stakeholders, people and private sector to find practical solutions to reach zero emissions in cities, focusing on a wide array of mitigation and adaptation strategies, from smart mobility/logistics, buildings, waste and energy infrastructures to social transformation towards building urban resilience.

Discussion and preliminary findings

From a bottom up approach, thousands of cities and local governments have committed to climate goals to 2020 and beyond, and are partnering to implement climate action plans. NAZCA platform - Non-State Actor Zone for Climate Action- currently captures the commitments to climate action of 2508 cities, both individually and –mainly- through cooperative initiatives.

While the existing literature has explored the mitigation potential – and to a lesser extent the adaptation efforts- of sub-national climate action networks, there is a need - and an opportunity as well - to get a deeper understanding of its further potential and conditions for dissemination [3]. To start addressing this gap, building on a set of existing experiences, we identified and synthesized supportive factors that are common to all initiatives and underlined their main features. From the analysis of these experiences we have identify key success factors for scaling up, with special focus on innovative elements and features.

Table 1. Brief description of climate action initiatives in cities under assessment.

Initiative/ platform	Leading organization	Goals and objetives
Zero Emissions Cities (ZEC)	World Business Council for Sustainable Development (WBCSD)	A community of citizens, governments, local stakeholders, business and solution providers working together since 2015 to get cities to a zero-emissions pathway.
Urban infrastructure Initiative (UII)	ICLEI World Business Council for Sustainable Development (WBCSD)	A multi-sector collaboration project between 14 leading global companies and 10 cities around the world, between 2010 and 2014, using a structured engagement process.
Urban Low Emission Development Strategy (Urban LEDS)	UN-Habitat ICLEI	Low emission urban development in 29 local governments in four emerging economy countries with the support of 8 European cities from 2012 to 2016, through innovative approaches to involve stakeholders.
C40	Steering Committee. C40 mayors serve in rotation on the Steering Committee, which provides strategic direction and governance for C40	Global network of more than 90 of the world's greatest cities, developing and implementing policies and programs that generate measurable reductions in both greenhouse gas emissions and climate risks.
100 Resilient Cities (100RC)	Pioneered by the Rockefeller Foundation	Aims to help individual cities become more resilient and to facilitate the building of a global practice of resilience among governments, NGOs, the private sector, and individual citizens.

[3] Hale, T. (2016). "All hands on deck": The Paris agreement and nonstate climate action. Global Environmental Politics, 16(3), 12-22.

Innovative features for a low-carbon transition in cities

1. Shared vision and master plan

Shared objectives and a common vision to achieve a sustainable urban development plan, ensuring that all actors work in unison.

2. Sustainability in the mainstream

Sustainable development is a common umbrella framework in all cities´ networks and highlight the importance of promoting technology and social change according to SDG´s.

3. Multistakeholder engagement and multidisciplinary approach

Multistakeholder and multisector involvement is key to achieving targets of low carbon emissions and resilience, broadening ownership, increasing public legitimacy and ensuring transparency. Partnering with majors, local government civil servants, private sector, academia and civil society actors is essential to drive transformational change. The way vulnerable people are framed and included in the cities´ strategies determine the potential success of adaptive action.

4. Neutral facilitator or bridging organization

A neutral facilitator act as a bridging organization, dedicated to promoting and facilitating multi-stakeholder engagement and collaboration.

5. Structured process, defined roles and collaboration process

A clearly structured process is set up, assigning roles to stakeholders, as well as responsibilities for financing actions and plans. Using methodological frameworks according to programs.

6. Transparency

Engagement occurs within a transparent and participative process. Supported by a recognized organization or reporting program to enhance transparency and accountability of climate action.

7. Peer-to-peer exchange

Mechanisms for sharing knowledge, experiences and best practices among members.

8. Tools

Cities are provided with guidance, tools, instruments, best practices and process management support through the process, according to cities' needs.

9. Testing ground

Innovative solutions are tested in concrete urban projects/ areas, before scale up, and local authorities and private actors play a key role in these developments.

10. Targets, Measuring and reporting

All initiatives support cities to adopt a data-driven approach and targets representing current best practice in sustainability. Progress is set and monitor based on well-recognized sustainability standards, targets and indicators. Monitoring and verification are key elements for periodic evaluations and for continuous learning.

Even though each process is shaped by its particular context – policy, economic, cultural context – these factors can be taken into account for replication and scale-up. Some of them are particularly relevant and can actively be addressed by a scaling-up strategy, like engaging actors and participatory processes, ensuring transparent process, bridging organization and knowledge and data exchange between partners. This goes hand in hand with SDG 11, which seeks to enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries by 2030.

Despite the risks faced by cities, their mitigation and adaptation potential, and the successful climate initiatives led by cities in different regions, many cities have not yet addressed climate change (UN-Habitat, 2016), and low-carbon urban development rarelly happens organically [4].

In this context, stakeholder's collaboration platforms can help overcome some barriers. Building partnerships and diverse networks with a wide range of stakeholders and the appropriate governance structures, is helping cities to understand risks, plan for the future and foster innovation.

[4] Building thriving, low-carbon cities: an overview of policy options for national governments. Friday, 09 February 2018 01:52. SEI 2018.

Some conclusions

Sustainable development cannot be achieved without significantly transforming the way we build and manage our urban spaces, as recognized by the 2030 Agenda for Sustainable Development. This will require fundamental transformations at all scales.

Cities' networks are starting to facilitate the transition towards a climate resilient development at regional and national level. These experiences evidence a complex and dinamic process for city stakeholders in the path of building a scalable plan towards low carbon resilient cities. A process that involves continuous learning by sharing, a collaborative approach and multistakeholder governance models.

These initiatives and platforms can be effective knowledge platforms for replication and scaling up. The challenge is to identify innovation and success factors across them and distinguish which elements are context-specific and thus need to be adaptated. They can also contribute to developing novel assessment frameworks that take into account the systemic linkages, synergies and trade-offs between urban systems and climate change action at the local scale.

But there is an identified lack of systematic learning about transitions at the municipal level and this represents an ideal opportunity to address it through collaborative transdisciplinary research.

Finally, demonstrating implementation progress is critical to achieving the climate goals altogether with all SDGs. Improving ways to share practical information for urban practitioners on climate change is fundamental for a number of reasons such as: 1) Foster peer-to-peer learning between cities, 2) Contribute to adapting best practices, 3) Promote the active participation of those involved.


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Challenges of Climate Change Adaptation Policy Implementation in Japanese Cities and Some Transitional Approaches with Scientists, Policy-makers and Stakeholders for Co-design and Co-production

0. Basic Idea of Transitional Approach

Figure 1 depicts an attempt to understand mainstreaming of adaptation strategy through four stages: (1) Implementation of climatic technologies in society starts with the development of technology (A. Technological Innovation). (2) The developed climatic technologies are incorporated into government adaptation strategy and bring about policy transformation and innovation (B. Policy Transformation). (3) Enforcement of new policies leads to changes in social systems that define public awareness and lifestyle, and institutions that define corporate activities (C. Transformation of Social Systems). (4) The ultimate goal of transformation of technology, policy, and social systems is to change society into an adaptive community in which all aspects adapt to climate change (D. Transformation of Society).

To implement climate change adaptation strategy effectively, diverse "social technologies" such as role-play simulation, scenario planning, and capacity building are suggested. It is hoped that applying these social technologies to various climatic technologies will encourage co-design and co-production. With these two innovations, drawing a road map to transformation of society adapted to future climate change is our final goal of the SI-CAT project.

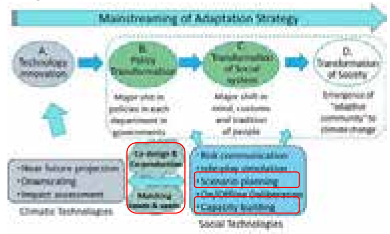

Fig. 1 Basic Idea of Transitional Approach

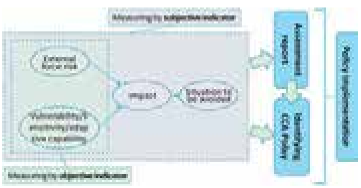
Fig. 2 Framework of Climate Change Adaptation Assessment

1. Capacity Building; Climate Change Adaptation Assessment for Local Officials

We developed a climate change adaptation assessment for local officials which consists of external force risk, vulnerability /sensitivity/adaptive capability, impact, and situations to be avoided (Fig.2). We administered the assessment sheet to some local governments and collected from almost departments of each local government. As the result of our previous nationwide survey to local governments tells that one of the most frequently raised challenges in preparing and implementing climate change adaptation strategies was the issues within the local government offices, such as "Differences in perception among government offices around segregation of duties and priorities, we collected the data from almost departments (Fig. 3). Table 1 shows an example of a part of the assessment report. We issued the report for each local government to build capacity and consensus among departments. We plan to add objective indicators from the output of climate models and others to the assessment report.

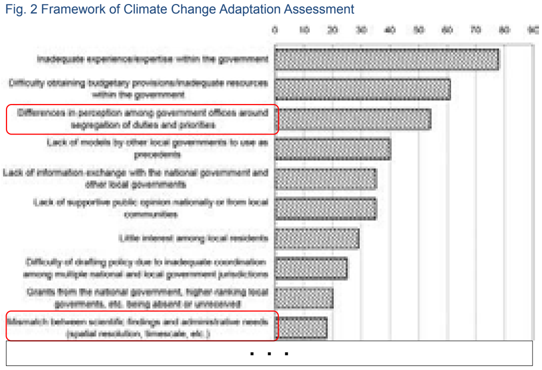

Fig. 3 Challenges for preparing and implementing climate change adaptation strategies in local governments

Table 1 An Example of Perceived risk sensitivity and adaptability in each Department

	Environment bureaus (N=3)	Disaster prevention bureaus (N=8)	Agriculture-related bureaus (N=3)	Health services bureaus (N=3)	Industry/Tourism bureaus (N=5)	Sum
Sensitivity						
People and property are located in areas that are low-lying or zero above sea level	0	2	1	0	0	3
People and property are located on (steep) slopes	0	3	0	0	1	4
People and property are located on soft ground	0	2	1	0	1	4
People and property are located in river basins prone to flooding	0	2	1	1	0	4
People and property are located in flood zones	0	2	1	0	1	4
・・・						
Adaptability						
Administrative policies/plans for coping with climate change impact risks	1	3	2	2	2	10
Administrative resources (staffing, budget) to promote coping with climate change impact risks	1	2	1	3	1	8
Infrastructure (levees, tide embankments, flood gates, sewers, water reservoirs, retarding basins, etc.)	0	5	1	0	0	6
Monitoring (hourly rainfall, etc.)	0	3	0	0	0	3
Resident and business preparedness for and understanding of climate change impact risks	2	2	0	1	1	6
Warning systems (disaster prevention, summer heat, etc.)	0	2	0	0	0	2
Readiness of evacuation sites	0	2	0	0	1	3
BCP (business continuity plans)	0	3	0	0	1	4
・・・						

2. Scenario Planning

Nagano is famous for its fruits production especially apple and grape. But the long term projection of climate change tells that Nagano will no longer be a production area of apple in 50 years. With this background, we have taken a scenario planning approach shown in Fig.4.

First, we conducted stakeholder analysis. We interviewed with the identified 24 stakeholders in total by snowballing sampling and clarified some concerns of them like this matrix. The picture shows stakeholder meeting to share the results of stakeholder analysis and make a influence diagram. Based on this local knowledge, we then input expert knowledge and examined some scenarios of climate change and social situation in Nagano by Delphi method with experts in climate science, agricultural technology and agricultural policy. We accepted comments back from the stakeholder to our draft scenarios. Finally, we plan to hold a scenario workshop to integrate local knowledge and expert knowledge involving the general public. Fig. 5 is the brochure which we put together as the final product. It describes the three scenarios and how to make it.

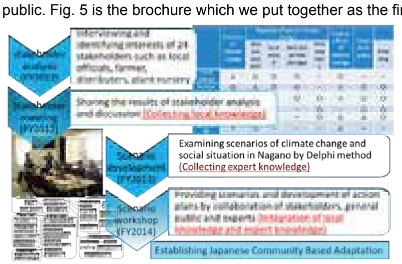

Fig. 4 Application of Scenario Planning to Climate Change Adaptation in Agriculture Issue in Nagano


Fig. 5 The Final Product of Brochure which Describes the Three Scenarios and How to Make It

3. Co-design Workshop with Scientists and Local Officials

Fig. 3 also suggests "Mismatch between scientific findings and administrative needs" should not be understated. Then, we held co-design workshops with scientists and local officials twice to date. We gathered almost 100 participants for each one-day workshop. One of the main issues to be discussed was "What is the helpful projection in terms of practical administrative planning".

The right part of Fig. 6 shows the result of text-mining with the minutes of the workshop. We classified the participants into three categories; local officials, scientists in local governments and scientists. The size of the circles of actors stands for frequency of the speaking, that is, local officials actively speak up because the number of them are large. The size of the circles of themes stands for frequency of being mentioned. The line thickness means the frequency that the actors mentioned. The factors that local officials are concerned about in examining adaptation strategy is that personnel rotation and collaboration with other departments, authorization by the Government. Meanwhile, scientists concerned about precision of the calculation results and projection, their points are absolutely different. We think the key players is scientists in local governments. They understand both concerns of the local officials and scientists, which means they will be good interpreter of them.

Fig. 6 Designing Co-design Workshop with Scientists and Local Officials
- Overview of the Discussions by Text-mining (right part) -

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Acknowledgment; This study was supported by the SI-CAT (Social Implementation Program on Climate Change Adaptation Technology) of the MEXT (the Ministry of Education, Culture, Sports, Science and Technology), Japan.

Ministério da Saúde
FIOCRUZ
Fundação Oswaldo Cruz

Climate Vulnerability System – An Urban Planning Tool

Martha Barata; Felipe Vommaro; Diana Marinho; Frederico de Oliveira; Heliana V. Silva

INTRODUCTION

Our research team is engaged in developing composite indicators to measure and evaluate the relative vulnerability of municipal population towards climate change. It aims to foster the creation of strategies that weaken, over time, the potential negative effects of climate change on municipal population.

The Municipal Index of Population Vulnerability to Climate Change (*MIPVCC*) is achieved using official secondary data bearing in mind the three components that represent an integrated vulnerability concept, according to IPCC framework - exposure, sensitivity and adaptive capacity. Those data are aggregated through a Climate Vulnerability System (*CVS*) that automatically calculates the *MIPVCC* and its components, builds thematic maps and allows the update and insertion of new data so that the index can always be up to date. It is an useful tool for planning and monitoring local adaptation strategies.

STUDY RATIONALE

Global and regional climate scenarios point to the risk of climate change for Brazilian states and cities (Marengo, 2011). There is a growing awareness on the Brazilian government, academia, and society about the need to build strategies to reduce its danger. In 2010, Congress passed the National Climate Change Policy Law (PNMC Brazil – Law Nº 12.187/2009). It called for the reduction of greenhouse gas and the adoption of adaptation strategies.

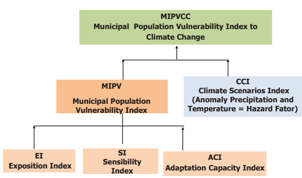
In order to design effective adaptation strategies and prioritize resource investment, it is critical to know how vulnerable a given population is to climate change. Therefore, our research efforts are concentrated in design MIPVCC for the Brazilian states marked in Figure 1. (Barata, MML et al, 2011, 2014, 2015; Confalonieri, U. et al, 2017, 2018; Quintão, AF, 2017).

Figure 1: MIPVCC for Brazilian States

METHOD

CONCEPTUAL MODEL OF *MPVCC*

The *MIPVCC* focuses on quantitative estimates applied to compare the population vulnerability between the municipalities inside each State. It is also concerned with adding new scenarios of climate change in order to determine the municipality most exposed and vulnerable to climate hazards.



$$MIPV_n = \frac{EI_n + SI_n + ACI_n}{3}$$

$$MIPVCC_n = \frac{MIPV_n + CCI_n}{2}$$

BUILDING AND READING *MIPVCC*

Exposition, sensibility, adaptation capacity and climate scenario index are normalized for being aggregated in MIPV and in MIPVCC.

$$In = \frac{\text{(PVI of the Municipality – Lower PVI between Municipalities)}}{\text{(Higher PVI between Municipalities - Lower PVI between Municipalities)}}$$

In = Normalized Index
PVI = Vulnerability Index of Dimension X
X = Exposition, Sensitivity or Adaptation Capacity

After normalizing the index, values ranged from zero to one, where the municipalities with a zero index were the least vulnerable, those with a one were the most vulnerable, and the others ranged somewhere in between.

WHY *CVS*?

The process of generating the MPVCCI is repetitive and its calculation is complex. It contains at least 04 macro indexes (EI, SI, CAI and CCI) and approximately 30 indicators. Their many sources of information are different and regularly updated. In this context, calculation using manual process is slow, error prone and inefficient.

The CVS should be a facilitator, which automates the calculation of the indexes and the generation of thematic maps of the MIPVCC and its macro-indexes.

It allows updating the data in the CVS database in order to:

- Keep the MIPVCC and macro-indexes updated
- Monitor the evolution of those indexes over the years

The CVS is constructed with free software components.

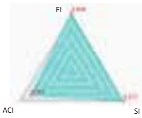
READING AND APPLYING *MIPVCC* PER *CVS*

Examples of some of the outputs of CVS are presented here.

The distribution of population vulnerability (MIPV) to climate change in the state of Maranhão/Brazil is presented and we observe that the relative distribution changes when we consider the Regional Climate Change Scenario (ETA- HADGEM).

In both maps we observe that the population of the city of Santa Luzia is the most vulnerable, so stakeholders should start focusing in the sensibility and exposition sphere of their population when they plan the reduction of their vulnerability.

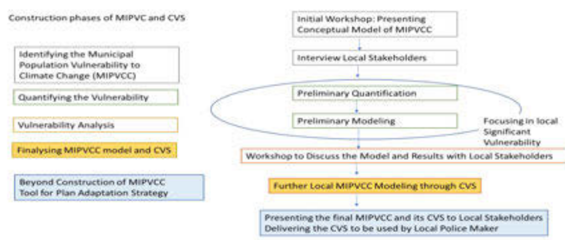
Participation of IE, IS and ICA in MIPV in Santa Luzia, Maranhão



MIPVCC in Maranhão

MIPV in Maranhão

ENGAGING STRATEGIC STAKEHOLDER (POLICE MAKER. SCIENTISTS AND PRACTIONERS)IN THE PROCESS OF CONSTRUCTION AND USE *MPIVCC* AND *CVS*



APPLYING *MIPVCC* AND *CVS* IN CITIES

This pragmatic approach is considered useful to plan and monitor the results of adaptation strategy for Brazilian states and it can it be tailored to be an urban planning tool. It is important to consider the following challenges, when building the tool:

- Select and tailor the appropriate indicators,
- Collect sufficient official data (data gap),
- Engage the municipal stakeholders in the process,
- Permanency of their use over time

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State Fund for Environmental Conservation and Urban Development of Rio de Janeiro

Joint impact of urban heat emission and large-scale heat wave event

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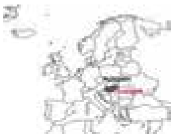
ABSTRACT



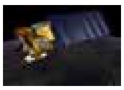
Artificial surface covers and buildings fundamentally determine the urban environment. Because of this complex relationship the city structure can be characterized by different local climate zones (LCZ) based on the ratio of built-in areas, general building height, and surface cover (Stewart and Oke, 2012). From the internationally defined 17 different LCZ classes 7 types (i.e. compact midrise, open midrise, open low-rise, large low-rise, dense trees, low plants, water) were identified in Budapest (Gál et al., 2015), which is the target area of this study.
Budapest is the capital and the largest city of Hungary both in terms of the total population (with about 1.7 million inhabitants from the total 9.8 million inhabitants in Hungary) and the spatial extent (about 525 km^2 from the total 93,000 km^2 area of the country). The city is divided by the river Danube – flowing from north to south within the city – into a hilly, greener Buda side with forests on the west, and the flat, more densely built-up Pest side on the east. The finer scale city structure is reflected in the urban heat island intensity fields with special focus on the building density and land cover types, which are also addressed by LCZ classes. To analyze the differences between LCZ classes within the city, we used surface temperature derived from the radiation data of 7 infrared channels measured by the sensor MODIS onboard satellites Terra and Aqua. The results can be used in urban planning to identify the hot spots within the city where the increase of vegetation cover might reduce the urban heat island intensity.

Data and methodology

Satellite Terra (EOS AM)
launched
in December 1999
polar orbit
at 705 km

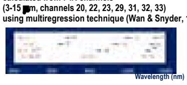
5 sensors
on-board
satellite Terra
(10:30 EQ):
MODIS, ASTER, CERES, MOPITT, MISR

Satellite Aqua (EOS PM)
launched
in May 2002
on polar orbit
at 705 km



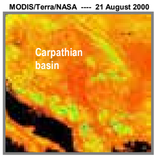
6 sensors
on-board
satellite Aqua
(13:30 EQ):
MODIS, AIRS, AMSU, HBS, AMSR-E, CERES

Sensor MODIS:
- -- Moderate Resolution Imaging Spectroradiometer
- -- Multispectral radiation measurements in 36 channels (VIS-TIR)
- -- Product MOD11: Land surface temperature (LST): calculated from 7 IR channels (3-15 μm, channels 20, 22, 23, 29, 31, 32, 33) using multiregression technique (Wan & Snyder, 1999)



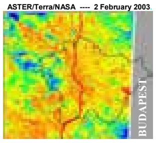
- -- spatial resolution: 250 m - 1 km
- -- continuous data since 07/2000 (Terra), 06/2002 (Aqua)
- -- both in day-time and night-time (UTC): 2-3 (Aqua), 9-10 (Terra), 12-13 (Aqua), 20-21 (Terra)

MODIS/Terra/NASA ---- 21 August 2000

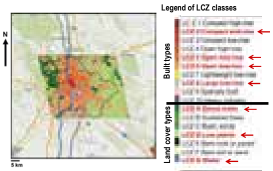


Sensor ASTER:
- -- Advanced Spaceborne Thermal Emission and Reflection Radiometer
- -- Multispectral radiation measurements in 14 channels (VIS-TIR)
- -- spatial resolution: 15 - 90 m
- -- data are limited (measurements are scheduled according to pre-ordered requests), measuring time: 8 minutes/orbit
- -- only on-board satellite Terra

ASTER/Terra/NASA ---- 2 February 2003



LCZ types within Budapest (Hungary) converted to the MODIS grid

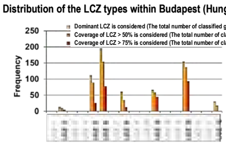


7 LCZ classes can be identified from the total 17 LCZ classes

The classification was done by Gál et al. (2015) based on Stewart & Oke (2012)

LCZ classes are defined on the basis of the following 7 parameters describing geometry and surface cover properties: sky view factor, aspect ratio, building surface fraction, impervious surface fraction, pervious surface fraction, height of roughness elements, terrain roughness class; and 3 parameters for thermal, radiative, and metabolic properties: surface admittance, surface albedo, anthropogenic heat output.

Distribution of the LCZ types within Budapest (Hungary) using different criteria for the definition



7 LCZ classes (indicated by black characters) can be recognized from the total 17 LCZ classes

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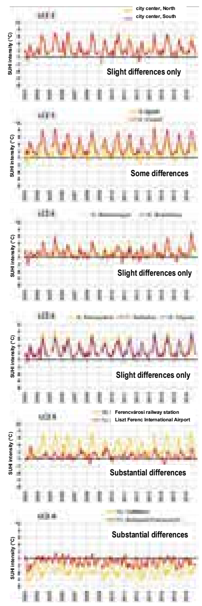
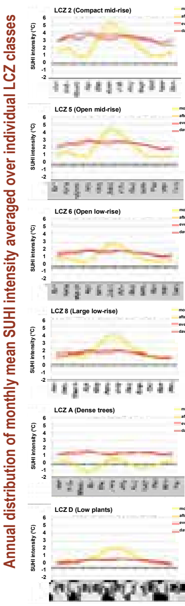
RESULTS

Variation of SUHI intensity within LCZ classes -- Comparison of grid cells classified as a given LCZ category



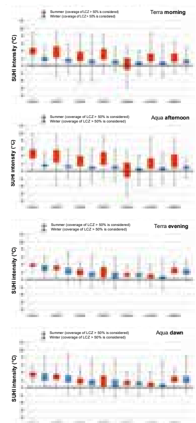
Annual distribution of monthly mean SUHI intensity averaged over individual LCZ classes



Selected grid cells representing LCZ classes with homogeneous coverage (~100%)

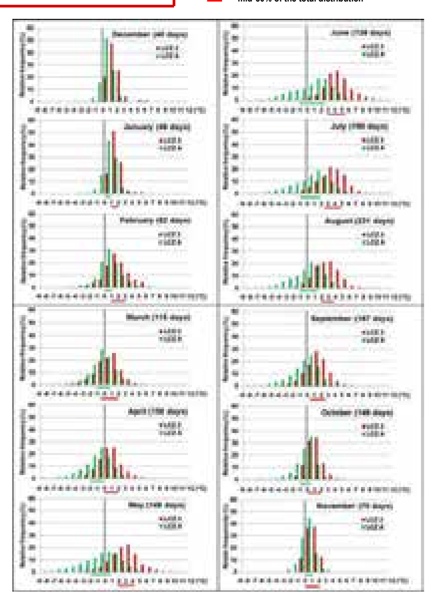
Grid cell	LCZ type	Name (location)
1	LCZ 2: Compact mid-rise	City Center, North
2		City Center, South
3	LCZ 5: Open mid-rise	Újpest
4		Csepel
5	LCZ 6: Open low-rise	Békásmegyer
6		Rákospalota
7		Sashalom
8		Kispest
9		Budatétény
10	LCZ 8: Large low-rise	Ferencváros railway station
11		Liszt Ferenc Int. Airport
12	LCZ A: Dense trees	Csillebérc
13		Budapesti Kamaraerdő

SUHI intensity distribution in summer and winter months in individual LCZ classes, 2001-2016



Histograms of monthly SUHI intensity calculated for all the grid cells within the selected LCZs, 2001-2016

mid-50% of the total distribution

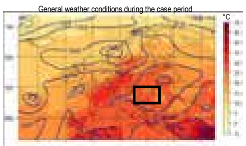


LCZ 2: Compact mid-rise (City center) — Higher SUHI intensity values
LCZ A: Dense trees (Buda Hills) — Lower SUHI intensity values

Case study --- Evolution of the SUHI spatial structure

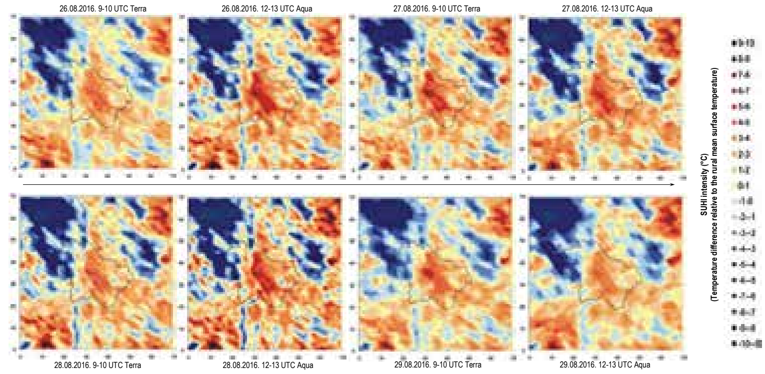
General weather conditions during the case period

Temperature (°C) and mean sea level pressure (hPa) in Europe, 12 UTC 26.08.2016. based on ERA Interim Database



Temperature (°C) in the Carpathian Basin, 12 UTC 26.08.2016. based on ERA Interim Database

26-29 August 2016: cloudless period (in the entire 70 km × 70 km domain)



Urban Heat Island Effects and Climate Warming Explain Earlier Plant Blooming

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Alberta PlantWatch

1. Citizen Science

The Alberta PlantWatch program: plantwatch.naturealberta.ca engages volunteers in tracking spring bloom and leafing times for common trees, shrubs and forbs. This phenology database includes over 57,000 records spanning three decades (Beaubien and Hamann 2011a). Since 2000, the program has been part of Canada PlantWatch www.naturewatch.ca.

Phenology (definition - study of the timing of life cycle events) data provide tools for climate change adaptation. As insects and plants both develop in response to rising spring temperatures, plant bloom dates can predict when insects will appear. Spring plant phenology can guide decisions in areas as diverse as city management of tree pests, maintaining pollinator biodiversity, and predicting the start of the spring allergy season.

Figure 1: map of observations in Alberta

Edmonton: increasing heat island effect

3. City Warming: 1/3 from heat island effect, 2/3 from climate warming

Cities can be 'heat islands'. Compared to the countryside, temperatures in cities are higher due to loss of plant cover (less cooling evapotranspiration), and an increase in buildings, roads, and emissions from furnaces and vehicles. As heat island effects of cities intensify over time due to population and economic growth this can add to general climate warming.

Edmonton's population increased rapidly from 1936 to 2016 with a corresponding increase in the heat island effect (Figure 3a).

There was an increasing heat island effect over the period 1936-2006 in both weather station data and plant phenology response, using data from urban and rural areas around Edmonton (Beaubien, 2013). There were differences in bloom time ranging from 1.7 to 4.5 days for two recent decades (1987 to 2006), with the earliest-blooming plant species in our sequence, aspen poplar (*Populus tremuloides*) showing the biggest urban - rural difference (Figure 3b) . Over those 70 years in urban Edmonton, the heat island effect accounted for one third of the total warming. We concluded that widespread warming (climate change) accounted for two-thirds of the observed phenology trends in Edmonton (Beaubien, 2013).

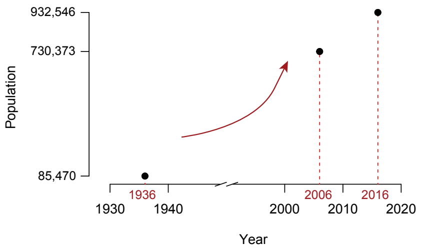

Fig3a. Edmonton's population from 1936 to 2016.

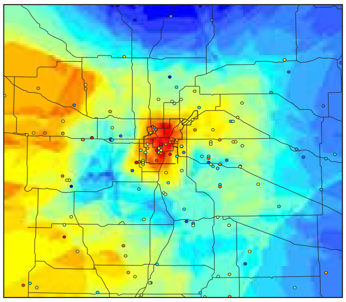

Figure 3b. Interpolated deviation for the average day of first bloom for aspen poplar (*Populus tremuloides*) for a 225×225 km area centered around Edmonton, AB.

Spring bloom shifts: 1936-2016

2. Two weeks earlier!

Analysis of the first 70 years (1936 to 2006) of central Alberta plant data showed a 2 week trend to earlier bloom for aspen (*Populus tremuloides*): (Figure2, see green line at bottom, note that this graph adds 10 more years data).

There was an increase in mean February temperatures of 5.3°C. Minimum or night time temperatures increased 6°C (Beaubien and Hamann 2011b).

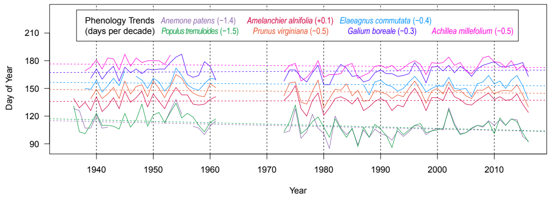

Figure 2. Trends in observed day of first bloom for the Central Parkland Natural Region of Alberta over 80 years (1936-2016). These are rural data only - Edmonton city data (warmer heat island) were not included.

Phenology helps the science of cities

4. Citizens track the biotic effects of increased warming and weather variability

The spring bloom and leafing dates can guide decision-making in many ways, including

- human health (allergy prediction)
- tree pest control
- best planting times for gardens (heat island effect is strongest in city centre)

Photo 1. Aspen (*Populus*) - catkins finishing pollen shed, with bee, by Loney Dickson

Photo 2. Aspen (*Populus tremuloides*) - leaves by Elisabeth Beaubien

Photo 3. Prairie crocus (*Anemone patens*) by Tina Regehr

References/ Special thanks

- Thanks to over 700 Alberta PlantWatch observers for reporting phenology data!

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Room for rivers and voices:
A comparison of the Room for the River approaches in Alberta and the Netherlands

Eva A. Bogdan

ABSTRACT

Historically, both Alberta and the Netherlands have focused on physical infrastructure approaches to flood mitigation. However, following near catastrophic flood risk in the 1990s, the Dutch government developed the *Room-for-River* (RfR) program, breaking from their 1000-year tradition of structural engineering flood defence for 'fighting the water' to 'living with water'. The RfR approach also shifted riverine flood management from a siloed sectoral and technological focus to a multi-disciplinary and spatial focus.

In Alberta, the high cost of the 2013 flood disaster and a growing sensitivity to the implications of climate variability triggered the reassessment of costly structural solutions and exploration of other approaches, leading to three RfR projects in the Town of High River, the Bow River Basin, and the Red Deer River Basin. Unlike transferrable technological change, RfR also requires social innovation through fundamental institutional, governance, and cultural changes, and hence is more challenging to implement.

The purpose of this research is to identify factors for shifting flood management paradigms and practices to adapt the Dutch RfR approach in Alberta at a broader scale beyond the three RfR projects. The transition governance framework is chosen to analyze policies, practices, and stakeholder engagement processes in implementing the RfR approach in both locations based on data collected from interviews, documents, and workshops conducted in Alberta (2015) and in the Netherlands (2017).

METHODS

This comparative case study consists of three projects with qualitative data collected from interviews, workshops, and documents. First, I conducted a case study of the social dimensions of flood risk governance in High River (n=38) in 2015 (primary data), to understand perceptions of, and responses to, flood management in Alberta. The questions cover decision-making processes, public engagement, the role of science, etc. While my research focuses on High River, participants also discussed flood-related issues throughout Alberta and their participation in the other RfR pilot projects.

Second, I conducted interviews (n=12) in the Netherlands in 2017 and asked similar questions for comparison to understand the Dutch approach to riverine flood governance. Third, I presented the findings from the first and second projects at three venues and asked participants (n=65) for feedback. These venues included UNESCO-IHE Institute for Water Education (n=14), Wageningen University (n=11) and Delft University of Technology (n= 40). Interviewees and workshop participants included decision-makers and advisors who are representatives of governments, scientific institutions, media, private sector, and NGOs involved in flood risk governance at the municipal, regional, provincial and federal levels. I also examined secondary data from reports and policy documents.

BACKGROUND

In the Netherlands, the flood scares in 1993 and 1995 triggered a shift in riverine flood management and the Dutch RfR Program (2006-2016) was created consisting of 34 projects. The RfR Program is considered exemplary internationally in terms of administrative cooperation, stakeholder engagement, integrated river management, and being on-time and within budget. In June 2013, Southern Alberta severely flooded, resulting in the first-ever declared state of provincial emergency. The Government of Alberta contracted the Dutch Deltares Research Institute for advice on flood mitigation, including the RfR approach, and also contracted Alberta WaterSMART to facilitate the BRB and RDRB RfR projects.

Table 1. Description of Alberta's Room for the River projects

	High River	Bow River Basin (BRB)	Red Deer River Basin (RDRB)
Purpose	Enhance discharge capacity of Highwood River.	To test whether the RfR philosophy & concepts are applicable.	To ensure that the finding of the BRB RfR project was not an anomaly, to refine the process and include ice jams.
Decision-makers	Government of Alberta and the Town of High River.	Technical Working Group and the BRB Council.	Technical Working Group, RDR Watershed Alliance, and RDR Municipal Users Group.
Stage completed	Removal of 2 neighbourhoods & obstacles Reshaping and maintaining river. Building and strengthening dikes.	Conceptual plans (projects not yet implemented).	Conceptual plans (projects not yet implemented).
Timeline	Removal of neighbourhoods announced Dec. 23, 2013 for Wallaceville & Mar. 14, 2014 for Beachwood.	February 2015.	June 2015.
Public engagement	No public engagement, most buyouts voluntary.	E-mail or comments on website.	E-mails and letters.
Finding	N/A	RfR is applicable in the Bow River basin.	RfR philosophy and concepts are also applicable to other basins.

Based on their involvement in the three RfR projects in Alberta and their knowledge about the RfR program in the Netherlands, what did Albertans value from the Dutch RfR approach?

- Making space for nature
- Collaboration & cooperation
- Public engagement & dialogue

"But in a flood you can, you can get out of the way... We've got to stop. . .
The whole Deltares report, Room for the River, it makes sense. We have to buy into that.
We have to embrace that as a community, as a province and country."
– Alberta interviewee (2015)

Transition Governance Framework

Governance is the ways in which stakeholders (public, private, non-profit, and hybrid agencies) both interact with, and influence each other, to make and implement decisions to achieve a set of goals. Governance includes all processes and structures of governing such as: interactions, decision-making, norms, rules, instruments, and institutions.

Extensive technical advances have been made in flood management, but to effectively address this wicked problem, better understanding and innovations are also needed in the social dimensions, including coordination of policies and practices as well as collaboration between stakeholders.

Despite growing interest in water and flood risk governance, the literature is limited in scope, fragmented, and lacking systematic comparative analysis. There is a knowledge gap for understanding the key factors for explaining stability and change in flood risk governance.

To address some of these gaps in understanding changes in governance and management practices, Farrelly, Rijke and Brown (2012) developed a transition governance framework to understand operational pathways for change.

Table 2. Operational factors for supporting transition governance

Structure	Process
S1. Narrative, metaphor & image (clear vision, story)	**P1.** Leadership
S2. Policy & planning frameworks & institutional design	**P2.** Capacity building & demonstration
S3. Economic justification	**P3.** Public engagement & behaviour change
S4. Regulatory & compliance agenda	**P4.** Research & partnerships with policy & practice

Farrelly et al. (2012) found a strong interplay between core governance structures and processes, suggesting there is a need to have all factors aligned for a system-wide transition to be successful.

RESULTS

Structure	Netherlands	Alberta
S1	• United goal: "*Keep our feet dry*." • Flood protection is a state of mind.	• No united goal, varied interests. • Flood-drought cycles = Infrastructure challenges.
S2	• Dual objectives: 1. Safety; 2. Spatial quality • *"Freedom within borders"* = Creative design that adheres to safety standards, budget, & timeline. • More bottom-up approach than in the past. • Budget for flood management separated from political cycle: "*Flooding issue is too important to be left to politicians.*"	• Respecting Our Rivers, not Room for the River, is the main flood mitigation approach – this does not include spatial quality. • More of a top-down approach. • Budget for flood management not divorced from political cycle.
S3	• Using national money for local projects is "*an offer you can't refuse*". • Turn threat into opportunity: NIMBY → PIMBY • Municipalities incorporate local wants/needs, into Blokkendoos software program to test scenarios and identify the best option.	• Deltares' report (Feb. 2015) finds Alberta engineering companies' initial recommendations for High River flood diversion and dam expensive & morphologically unsustainable. • "*Never has a piece of controversial public policy, like buying out Wallaceville, had a payoff so quickly.*"
S4	• 1995 National government passed regulation to restrict development in floodplains. • Second Delta Committee (2007), Delta Act (2011), Delta Programme. • EU Floods Directive (2007): focus on prevention, protection and preparedness.	• 2012 High River's Council enacted a bylaw to prevent future floodway development, the RfR approach helped enforce these regulations. • 2013 Government of Alberta enacted Bill 27 of the MGA to restrict floodway development in but to date (Mar. 2018) it has not been put into effect.

Process	Netherlands	Alberta
P1	• Many visible leaders, including those in executive positions of the Program, national government ministers, municipal government politicians, two farmer chairmen who built trust between farmers and the government and negotiated, and others (see UNESCO, 2015)	• No visible leader or champion for RfR in general, perhaps because the buyouts were controversial. • Mayor of High River supportive of RfR. • Director of Alberta WaterSMART interviewed by the media about RfR in Alberta.

P2	• Social and technical learning, share challenges & successes, build relationships, at events & workshops.
	• *"Build RfR community on all levels with high degree of ownership."*
	• Role-playing & simulation games.
		• Two conceptual RfR workshops in RDRB and BRB:
		  • Water experts (general public not invited);
		  • Technical learning; and
		  • Breadth of topics and perspectives
		  • Participants want more such opportunities.

P3	• Slow decisions :2-4 years engagement, 10 years. • Respect for people and acknowledge relocation is hard: $ compensation, support, & grant wishes. • NL 154 home buyouts → 99% success rate. • Design of meetings: Face-to-face, market atmosphere, kitchen-table talks.	• Quick decisions: within 1 year of flood. • Public not asked about THR buyouts, decision made at municipal and provincial level: $ compensation. • AB 254 home buyouts offered → 33% success rate. • Design of meetings: Lacked two-way open dialogue about long-term, mostly not face-to-face.
P4	• Rivers mapped & tracked. • High Water Risk Campaign: Find out water level risk for each community, post photo on social media .	• Rivers mapped where most densely populated. • Many residents don't understand their flood risks .

CONCLUSION

My research found that Albertans support the RfR approach and want to shift away from mega-infrastructure approaches. The two pilot project studies found that RfR is applicable to other watershed basins. Will this shift happen? This comparative study found that more of the operational factors have aligned for a system-wide transition to facilitate the successful implementation of the RfR Program and projects in the Netherlands than in Alberta. Therefore, in Alberta further transition is not likely to occur while there is considerable misalignment in the factors supporting transition governance.

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PhD RESEARCH

I examine perceptions and practices of flood management in the Town of High River, Alberta, the community most impacted by the 2013 Alberta floods. More broadly, I am interested in how diverse sets of values, viewpoints, and interests are deliberated and decided on in a democratic approach to natural resource management and disaster management.

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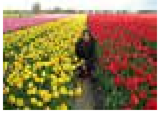

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Conseil de recherches en sciences humaines du Canada
Canada

RESEARCH PROGRAM ON Sustainability Policy and Management

Public Capital for Low-Carbon Urban Energy: Current Trends and Future Directions in the U.S.

THE EARTH INSTITUTE COLUMBIA UNIVERSITY

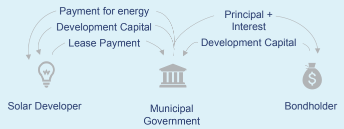
Allison Bridges
Columbia University, Earth Institute, Research Program on Sustainably Policy and Management

What can city governments do to increase the amount of electricity generated from renewable sources?

The City Toolbox: Financing Renewable Energy

The Rise of Green Municipal Bonds

- Usually tax-exempt, newly issued municipal bonds totaled US$ 472 billion in 2017.
- Green municipal bonds have experienced steady growth since 2013 with the highest annual issuance reaching US$ 11 billion in 2017 (EMMA, 2018).
- The type of capital project that qualifies as environmentally beneficial is highly variable across green bonds.
- Debates continue regarding the validity of the green designation and the environmental impact of the investment.

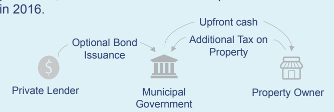


Municipal Green Bonds, risks and mitigation measures

Risk	Mitigation
Ability to offer investment grade green bonds	Loan loss reserves and loan guarantees
Inadequate environmental benefits	Adherence to Green Bond Principles
Additional administrative requirements	Efficient process for third-party verification

Property Assessed Clean Energy (PACE)

- In the U.S., cities can designate certain areas as special assessment districts that allow for additional taxes.
- District bonds – issued based on the tax revenue – can then be used to finance infrastructure upgrades.
- Special assessment taxes for energy infrastructure enables individual property owners to make solar or energy efficiency retrofits.
- Despite regulatory risks and the need for better consumer protection, PACE bond securitizations passed US$ 1 billion in 2016.



PACE Program, risks and mitigation measures

Risk	Mitigation
Loan default/foreclosure	Underwriting, Debt Service Reserve Fund
Difficult to ensure low interest costs	Credit enhancement
Low project quality	Quality management plan

Shared Investment Costs

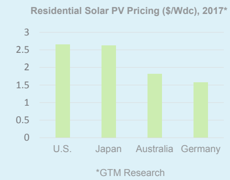
- Both public-private partnerships and community partnerships offer shared financing arrangement for distributed generation (DG) and microgrids.
- Community solar projects, enabled through state net-metering laws, are most often a partnership between individuals, utilities, non-profits, and business entities.
- Innovative financing arrangements have supported the installation of over 100 MW of community solar throughout the U.S. (SEIA, 2018).
- Public-private partnerships are also increasingly used to develop microgrids using various financing arrangements including direct ownership, vendor financing, energy service contracts, power purchase agreements, leasing, debt financing, bonds, Green Banks, and build-operate-transfer agreements.
- Microgrids can include various power generating sources including combined heat and power, wind, solar, biomass, fuel cells, and battery systems. Total U.S. investment in microgrids has passed US$ 12 billion.

Municipal microgrids, risks and mitigation measures

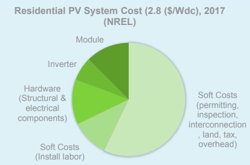
Risk	Mitigation
Power quality	Simulated test systems, load bank, redundancy
Cyberattacks	Cybersecurity systems and staff training
High cost of installation	Partnerships can lower costs

Fees and Taxes

- The U.S. price per watt for residential solar is among the highest in the world due to differences in wages, taxes, permitting fees and hardware.



- Although lower module cost and greater competition has reduced total system capital cost, "soft" costs (labor and overhead) account for over 68% of residential system costs.
- Fee reductions, permitting wavers, and streamlined services can help reduce costs.



- Bonuses to promote a particular type of development have also been used to promote new construction that incorporates DG or energy efficiency.
- Tax strategies for renewable energy, such as the Production Tax Credit and the Investment Tax Credit, are more common at the federal and state levels. However, tax abatement strategies for renewable energy are also used at the municipal level.
- By taking advantage of federal, state, and local tax incentives, including tax-equity financing for larger projects, developers can significantly reduce financial risk and improve return on investment.
- The tax-exempt status of government-owned utilities is also contributing to a renewed interest in municipal utilities.
- Without payments to shareholders, many municipal utilities can offer better rates and more reliable service, but regulatory hurdles often impede the ability of new companies to enter the market.

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- National Renewable Energy Laboratory (NREL)
- Solar Energy Industries Association (SEIA)
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What are the implications for cities that promote capital projects for distributed energy resources (DERs) and microgrids?

New Institutional Capacity for Strategic Energy Planning

- Ecologically modern urban energy systems face challenges in the adoption and integration of new modes of energy generation, distribution, management, and regulation.
- Municipal Energy Departments are needed to ensure system coherence, to evaluate and inspect new projects, and minimize risks and negative externalities.

The Resiliency Imperative: Identifying Synergies

- Disaster response teams require power for critical urban functions such as health services, water and sanitation infrastructure, and public safety.
- Current strategies to address electrical system vulnerability include redundant DG systems, plug-in electric vehicles as alternative home power sources, and microgrids (Clean Energy Group, 2016).
- The PACE program can finance improvements for resistance to wind, flooding, tornados, and seismic activity.
- Power plants are vulnerable to storm events and sea level rise. Additionally, climate change induced water scarcity could impact the ability to cool thermoelectric plants. Globally, water scarcity could result in reductions in usable capacity of 81–86% of thermoelectric plants (van Vliet et al., 2016).

What are the research gaps and new trends in the integration of urban energy systems with DERs and microgrids?

Tracking the Transition

Blockchain and Cryptocurrency

- At the urban level, blockchain technology – using a network of computers to maintain an encrypted ledger – has the potential to reduce transaction costs and facilitate a local energy marketplace with more producers and consumers than centralized systems.
- Although the technology may have greater potential in utility scale markets and virtual power plants, application in microgrid or DG projects will likely improve as new solutions to verification and accounting challenges are developed.
- Increasingly, specific cryptocurrencies for energy trading are available. Blockchain-based currencies, backed by units of renewable energy, are new to the market and vary in terms of measurable output and contribution to emissions reduction.
- The trend is likely to continue as more specific data is used to back green cryptocurrencies.

Real Estate Valuation and New Market Dynamics

- Real estate developers have sufficient access to capital to develop DG and microgrid projects and may value long-term energy independence.
- As they seek increasing use-values and stacked value streams, they are well positioned to take advantage of market openings that occur as utility companies begin to lose control.
- One aspect of DG and microgrid development that is still poorly understood is the impact of on-site energy assets on property value as well as the monetary value of avoided loss.
- Research suggests residential and commercial purchasers of DG technologies may increase the value of their properties.
- Establishing institutional structures for collaboration and conflict resolution will help safeguard the unique status of the energy system as a public good in a new market.

Potentials and Constraints to Achieving Low Carbon Urban Development in Developing Countries: A Case Study of Kaduna, Nigeria

Ahmadu Bello University Zaria - Nigeria

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1. INTRODUCTION

Cities are at the forefront of the current debate and efforts towards achieving global sustainability. Sustainable development as it relates to urban planning and cities is concerned with the integration of land use and transportation systems in such a way that enables a modal shift from private automobile use to public transit and non-motorized modes of travel. The argument on the need to use built form and its relation with transport to reduce energy consumption and consequently emissions is well recognized in developed countries but perhaps less so in developing countries. If the goals of sustainable development are to be realized, cities in developing countries - where the highest rates of population growth and urbanization are currently being witnessed - need to be organized to grow along more sustainable trajectories. This paper examines the potentials and constraints to achieving low carbon development in cities of developing countries using Kaduna in northwest Nigeria as a case study. The study utilized secondary data on the current form and morphology of Kaduna, existing housing and urban transportation realities as well as extant urban planning systems and strategies to determine the potentials and constraints to future low carbon development. The paper concludes by making recommendations on how the identified potentials to achieving low carbon development in Kaduna can be exploited while at the same time taking action to reduce the constraints in order to chart a path to future low carbon development for the city.

2. ABOUT KADUNA

The city of Kaduna is located in the northern Guinea savannah zone of Nigeria. It lies between latitudes 10 and 11 degrees north and longitudes 7 and 8 degrees east at an altitude of 645 m above sea level. In the hierarchy of Nigerian cities, Kaduna is considered a relatively young city. It was established by the British colonial administration headed by Lord Frederick Lugard in 1912 (Haruna, 2012). By 1919, 7 years after its establishment as the capital of the Northern Nigerian region, the estimated population was only 3,000. By 1930, it had risen to 10,000 people – an increase of 330%. Between 1952 and 1963, Kaduna recorded an annual average growth rate of 12.5%. 10.1% higher than the 2.4% average growth rate estimated for developing countries. From 1963 to 1985, Kaduna is estimated to have grown at an average of 7% per annum. Two types of urban growth are discernible in Kaduna – growth by fusion and outward expansion of the city's built mass. The former was basically the annexation of adjoining villages while the latter was the outward expansion of the city in directions where there were no previous settlements (Agboola, 1986). Between 1917 and 1930, the total extent of the city was 12.5km². In 1982, it had grown to approximately 100km2 and by 1985 it was estimated at 140km2 (Agunbiade et al., 2012). By 2010, Kaduna's physical extent had grown to 420km².

3.0 METHODS

Data on urban form and morphology, existing housing and urban transportation realities as well as extant urban planning systems and strategies was obtained from published works, survey reports and government documents. This data was used to hypothesize the potentials and constraints to low carbon urban development in Kaduna.

4.0 RESULTS

a) Description of Urban Form in Kaduna (Average City Level Values)

Accessibility	0.72 km
Residential Population Density	40 Pers./Ha
Land Use Diversity	0.073

Source: Bununu (2016)

b) Potentials for Low Carbon Development in Kaduna

- Bridging the energy deficit through investment in renewal energy sources such as solar and wind
- Integration of urban renewal into mixed use and high density housing programmes aimed at addressing the housing deficit (National housing deficit put at 17 million units)
- Development of a viable integrated urban transportation system in order to reduce automobile dependence

c) Constraints to Low Carbon Urban Development in Kaduna

- Lack of political commitment and allocation of resources to undertake effective urban planning
- Weak urban governance structures and a dearth of technical skills and awareness in sustainable urban development and its overall benefits among technocrats and decision makers
- Existing urban planning policies that still emphasize excessive zoning and segregation of land uses
- Rapid urbanization alongside high levels of urban poverty
- Informal settlement development and informal urban economic base – weak financial capacity of urban local government
- Centralized city administrative system as opposed to a decentralized system

5.0 CONCLUSION

- The current growth and development trajectory of Kaduna is along an unsustainable path that would lead to an environmentally unsustainable future
- Political will and focused leadership appears to be the missing as well as most critical ingredient in overcoming the constraints and harnessing the opportunities inherent in the potentials of low carbon development

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RESIN

SUPPORTING DECISION – MAKING FOR RESILIENT CITIES

A CLIMATE RISK TYPOLOGY OF EUROPEAN CITIES AND REGIONS

The RESIN Climate Risk Typology supports adaptation and resilience planning and action by offering users the means to describe, compare and analyse climate risk in European cities and regions.

Why was the Typology developed?

What does Europe's climate risk 'landscape' look like? Spatial patterns of climate risk exist, but approaches to visualise and analyse these patterns from a European perspective are lacking. This is a barrier to strategic adaptation planning and resource allocation. The RESIN Climate Risk Typology addresses this issue by providing an innovative platform to enhance understanding of climate risk in European cities and regions.

What scale does the Typology operate at?

The Climate Risk Typology is formed at the scale of European NUTS3 regions, which are defined as 'small regions'. NUTS3 regions are part of a system that subdivides the economic territory of Europe to support statistical data gathering, socio-economic analysis and the framing of European policies. NUTS3 regions are a population-based classification system, and contain between 150,000 – 800,000 people. There are 1342 NUTS3 regions in Europe. The density of NUTS3 regions across Europe varies. For example, there are 402 in Germany, 21 in Sweden and 5 in the city-region of Greater Manchester (located in North West England).

How was the Typology developed?

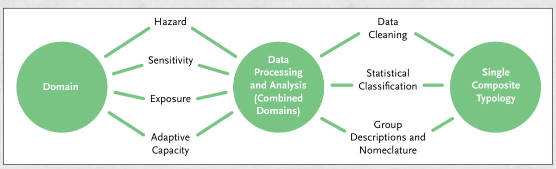
The Climate Risk Typology is formed around the IPCC AR5 risk framework. Here, risk is a function of climate hazards, and exposure and vulnerability (which encompasses sensitivity and adaptive capacity) to these hazards. The Typology is based around a set of indicators that reflect the elements of the IPCC's climate risk framework. Some indicator data was available from publically accessible data sources. In a number of cases, new indicators need to be created specifically to inform the development of the Typology. Table 1 includes examples of the Typology indicators.

Following indicator data gathering and creation, this data was cleaned and processed to identify indicators to be retained to develop the Typology. Cluster analysis was then applied to these indicators to define discrete groups of NUTS 3 regions based on their underlying climate risk characteristics. Each cluster forms a climate risk 'type.' This method is visualised in Figure 1.

Table 1: Examples of risk-based indicators underpinning the Typology

Indicator Domain	Indicator Details	Indicator Examples (at the NUTS3 scale)
Hazard	IPCC scenarios RCP4.5 and RCP8.5 assessed for 2036-2065 compared to 1981-2010.	Consecutive dry/wet days, number of very heavy rain days (>20mm), number of heat wave days (>35°C), number of tropical nights (>20°C), min/max temperature.
Exposure	Exposure of infrastructure and people to river flooding (1/100 year return period) and projected sea level rise.	Road network, rail network, rail and bus stations, ports, airports, energy generation, built environment, hospitals, people.
Sensitivity	Socio-economic data relating to susceptibility to harm from hazards. Indicators reflect change over time.	Total population, population <15 years and >64 years, population density, projected population change and net migration.
Adaptive capacity	Data relating to capacity to adapt to hazards should they occur. Some indicators reflect change over time.	GVA, total employment, number of hospitals per 1000 population, urban green space area, length of road network.

Figure 1: Climate Risk Typology Method

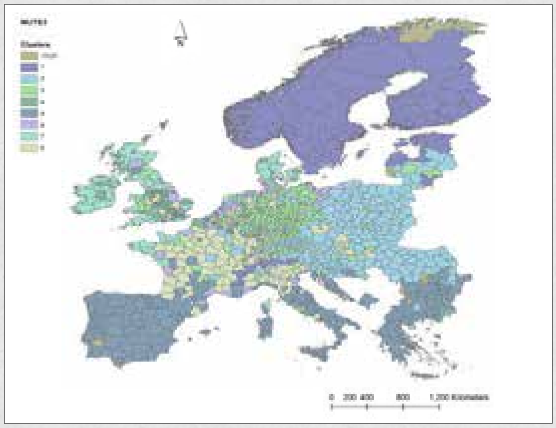


The Prototype Climate Risk Typology

Figure 2 provides a visualisation of one Typology cluster - cluster 7. The red line shows the climate risk indicator averages for Europe's NUTS3 regions, and the blue line indicates where this cluster falls in comparison to these averages. Figure 3 maps the prototype Climate Risk Typology output. This organises Europe's 1342 NUTS3 regions into a number of different Typology clusters. NUTS3 regions falling within a cluster share similar climate risk characteristics.

Figure 2: Climate Risk Typology cluster 7 – indicator spider diagram

Figure 3: Prototype Climate Risk Typology for Europe's 1342 NUTS3 regions



Cluster 7 (see Figures 2 and 3) is described here as an illustrative example of the typology output. Cluster 7 is a group of NUTS3 regions that contain relatively high levels of young people compared to other EU regions. This segment of the population is, for the most part, projected to expand further by 2050. They are regions where people and infrastructure are significantly more exposed than the EU average to coastal flooding associated with future sea level rise, but are less exposed to current fluvial flood events. In the future these regions are projected to experience a notable increase in the number of days with very heavy levels of precipitation. However, relative to other EU NUTS3 regions, they are projected to experience fewer high temperature hazards.

How can the Typology be utilised?

The Climate Risk Typology will be housed within an interactive online portal that provides data and functionality to describe, compare and analyse climate risk in European cities and regions. The portal will enable users to find cities and regions that share similar climate risk characteristics, concerning the hazards they face, and their levels of exposure and vulnerability to these hazards. The Typology can be viewed as a decision-aid to support more efficient and effective forms of urban adaptation to climate risks. It is designed to enhance the understanding, assessment and response to climate risk. The principal uses of the Typology include:

- Description/communication of climate risk: Visualisation of risk types and indicator data.
- Analysis: Exploring climate risk spatially.
- Strategy and planning: Forming adaptation/resilience strategies to reduce climate risk.
- Collaboration: Developing city/region networks.

Who can benefit from using the Typology?

The Climate Risk Typology will be most useful for three core user groups:

- Decision-makers who are looking to better understand and communicate climate risk.
- Planners engaged in developing climate change adaptation and resilience strategies.
- Researchers working on climate change adaptation and resilience.

What are the next steps for the Typology?

The remaining tasks to undertake prior to the completion of the Typology are:

- Consult on the prototype Climate Risk Typology.
- Finalise the Climate Risk Typology output.
- Complete the online portal to house the Typology outputs and underlying indicator data.

The Typology and its supporting online portal will be finalised by the end of October 2018.
To find out more or request to be involved in the Typology consultation please email

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China's Low Carbon & Green Cities: Progress and Prospects

Introducing the new 'China LOGIC' city index (and 2017 index scores), to measure the transition toward energy sustainability and an early peak of carbon emissions.

Innovative Green Development Program (iGDP)
HU Min, YANG Li, Alek CANNAN, CHEN Meian, LI Ang, WANG Yanhui

Lawrence Berkeley National Lab (LBNL)
ZHANG Jingjing, Stephanie OHSHITA, David FRIDLEY, Nina KHANNA, ZHOU Nan

Energy Foundation China (EFC)
LIU Shuang, CHEN Lingyan

Introduction

China has reached a genuine turning point. With the urban population still expected to increase by more than 300 million people over the next 15 years, Chinese cities will continue to expand. The choices that China's city leaders and policy-makers make today will significantly shape future development patterns.
China is taking seriously the challenges of environmental pollution, resource use, and climate change. And China is moving in the right direction for green & low-carbon cities.
Yet there remains a need for a practical framework to measure, report, and analyze the progress made in Chinese cities – across a balanced set of green & low-carbon indicators. This project developed the Low-Carbon & Green Index for Cities (LOGIC) to meet the need.

LOGIC is a new index intended to provide a holistic assessment of China's transition to both "green" and "low-carbon" urban development. "Green" indicators evaluate environmental parameters related to urbanization - air quality, water use, solid waste, transportation, and urban green space. "Low-carbon" indicators measure reduction of GHG emissions and climate change, with a focus on energy-related CO_2.
LOGIC can be used to track city performance over time in order to inform current and future policy. And LOGIC provides a data gathering framework to track and support China's green transition. The 2017 LOGIC report analyzed data from 115 Chinese cities, and compared recent progress from 2010 to 2015.

Overview of the LOGIC Index

LOGIC is a composite index, with **overall scores** ranging from 0 to 100.
LOGIC is multi-dimensional, made up of a set of **seven low carbon and green categories and sub-categories**, including:

- Energy & Carbon Category – further divided into four energy-use sub-categories: *Energy & Power*, *Industry*, *Buildings*, *Transport*
- Economic Dimension Category
- Environment & Land Use Category
- Policy & Outreach Category

These categories and sub-categories are further defined by a total of **23 indicators** – which are measurable green and low carbon parameters, for which data can be collected at the city level.
The indicators are each defined with **performance benchmarks,** of which there are three types: 1) international best practice, 2) China national target, or 3) as relative ranking in this study.
The categories and indicators are **weighted for relative importance**, and then combined to **calculate an overall index score** for each city. The overall index scores (or category/indicator breakdowns) can be compared for individual cities, groups of cities, or by changes over time.

Index Framework, Indicator Weighting, & Benchmarks

Category and Indicator Weights: categories and indicators in LOGIC may not have equal influence and importance. Assigning weights allows relative emphasis. LOGIC aims to give more weight to sectors and activity with greater influence on energy-use and carbon emissions.

Performance Benchmarks are used to normalize the city data for each indicator. Benchmarks represent a best-possible reference value, and come from one of three types:

- International Best Practice – for indicators with accepted global metrics, these come from best-in-class international cities, or relevant international standards (e.g. water use via Hong Kong, or WHO PM2.5 standard, etc.)
- China National Target – for indicators with targets/standards established by Chinese policy, these are set at the policy value (e.g. renewable energy targets, and air quality blue sky standards, etc.)
- Best City in Sample Statistics – for other indicators, especially particular to China, these are based on the best-performing cities in the study sample (e.g. 20% better than the average of the 10 best performing cities, etc.).

Primary Categories: Name	Weight	Primary Categories: Name	Weight	Indicators: Name
Energy & Carbon	[illegible]	Energy & Power	[illegible]	CO_2 / Capita
				Energy Consumption / Capita
				Non-Fossil Fuel Energy
		Industry	[illegible]	Industrial Energy Intensity
				Heavy Industry GDP Share
		Transportation	[illegible]	Public Trans Vehicles / 10,000 ppl
				Urban Rail Extent
				Bus Trips / Capita
		Buildings	[illegible]	Green Buildings Share (Part)
				Residential Energy / Capita
				Commercial Energy / Employee
Economic Health	[illegible]	Economic Dimension	[illegible]	Energy Consumption / GDP
				CO_2 Emissions / GDP
Environment & Land Use	[illegible]	Environment & Land Use	[illegible]	Solid Waste / Capita
				Blue Sky Days (or AQI)
				PM2.5
				Water Consumption / Capita
				Energy & Environ Budget Ratio
				Green Space / Capita
Low Carbon Policy, Climate Adapt. & Outreach	10%	Policy Dimension	[illegible]	Low Carbon / Climate Plan
				Renew. / Alt Energy Strategy
				Climate Resilience Plan
				Low Carbon / Public Publicity

City Selection and Grouping

The 115 cities included in the project sample represent a diverse range of different population sizes, income levels, economic stages, and geographies. Four types of City Groupings are defined for analysis and comparison. The groups and numbers of cities of each type are listed here.

Economic Groups	Size Groups	Region Groups	LC Pilot Status
47 **Industrial (I)** Industry dominated, lower GDP	7 **Mega** Cities with population >10M	50 **Eastern** Industry dominated, lower GDP	54 **LC Pilot Cities** Among China's pilot cities and provinces
58 **Transitional (T)** From heavy industry to services	20 **Very Large** Cities with population between 5-10M	26 **Central** Industry dominated, lower GDP	61 **Non-Pilots** Other cities not involved in pilots
10 **Post-Industrial (P)** Relatively wealthy, highly urbanized	84 **Large** Cities with population between 1-5M	12 **Northeastern** Industry dominated, lower GDP	
	4 **Med/Small** Cities with population <1M	27 **Western** Industry dominated, lower GDP	

Key Findings

China's Cities Are Getting Greener
Overall low carbon and green index scores improved from 2010-2015

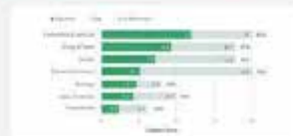
The average overall index score across all of China's cities grew 2.5 points, or 6.6%, from 2010 to 2015[1]. In aggregate, cities of all types saw growth in their average overall scores – economic groups, size groups, and pilot groups all saw LOGIC score growth, ranging from 4% to 13%, respectively. China's large "Mega" cities, "Post-Industrial" cities, and Low-Carbon Pilot cities performed particularly well over this period.

China's Cities Are Seeing Green Growth
90+ out of 115 cities saw both GDP growth and LOGIC growth from 2010-2015

All of the 115 cities in the sample saw GDP growth from 2010-2015 (from +40%, to more than +100% growth over the five years). More than 90 cities also had increased LOGIC scores over the same period – some with slight increases, others with up to a 25% increase. Among these, there are two unique clusters of high performing cities (see figure). Cities in both clusters show that green & low-carbon goals need not come at the expense of the economy.

But Chinese Cities Still Have Significant Potential to Improve
Green & low-carbon performance on average reaches 45% of LOGIC potential

While LOGIC scores and economies have both grown in recent years, the average overall index score for all Chinese cities in 2015 is still only 44.9, out of 100. Chinese cities have room to improve. Yet, some cities did achieve high scores; and those best-performing cities indicate a positive pathway for all cities to catch up. And LOGIC by definition is ambitious – its indicators are designed using world-class green benchmarks and are intended to push Chinese cities to do more, and quicker.

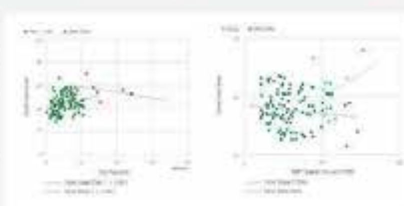


China's Low-Carbon Pilot Cities Are Leading the Way
Pilot cities have higher LOGIC scores, and their scores are improving faster

In 2015, average overall index sores for China's Low Carbon Pilot cities was 47.0, compared to 42.9 for non-pilot cities. Furthermore, Low Carbon Pilot Cities make up 80% of the list of Top 20 LOGIC cities in 2015 (despite being less than half of the sample population). Pilot cities also saw a quicker increase in their scores over the 2010-2015 period. China's low-carbon pilot program is working so far, although more work is required to fully achieve China's green & low carbon goals.

Large (but not too large) Cities, and Post-industrial Cities Are Greener
Green & low-carbon policies must pay special attention to city size and economy

LOGIC results show that cities with larger populations have higher overall index scores – except for the largest mega cities (population <11 M), whose scores decline with population. Also post-industrial cities (Group P) show a decoupling between economic growth and carbon emissions & pollution. There appear to be turning points for mega-cities and cities making the shift in economic development pattern from manufacturing (and transitioning) to post-industrial economies.



Recommendations for Chinese Policy Makers

- Cities should continue to use comprehensive data-driven analysis to evaluate, track, and compare low-carbon and green performance.
- Cities can use the LOGIC framework to accelerate progress and promote the best green & low-carbon pathways according to specific needs.
- Cities should continue strong political leadership, and accelerate pilot efforts, to ensure consistent follow-through on low-carbon commitments.
- Mega-cities need special attention, to avoid backsliding on green & low-carbon goals.
- As the next critical step, city leaders can apply lessons from the best LOGIC cities to prepare integrated low-carbon action plans for decision making and action.

Local-scale urban climate and flood regulation within a Singapore city green-space: A case study of Bishan-Ang Mo Kio Park

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1. INTRODUCTION

Like most tropical, coastal cities, Singapore (1° N 104° E) has **high exposure** to climate extremes e.g. **sea level rise, flooding & droughts affecting water resources, and extreme heat & urban heat islands** (NCCS, 2015). Singapore's exposure is compounded by its rapid urbanisation; much of **its natural rainforest and mangrove environment has been converted to urban, built up area** housing its burgeoning population (1959 = 1.59 million; 2017 = 5.6 million).

The twin stressors of increased exposure to climate hazards and heightened demographic sensitivity, are detrimental to Singapore's vulnerability to climate change. However, **effective and integrated centralised planning** has been a major factor in both increasing its capacity to adapt, and minimising Singapore's overall climate vulnerability e.g. reduction of drought and flooding impacts on Singapore's water security (Tortajada et al., 2013).

This poster describes **a successful case study** of how a major and popular **urban park in Singapore enables effective urban climate and flood regulation to the benefit of adjacent residents and to visitors.**

2. CASE STUDY - BAMK

Located in Central Singapore within a major high-density residential area (258,000 residents over 21.5 km^2), Bishan – Ang Mo Kio Park (BAMK) is one of Singapore's largest urban parks (62 ha). It underwent **extensive redevelopment from 2009–2012** which cost S$76 (US$54) million (Fig 1 & 2); the major change being a canalised 2.7 km stretch of the Kallang River converted to a 3.2 km "natural" river floodplain through water-sensitive urban design techniques (e.g. soil bioengineering, cleansing biotopes, and vegetated swales). The additional **supporting and provisioning ecosystem services** arising from the naturalisation of the river also resulted in a 30% increase in species diversity within BAMK.

Fig. 1: BAMK in 2006 with canalised Kallang River (left); BAMK in 2012 with naturalised river (right)

QR Code above links to time-lapse video of transformation

The makeover was planned under the Public Utility Board's (PUB) **Active, Beautiful and Clean Waters (ABC) Programme** (PUB, 2014); a long-term initiative transforming local water bodies beyond their primary functions of drainage and water supply into vibrant, **new, multi-functional spaces** for **enhanced cultural ecosystem services** e.g. community bonding and recreation.

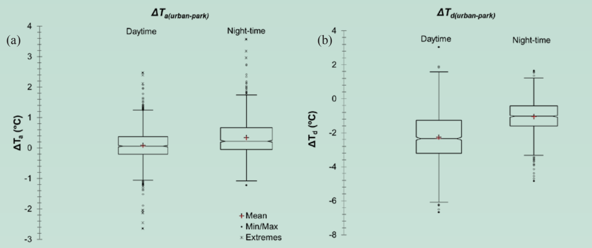
Fig. 2: Additional details of ABC programme applied to BAMK (Straits Times, 2012)

3. BAMK REGULATORY SERVICES

A measurement campaign over five months (Jul–Nov 2017) examined the **climate regulation** of BAMK vegetation relative to its "urban" surroundings. Six Onset Hobo U23 Pro T/RH sensor-loggers measuring air temperature and humidity were deployed throughout the park. "Urban" reference temperature and humidity were obtained at the Ang Mo Kio Automated Weather Station sited within a compact, high-rise residential area 4 km from BAMK, which is maintained by Singapore's Meteorological Services.

Generally, **increased vegetation in BAMK contributed to significantly lower nocturnal park temperatures** vs. daytime (Fig. 3a), with **mean (maximum) cooling of ~0.4 (~3.5) °C**. There was also a significant "**humidity island**" in BAMK, with a **urban moisture deficit (significantly larger during the day vs. night)** measured at the reference station with the park sensors (Fig. 3b).

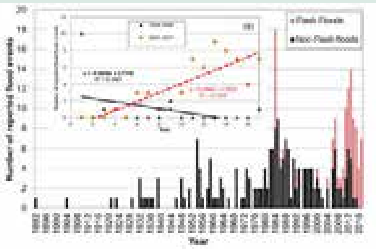
Fig. 3: Box-plots of "urban" vs. park differences in hourly (a.) air and (b.) dew-point temperatures during BAMK measurement campaign. Notches in plots indicate 95% confidence intervals around median.



The naturalised river also **regulates local flood impacts arising from extreme rainfall** events, which have recently been more frequent and intense in Singapore (Chow et al., 2016). These **flash floods cause considerable economic damage when severe**; a 2010 event in Singapore resulted in insurance claims totalling S$23 million. The floodplain efficiently conveys run-off within its watershed, **minimising flooding risk along adjacent residential areas when heavy rain occurs** (Fig. 4). Despite the significant increase of documented flash floods in Singapore since 2000 (Fig. 5), **no reported floods or surface inundation were reported in the BAMK area since 2012** from either governmental or archived media sources.

Fig. 4 (left) : "Normal" channel flow conditions in the Kallang River within BAMK (top) and flood conditions (bottom) during a heavy rain event. QR code on the left links to video of flood event on 13 Jul 2017

Fig. 5 (below) : Reported Singapore flood events via archival media reports from 1892–2016; insert (a) shows OLS linear trend of reported flash floods from 1984–2000 (black) and 2001–2016 (red dashed) (updated from Chow et al. 2016).



4. TAKE-HOME POINTS

Ahren (2011) notes several integrated strategies that urban planners and stakeholders in any city should consider applying when **maximising urban resilience to (climate) hazards**. BAMK's successful redevelopment exhibits aspects of these strategies that would be transferable across most (if not all) urban contexts:

- **Expanding the multi-functionality of spaces** (e.g. the combined climate and flood regulation of BAMK vegetation) and **maximizing the biodiversity and social diversity of adaptation development measures** (e.g. the variety of recreational spaces and increase in species diversity within BAMK);
- **Enhancing multi-scale networks and increasing system connectivity** (e.g. BAMK is an important component of a island-wide network of green corridors**), that spreads hazard risk through redundancy and modularisation** (e.g. effective flood control within BAMK reduces the 'levee' effect downstream)**;**
- **Anticipatory adaptive design and planning to account for imperfect knowledge** (BAMK was part of the ABC Programme that manages rainwater drainage along sources, pathways, and receptors to (a.) reduce flood risk and (b.) maximise water resources in the advent of adverse climate change).

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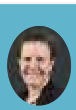


Cross-sector Partnerships for Implementing Local Climate Mitigation Plans

Dr. Amelia Clarke, School of Environment Enterprise and Development, University of Waterloo, Canada

In collaborate with: Megan Meaney, ICLEI-Local Governments for Sustainability, Canada; Dr. Adriane MacDonald, University of Lethbridge, Canada; Eduardo Ordóñez-Ponce, University of Waterloo, Canada; Dr. Mark Roseland, Simon Fraser University, Canada; Dr. M. May Seitanidi, Kent University, United Kingdom; Denise Yoon, Korea Institute Center for Sustainable Development, South Korea; Xinyu Sun, University of Waterloo, Canada; Alicia (Yushuo) Cai, University of Waterloo, Canada; Dr. Odeeth Lara-Morales, University of Waterloo, Canada

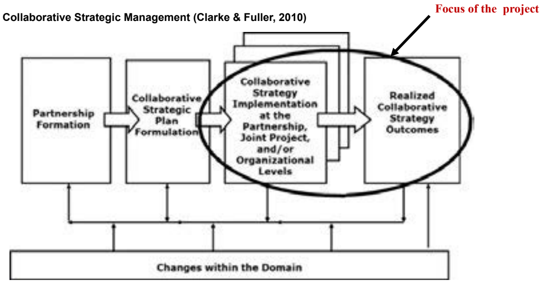
Aim of the Project

The overall goal of this research project is to help local governments around the world more effectively implement Local Agenda 21s (and other community sustainability plans, including community climate action plans), and transition toward a local green economy. The project examines how stakeholders should configure to achieve results.

Theoretical Positioning = Strategic Management

- Inter-organizational Collaboration Literature
- Cross-sector social partnerships (e.g., Selsky & Parker, 2005)
- Collaborative strategy (Clarke & Fuller, 2010; Huxham, 1993)
- Structure (Clarke, 2011; Huxham & Vangen, 2000)
- Progress/Outcomes (Lin, 2012; Roome,1992; Roseland, 2012)

Figure 1: Collaborative Strategic Management (Clarke & Fuller, 2010)



Collaborative Community Sustainability Plans

- Complement regulatory and market-based approaches
- Over 25 years of Local Agenda 21s (or equivalent); so much can be learned about implementation (Clarke, 2014)
- Climate mitigation goals can be integrated in the sustainability plan, or separate climate action plans (corporate & community) (Clarke & Ordóñez-Ponce, 2017)
- Community sustainability plans: integrated content - economic, social and ecological - which is broader than the jurisdiction of any one organization (i.e., community-wide)
- Numerous cross-sector partners (public, private and non-profit) and voluntary involvement
- Generally, a deliberate collaborative strategic plan with a distinct formulation and implementation phase
- Long-term in their vision
- Bounded by a geographic (local) region = town, city, municipality, region or territory.
- Numerous variations in implementation structures

Important Structural Features of the Partnership

Figure 2: Key Features of a Cross-Sector Partnership for Implementing a Collaborative Plan (Clarke, 2011; 2012)

Methodology

- Preliminary qualitative and quantitative research to determine key variables and pilot survey instruments
- 1st survey to local governments around the world, offered in English, French, Spanish and Korean. Distributed through ICLEI world secretariat and ICLEI regional offices to its membership = 111 completed (6 continents).
- 2nd survey to partners in four larger partnerships. 100+ partners each.
- Recent case studies of four Canadian community climate action plans at milestone 5 .

Figure 3: Variables and Relationships Being Studied (MacDonald, Clarke, Huang, Roseland & Seitanidi, 2018)

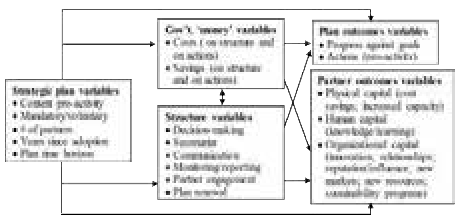
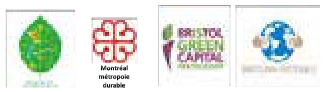


Figure 4: Four Cross-Sector Partnerships Being Studied, Including Surveys to Partners (Ordóñez-Ponce & Clarke)



Preliminary Results - Survey 1 on Partnership to CO2e

- Studied the relationship between partnership structural features and three plan outcomes (progress made towards climate goals, community-wide climate actions, and GHG reduction).
- For the first two dependent variables (n=72 cities); for the last one (n=24) due to available data
- Complete results available (Sun & Clarke, working paper)

Table 1. The Relationships Among Plan Characters, Plan Structures, and Plan Outcomes

		Community-Wide CO2e Emission Reduction (n=24) (significant relationship = yes)
Population Range		Yes
Plan Age		Yes
Plan Time Horizon		
Number of Partners		
Plan Pro-activity		Yes
Oversight	Oversight Entity	Yes
	Decision-Making	Yes
Mechanism for Partner Engagement		
Community-Wide Climate Actions		Yes
Mechanism for Monitoring		
Communication		

Canadian Community Climate Action Plan Study

- Examined plan implementation structures, plan outcomes, and partner outcomes in four Canadian cities: District of Saanich (British Columbia), City of Guelph (Ontario), City of North Vancouver (British Columbia), and City of London (Ontario)
- All are at milestone 5 in the community stream of the FCM Partners for Climate Protection program
- Results = Fewer than 10 partners each (government, utilities, key NGOs)
- Results = Included all five structural features, though most used government for oversight and not a committee
- Will allow short-term goals (e.g., 15% reduction) but not long-term goals (e.g., 80% reduction in GHG emissions by 2050)
- Complete results available (Wong, Clarke & Ordóñez-Ponce, working paper)

Preliminary Results - Survey 1 on Money to Progress

- Studied the relationships between money variables, some partnership structural features and two plan outcomes (progress made towards sustainability goals, community-wide climate actions).
- For the two dependent variables (n=106 cities)
- Complete results available (Cai, Clarke, MacDonald & Lara-Morales, working paper)

Table 2: Summary of Significant Findings on Money to Sustainability Progress

Independent Variables	Progress (Dependent Variable)
Contributed resources internally	Direct (b_0 = 1.944, b_1 =0.162, R^2= 0.104, F (1, 84) = 1.649, p<0.01)
Contributed resources for partnership structure	Direct (b_0 = 2.104, b_1 =0.110, R^2= 0.225, F (1, 85) = 4.523, p< 0.05)
	Mediated by community- wide actions (indirect effect b=0.03, BCa CI [0.0026, 0.0814])
	Moderated by partner engagement (b= -0.114, t= -2.618, p=0.01, 95% CI [-0.201, -0.028])
Contributed resources for community-wide initiatives (e.g., by partners)	Mediated by community- wide actions (indirect effect b=0.04, BCa CI[1] [0.0084, 0.1193])
	Moderated by partner engagement (b= -0.114, t= -2.359, p< 0.05, 95% CI [-0.211, -0.018])
Attracted resources from partners	Direct (b_0 = 2.103, b_1 = 0.102, R^2= 0.059, F (1, 82) = 5.178, p<0.05)
	Mediated by community- wide actions (indirect effect b=0.02, BCa CI[1] [0.0012, 0.0775])
	Moderated by partner engagement (b= -0.054, t= -2.746, p< 0.01, 95% CI [-0.092, -0.015])
	Moderated by number of partners (b= -0.162, t= -2.549, p< 0.05, 95% CI [-0.289, -0.036])

Implication and Conclusions

- Community Sustainability Plans (including Community Climate Action Plans) provide an umbrella strategy that considers community-wide goals.
- Policy coherence between governments and between other entities will be needed.
- In terms of implementing community-wide climate goals, engaging partners is critical for making progress.
- The structure of the partnership is very important.
- Large cross-sector partnerships (100+ organizational partners) enable a critical mass of collective action.
- More research is needed on the means of reaching community-wide goals and a local low-carbon economy.

SDG Targets (other than Climate Action = SDG #13)

Sustainable Development Goal #11 - Sustainable Cities and Communities

Target 11.3 - By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

Sustainable Development Goal #17 - Partnerships for the Goals

Target 17.17 - Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships

For more information, including publications/references

- **Project website: https://uwaterloo.ca/projectla21**
- Email: Amelia.Clarke@uwaterloo.ca
- Twitter: @DrAmeliaClarke and #ProjectLA21
- For a forthcoming project report (which will cover all project results) – provide your business card.

Funders

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Citizen Science to Understanding Climate Change: Science-Based Evidence for Decision Making in Latin America

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What is Citizen Science?

Citizen Science refers to the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources. Participants provide experimental data and facilities for researchers, raise new questions and co-create a new scientific culture. While adding value, volunteers acquire new learning and skills, and deeper understanding of the scientific work in an appealing way. As a result of this open, networked and trans-disciplinary scenario, science-society-policy interactions are improved leading to a more democratic research based on evidence-informed decision making[1].

Background

Climate change is a complex field that is increasingly being studied by different areas. In Latin American cities, the exposure to pollutants as well as the amount of greenhouse gas emissions is still unknown to local governments. The knowledge on the degree of vulnerability and the risk reduction is still a challenge for all Latin American communities to clearly recognize the impacts of climate change in cities.

Latin America Overview

With 80% of its population living in cities, Latin America and the Caribbean is the most urbanized region on the planet. Located here are some of the largest and best-known cities, like Mexico City, São Paulo, Buenos Aires, Rio de Janeiro, Bogota, Lima and Santiago[2]. At least 100 million people are exposed to levels of air pollution above those recommended by the World Health Organization (WHO)[3].
According to Breathelife2030.org platform in most cities around the region, the levels of PM2.5 particles are dangerous.

Figure 1. PM 2.5 Concentration in Major Urban Centers in Latin America Breathelife2030.org Platform

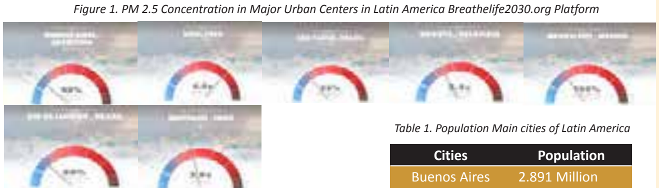

Table 1. Population Main cities of Latin America

Cities	Population
Buenos Aires	2.891 Million
Lima	9.752 Million
Santiago	5.150 Million
Sao Paulo	20.000 Million
Mexico City	21.800 Million
Bogota	8.300 Million
Rio de Janeiro	6.000 Million

Key Gaps

- The scientific community needs to obtain more data to understand the dynamics of the climate in each of the cities.
- This information must be clear, real-time and accurate in order to conduct scientific research.
- In Latin America, there are not enough laboratories to measure weather and climate indices and the gap between technology and science is still large.
- Data are insufficient to study climate change and extreme events in cities, which further complicates the reduction of risk and the strategy to follow to mitigate these events.

Pollution and Global Warming in Cities

Cities must address climate change. More than half of the world's population is urban, and cities emit 75% of all carbon dioxide from energy use.[4]

In the case of latin american cities, it is imperative to identify all sources of CO_2 emissions and other greenhouse gases to understand all climate systems interactions. Climate science must be focused on the five climate components: the atmosphere, the hydrosphere,the cryosphere, the geosphere, and the biopshere, all of which play important roles and should be integrated on cities research.

Figure 2. Earth's Climate System and Cities

Big Data Era

Citizen Science could be helpful developing climate data science to better understand how extreme weather phenomena and climate change are related. The digital era, big data, data science, IoT, low cost high tech, open data are keys to climate change research.

Regional Challenges & Youths

- Youths are key to effective community decision making and integrated vision to sustainable development of cities.
- Goverments need to provide cross-disciplinary research and comparative studies. South-South Cooperation, science diplomacy, and evidence based-practice on national agendas.
- Goverment strategies for young researchers as scientists of future and sustainable development.

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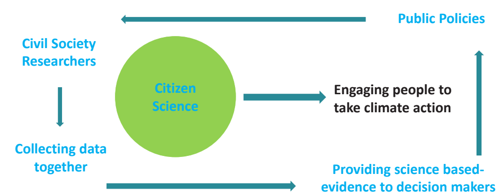
Objectives

In order to achieve the Sustainable Development Goals, leaving no one behind and emphasizing in goal 13. Climate Action, and goal 11. Sustainable cities and communities, on the Paris Agreement, the Sendai (DRR) and NUA, the scientific community must use the resources it has available and work hand by hand with citizens to break down the gaps between the lack of information and the formulation of public policies with decision makers.

How Citizen Science Works

Collaborative Research:



Citizen Science Benefits

- In the case of cities, citizen science is the key to obtaining new climate parameters to further develop research and knowledge about climate change, but also to create ***climate literacy*** and ***meteorological awareness*** or ***weather culture*** in citizens to face and mitigate climate events.
- Citizen participation and young scientists are crucial agents of change to collaborate in research for science to reach society.
- Citizens can participate in the measurement of pollutants, count emissions of greenhouse gases in their industries and homes with suitable technology and scientific verification, while also obtain meteorological data such as temperature and precipitation.

Recommendations

- The local pollutants inventories are registering: $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, CO but it is necessary to increase the measurements and incorporate new compounds such as VOC's.
- Local goverments need to have a regional inventory and co-create a Climate Change Observatory in our cities and communities.

Latin American Cities; Citizen Science Current Projects

1.Understanding flood risk in a changing climate : Understanding flood risk in a changing climate is our first Citizen Science Alliance in Mexico City between RedLAtM and Naj Hub organizations. Students from School of Higher Studies Aragon have chosen a major issue that affects them at school. In the event of heavy rainfall, the school is inundated and their safety is at risk. Up to this date, we do not know the real cause of flooding.

www.najhub.org

2.SMN Argentina Extreme Weather Conditions
http://alertamos.smn.gov.ar/

3.Climandes-SENAMHI Peru. Engagement with indigenous people
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Building Capacity by Building Bridges: Lessons from Developing the Dublin Region's Climate Change Action Plans

Dr. Sabrina Dekker, Climate Change Researcher, PhD, MPP, MPA, BA
Codema - Dublin's Energy Agency

codema
Dublin's Energy Agency

Climate change is the most pressing global public policy challenge facing governments today. International agreements, most recently the Paris Agreement, recognise the impacts of climate change and have been developed to unify national governments in a commitment to address the anthropogenic causes of climate change.

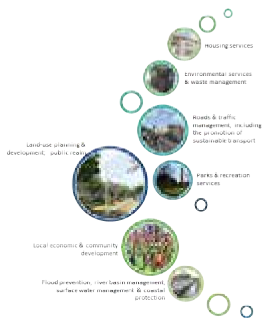
In response to this call to action, the Irish Government has published *The Climate Action and Low Carbon Development Act 2015, The National Mitigation Plan, The National Adaptation Framework,* and *The National Planning Framework,* which set out how Ireland will achieve its international and European commitments, and transition to a low carbon society. To provide local authorities with support, the Environmental Protection Agency (EPA) has developed a *Local Authority Adaptation Strategy Development Guideline*.

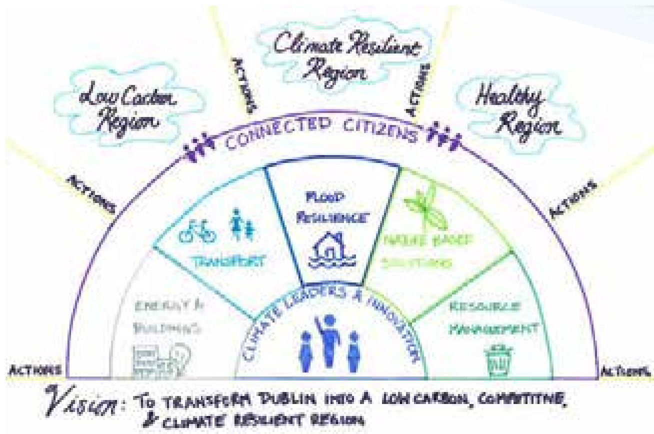
It is in this context that the four Dublin Local Authorities (DLAs) are developing their Climate Change Action Plans collaboratively through Codema – Dublin's Energy Agency. The four DLAs are signatories of the EU Covenant of Mayors for Climate and Energy, which requires members to develop and implement climate change action plans and commit to reducing their CO_2 emissions by 40% by 2030.

These plans lay out the role that the DLAs have in responding to the present and future climate change risks facing the Dublin Region, and the actions that are being taken to achieve climate resilience. An extensive process that involved meetings and workshops with DLA staff, comprehensive analysis of the DLAs' emissions, and evaluation of best practice internationally, was undertaken by Codema and forms the basis of the actions that have been developed by DLA staff to respond to these challenges. The process aimed to overcome the barriers that are common to local governments globally, such as:

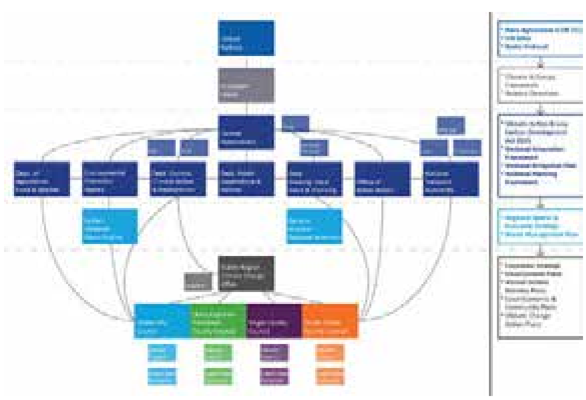
- **Financial capacity**
- **Legislation and regulatory landscape**
- **Data – availability, reliability, validity and its use**
- **Political interests**

Furthermore, the DLAs face unique challenges due to their limited remits:





Institutional & Policy Context



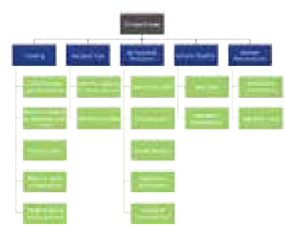
Methodology

The Action Plan Process - 5 Steps

The methodology used to develop these Climate Change Action Plans was based on the International Council for Local Environmental Initiatives (ICLEI)'s Five Milestone Approach. The Milestones were adapted to meet the DLAs' needs.

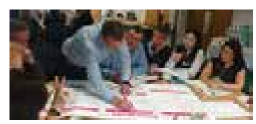
Milestone 1 - Initiate

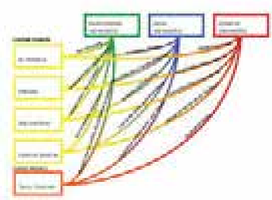
Codema produced *A Strategy Towards Climate Change Action Plans for the Dublin Local Authorities* to begin the process. Next, the present climate change impacts of sea level rise, flooding, extreme weather and pollution, and how they interact with current challenges across the Dublin Region, were assessed.



Milestone 2 - Research

Codema engaged DLA staff via one-to-one meetings, and organised a series of workshops to identify actions currently underway and potential future actions. These workshops brought together DLA staff to discuss the challenges and opportunities in addressing climate change, and their ideas for how to climate proof their operations and service delivery. Vitally, the workshops provided an opportunity for staff to collaborate with each other. Simultaneously, Codema established the DLAs' adaptation and mitigation baselines, which show the current level of GHG emissions for the DLAs and the climate change related risks facing the region.





Results

Milestone 3 - Four Plans of Action

The four DLA Climate Change Action Plans account for the unique identities of each DLA, unified under a common vision and objectives. Furthermore, they are focused on the DLAs' remits and include both the ongoing and planned adaptation and mitigation actions in response to climate change.

The plans are guided by two overarching themes:

1. Climate Leaders and Innovation – to lead by example by climate proofing their operations and service delivery
2. Connected Citizens – to influence behaviour by providing information and learnings from experience

These two themes serve as the basis for the actions which fall into five interconnected areas - Energy and Buildings, Transport, Flood Resilience, Nature Based Solutions and Resource Management. The success of the actions is dependent on collaboration across departments, and leadership that supports ownership of the actions in the plans.

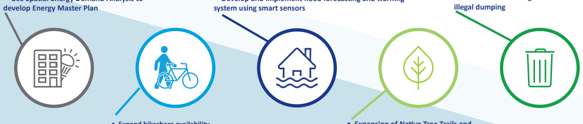
In showing leadership in responding to climate change, the DLAs aim to demonstrate to citizens how they can address climate change across the five action areas.

Sample of Actions

- **Make citizens aware of their energy use via Home Energy Savings Kits**
- **Use Spatial Energy Demand Analysis to develop Energy Master Plan**

- **Use soft solutions for flood risk management: green infrastructure and intergrated wetland management**
- **Develop and implement flood forecasting and warning system using smart sensors**

- **Expand and develop Small Business Innovation & Research programme to address urban challenges such as illegal dumping**



- **Expand bikeshare availability, station and stationless**

- **Expansion of Native Tree Trails and countywide network of greenways to promote active travel, recreation and biodiversity**

Next Steps

Milestones 4 & 5 - Implement & Monitor

The next step is for the DLAs to set up their regional climate change office, as per the recent directive from National Government. The role of this new office will determine how the plans are implemented, monitored and updated.

A critical challenge in the implementation and monitoring of the plans is data. While staff were able to identify and discuss the vulnerabilities stemming from climate change and the actions to address them, the need for localised, reliable, and valid data was emphasised for developing action indicators. Presently, the DLAs are reliant on various central government departments for data on air quality (Environmental Protection Agency), transportation (National Transport Agency), energy (Sustainable Energy Authority of Ireland), and flood risk (Office of Public Works). This challenge of accessibility and availability of data impacts on policy decisions, and the ability of the DLAs to monitor their progress on their climate change actions.

These Climate Change Action Plans are the starting point for present and future action on climate change, and an opportunity to create a resilient Dublin Region. The plans will also strengthen the capacity of the DLAs to encourage citizens to contribute to the region's resilience, and Ireland's transition to a low carbon society.

Lessons & Reflections

Bringing the four local authorities together was key in developing these plans, for a number of reasons. It allowed for:

- Opportunities to talk to counterparts within and across the DLAs
- Building trust and relationships
- Starting a dialogue about what each person/department is doing already and can do
- Highlighting barriers and challenges that will affect implementation, and monitoring and reporting
- Ownership, accountability and leadership

Lessons for facilitators of the process:

- Value the expert knowledge of staff
- Be ready to learn, listen and understand
- Be a caretaker of the process, document it
- Be aware of the challenges, negotiate the barriers and find pathways to common ground
- Facilitate opportunities for connecting staff to resources to strengthen their capacity

Codema is Dublin's Energy Agency and works with the four Dublin Local Authorities to help them improve their energy efficiency and reduce carbon emissions in the Dublin region.

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Comhairle Cathrach Bhaile Átha Cliath Dublin City Council | dlr Comhairle Contae County Council | Comhairle Contae Fhine Gall Fingal County Council | Comhairle Contae Átha Cliath Theas South Dublin County Council

Business Model Innovation and Climate Change Adaptation

Dr Jose Di Bella

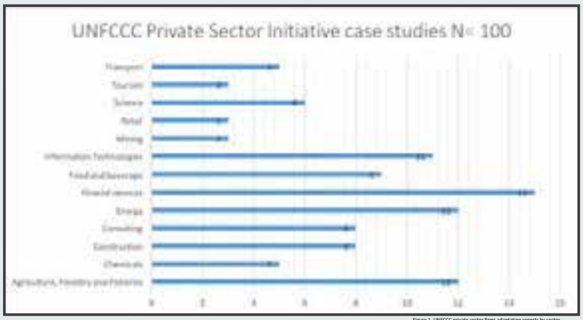


Figure 1. UNFCCC private sector firms adaptation reports by sector.

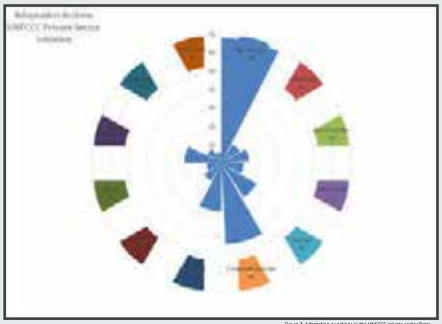


Figure 2. Adaptation as actions in the UNFCCC private sector firms.

Introduction

Effective national adaptation systems rely on a broad range of actors playing differential but complementary roles in climate change adaptation according to their accepted functions and capacities. A renegotiation of the social functions of individual firms is necessary to make possible equitable adaptation processes, where the opportunities presented by climate change are open to all actors and the costs of climate impacts are shared proportionally to the changing social, economic and environmental conditions.

The IPCC recognises deliberate actions of the private sector that contribute to adaptation can arise from business model approaches (SREX 2012, p.347).

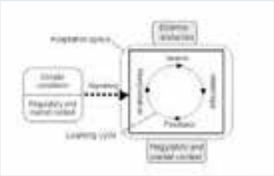
- What types of adaptive actions are deployed by firms in the private sector?
- How are these linked to host communities' adaptive capacities?
- What are the sources of business model innovation that contribute to adaptation?

The changes in organizations in response to climate impacts can be examined by looking at changes in business models, and the relationship these have with other individuals, groups or communities.

Adaptation, Organizational Learning and Business Models

Adaptation in human systems can be a "process, action or outcome" (Smith and Wandel, 2006: 282). Biagnini et al. (2014) propose that adaptation actions refer to the tangible actions that can modify institutions, policies, programs, or the environment in response to experienced or predicted climate change impacts. These adaptive actions are best understood when broken into means-end chains (Eisenack and Stecker, 2013). Adaptive actions can be developed or deployed through social learning (Pelling, 2008), and innovation as a form of adaptation (Rodima-Taylor, 2012) has the potential to trigger transformational processes.

A firm-centred view of adaptation



Organizational Learning by Berkhout (2004)

Aims and research gaps

- Processes and mechanisms of adaptation linked to co-production and innovation.
- Information and knowledge sharing of climate relevant knowledge by the private sector.
- Distributional consequences and opportunities of climate responses of small, medium and large enterprises at local levels.

Method

- Analysis of case study reports and documents submitted by private sector firms to the UNFCCC private sector database (Figure 1).
- Qualitative coding suing NVIVO to categorize adaptive actions by sector (Figure 2), beneficiaries of adaptive actions and linkages of different actions to business drivers.
- Case study field research into two different production and supply systems of large firms operating in locations of high climate risks and impacts.
- A field observation journal, mapping and qualitative interviews used to identify and describe business models, map relationships and examine adaptive actions, including use of climate information, integration of technology and local forms of innovation.

Key findings

- Business model practices that don't account for adaptation planning and undertake adaptive actions create trade-offs and can limit flows of information necessary for local adaptation.
- Firms signal different types of messages through adaptive responses that can shape local adaptation spaces.
- Signaling can widen adaptation space by encouraging cooperative adaptation responses, these originate from co-production of innovations, sharing information necessary for adaptation planning and integration of local adaptive practices into business models.

The integration adaptation planning into the firm's business model can widen adaptation space through the co-production of adaptive actions with host communities, systematising exchanges of information necessary for adaptation planning and promoting knowledge sharing between the firm and local actors, such as direct suppliers, employees and households and competitor firms.

Degrees of change in business models

Incremental change: Adjustments to organisation's operational routines in response to climatic conditions.

Reconfiguration: Changes in the organisation and the relationships in a system.

Transformation: Radical change of the organisation's functions, processes, services, assets or systems in response to climate change impacts.

Figure 4. Case Study 1 Urban Farming Supply Chain in San Jose, BCS, Mexico.

A relational view of adaptation

Individual firms can begin by understanding adaptive choices to open space for egalitarian forms of adaptation for the firm and local associates. This can change accepted business models driven on solely profit calculations to longer range planning that account for social views of adaptation.

Leveraging the private sector in adaptation

A business model aligned with a social view of adaptation integrates information, knowledge and practices of host communities to manage climate risks and impacts. This implies leveraging resources and capabilities of the firm to invest in long term adaptation planning with a variety of local stakeholders.

Recognised Signal Patterns from Adaptive Actions

Signal type	Description	Example
Cooperation	These actions signal to external actors the firm's willingness to cooperate through resources or expertise in climate change adaptation activities.	Holding a forum or commissioning a joint adaptation analysis, in cases such as the guilds and associations. This signalled to competitor firms a willingness to cooperate to mitigate climate impacts.
Competition	This signal to associates or supplier's competition for resources in the same geographic location and members of the same supply chain or assemblage of local actors.	When a specific volume of goods or services can only be sourced from a single region to reduce risk for the firm, capping the volume at of the overall supply signals that suppliers need to compete for allocations
Dependence	These signals emerge from actions that indicate to associates or stakeholders that climate- or disaster-related losses will be subsidised or absorbed by the firm.	Subsidising the losses in climate events without feedback or corrective measures required to prevent or compensate for these losses.
Indifference	This signal originates from actions that have consequence for information or resource exchanges, but are ignored or not communicated disrupting feedback and learning loops.	In case studies the lack of feedback on exemplary quality of products or failure to examine infrastructure losses, conflicts on water use or benefits of new technologies.
Command	This signals the firm's intention to overtake or appropriate adaptation resources or adaptation spaces.	In cases of limited adaptation options or trade-offs, aggressive firm behaviours to dominate potential adaptation spaces through deployment of resources or experts, or policies favourable solely to limited actors in each location that benefit the firm.
Stability	These actions signal deliberate efforts made by the firm to maintain functions and system stability across the assemblage, through focus on performance or reinforcing vulnerable or exposed units.	The firm offers to establish supply partnerships and rely on long-term agreements that place sourcing responsibility on their partners.

In cities, a future research agenda on the private sector and adaptation

- What types of firms are undertaking adaptive actions in urban environments or supporting adaptation through daily business practices?
- How do they use or share information necessary for adaptation planning?
- How can local municipal regulation and policy create incentives for the private sector to undertake cooperative adaptation planning and investments?
- How do individual firms link to municipal adaptation planning processes and delivery of basic services?
- What new technologies can assist in visualising business relationships to integrate new information in business models for adaptation?

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The impacts of natural disasters on urban planning : technology and regulations

Vivian C.K. Dombrowski

1. INTRODUCTION

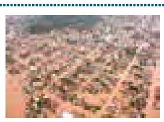
The world phenomenon of urbanization developed rapidly causing some problems, especially about geographical space, environment and economic development.
The impacts of natural disasters as elements of urban planning should be considered in the management of the city, especially rainfall, floods and landslides, which is increasing exponentially with the climate changes and require more preventive measures and an accurate response after they had occurred.
Some applicative, geographic information system (GIS) technology and SMS/Text messages are effective alternatives that have helping population to avoid more damages and also to prevent them before the disaster had occurred.

2. RESEARCH QUESTION

How technology can be able to prevent the damages of natural disasters in the cities and how it can be within accessible to the population?

3. METHODS

Analyze the urbanization phenomenon and how it has influenced in the current rban scenario.



Perceive the influence of climate changes in the cities and the risks of natural disasters

Understand how the damages could be prevent or more rapidly repared , especially the people's safety.

Find what are the technology available and how people can use them for their safety

4. TECHNOLOGIES

Applicatives

twitter

Disaster Alert

Stay Safe

SMS/Text Message

NATURAL DISASTERS ALERT SMS

- The pioneer project in Brazil to save people of natural disasters .
- Text message to inform people about possible bad weather conditions.
- The text message system is provided by the civil defense of State of Paraná with the SIMEPAR (Meteorological System of Paraná).

- **How it works?** SIMEPAR and CIVIL DEFENSE send the information about the weather conditions to a central of mobile phones and then they send the text messages to all the registered phones.
- To register: send a message to 40199 with the Code Post . It's free of charge.
- The information about the weather is available for 3 hours.

5. RECOMENDATIONS

- Many cities have been suffering of the rapidly urbanization problems including population increasing in large centers, lack of space and housing, environmental degradation, deforestation, pollution, real estate expansion, economic interests .
- Climate changes and natural disasters caused by them are a reality in all cities of the world and soon or later many of them will suffer some kind of natural disaster unless it would be prepared to avoid it.

- Applicative, crowdsourcing, GIS and SMS Text are some technologies that can help the cities and the population to prevent some damages or be prepared for some meteorological catastrophe. They also can be able to help people to keep safe after some natural disaster has occurred .

- Urban policies should include such technologies as elements of their regulations, making their development mandatory, as well as enabling the population to make use of it.

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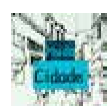
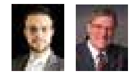


CESAR CANADIAN ENERGY SYSTEMS ANALYSIS RESEARCH

A Compendium of Canadian Provincial Climate Change Mitigation Actions

Moe S. Esfahlani[1,2], esfahlani@ucalgary.ca



David B. Layzell[1], dlayzell@ucalgary.ca

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UNIVERSITY OF CALGARY

INTRODUCTION

In the 2015 Paris Climate Agreement [1], Canada committed to reduce greenhouse gas (GHG) emissions to 30% below 2005 levels by 2030, and to do its share to keep global warming below 2°C by 2050 (*ca.* -80% of 2005 GHGs). The **Pan Canadian Framework** [2] recognizes the important role of provinces in defining and implementing the strategies to achieve these targets.

With support from the National Energy Board, CESAR engaged with all 10 provincial governments and drew on their published reports to summarize mitigation measures associated with each of the 7 economic 'sectors' that are being studied in the CESAR Pathways Project.

The preliminary findings from this exercise are being used by CESAR to inform technology and behaviour-rich scenario models that define Pathways to more sustainable energy systems.

METHODS

Using the research process summarized in **Figure 1**, we:

- Consulted with **33** policy makers on the climate change file across Canada's 10 provinces [3];
- Compiled more than **50** key documents describing provincial or federal policies, programs or regulations [4];
- Extracted more than **330** references from the literature [5];
- Assessed and extracted climate change measures being considered or already implemented;
- Developed metrics to quantify the measures in terms of:
  - ***Engagement:*** *Score / (Score + Blank Count)*

This reflects the engagement of each mitigation measure by provinces.

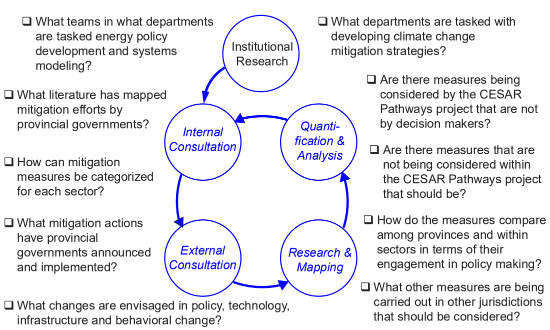

Figure 1. Research Process and Questions

RESULTS

Sector	Mitigation Measures	Engagement	BC	AB	SK	MB	ON	QC	NB	NL	NS	PEI
Personal Mobility (174 pt)	Renewable Fuel Standards	80%										
	Public Transit Infrastructure	76%										
	Vehicle Efficiency	76%										
	Electric Vehicle Infrastructure	64%										
	Carbon Tax	52%										
	Electric Vehicle Incentives	47%										
	Car Sharing	29%										
	Autonomous Vehicles	16%										
	Transportation as a Service (TaaS)	0%										
Supply Chains (203 pt)	Interprovincial Partnerships	91%										
	Renewable Fuel Standards	77%										
	Infrastructure Investment	68%										
	Multi-modal	63%										
	Vehicle Efficiency	62%										
	Intelligent Transport	61%										
	Carbon Tax	48%										
	CNG	38%										
	Mode-shift	32%										
	Electric or Fuel Cell Vehicles	0%										
Built Spaces (302 pt)	Community Energy Resources	90%										
	Energy Performance Standards	89%										
	Energy Efficiency	88%										
	Walkability	88%										
	Municipal Emission Management	76%										
	Appliance Efficiency	74%										
	Efficient Infrastructure	65%										
	Home Retrofit	63%										
	Indigenous Initiatives	56%										
	Urban Densification (through TaaS)	0%										
Energy Using Industries (225 pt)	GHG Reporting	87%										
	Efficiency & Electrification	78%										
	Innovative Technology	73%										
	Fuel Switch (Low Carbon)	70%										
	Carbon Tax	53%										
	Cap and Trade	53%										
	Renewable Energy Incentive	48%										
	GHG Limits & Targets	39%										
	Carbon Capture and Storage	38%										
Biosectors (239 pt)	Forest/Wetland/Agroforestry	88%										
	Waste Management	84%										
	Biomass/Biofuel/Cogen	73%										
	Manure Management	74%										
	Nutrient Management	70%										
	Carbon Offset Trade	67%										
	Agricultural & Range Management	49%										
	Carbon Sequestration	45%										
Power Generation (245 pt)	Interprovincial Transmission	94%										
	Renewable Targets & Subsidies	92%										
	Demand-Side Management	79%										
	Coal Phase-Out	73%										
	Distributed Generation	72%										
	Carbon Pricing	63%										
	Nuclear	43%										
	Cogeneration	29%										
	Capacity Market	24%										
Fossil Fuels Industries (78 pt)	Innovative Technology	53%										
	Carbon Tax	53%										
	Cap & Trade	49%										
	Cogen	41%										
	CCS/ CCUS	39%										
	Demand Reduction	0%										

Not Applicable | 3 pt. Legislation & Regulation | 1 pt. Expected soon | 2 pt. Policies, Programs & funded initiatives | 1 pt. Expected soon | 1 pt. Strategies & Action Plans | Opposed

NOTE:

❑ Measures within the *Personal mobility & Supply Chain Sectors* have low engagement scores (174-201), but due to potential impacts on cities and oil production, are considered by CESAR to be among the most important sectors to achieve systems change.

❑ The high engagement score (302) reflects the fact that *Energy Efficiency* measures pay back, quickly and are popular with voters.

❑ Canada's vast natural resources in a world with a rapidly growing population suggest that these sectors may grow significantly by 2050. Reducing both their energy and their process emissions is likely to be a major challenge.

❑ Greening and growing the grid to meet new demand will be more challenging for some provinces than for others.

❑ Improved technologies and efficiencies are critical, but eventually demand reduction is needed.

CONCLUSIONS

The consultation and review process carried out in this project has identified many similarities and differences among provincial governments in terms of their climate change mitigation measures.

The study only identified the classes of measures and quantifies and compares their "Engagement" in policy making; an interprovincial comparison of differences in policy deployment and their likely GHG impacts are beyond the scope.

Insights from this work will inform **CESAR's Pathway Project** in which we define and model the nature and timing of technology, infrastructure and behavioural changes in Canada's energy systems to achieve climate change commitments.

CESAR's current work (other posters) has revealed that to achieve this goal, mitigation measures will be required that are beyond current policy efforts as mapped here.

Some of these initiatives will need to embrace and harness disruptive change in order to successfully address problems in human systems beyond GHG emissions.

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[2] https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html

[3], [4], [5] For a full list of references (**54** provincial contacts, **58** key documents, **332** online references) please contact the authors.

- ACKNOWLEDGEMENT -

We thank the National Energy Board for facilitating this project component by providing partial funding for provincial consultations.

Evolution of Community-wide GHG Footprint Approaches: Key Learnings from Implementation in Denver, Colorado

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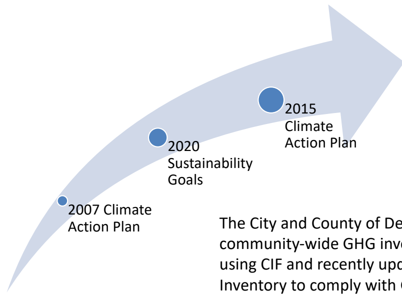
LEIF, LLC & University of Minnesota Center for Science, Technology and Environmental Policy

Abstract

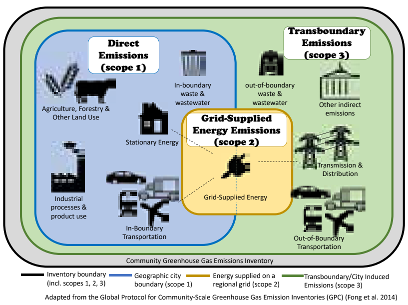
Various carbon footprinting approaches for cities have been developed over the past decade to account for the in-boundary and transboundary greenhouse gas (GHG) emissions associated with community-wide activity of homes, businesses, and industries located in cities. Here we focus on two protocols addressing community-wide GHG emissions; the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), which is the standard developed in 2014 for 7,478 cities submitting inventories through the Global Covenant of Mayors for Climate & Energy, and the Community-wide Infrastructure Footprint (CIF) methodology, which is similar to the ICLEI US Community Protocol that has been applied in cities since 2010 and British Standards Institute PAS 2070 Direct plus Supply Chain methodology. As cities strive towards a common reporting approach, this work addresses the similarities and differences between GPC and CIF to determine what they can learn from each other. Using Denver as a case study, we compare the GPC and CIF methods to gain better understanding for cities and practitioners developing GHG inventories.

Denver Case Study



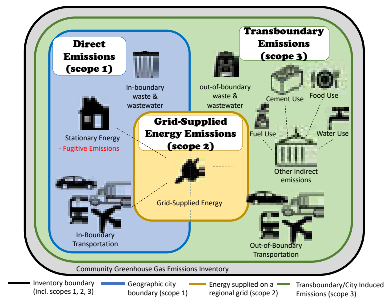
The City and County of Denver has performed community-wide GHG inventories since 2007 using CIF and recently updated their 2015 Inventory to comply with GPC Basic+

GPC: Scope 1,2,3 Emissions



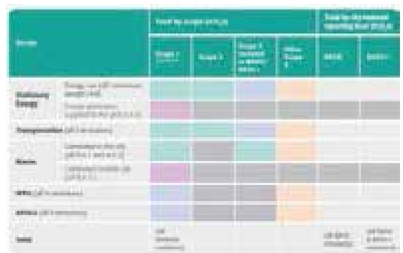
Adapted from the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) (Fong et al. 2014)

CIF: Emissions supporting Local Infrastructure Provision



Adapted from Ramaswami et al 2017

GPC/CIF Sectoral Comparison



Green + Purple + Blue sectors addressed in GPC Basic+
Green + Purple + Orange sectors addressed in CIF

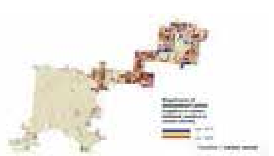
GPC BASIC+ Results

Uncertainty in BASIC+ sectors (IPPU and AFOLU)

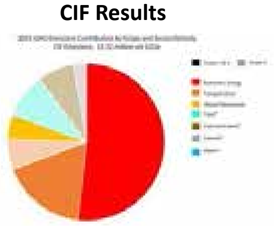
The GPC Basic+ methodology applied to Denver's 2015 inventory adds additional emissions (~1%) due to the inclusion of Agriculture, Forestry, and Other Land Use (AFOLU) change and Industrial Products and Products Use (IPPU) sectors.

-Example below shows how carbon sequestration from different land use types is accounted for; such assessments need standardization and more scientific research on how to account for urban vegetation

-IPPU difficult to quantify at city-scale because of data gaps in economic/production data



CIF Results

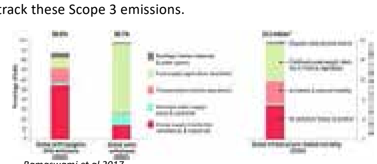


Which Scope 3 Emissions should cities track?

As cities pursue policies such as electrifying transportation and localizing food production, it is important for all cities to consistently account for baseline emissions resulting from the supply chains of key materials supporting food, transportation, and construction activity. We highlight three embodied emissions that are optional in GPC but required in CIF

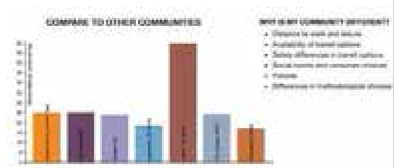
- Food Production
- Fuel Production
- Cement Production

We recommend cities to track local diet characteristics, alternative vehicle fuel, and building area (sq ft) data in order track these Scope 3 emissions.



Ramaswami et al 2017

Benchmarking



Tracking Over Time

Inventory Year	GHG Emissions (mt CO2e/year)	On-Road VMT Per Capita
2007	2.6 million	24 mi/person/day
2015	2.3 million	25 mi/person/day

Benchmarks allow cities to compare sectoral changes in activity/use to changes in emissions intensity

Recommendations

The Community-wide Infrastructure Footprint use-based approach has a strong focus on benchmarking activity use intensities, such as energy use per GDP and vehicle miles traveled per capita. We recommend that cities consistently track these metrics that directly inform the progress in each sector over time and are helpful for comparison of resource efficiency between different communities.

Examples:
1. Tracking building materials use (cement use/capita)
2. Benchmarking Commercial Building Energy Use (energy use/sq ft)
3. Tracking Electric Utility Emission Factors (CO_2/kwh)

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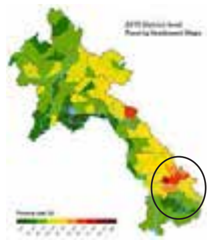
References
1. 80 x 50 Climate Goal: Stakeholder Report. (2017).
2. Fong, W. K., Sotos, M., Doust, M., Schultz, S., Marques, A., & Deng-Beck, C. (2014). Global Protocol for Community-Scale Greenhouse Gas Emission Inventories.
3. Hillman, T., & Ramaswami, A. (2010). Greenhouse Gas Emission Footprints and Energy Use Benchmarks for Eight US Cities. Environmental Science & Technology, 44(6), 1902–1910.
4. Ramaswami, A., Russell, A., Culligan, P., Sharma, K. R., & Kumar, E. (2016). Meta-principles for developing smart, sustainable, and healthy cities. Science, 352(6288), 940–943.

VULNERABILITY ASSESSMENT & ACTION PLANNING IN HIGHLY VULNERABLE CONTEXTS IN LAO PDR

1. CONDUCT BACKGROUND DATA GATHERING AND CONSULTATION

- Get access to the most recent census
- Review government policy and strategy documents
- Analyze reports from other development partners
- Consult national and local stakeholders
- Analyze climate change historical trends and future projections

→ **Output: Comprehensive background and overview of the baseline situation**



2. PRIMARY DATA GATHERING

- Identify gaps in the census data
- Define survey and consult with stakeholders and communities
- Innovate by using Kobo Toolbox, low-cost tablets and excel database to gather data from individual villages
- Convert to web-based infographic
- Compile data and distribute to local stakeholders

→ **Output: Local database developed with detailed information at the village level based on community perception and experience**

3. GIS ANALYSIS

- Analyze surrounding eco-systems
- Identify changes over time
- Overlay man-made developments that present further threats to the environment
- Build a comprehensive picture of ecosystem services that urban and surrounding rural areas depend on
- Make use of innovative open source software!

→ **Output 1: Changing environment and ecosystem services understood**

- Analyze critical infrastructure
- Identify changes over time
- Highlight where infrastructure is likely to be impacted by climate change related hazards
- Find areas where a lack of infrastructure reduces adaptive capacity
- Begin to identify where infrastructure may be stretched or unable to cope in the event of a disaster

→ **Output 2: Infrastructure coverage established and weaknesses identified**

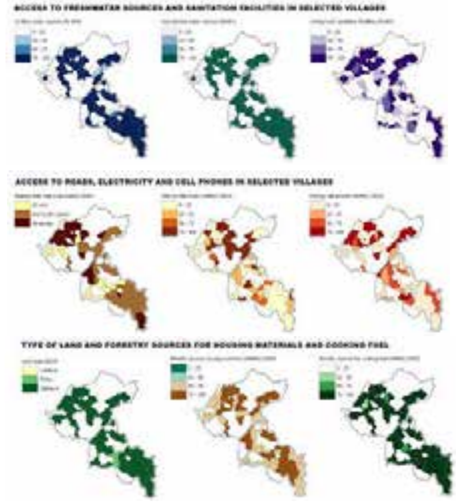
CLIMATIC FEATURES, NATURAL HAZARDS AND OBSERVED IMPACTS

SPATIAL DISTRIBUTION OF MAIN PUBLIC FACILITIES AND BASIC SERVICES

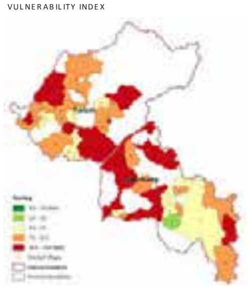
ACCESS TO FRESHWATER SOURCES AND SANITATION FACILITIES IN SELECTED VILLAGES

ACCESS TO ROADS, ELECTRICITY AND CELL PHONES IN SELECTED VILLAGES

TYPE OF LAND AND FORESTRY SOURCES FOR HOUSING MATERIALS AND COOKING FUEL

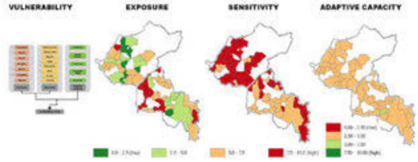


VULNERABILITY INDEX



TERRITORIAL LINKAGES AND SPATIAL STRUCTURE

VULNERABILITY EXPOSURE SENSITIVITY ADAPTIVE CAPACITY



4. SPATIAL ANALYSIS AND VULNERABILITY INDEX

- Use the Matrix of Functions as a way to generate a functional hierarchy of villages
- Create an isopleth map (in GIS or by hand) showing the territorial linkages between the settlements and identifying cluster settlements
- Develop a simple vulnerability index using direct and proxy measures for exposure, sensitivity and adaptive capacity
- Overlay the spatial analysis and the vulnerability index, to identify 'hotspot' areas to implement priority adaptation actions

→ **Output: 'Hotspot' areas identified leading to action prioritization**

5. PLANNING FOR ACTION

- Consult communities and local government about VA findings
- Use the spatial analysis and other visual materials generated during the VA
- Use a tool like UN-Habitat's Planning for Climate Change (available online)
- Develop a short list of actions for detailed engineering design and economic analysis
- Work together for climate resilience!

→ **Output: Action plans developed that communities, local government and other stakeholders can partner on to make cities and communities more resilient**

PLANNING FOR ADAPTATION AND BUILDING RESILIENCE: STRATEGIC AREAS OF INTERVENTION

CONTACT

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Ministry of Public Works and Transport
Vientiane Capital, Lao PDR

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Like us on Facebook @AFprojectLaos

ADAPTATION FUND

UN-HABITAT FOR A BETTER URBAN FUTURE

DEVELOPMENT OF A CARBON NEUTRAL COMMUNITY EDMONTON'S STORY


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District Energy Specialist
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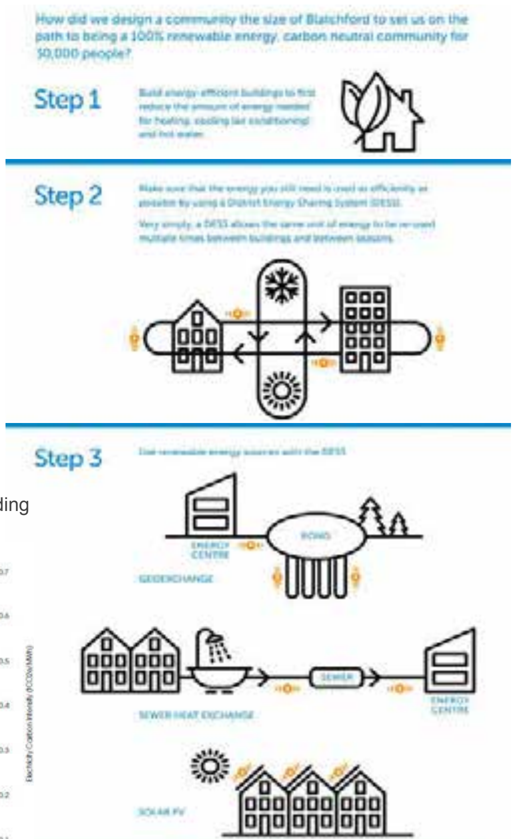
Vision

Blatchford will be home to up to 30,000 Edmontonians living, working and learning in a sustainable community that uses 100% renewable energy, is carbon neutral, significantly reduces its ecological footprint and empowers residents to pursue a range of sustainable lifestyle choices.

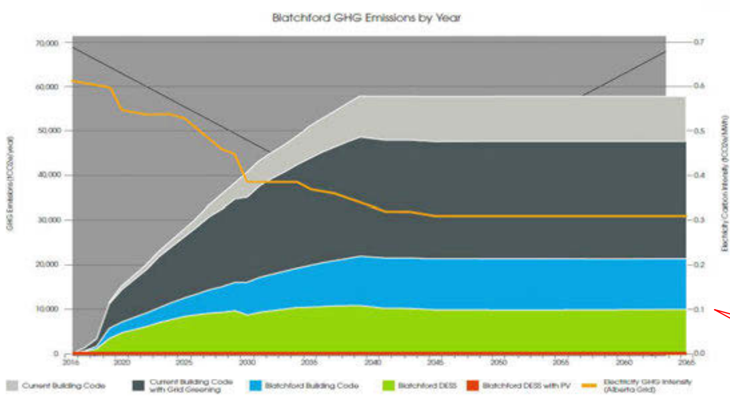
Blatchford Energy Strategy



Community Overview

Quick Facts

- 1st community of its kind in Canada
- 217 hectares of Municipal Airport Land Redevelopment
- 42,038 tonnes/year of Greenhouse Gas Emissions reduction
- Over 90% of the materials are diverted from the landfill from former airport building



The result? 74% fewer greenhouse gases than a business as usual community

1927	City Centre Airport opens
2008	Edmonton City Council begins discussing redeveloping the airport land into a new urban residential and commercial community
2009	Edmonton City Council votes to implement a phased closure of the City Centre Airport
2012	The community is named Blatchford to honor Kenneth Blatchford, former Edmonton Mayor who helped establish Canada's first municipal airfield
2013	City Centre Airport officially closes at 4:49 PM on Saturday, November 30
2014	City Council approves the development plan for the community. Site preparation including removal and recycling of buildings begins
2015	Construction, including site grading and excavation for the first stormwater pond, begins on the first phase of of residential development and a section of the central park
2016	Preparation for residential construction continues. A municipal utility is formed to provide heating, cooling and domestic hot water for the residents and businesses through the District Energy Sharing System
2017	Construction on site including installation of storm, sanitary and water services along with District Energy Sharing system piping
2018	Construction start for Phase 1 of the District Energy Sharing System
2019	First residents and businesses planned to move in to Blatchford

@Blatchfordyeg facebook.com/BlatchfordEdmonton

Blatchford

CITIES 2018 CONFERENCE IPCC

EXTREME TEMPERATURE EVENTS AND HEALTH IMPACT ON OLDER ADULTS LIVING IN BUENOS AIRES. COMPARATIVE ANALYSIS OF 3 STUDIES.

FONTAN, SILVIA[1]; RUSTICUCCI, MATILDE[2]
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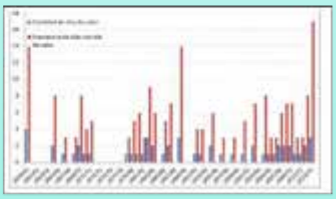
[2]DEPARTAMENTO DE CIENCIAS DE LA ATMÓSFERA Y LOS OCÉANOS - FACULTAD DE CIENCIAS EXACTAS Y NATURALES UNIVERSIDAD DE BUENOS AIRES / CONICET (DCAO-UBA/CONICET) e-mail: mati@at.fcen.uba.ar

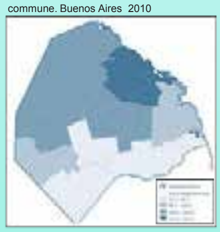
INTRODUCTION

Buenos Aires City shares the pattern of increased extreme temperature events, the frequency of extreme heat waves, thus, increasing temperatures, increasing life expectancy with a progressive increase in the population of older adults and the increasing prevalence of chronic diseases and obesity make it necessary to produce knowledge oriented towards taking timely measures targeted at urban populations.

Heat waves and frequency of days with waves in Buenos Aires between 1959 2014.



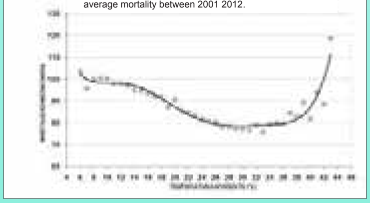
Persons 65 years old and over for every hundred children under 15 years of age, by commune. Buenos Aires 2010



Buenos Aires City by commune. Population 65 years old or more. 2010

Three studies that analyze the relationship of extreme heat wave events with morbidity or mortality of older population.

Buenos Aires. Daily apparent temperature vs. daily average mortality between 2001 2012.



Almeira , G: Rusticucci , M; Suaya , M. 2016. Relationship between mortality and extreme temperatures in Buenos Aires and Rosario. Meteorologica Vol 41, 2 Page 65-79. Open Access

Mortality and HW 2001-2012: In the city of Buenos Aires there is a u-type relationship between mortality and the maximum, minimum and apparent daily temperatures between 2001/2012. Rusticucci, Suaya and Almeira (2015) observe that the affections vary between 20-80% of excess mortality during heat waves, 70-80% of the deceased people are over 65 years of age. Men and women are equally affected, but people over 65 represent 70-80% of deaths under heat waves.

Mortality and HW in the warm semester 2013-2014: In this research, the effects of heat waves were analyzed and characterized, showing a significant increase in mortality and risk ratio in older people on the 9 days of heat wave in Buenos Aires

Chesini , F; Fontan, S and Savoy , F. 2017. Heat waves mortality in the warm semester 2013-2014 in the central and northern regions of Argentina. Ministry of Public Health .

Morbidity and HW 2005- 2010: In this study authors show the relation between the occurrence of heat waves and the number of cases of hypertensive diseases and ischemia.

Chesini , F; Fontan, S; [et al.] 2015. Climatic variability and its impacts on health in cities of Latin America : Buenos Aires, Santiago, Montevideo, Salto and Manaus . Ministry of Health of Argentina

Conclusions

Studies compared here, reports the association between the extreme event, heat wave and the impact on health of the elderly in the City of Buenos Aires. Considering that the City has a demographic profile of aging and that extreme events have experienced an increase in decadal values, it is necessary to deepen interdisciplinary research. New perspectives of analysis and methodology to characterize living condition of this population and their distribution in the different communes of the City would allow better policies of prevention and care strategies in a climate change scene.

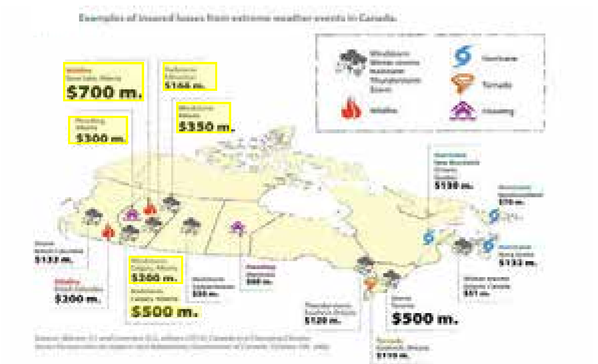
A REGIONAL CONTEXT: PLAN B FOR RAPID ADAPTATION, GHG REDUCTIONS AND RESILIENCE IN THE BUILT ENVIRONMENT

Kalum Galle, Morrison Hershfield Ltd.
Nils Larsson, International Initiative for a Sustainable Built Environment (iiSBE)

INTRODUCTION:

This poster is developed to provide a solid regional emphasis for Plan B for rapid adaptation, GHG reductions and resilience for the built environment position paper developed by sixteen members and associates of iiSBE (the International Initiative for a Sustainable Built Environment). It argues in extreme climate driven events localized in urban population centers may trigger governments and policy makers to take action to mitigate risks associated with the impact of climate change. Though the paper elaborates on various key actions to rapidly respond to extreme climate and weather conditions, identification of regional vulnerabilities and risks are regarded as a necessary preliminary step.

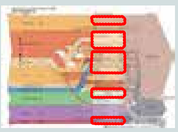
Having to endure various climate driven catastrophic events over the past decade such as floods, droughts, forest fires and intense hail storms, cities in Alberta have begun to build climate resiliency into their future planning. This poster intends to capture some of the key the actions being taken and challenges being faced by various provincial and municipal government fronts such as the introduction of new minimum energy performance requirements in building codes, implementation of carbon tax, and greater emphasis on durability and urbanization strategies designed to limit urban sprawl.



IPCC WGII, AR5: Summary for Policymakers

RCP = Representative Concentration Pathway.
RCP 2.6 assumes a GHG peak of 490 ppm before 2100, then declining;
RCP 8.5 assumes 1370 GHG emissions by 2100, and rising

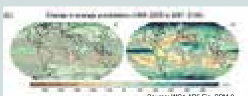
http://www.iiasa.ac.at



The built environment is implicated in many sectors of GHG emissions

Source: IPCC AR5

CO2 emissions have very long-term effects on global temperature and sea level



Source: WG1 AR5 Fig. SPM-8

Economic v. insured catastrophe losses 1970-2015

Source: Swiss Re Economic Research & Consulting, 2015, in Investing for Resilience, ClimateWise, University of Cambridge, December 2016

Predicted climate change impacts on the built environment

Global trends	Likelihood of future trends	Examples of major projected impacts
Warmer and fewer cold days and nights over most land areas	Virtually certain (99% probability)	Reduced energy demand for heating, increased demand for cooling, declining air quality in cities
Warmer and more frequent hot days and nights over most land areas	Virtually certain (99% probability)	
Warm spells / heat waves: frequency increases over most areas	Very likely (90% probability)	[illegible]
Area affected by droughts increases	Likely	Water shortages ; reduced hydro generation potential; potential for population migration
Heavy precipitation events: frequency (or proportion of rainfall from heavy falls) increases over most areas	Very likely (90% probability)	[illegible]
Intense tropical cyclone activity increases	Likely	[illegible]
Increased incidence of extreme high sea level (excludes tsunamis)	Likely (rising trend)	[illegible]

Examples of links between climate change effects and the building sector

Global effects	Specific effects	Examples of secondary effects
Higher global temperatures	Higher summer temperatures Reduced [illegible] Increased insect population	Population health impact Need for more mechanical cooling Higher operating costs Increased energy consumption Need for insect control
High winds	Wind damage to structures	Repair and/or rebuild
Drought	Water supply problems Soil instability Forest fires	Ration or import water supplies Prohibit new construction Repair and/or relocate Rebuild
Increased precipitation & floods	Flood damage	Rebuild and/or relocate

Key Issues:

Climate change has definitely arrived;

Key industry and government leaders have hesitated too long to implement adequate long-term mitigation measures;

Measures that have been implemented tend to be of the no-regrets and painless variety, but these are not sufficient to make the major and rapid reductions that are needed;

If no serious measures are introduced quickly, the probability of serious economic disruption and social unrest is high;

In view of these factors, we believe that regionally-sensitive plans for more rapid action are urgently needed, and we present a number of long-term and short-term proposals along these lines.

Key Actions:

a. Identify regional vulnerabilities and risks
b. Actions starting now, but requiring continuous implementation
   1. Establish sustainability performance targets for neighborhoods
   2. Reduce carbon emissions
   3. Clean energy and renewables
   4. Support development of Synergy Zones
   5. Reduce risks from climate hazards such as flood, winds, drought and forest fires
   6. Mitigate heat-island effect
   7. Encourage urban agriculture
   8. Ensure very high performance of new buildings
   9. Limit embodied energy and emissions
   10. Undertake intensive and deep green renovations
   11. Support a shift from private to public transport
   12. Strengthen equipment and appliance efficiencies
   13. Limit peak electrical demand
   14. Assess and monitor performance, track key indicators and maintain data

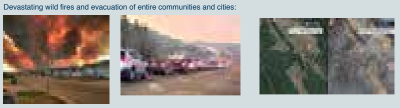
Actions for rapid implementation:

15. Protect critical facilities and infrastructure
16. Prepare to house relocated populations
17. Freeze new development and construction

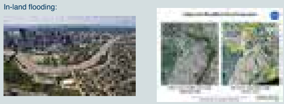
Source: Plan B for rapid adaptation, GHG reductions and resilience in the built environment; v5, 01 March 2018

Regional Vulnerabilities for Alberta

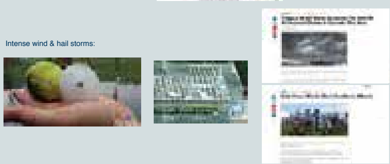
Devastating wild fires and evacuation of entire communities and cities:



In-land flooding:

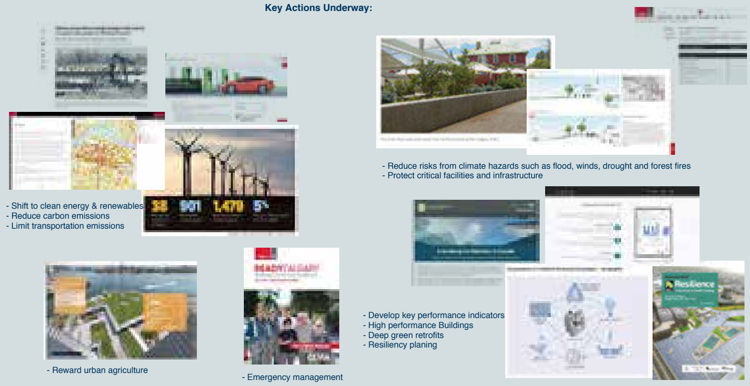


Intense wind & hail storms:



Policy level actions by Federal, Provincial and Municipal level includes: Implementation of Climate Change Action Plans, Putting a price on carbon emissions, adaptation of municipal Sustainable Building Policies, as well as implementation of stricter energy and building codes.

Key Actions Underway:



- Shift to clean energy & renewables
- Reduce carbon emissions
- Limit transportation emissions

- Reduce risks from climate hazards such as flood, winds, drought and forest fires
- Protect critical facilities and infrastructure

- Reward urban agriculture

- Emergency management

- Develop key performance indicators
- High performance Buildings
- Deep green retrofits
- Resiliency planing

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Mapping Urban Form and Ecological Infrastructure by Combining Global Datasets

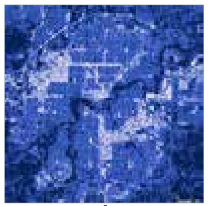
Melodie Green*, Ted Huffman, Bahram Daneshfar, Andrew Davidson, and Tim Martin

*AgroClimate, Geomatics, and Earth Observations Division, Science and Technology Branch, Agriculture & Agri-Food Canada, Ottawa, Canada

Innovation

Landsat-based global map datasets allow us to iron out spurious differences between higher-resolution datasets that meet at administrative boundaries. We recently discovered we can also use USGS Global map datasets to distinguish between different kinds of Settlement in our Land Use Time Series Maps. Parking lots are meaningfully different from parks, and until now we have not had a way to offer this kind of differentiation consistently across the country.

USGS Global Bare Ground 2010 allows us to see highly reflective, hardened, unvegetated surfaces



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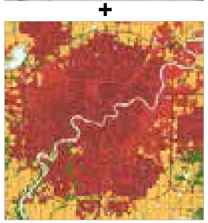
USGS Global Tree Canopy 2010 allows us to see urban forests, leafy neighbourhoods, and grassy open spaces

+

Originally, the only distinct subclass of Settlement we could identify was Roads

Original		USGS Bare Ground 2010: None (0%)	1-30%	31-50%	Very high (>80%)
USGS Tree Canopy 2010	None (0%)	Settlement	Settlement	Settlement	Settlement
	1-20%	Settlement	Settlement	Settlement (very few pixels)	
	21-50%	Settlement	Settlement		
	51-80%	Settlement	Settlement		
	Very high (>80%)	Settlement	Settlement		



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We can now use the Global Bare Ground and Tree Canopy datasets to differentiate Settlement into meaningful subclasses

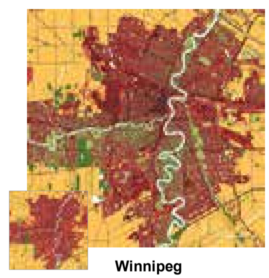
Revised		USGS Bare Ground 2010: None (0%)	1-30%	31-50%	Very high (>80%)
USGS Tree Canopy 2010	None (0%)	Vegetated Settlement	Undifferentiated Settlement	High Reflectance Settlement	Very High Reflectance Settlement
	1-20%	Vegetated Settlement	Vegetated Settlement	Undifferentiated Settlement (very few pixels)	
	21-50%	Vegetated Settlement	Vegetated Settlement		
	51-80%	Settlement Forest	Settlement Forest		
	Very high (>80%)	Settlement Forest	Settlement Forest		

Result

We can now differentiate built surfaces from vegetated surfaces on our national Land Use maps. The effects are consistent across the country, and allow comparisons of major Canadian cities. Ecological infrastructure is crucial to climate risk and resilience, urban heat island effects, and stormwater management. There are both immediate and long-term implications of urban form. This additional level of detail will help researchers and policy-makers to see and communicate insights about how urban form and ecological infrastructure contribute to climate resilience.

Edmonton

Vancouver



Winnipeg

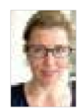
Background

Our 1990, 2000 and 2010 Land Use Time Series maps cover all areas of Canada south of 60°N at a spatial resolution of 30 metres.

The Land Use Time Series maps were developed in response to a need for explicit, high-accuracy, high-resolution land use data to meet Agriculture and Agri-Food Canada's commitments in international reporting, especially for the annual National Inventory Report (NIR) to the United Nations Framework Convention on Climate Change (UNFCCC), the Agri-Environmental program of the Organization for Economic Co-operation and Development (OECD) and the FAOSTAT component of the Food and Agriculture Organization of the United Nations (FAO).

The Land Use classes follow the protocol of the Intergovernmental Panel on Climate Change (IPCC), consisting of Settlement, Water, Forest, Cropland, Grassland, Wetland and Otherland, with further differentiation within those classes where available.

Refinements are ongoing, and a 2015 map is in development.



Comments welcome!
Melodie.Green@canada.ca

Canada

Climate change in the building sector: a scenario analysis in the Mediterranean basin

Maurizio Cellura, Francesco Guarino, Sonia Longo, Giovanni Tumminia

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Introduction & objectives

The paper presents an energy simulation-based study to investigate the impacts of climate change on the building energy use for heating and cooling in the Mediterranean basin.

The air temperature of 24 different general circulation models (GCMs), produced by the World Climate Research in the context of Fifth Coupled Model Intercomparison Project (CMIP5) [1], were analysed using different metrics for selecting the most suitable GCM to be used for climate change impact analysis. The data of the selected GCM were used as input to a downscaling method known as "morphing", to generate hourly weather files for 3 future time projections (2035, 2065 and 2090). Finally, in order to assess the building energy use for heating and cooling for the next century, simulations for different case studies were conducted.

Materials & methods

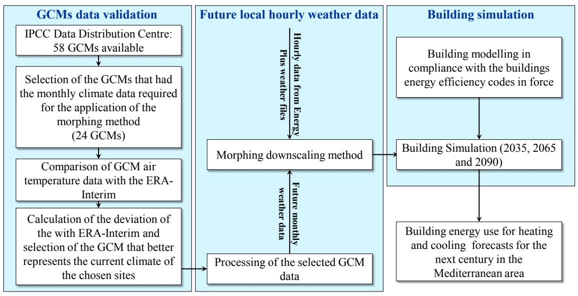

Fig. 1 - Sketch of the methodological framework

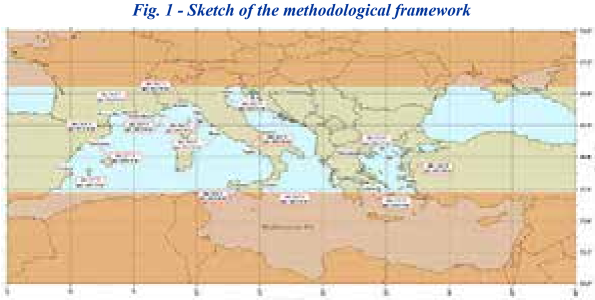

Fig. 2 – Yearly mean value of dry-bulb temperature (dbt) and global horizontal radiation (ghr) for the 15 southern Europe cities chosen

Results on GCMs data validation

The GISS-E2-H-CC model is characterized by the mean bias error (MBE) closest to zero, while the CESM1(Cam5) model is characterized by the lowest Root mean square error (RMSE) and lowest Coefficient of variation of the root mean square error (CV(RMSE)).

The CESM1(Cam5) model was identified as the GCM to construct future climate weather. This might stem from the fact that MBE would not provide enough diagnostic to justify its inclusion, over other measures, in an array of model evaluation measures [2].

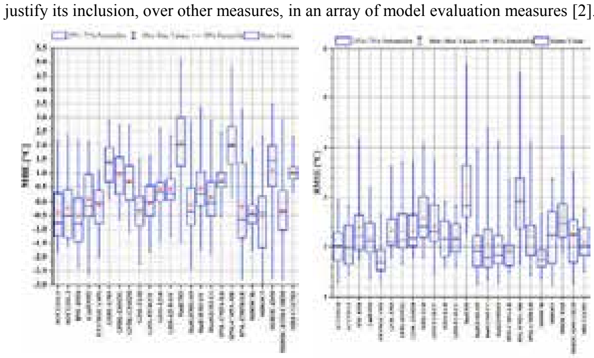

Fig. 3 - MBE and RMSE for the air temperature data of the 24 GCMs analysed against ERA-Interim

Results on future local hourly weather data

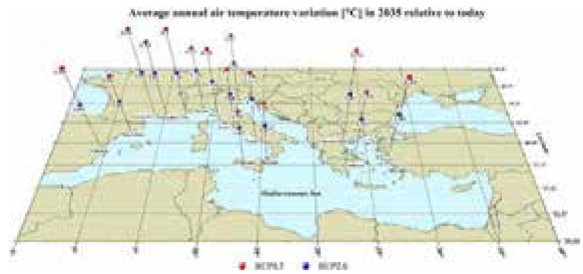

Fig. 4 - Increase of yearly air temperature for 2035 relative to the current situation under RCP2.6 and RCP8.5 scenarios

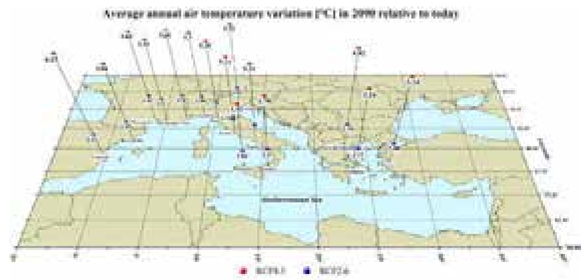

Fig. 5 - Increase of yearly air temperature for 2090 relative to the current situation under RCP2.6 and RCP8.5 scenarios

Results of building simulation

Heating and cooling variation relative to the current situation [%]								
	2065				2090			
	RCP2.6	RCP4.5	RCP6.0	RCP8.5	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Marseille	14.4	20.3	14.1	29.5	11.6	20.1	25.7	46.1
Montpellier	17.8	26.2	17.6	36.4	14.0	26.1	31.6	58.4
Nice	14.2	22.9	16.6	40.0	11.1	22.7	32.2	64.6
Athens	21.2	24.9	24.2	37.1	21.3	28.6	30.6	56.4
Thessaloniki	13.7	16.5	7.4	24.1	14.4	18.7	20.6	39.2
Genoa	30.5	38.2	30.3	52.1	27.1	37.4	48.3	73.1
Messina	22.9	30.6	24.3	55.1	22.0	32.0	43.9	72.9
Naples	16.0	21.0	17.0	38.6	14.4	22.8	29.0	54.7
Palermo	22.0	27.7	27.0	52.5	20.6	33.1	42.3	70.0
Pisa	5.9	9.6	7.2	17.3	3.9	9.1	13.1	29.2
Rome	13.7	18.8	14.3	32.4	12.3	19.4	26.3	48.3
Venice	3.6	4.9	2.9	8.9	2.5	5.1	5.9	18.4
Barcelona	8.4	11.6	5.6	19.4	5.4	11.7	18.3	34.4
Valencia	50.8	62.0	58.7	85.3	50.8	74.7	76.5	119.7
Izmir	20.5	26.0	25.0	34.4	21.4	28.7	30.5	55.1

Tab. 1 - Variation of heating and cooling energy demand for 2090 relative to the current situation under the different scenarios

Conclusions

This work is aimed towards buildings designers and practitioners of non-steady-state building simulation, since the evolution of predicting weather data for the next decades is one of the research challenges of the years to come. It is also aimed to policy makers since it offers figures and data about what could happen in the building sector in the southern Europe if no turning points are performed in the current energy policies.

Future work

Combination of different GCMs data to better fit the ERA-Interim with various techniques is being tested: preliminary results indicate that minimizing RMSE on a linear combinations of models could lead to miss the trend and cause non-realistic results in some cases. Other aggregation techniques are under evaluation.

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[2] Willmott CJ. Some Comments on the Evaluation of Model Performance. Bull Am Meteorol Soc 1982;63:1309–13.

Assessment of three dynamical urban climate downscaling methods

Application for Brussels and Paris

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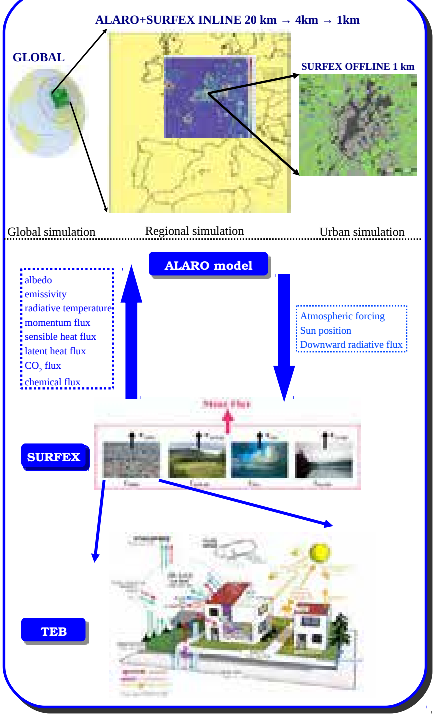
Today , scientists, urban planners and policy makers are beginning to work together to understand and monitor the interaction between urban areas and climate change and to consider adaptation and mitigation strategies.

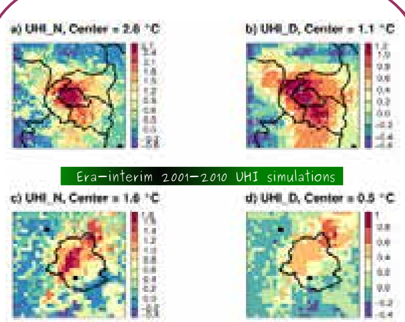
To maintain or improve the quality of living in cities, urban planners need detailed information on future urban climate on residential scale.

However, because impervious surfaces cover only less than one percent of the world's land area, **most of the global circulation models that are utilized for climate change research do not account for urban surfaces (IPCC AR4/AR5)**.

Dynamical Downscaling using Regional Climate Simulation



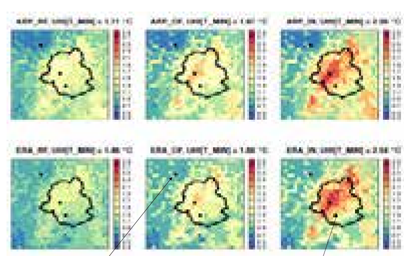
Present climate



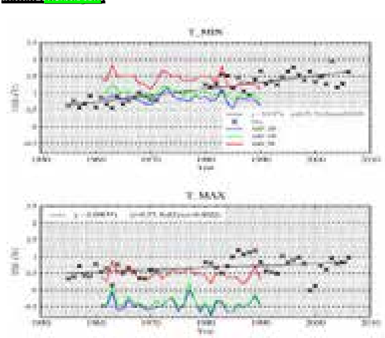
The UHI is defined as the difference between the temperature of the air inside the city and the average temperature of the air in the surrounding rural areas. This difference is higher during the night but in this study it was analyzed for the minimum temperature (overnight) and maximum temperature (daytime) called nocturnal and daily UHI, respectively.

Brussels's UHI for the present climate

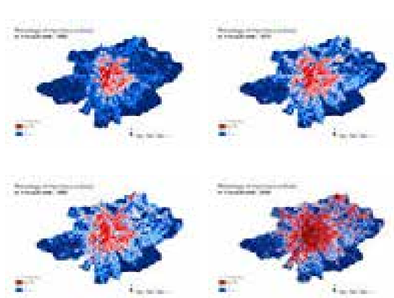
Nocturnal UHI

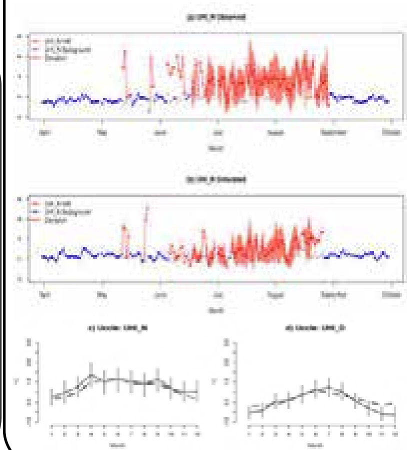


Comparison with observation from a sub-urban station (Uccle) and a rural station (Brussegem)

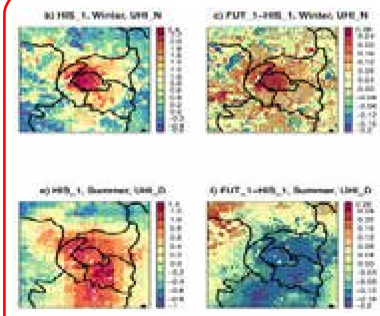


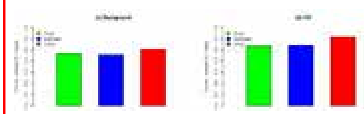
Historical Brussels urbanization



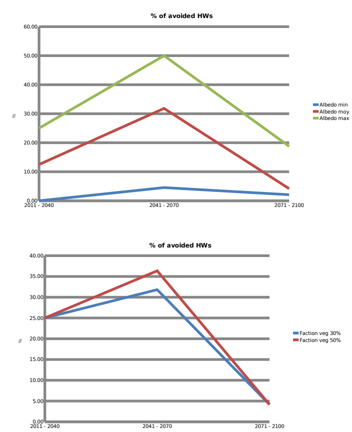


UHI under future emission scenario





We spend now on average 1.62 hours per day of HW at a dangerous level and that will rise to 2.25 hours



Conclusions

1. The responses of urban and rural areas to climate change are NOT THE SAME.

2. The feedback between urban environment and climate change is very important for urban impact studies.

3. Compared to the warming due to climate change (an increase of few degrees), changes in the magnitude of the UHI remain very low (a decrease of of a few tens of degrees in the city center).

4. Climate change will, on average, have a limited impact on the UHI intensity, however, large impacts can be expected from the combination of urban development and potentially more frequent occurrence of extreme climatic events such as heat waves.

References:

- *Rafiq Hamdi, H. Van de Vyver, R. De Troch, P. Termonia. Assessment of three dynamical urban climate downscaling methods: Brussels's future urban heat island under an A1B emission scenario. International journal of climatology, In press, DOI: 10.1002/joc.3734.*
- *Rafiq Hamdi et al., 2015:* Future climate of Brussels and Paris for the 2050s under the A1B scenario. Urban Climate, 12, 160-182.http://dx.doi.org/10.1016/j.uclim.2015.03.003
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CitiesIPCC Cities & Climate Change Science Conference 4-8 March 2018@Edmonton, Alberta, Canada

Recent progress in local governmental planning for climate change adaptation in Japan

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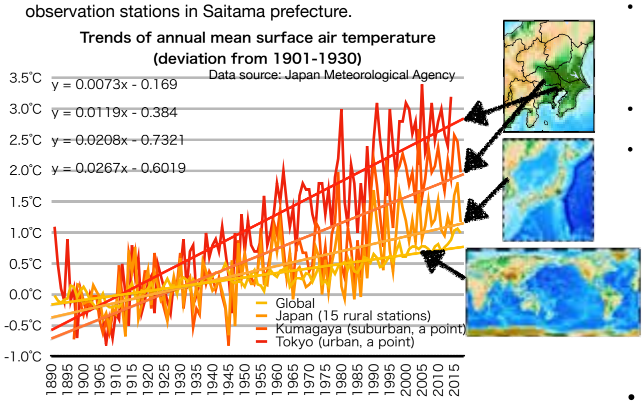
1. Background

- Tokyo Metropolitan area (i.e., southern part of Kanto district) is known for one of the hottest area in summer in Japan. Especially in Saitama prefecture (north to Tokyo), the daily maximum temperature sometimes reached to 40 °C. Temperature rise from 1897 to 2017 is more than 2 °C at observation stations in Saitama prefecture.



- In this area, land use and land cover (LULC) has been changed during recent century. Although national population in Japan has taken a downward turn in 2015, population in the area still increases, and LULC change in this area is still in progress due to urban concentration. Population is more than 30 millions in the Tokyo Metropolitan area.
- In planning adaptation strategy in local/provincial governmental scale, we are required to estimate accurately the time when the temperature rise reached to +1.5 / 2 °C. It is essential to quantitatively clarify each source of uncertainties in predicting future regional climate.

2. Local (prefectural/provincial) governments in Japan

History of climate change adaptation policy in Japan

Year	Event
Aug. 2015	Agricultural plan for adaptation to the impacts of climate change was established by Ministry of agriculture, forestry and fisheries.
Nov. 2015	National plan for adaptation to the impacts of climate change was established by the Cabinet office.
Nov. 2015	National plan for adaptation to the impacts of climate change was established by Ministry of land infrastructure.
Dec. 2015	Paris Agreement was adopted by consensus at the 21st Conference of the Parties of the UNFCCC (COP21) in Paris
Mar. 2016	Local governmental plan for adaptation to the impacts of climate change was established in Saitama Prefecture (One of the earliest local governmental plan in Japan.)
Aug. 2016	Guideline for climate change adaptation planning was established by Ministry of the Environment.
Aug. 2016	Climate change adaptation information platform "Adaptation" was opened by Ministry of the Environment. (Web tools which enable end-users to access climate change adaptation information) A-PLAT AP-PLAT
Feb. 2018	Japan's cabinet approved National law about climate change adaptation. (The law will be submitted in the next Diet session and will take effect soon.)

- Seventy-nine percent of prefectures (37/47) and 60 percent of designated cities (12/20) described their approach to climate change adaptation in their official documents. (Hara & Shimada, 2017)
  - Seven prefectures and one designated city established their own climate change adaptation plan.
  - 30 prefectures and 11 designated cities added a climate change adaptation strategy to climate change mitigation plans, environment action plans, or environmental white papers.

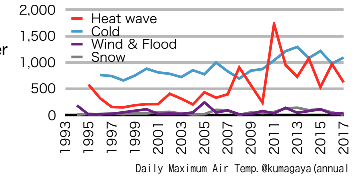
3. How to accelerate climate change adaptation planning in local governments

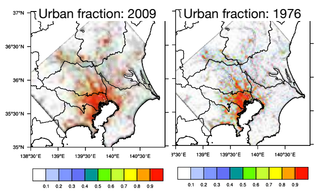
- National law to mandate local governments to establish climate change adaptation plan.
  - The national law mandates national government to assess the climate change impact every five year.
- Research fundings by national government to local governments for climate change adaptation planning
- Providing information on climate change adaptation by "A-plat" for local governments in Japan & "AP-plat" for other countries.
- SI-CAT/S-8 climate change downscaler for projecting future local climate which can land-use change

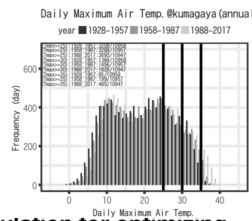
Acknowledgment
A part of this work was supported by "Social Implementation Program on Climate Change Adaptation Technology" (SI-CAT) funded by the Ministry of Education, Culture and Sports, Science and Technology (MEXT), Japan. We express our deep and sincere gratitude to these research funds.

4. Examples of climate change adaptation —thermal environment—direct collaboration of WG I scientists and end-users (psolicy makers)

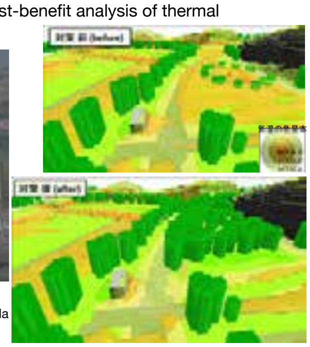
- Due to temperature rise by the global climate change (GCC) and urban heat island (UHI), thermal environment in summer is getting worse.
- Heat wave is one of major natural disasters in Japan.
- Mitigation and adaptation for UHI is sometimes same as them for GCC.





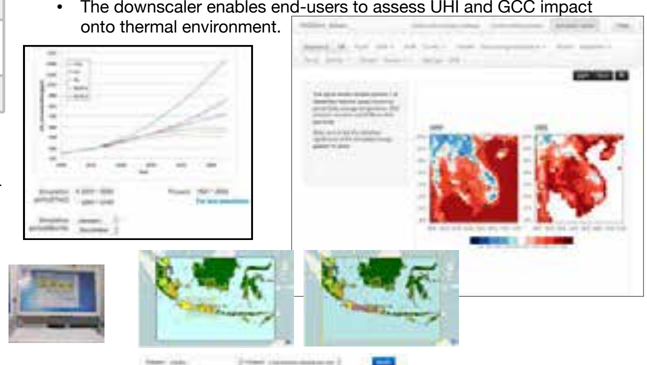


- **Super high-resolution fluid simulation for optimizing thermal environment mitigating tools (trees, high-albedo/water-retentive pavements, pergola etc.)**
  - This simulation enable us to cost-benefit analysis of thermal environment mitigating tools.



Numerical simulations & visualization
Courtesy of Drs. Ryo Onishi and Keigo Matsuda

- **Climate change downscaler which can assess the impact both climate change and land use/land cover change onto thermal environment**
  - The downscaler enables end-users to assess UHI and GCC impact onto thermal environment.



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Plenary Summaries
Parallel sessions summaries
Conference Posters
References
Annexes

The significance of city-to-city learning in transnational climate networks: a global perspective

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Cities & Climate Change Science Conference – March 5 – 7, 2018 – Edmonton, Alberta, Canada

Overview

Increasingly regarded as climate governors cities are joining together in transnational municipal networks (TMN) that address climate change mitigation and since recently also adaptation and resilience. The presented research provides a global picture of one under-researched key aspect of these networks: city-to-city learning (C2CL) and the exchange of knowledge and experiences among the member municipalities. The key question here is about the usefulness of these knowledge sharing processes in practice, and how existing networks can support them.

Inquiry

- **Method:** guided expert interviews (open ended questions).
- **Target groups:** municipal policymakers (e.g. sustainability or climate managers) and representatives of some TMN (e.g. program managers or network directors).
- **Survey period:** between April 2016 and July 2017.
- **Number of interviews:** 42 in-depth interviews, 35 with representatives of cities and 7 with representatives of networks.

Figure 1: Cities of interviewed stakeholders.

Results

By interviewing municipal and network representatives globally this study analyses how C2CL is conceived within TMN, perceived by the involved stakeholders and how far it is useful to cater the needs of cities engaging in climate resilience building.Table 1 provides an overview of the main results.

Table 1: Main results of the conducted interviews with city and TMN representatives

Why are cities joining networks and what are the perceived added values of a membership?	What kind of knowledge is transferred and what knowledge are cities interested in?	How do networks facilitate C2CL and what different forms of C2C collaboration exist?	What are the obstacles for C2CL in networks?	What opportunities for improvement exist?
Creating a platform for knowledge sharing Getting in touch with and learning from frontrunner cities Facilitating the creation of valuable personal contacts Putting the city's work into a broader context Gaining recognition at national and international levels Gaining (easier) access to funding Raising the profile of the work within the city council Sharing of best practices	Both technical and other specific knowledge Solution based knowledge (e.g. practical tools that can be implemented right away) When scientific knowledge, then contextualised say for the audience Implicit or informal knowledge (e.g. guidance on how to prepare funding grant applications)	Common tools: Webinars Network newsletters Seminars Workshops & conferences Specific C2C workshops Examples for network programs: Mayors Adapt City Twinning Programme UNISDR City to City Sharing Initiative	Limited capacities (time, staff, expertise) Lack of financial resources Lack of private partner involvement (in some networks) Language barriers Changing administrative or political priorities (in the cities) Big gap in the governance capacities between large or global and midsized or second tier cities (upscaling and downscaling best practices) Finding private partners for resilience or adaptation more difficult than for mitigation	Stronger involvement of the private sector (in some networks) Improved collaboration and coordination among different networks Connect with non-network member cities Stronger interaction with experts (facilitated by networks) Stronger linkages with Regional governments and CSOs Provision of standardized training courses on CC adaptation/mitigation Support training on project and funding application programs

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What is city-to-city learning?

Background

- Term first used in 2009 by Seymoor et al. (examining the knowledge sharing processes between cities that joined the city PLUS sustainability network).
- Academic definitions of C2CL are emerging (e.g. Lundby and Sjöberg 2013; Koop and van Leeuwen 2015 and 2017; van Herk et al. 2016a), but still quite rare.

Main reasoning

- Accelerated learning among municipal decision makers through exchanges (peer learning).
- Key component of a cities response to the opportunities and challenges caused by a rapidly changing urban environment.
- Fostering the joint creation of new knowledge in cities, in turn empowering local governments, creating a collective voice.

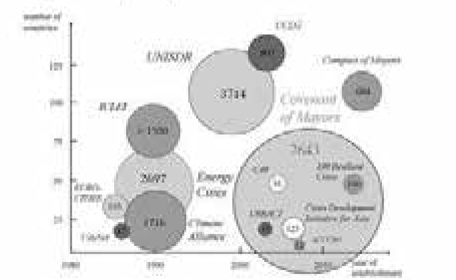

Figure 2: Number of member cities (within the circles), number of different countries of the member cities (y-axis) and years of origin of transnational city networks (x-axis) in climate change adaptation (data from November 2017); source: modified from van Herk et al. 2016b

Critical emerging challenges and questions

- Discussing the role of pioneering cities in providing useful solutions for upscaling their best practices.
- Avoiding the consolidation of a global climate stakeholders elite operating outside of democratic control.
- Facing the challenges of involving the private sector for financing climate actions whereby the networks can act as a matchmaker.
- Gaining a better understanding of the usefulness of the specific TMN programs to support C2CL (e.g. Mayors Adapt City Twinning Programme) or non-TMN facilitated projects with a similar format (e.g. North Sea Region Interreg BEGIN).
- Developping practical but proven guidance, frameworks or principles as a sort of standard for C2CL.

Conclusion

- Only since the last few years C2CL is slowly but explicitly being named, studied and documented.
- The results reveal that it is generally recognized that cities do need to engage in C2CL networks, with thpurpose of mutual learning and data, strategy and experience sharing.
- Cities engaging in networked learning are often looking for practical exchange on progresses, but also aim to connect with cities that face similar challenges.
- However, what this study brought to light is that the truly perceived added value of these TMN resulted to be within their function as facilitators of personal contacts among key municipal stakeholders.

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GRAN SASSO SCIENCE INSTITUTE
CENTER FOR ADVANCED STUDIES INFN

EARTHWATCH INSTITUTE

Urban Green Infrastructure and Citizen Science: transformative collective action in the face of climate change and urbanization

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1. INTRODUCTION

Cities are becoming increasingly populated and overwhelmingly difficult to understand and manage, a situation exacerbated by the rapid detrimental effects of **climate change** and **urbanization**. There is urgent need to develop new institutional, technical and social tools to help mitigate the impacts of air pollution, extreme heat and flooding events that threaten urban populations.

Collective action is needed to link the efforts of citizens, government agencies, businesses, research institutes and other stakeholders. Three key approaches can address this need: **i) increasing our understanding through scientific research, ii) engaging diverse communities in relevant activities and iii) enabling tangible actions that advance mitigation and adaptation efforts.**

Citizen science integrates all three approaches to provide **scientific-based evidence** for measures to promote **long-term sustainability in urban areas** whilst simultaneously enabling citizens to take action themselves.

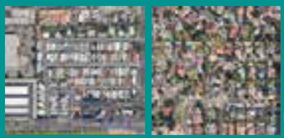
Our Aim: perform key research in Green Infrastructure through Citizen Science for urban sustainability

We present **two citizen science projects** that cover the knowledge gap by integrating key interdisciplinary research aimed at understanding how **blue** and **green infrastructure (GI)** in major cities have the potential to **mitigate climate change and facilitate resilience.**

2. THE PROJECTS

URBAN RESILIENCY PROJECT

The problem



MORE GREEN = BETTER AIR
BUT - ACCESS TO GREEN NOT EQUAL

Both high temperatures and poor air quality have direct effects on human health and well-being and have important interactions in their biophysical causes and human health impacts. Retrofitting current and designing future cities to reduce health impacts associated with hotter and more polluted urban environments is a critical need.

Our research

The effectiveness of alternate approaches, especially GI, for modifying local environments and reducing health impacts are not well characterized and generally lack uncertainty assessments from field measurements.

We address uncertainties through citizen science enabled field measurements, satellite observations, and atmospheric models focusing on the greater Los Angeles, CA megalopolis, a region of 18 million residents.

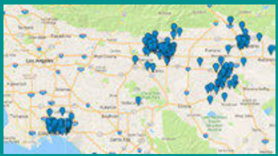
Methods

Sensor located at in a citizen scientist's back yard

- Deployment of 18 ozone and ~ 300 air temperature sensors facilitated by citizen scientists supported by academic scientists and local partners.
- Citizen scientists also participated by mapping local land cover surrounding sensors using the online Habitat Network tool (www.yardmap.org/) and collecting data about individual trees in their sampling plot.

Results

- **Stakeholders**: 104 homes, 14 educational institutions (high school and college/university), and 18 other partner institutions.
- Participants: 300 people in field data collection, and ~750 students from K12 schools in deployment of sensors.
- **Findings from field data**: Fine scale variation drivers were evident in i) extensive variability in both O3 (>40ppb) and air temperature (>2 C) at the scale of 1-4 km, and ii) contrasting dependence of sensor O3 concentration with wind speed, direction and air temperature.
- **Models**: the magnitude of mean Ta and O3 distributions and local spatial variability were consistent with observations (made by The Weather Research and Forecasting models) from our sensor network, all showing that largest spatial variations of Ta occurs in the pocket areas surrounded by the well-developed urban centers

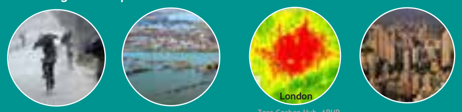


Data points from sensors deployed in LA

SUSTAINABLE CITIES PROJECT

The problem

Flooding and soil pollution | Urban Heat Island Effect



New approaches and integrated policies are needed to maintain and improve the quality of life for urban dwellers and the adaptive capacity of cities to climate change

Our research

Focuses on the role of blue-GI to support cities in adapting to flooding and urban heat island effect, consequences of climate change and urbanisation

Methods

- **International:** Focus on key challenges in urban areas around the globe
- **Targeted:** Considers regional climate impacts and local objectives in urban growth and sustainability
- **Collaborative:** Each project is led by leading research institutions, data collected by citizen scientists and supported by metropolitan and regional policy leaders
- **Interdisciplinary:** research will integrate different research fields and technology for a holistic understanding of GI

State-of-the art and traditional methodologies are used to understand the ecosystem services of various Green Infrastructure

Examples of methodologies used are: a) chlorophyll content (plant productivity), b) theta probe (soil moisture), c) mini-disk infiltrometer (soil water infiltration) and d) Infrared images (microclimate)

Results

Citizen scientists collecting soil hydrology data in an urban park

Preliminary research results from the European project suggest significant differences in productivity of urban trees and soil properties under differing land managements

Urban trees within the same park exhibited differing chlorophyll content, canopy cover, soil nutrient and hydrological profiles, dependent on whether leaf litter was removed or not

Corporate and individual citizens expressed increased knowledge and interest in climate change and urbanisation issues after participating in the field research

3. DISCUSSION & CONCLUSIONS

- Our projects demonstrate the benefits of GI and the importance of data gathering and the valuable local knowledge of specific environmental characteristics provided by citizen scientists
- The research on the **Urban Resilience Project indicates** that: 1) climatic and air quality can vary across very small scales in urban environments. Patterns can be modelled but require further refinement by incorporating the impact of local vegetation to fully capture extremes

  2) GI can provide benefits but the uncertainty around their benefits impact the uptake of GI by community members and local organizations
- The first phase of the **Sustainable Cities Project** suggests that land management of urban parks may have direct impacts on the ecosystem services that urban trees provide to mitigate the effects of flooding and urban heat island effect
- Further global research of the Sustainable Cities Project will provide key information of the best practices to support urban GI related to wetlands, rivers, bioswales, and water supply
- The findings of the global project will be handed to relevant local authorities and environmental agencies to support strategic decisions on land and urban GI management
- Our projects demonstrate that citizen science allows the collection of large quantities of data across vast geographical areas, and has been remarkably successful in advancing scientific knowledge, and providing knowledge to communities to empower their own action (as previously found- Garbarino et al 2016)
- Here we suggest that integrating the efforts of citizens, government agencies, businesses, research institutes and other stakeholders can have stronger and long-term impacts for sustainable cities

4. NEXT STEPS

To learn from our experience and face challenges, such as:

- The differences of vocabulary amongst the different stakeholders
- Data quality check: finding optimised ways to control data obtained in the field
- Data management: creation and sharing
- Creating platforms that empower people to continue their engagement after their field research experience

Our next steps also include finding the best approaches to integrate our scientific findings at a global scale.

We are constantly improving our protocols and work amongst the best trained professionals and leading researchers to make sure we have the best practices and learn from experience.

Acknowledgments: Darrel Jenerette, Jun Wang for their research on the Urban Resiliency Project. HSBC for co-creation of Sustainability Programme. Funding from, NASA Earth Sciences program, local partners and the community members who helped collect the data. Julie Ripplinger, Sofia Koutzoukis, Dion Kucera, Cui Ge and Lorena Garcia Castro assisted with the research.

Reference: *Garbarino, J., & Mason, C. E. (2016). The Power of Engaging Citizen Scientists for Scientific Progress. Journal of Microbiology & Biology Education, 17(1), 7-12*

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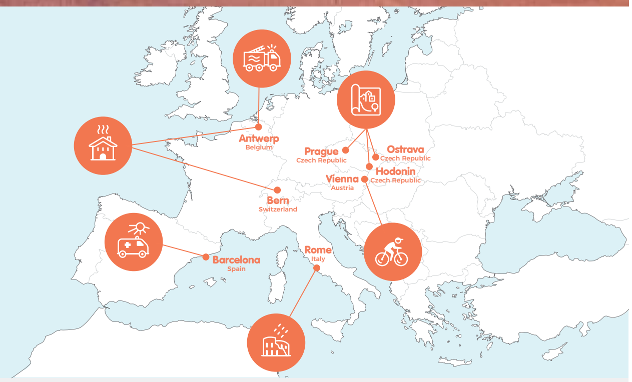
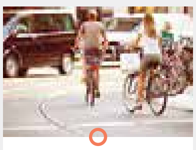
CREATING KNOWLEDGE. INSIPIRING ACTION

Plenary Summaries
Parallel sessions summaries
Conference Posters
References
Annexes

Your one-stop shop for urban climate data and services.

- Active mobility
- Building Energy
- Cultural Heritage
- Emergency Planning
- Health
- Urban Planning



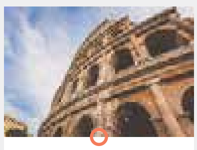


Active mobility

Active mobility (walking and cycling) is an essential and basic form of mobility and more than an alternative to car use, especially in cities. It improves health, saves space and is environmentally friendly. The attractiveness of active mobility is influenced by a number of factors, including weather and climatic conditions. Climate-fit.city implements and demonstrates an urban climate service for active mobility (focus on cycling) in Austria's capital Vienna.

Building Energy

Climate change, and in particular urban heat effects, are expected to have a large influence on the energy consumption and thermal comfort of buildings. However, using meteorological data which incorporates effects of climate change and characteristics of cities (e.g. vulnerability to the 'urban heat island' phenomenon) is not currently a standard practice in building simulation. Within Climate-fit.city, these effects will be analysed with the help of a building simulation tool.



Cultural Heritage

Climate change is already impacting the conservation and exploitation of historical sites. While extreme rain events damage the fragile materials, excessive heat stress during heat waves in combination with air pollution and allergenic pollen leads to unbearable conditions for tourists. To protect the cultural heritage sites for future generations as well as to safeguard their touristic exploitation demands a long-term vision. This vision needs to include future climatic conditions.

Emergency Planning

Climate change leads to increasing frequencies and severity of extreme weather conditions such as increasing rainfall intensities, pluvial, river and coastal flooding, heat stress, etc. The city emergency planning needs to be revised in view of the changing climate. Together with the user, a tool will be implemented to quantify the socio-economic consequences of pluvial inundation, using readily available spatially referenced land use data (locations of houses, hospitals, schools,...).

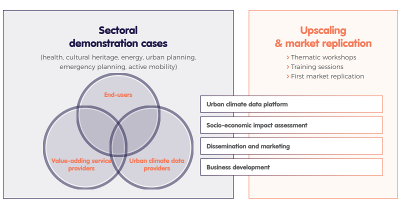
Health

The urban environment is a key determinant of population health and health inequalities. In particular, the urban heat island effect, which causes temperatures to rise in cities, is known to exacerbate the effects of heat on population health. To help decision-makers in the health sector to formulate appropriate strategies and emergency plans, the Climate-fit.city's urban climate service for health will comprehensively describe the associations between the urban environment, the local climate, the daily mortality registers and the socio-demographic profiles of cities at a neighbourhood level.

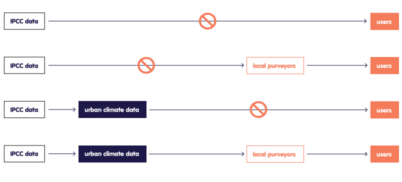
Urban Planning

Urban developments and infrastructure investments have long term lifecycles. Quality of life is increasingly high on the political agenda. Cities want to be informed about the assessment of the city's potential for further development with respect to the threats of urban climate change. Trade-off analysis between densification of urban development versus the resilience to urban climate change and the modelling of city development and the associated urban cooling capacity towards various climate change scenarios are desired.

METHODOLOGY

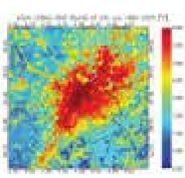


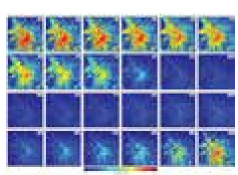
USERS - PURVEYORS - DATA PROVIDERS: THE PUZZLE

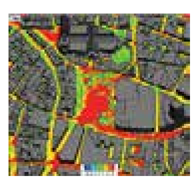


URBAN CLIMATE DATA: WHY?

- IPCC climate data is too coarse for direct use in cities
- Also, cities affect their own climate:
  - Urban heat island phenomenon creates stronger heat waves
  - Urban impermeable surfaces cause a higher risk of flooding







Climate-fit.city is developed as part of the PUCS project, which has received funding from the European Union's H2020 Research and Innovation Programme under Grant Agreement No. 73004

Asset based Approach for Enhancing Resilience of Urban Poor in the context Climate Change:

How far is it Transformative Climate Action in Bangladesh?

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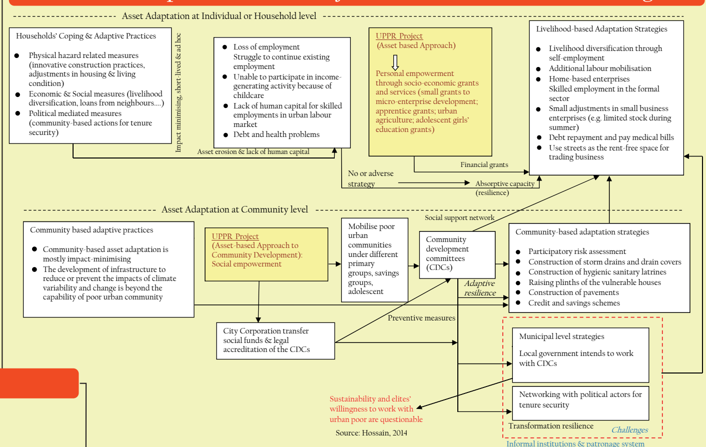
Khulna university

Climate Change and Urban Poor

Cities in the global South are particularly at risk in the context of climate change. The risks from a changing climate for the urban poor are often even greater, exacerbated by the multiple deprivations that they face living in the urban environment and these deprivations range from insecurity of land tiling or shelter and relatively high rent, poor commuting facilities, to minimal credit or capital support and limited access to service delivery (such as water, sanitation, waste disposal, public safety, health care and education).

The poor are not helpless victims and rather argues that they have plenty of assets which can form the basis of coping with and adapting to climate change and climate extremes.

The Impacts of UPPR Project in terms of Resilience Building



Nexus between Asset-based Approach and Resilience

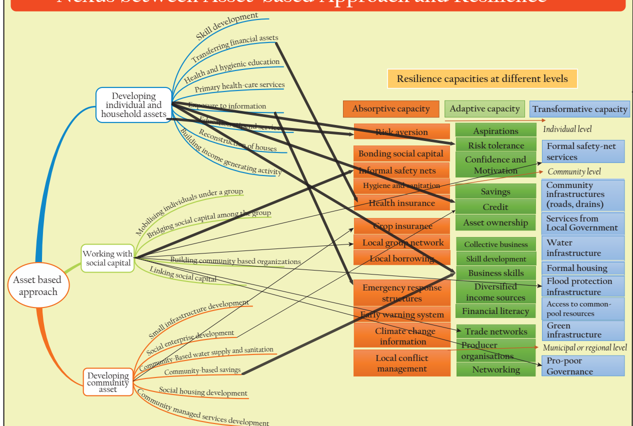
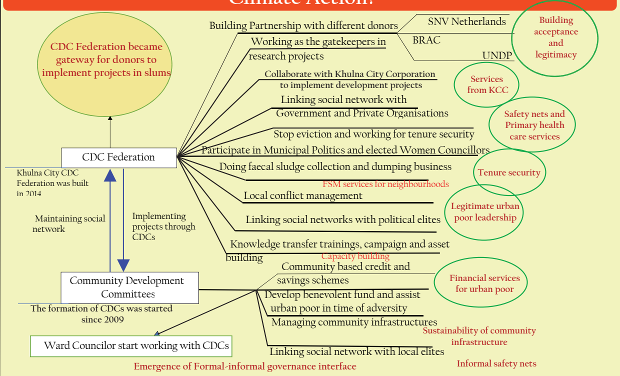


Figure 1:Conceptual Framework of Asset-based Approach and Resilience Capacity

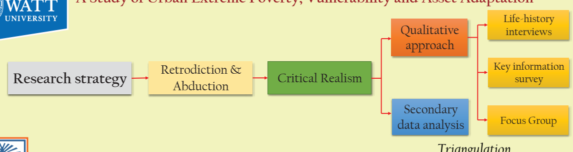
Does Asset-Based Approach Consider as Transformative Climate Action?



Research Design

HERIOT WATT UNIVERSITY

2011-2014 Pro-Poor Urban Adaptation to Climate Change in Bangladesh: A Study of Urban Extreme Poverty, Vulnerability and Asset Adaptation

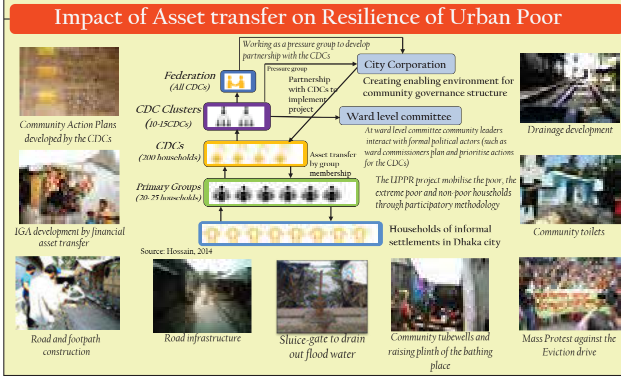


2017-2018 Community Mobilization Strategy for Building Urban Poor Organization: The Role of Urban Partnership for Poverty Reduction Programme

A detailed comparison of five slum and squatter settlements was undertaken, and findings of questionnaire survey were triangulated by discussions with key informants and analysis of the academic and "grey" literatures.In each settlement, we applied the same methodology for data collection:

- introduced research objectives and purposes to community leaders and conducted a community mapping;
- conducted a questionnaire survey of all households;
- conducted focus group discussions with primary group members and members from community development committees (CDCs); and
- held discussions with key informants about our findings, to check accuracy and validity.

Impact of Asset transfer on Resilience of Urban Poor



Lessons Learnt from Khulna City, Bangladesh

- The CDC Federation case indicates promising signs of sustainability that was being achieved through building collaborations with different institutions and donors. In order to achieve and sustain transformative changes, it is essential to call for a major rethinking and wholesale change in urban governance and its enabling environment. In this case, it is essential to build collaboration between the key agencies or institutions affecting urban development and poverty reduction. Central government should focus on development authority and city corporation, as part of a comprehensive effort by Ministry of Local Government and Rural Development (MLGRD) to strengthen local government and agencies influencing Khulna's development. In general, with clear roles and responsibilities, agencies should be given authority, but made accountable for implementation. In addition to key public institutions, strengthening the voice and the ability of citizens (especially different categories of the urban poor) to reveal their preferences and hold their governments to account, will be essential in sustaining the reform of city. In addition, poor urban communities' participation in urban development planning, financial management and service delivery is also important.

- While there have been important steps forward in Khulna City, Bangladesh in community mobilisation and community-led service provision, attention must be paid to CDC Federation to ensure that grassroots mobilisation becomes a vehicle for breaking, rather than reinforcing, existing social order and inequalities. Therefore, community-managed savings groups in slums and squatters can be taken in order to strengthen their capacity for grassroots mobilisation.

- Understanding the issue of tenure security, it recommends integrating tenure security issues in asset-based approach. Advocacy role of NGOs can be instrumental in this regard. Understanding the complex nature of tenure status of the urban poor this study does not recommend for any site and services scheme rather this study advocates for building a synergy among different stakeholders to protect the urban poor from any perceived threat of eviction.

- There is heterogeneity among the urban poor considering their level of poverty. From the observation urban extreme poor can be categorized as extreme transitory, destitute and extreme chronic poor. There are significant differences among these groups in terms of asset, education and literacy. However, these divergences were not addressed in this project as the project interventions were not targeted considering the level of poverty among the urban poor.

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Having our cake and eating it

Accurately measuring city-level GHG emissions alongside assessing the impact of mitigation measures

Dr Ross Hunter, Nicola Webb, Dr Rose Bailey and Glen Thistlethwaite

Problem

Standard emissions inventories are not designed for mitigation policy tracking

Why are cities so important for climate change action?

Today, cities are at the forefront of climate action. With large populations, key financial centres and often coastal locations, cities are vulnerable to the effects of climate change.

They also have a unique opportunity to use their devolved powers and relative policy freedoms to act quickly and efficiently, to deliver more immediate results.

Cities contribute 70% of global anthropogenic GHG emissions.

What is the problem with current city inventory practice?

The Global Protocol for Community-Scale Greenhouse Gas Inventories (GPC) is the city standard for reporting GHGs. It states that "An inventory enables cities to understand the emissions contribution of different activities in the community. It allows cities to determine where to best direct mitigation efforts, create a strategy to reduce GHG emissions, and **track their progress**."

It is this last part which is proving difficult for many cities – and countries. Inventories are often built using the best available data, or the data which is specified as necessary in emissions inventory guidance.

Generally, data and methods used in inventories mean it is not possible to connect emissions compiled in the inventory with GHG mitigation policies. Therefore, emissions inventories are not policy sensitive.

Solution

City and policy specific inventories

Why are cities uniquely placed to produce inventories which work for them?

Cities are dynamic and flexible communities in an excellent position to learn from and use the good practice developed at the national level. They are able to be less focused on compliance reporting as is the case at the national level and can shape this knowledge to focus on city-specific needs.

Steps to a more policy sensitive inventory:

1. Conduct a policy sensitivity assessment.
2. Identify gaps and problems.
3. Use the assessment to focus inventory improvement program.
4. Identify new methods, data sets and data requirements which might be additional to the GPC requirements, but focused on reflecting policies.
5. Produce an intelligent and dynamic emissions inventory which works for your city government.

Outcomes

1. An inventory which can quantitatively track progress of policies in GHG emissions.
2. A direct link between policy action and city level GHG emissions trends – including projections.
3. Reduced need to develop wider indicators to assess policy.
4. Happier policy makers.

Case study – City transport plan

Mitigation	Desired outcome	Difficulties in inventory tracking	Source of data to assess impact
Improvement of infrastructure for sustainable transport.	Car drivers switch to walking or cycling, lower congestion, reduce emissions.	Walking and cycling will never be visible directly in an inventory.	Survey of transport users. Tracking of car journey reductions.
Introduce a cleaner bus fleet.	Reduction of emissions from public transport.	City inventories often scale emissions based on national bus fleet information.	Mitigation implementation includes requirement for city bus operators to report fleet information (e.g. age, fuel consumption, type of vehicle).
Introduce electric vehicle charging network.	Increased number of electric vehicles, decreased fuel consumption, lower emissions.	City inventories often scale emissions based on national vehicle fleet information.	Smart charging meters to record and report information. City vehicle fleet surveys and automatic vehicle recognition data to improve inventory data on vehicle and fuel types.
Improve train/tram service.	Car drivers switch to rail, lower congestion, reduce emissions.	Reduced car use can be tracked, switch to rail is difficult to observe.	Rail companies to record and report city-specific data (e.g. ticket sales, type of train, number of people, average journey length).

Where do we come in?

- Ricardo Energy & Environment is an internationally renowned consultancy with world-leading energy and environmental expertise.
- We have long-standing experience with compilation of national GHG inventories (including the compilation of the UK national GHG inventory for over 20 years).
- Our team of inventory experts cover energy, transport, industrial processes and product use (IPPU), waste and agriculture sectors. We contribute to the development of inventory guidance and are regularly involved in UNFCCC review processes.
- We also have considerable experience in providing tailored capacity building to government experts who are responsible for inventories and Monitoring, Reporting and Verification (MRV) tasks.

Ross is Ricardo's Business Area Manager for Air Pollutant Emissions Inventories. He has 14 years' experience providing scientific support to the development of policies across climate change and air quality. He brings an in-depth knowledge of how scientific analysis and advice is used in the development of policy at the local, national, European and international levels. He is a qualified United Nations Framework Convention on Climate Change (UNFCCC) Expert Reviewer.

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Projected Impacts of Climate Extremes over Selected African Coastal Cities under 1.5̊C and 2.0̊C Global Warming.

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Introduction

- African coastal cities are vulnerable to climate change due to their high exposure, low adaptive capacity and high population density.
- Discussions about setting goals to limit global warming by a predefined threshold have been actively ongoing since the mid-1990s. COP16 in 2010 set this threshold at 2°C while COP21 set an ambitious 1.5°C target.
- Whilst several studies have investigated future projections of extreme climate over several African regions based on CORDEX simulations (Giorgi and Gutowski 2015), most of them focused on:
  - Impacts at the end of the 21st century (Abiodun et al., 2017; Dosio, 2017).
  - Based on results of either a single or small set of CORDEX simulations, *mainly due to limited number of available simulations* (Endris et al., 2013; Dosio and Panitz, 2015; Pinto et al., 2015)
- In this study we:
  - utilized current and most complete CORDEX Africa ensemble consisting of 25 simulations under Representative Concentration Pathway (RCP) 8.5 – More robust than a single or small set of CORDEX simulations (McSweeney et al., 2015).
  - Analyzed the response to rainfall & temperature extremes over – Cape Town, Durban, Dar es Salaam, Maputo & Mombasa, when projected global temperatures reach 1.5̊C and 2.0̊C.

Data and Methods

Area of study:
- Spatially this study considers Southern Africa, defined as the region lying between 36°S to equator and 10° - 52°E, with focus on 5 coastal city regions.

Datasets:
- 25 CORDEX-Africa simulations driven by the **RCP8.5** - comprises the largest ensemble and may also be considered the most realistic business-as-usual scenario given the current trajectory of greenhouse gases emissions (Taylor et al. 2012).

Methods:
- Global Warming Levels (GWLs): - Although different definitions exist in the literature, all generally start with some pre-industrial baseline and use an averaged window period e.g. 15, 20 or 30 years to compute departure from the baseline and arrive at when the GWL of interest is reached.
- The timing for these levels is commonly defined as the centre year of a long enough period when global mean temperature reaches predefined anomalies (1.5, 2, 2.5°C etc.) relative to preindustrial levels (1861-1890 in this study) as it is available across all CMIP5 historical simulations.
- Given the RCM downscaled data begins at 1950 and that the RCP scenarios begin in 2006 we define our control period for the present/recent climate as 1971- 2000. The corresponding 30-year period is then extracted from the downscaling RCM for analysis.

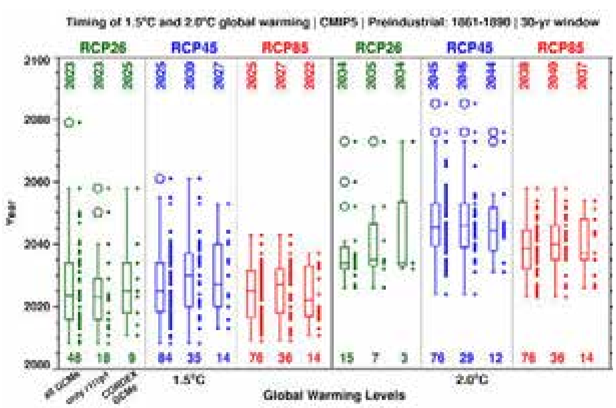

Fig 1: Timing of 1.5 and 2ºC GWLs under 3 RCPs for the grand CMIP5 ensemble (left), only the first member for each GCM if there was an ensemble available (centre) and the GCM subset that used in CORDEX Africa (right). Numbers at the bottom show the number of GCM simulations reaching the 1.5 and 2ºC GWLs and numbers at the top show the median year of GWL timing. Individual GCMs are represented by dots while ensemble statistics by whisker boxes.

Results

- There are several methodologies used to determine the robustness of climate change signal (Collins 2013). We consider a climate change signal robust if the following two conditions are fulfilled:
  - More than 80% of model simulations agree on the sign of the change.
  - The signal to noise ratio (SNR) ≥ 1.
- We analyzed mean precipitation and temperature fields as well as two extreme indices from the Expert Team on Climate Change Detection and Indices (ETCCDI):
  - Consecutive Dry Days (CDD) and Consecutive Wet Days (CWD).
- Analysis done both on annual and seasonal time scales.

Projected changes

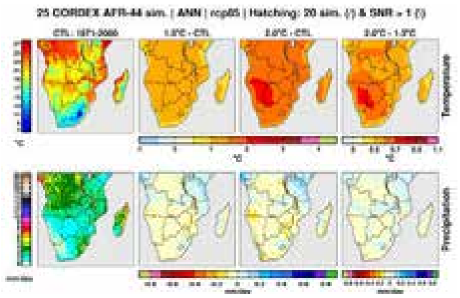

Fig 2: Annual changes in temperature (first row) and rainfall (second row) under 1.5 and 2.0 ˚C global warming. First column shows annual mean temperature and rainfall for control period , second and third columns show differences in annual mean temperature and rainfall between future and CTL during 1.5 and 2 ˚C GWLs, respectively and fourth column shows differences between 2 and 1.5˚C. Hatching shows areas where at least 80% of the simulations agree on the sign of the change and SNR > 1. For temperature all grid boxes satisfy the two criteria and the hatching is not shown.

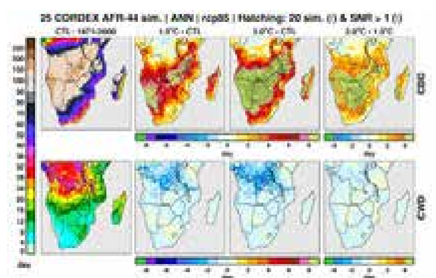

Fig 3 : Annual changes in CDD (first row) and CWD (second row) under 1.5 and 2.0 ˚C global warming based. First column shows number of CDD and CWD for control period. Second and third columns show projected changes in CDD and CWD between future and present under 1.5 and 2˚C global warming periods, respectively. Fourth column shows differences in CDD and CWD between 2 and 1.5˚C. Hatching shows areas where at least 80% of the simulations agree on the sign of the change and SNR > 1.

Discussion

Table 1 : Projected Annual (A) and seasonal (S{dominant season at each city}) changes in temperature (Temp), precipitation (Precip), CDD and CWD together with broad implications on **Water sector** (directly impacts other sectors: - Agriculture, Health etc). Double pointed arrow show that the change signal is NOT robust.

City	Temp A	Temp S	Precip A	Precip S	CDD A	CDD S	CWD A	CWD S	Broad Implications
Cape Town	↑	↑	↓	↓	↕	↕	↕	↕	Experienced its worst drought on record. Temp, Precip, CDD & CWD projections, suggests a possibility of frequent drought events in the future. Resilient water supply systems are required – desalination, management strategy (R&D) - taking advantage of years of sufficient precip to prepare for dry years etc.
Durban	↑	↑	↕	↕	↕	↕	↕	↕	Projected increase in temperature and increase in precip for Durban. Further studies required to ascertain whether temperature increases will offset any benefit from increased rainfall.
Maputo	↑	↑	↕	↕	↕	↕	↕	↕	Received below normal precip during 2017/2018 summer season. projected increase in temperatures and decrease in rainfall, suggests a possibility of diminishing summer rainfall . Calls for resilient water supply management.
Dar es Salaam / Mombasa	↑	↑	↕	↕	↓	↕	↕	↕	Received normal to above normal precipitation. Projected increase in temperature, annual and seasonal (MAM) rainfall and decrease in seasonal CDD for Dar es Salaam and Mombasa. Further studies required to ascertain whether the temperature increases will offset any benefit from increased rainfall.

Conclusion

- Study region warms faster than the global mean, up to more than 1˚C under the 1.5˚C and ≥ 1.5 ˚C under 2 ˚C GWL compared to the control period.
- There is a general statistically insignificant decrease in the number of CWDs and increase in the average duration of CDD at the five cities.
- Further investigation required to ascertain whether the temperature increases will offset any benefit from increased rainfall at Durban, Dar es Salaam and Mombasa.
- These results suggest that actionable policies geared towards adaptive strategies to alleviate the impacts of global warming are needed.

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Towards an Integrated Vulnerability and Risk Assessment Framework for Cities Prone to Climatic and Non-Climatic Hazards

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1. INTRODUCTION

Most cities are exposed to both climatic and non-climatic hazards. This necessitates an integrated approach to assess vulnerability and risk, in the absence of which:

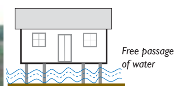
a) Policy interventions could be sporadic and fragmented;
b) Balancing between adaptation options, which are often costly, for climatic and non-climatic risks would be more challenging; and
c) It could be overlooked that an adaptation option that work for a specific hazard could counteract in case of another hazard.

Following the Great Earthquakes of 2015 in Nepal, seismic resilience has gained much attention in the country's policymaking domain although climate-related disasters are more frequent than earthquakes, causing immense loss of lives and properties every year. Most safety policies (e.g., building codes) dictate *how* buildings should be built rather than *where* they should (not) be built. It is not unusual to see the so-called 'seismic resistant' structures on sites prone to floods and landslides.

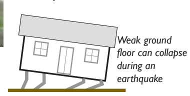
As a setback for risk-informed planning, the crucial concepts of vulnerability and risk are defined differently and often contrastingly in disaster risk reduction (DRR) and climate change adaptation (CCA) research streams, and often even within the research streams.

Building code alone does not save a building if it is not built on a safe site. If a risky site cannot be avoided, then instead of overinvesting for the sake of building code compliance, constructing a light structure would be wiser.

Image: http://kipushahid.blogspot.com/2012_09_16_archive.html



Flood-proof house



Soft-Story Structure

Nepal	Population: 26.5 million (2011) Area: 147,181 sq. km
4th	most climate change vulnerable country (Maplecroft's Climate Change Vulnerability Index 2011)
11th	most earthquake-prone country (drrportal.gov.np)
2/3rd	of total population now live in municipalities

More recently, the Fifth Assessment Report (AR5) of the United Nations Intergovernmental Panel on Climate Change (IPCC) has aimed at unifying notions of DRR and CCA into an integrated disaster risk management (DRM) approach to define, assess, and address risks. Unlike in the previous assessments, the AR5 puts risk at the core of CCA framework (see Field et al., 2014).

However, the AR5 lacks providing an operational framework to:

a) Translate theory into practice; and
b) Treat both climatic and non-climatic risks in a holistic manner.

The AR5 also fails to articulate "the causal chains among the various concepts... thus limiting the possibility of deriving uncontroversial operational assessment methods" (Giupponi et al., 2015).

This research aims to fulfil these gaps through an integrated vulnerability and risk assessment (VRA) framework for city systems. The framework follows the AR5 concepts, and builds on the previous works developed during Nepal's National Adaptation Plan (NAP) formulation process in 2016/17 (see MoPE, 2017).

2. INTEGRATED VRA FRAMEWORK

The city components – sub-systems (e.g., communities, neighborhoods) or sectors (e.g., housing, transport, energy, economy) – are composed of people, assets, and infrastructure. The component under consideration is paired with specific hazard drawn from a list of hazards mapped for the entire city system. Identification of hazards is basically a scientific study although perception surveys, observations, and traditional knowledge are also often useful.

In the framework, VRA is performed for each hazard. Vulnerability (V) is a function of sensitivity (S) and adaptive capacity (C), expressed as : **V=S/C**. Risk is the function of hazard (H), exposure (E), and vulnerability (V), expressed as **R=HxExV**. Each variable is assigned a normalized value (0 to1) such that if any variable is zero, risk is also null. Risks can thus be ranked or compared.

Depending on the scale of risk, impacts are qualitatively defined. *Adaptation options are identified for each hazard, and later combined for screening.* This is *different* from other approaches whereby risk is identified for all hazards, and adaptation options are sought for the combined impact. The latter approach could be ineffective particularly when adaptation options are conflicting.

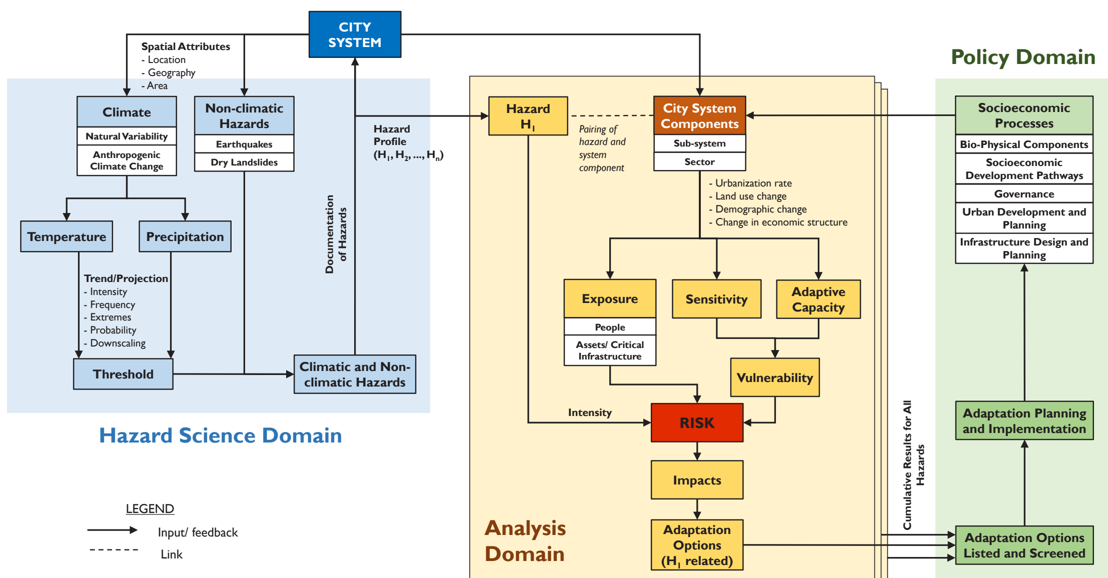
Adaptation planning and implementation should influence socioeconomic processes so as to reduce sensitivity of the city system and/or increase its adaptive capacity. The influence on exposure, on the other hand, depends on whether the city adopts "development-first" approach or "hazard-based" approach.

3. WAY FORWARD

The proposed VRA framework aims to articulate the causal chains among the AR5 concepts of exposure, vulnerability, and risks, among others. It allows treatment of both climatic and non-climatic hazards.

There are three distinct domains – the hazard science (e.g., climate science, seismology) domain concerned with the analysis of hazard data; the core analysis domain; and the policy domain concerned with adaptation planning and implementation. Thus the framework also facilitates communication between three different actors: scientists, technical analysts, and policymakers.

Despite useful flexibilities, the framework can be vulnerable to oversimplification, particularly while assigning normalized values to the indicators representing variables. Identification of and consensus on indicators is a challenging task, especially when important data are unavailable. As a future study, the framework should be tested with real-world examples.



INTEGRATED VRA FRAMEWORK FOR CITIES

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Dynamics of climate change vulnerability and exposure in urban areas

Introduction

Dynamics of vulnerability and exposure has received little attention so far in climate risk assessments (Jurgilevich et al. 2017). We need methodological advances to assess or analyse future vulnerabilities and exposures, and conceptual advances to understand what drives them (IPCC 2014). IPCC states with high confidence that future vulnerability is driven by non-climatic factors, i.e. dynamic socio-economic processes, which are impossible to assess or project with quantitative methods commonly used in current risk assessments (IPCC 2014).

Research approach

We developed a methodology based on qualitative and participatory methods, to explore key drivers of future vulnerability and exposure in the city of Helsinki by 2050. We integrated the use of socio-economic and land use change scenarios with a participatory mapping method using SoftGIS to visualise the spatial changes of selected vulnerability and exposure indicators. Figure 1 presents the operational framework of our research.

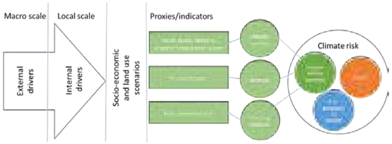


Figure 1. Operational framework. Based on Kazmierczak 2015; Lindley et al. 2011; Oppenheimer et al. 2014 and Bennett et al. 2016

Figure 2 presents our methodology step-by-step.

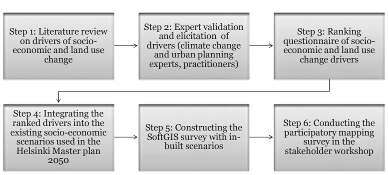


Figure 2. Methodology

Results

The results of driver selection, elicitation and ranking (see steps 1-3 in Figure 2) show that the key drivers of socio-economic development and land use change are both external and internal to the analysed area (see Table 1). The variety of drivers suggests the necessity of including multiple planning/policy areas (urban planning, social services, healthcare, infrastructure, rescue services, etc.) or possibility to reduce vulnerability through several alternative solutions.

Results of driver selection (steps 1-3 Fig. 2)

Key drivers of socio-economic and land use change in Helsinki up to 2050
Demographics
1. Migration (in and out) IE
Economy
2. State of the economy at the national level E
Governance
3. Environmental policies E
4. Mitigation policies E
5. National regulation and legislation E
City structure, development and infrastructure
6. Transport and accessibility I
7. Public sector as the driver of the city development I
8. District (social inequality) I
9. City model/structure (densification vs. dispersion) I
10. Helsinki unification with Espoo/Vantaa (Metropolitan area) I
11. Form and functioning of critical infrastructure (water, ICT, energy) I
Macro context factors
12. Climate change secondary effects (social, technological, political and economic changes as a result of climate change impacts) E

Table 1. Key drivers of socio-economic and land use change in Helsinki in 2050. I - refers to internal and E - external driver.

Next, the key drivers were integrated into the socio-economic scenarios developed during the Helsinki Master plan 2050 (Helsingin yleiskaava 2013; step 4 Fig. 2). The **three resulting scenarios** are:

1. **Negative**: slowing development – dispersed city structure
2. **Balanced**: balanced growth of the region – multi-centred structure
3. **Fast**: fast growth – dense mono-centred city

Scenarios were then integrated into SoftGIS questionnaires as background materials and discussed in the workshop.

Results of SoftGIS survey (steps 5-6 Fig. 2)

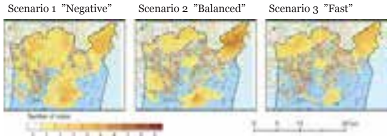
The results from the SoftGIS questionnaire reflect on overall spatial changes of indicators rather than causal links between certain drivers and changes. One can make assumptions based on the differences in the key drivers of change in scenarios and changes reflected in answers spatially. Establishing direct causal links is not possible with this method, but one can observe the changes of spatially explicit indicators according to different scenarios as a whole. Figures below show the changes marked by workshop participants according to three different scenarios (example questions).

1. Reducing green areas

Scenario 1 "Negative" Scenario 2 "Balanced" Scenario 3 "Fast"

2. Low population density areas

Scenario 1 "Negative" Scenario 2 "Balanced" Scenario 3 "Fast"

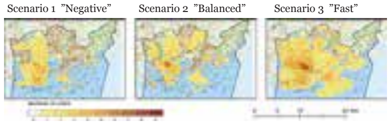


3. High population density areas

Scenario 1 "Negative" Scenario 2 "Balanced" Scenario 3 "Fast"

4. Areas where apartment prices may increase significantly

Scenario 1 "Negative" Scenario 2 "Balanced" Scenario 3 "Fast"



5. Areas where social inequality may increase significantly

Scenario 1 "Negative" Scenario 2 "Balanced" Scenario 3 "Fast"

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Plenary Summaries | Parallel sessions summaries | Conference Posters | References | Annexes

GOVERNING TRANSITIONS TO A LOW CARBON CITY: A CASE STUDY OF GLASGOW, SCOTLAND

Katherine Sugar, School Of Geographical And Earth Sciences, University Of Glasgow

The Context Of Glasgow

Geographic: West coast of Scotland, UK. 615,000 inhabitants (11.3% of total population of Scotland). By 2037, the population is projected to increase by 15.1%. Largest city in Scotland, fourth largest in the UK.

Historical: Heavy industry (e.g. shipbuilding, steel and coal) during 1880s. Glasgow become popularly known as 'The Second City of the Empire' at that time.

Economic: Seeking to reposition itself as a post-industrial, entrepreneurial city. The City has experienced significant growth in its commercial and financial sectors, contributing £19.25 billion GVA per annum to Scotland's economy.

Social: High levels of social and economic inequality, deemed "The Glasgow Effect". Glaswegians have a 30% higher risk of dying before 65 years old than people in comparable de-industrialised. UK cities, e.g. Liverpool and Manchester. In 2012-2014, 1/3 households in Glasgow lived in fuel poverty.

Environmental: Glasgow emitted approximately 2,000 kilo tonnes of CO2 in 2012, predominantly from electricity. In 2016, air quality pollution measurements exceeded PM10 levels. Glasgow City Council (GCC) has committed to ambitious climate change targets, with commitments to making the city one of Europe's most sustainable cities within 10 years, and a 40 % reduction of greenhouse gases by 2030.

Research Methods

- Completed as part of a Master's thesis in June-Aug 2016.
- interviews: 16 in-depth interviews were conducted with a diverse range of actors within the public, private and third sector.
- Secondary documentary analysis e.g. policy documents, newspaper articles, websites
- Participant observation and site visits e.g. Glasgow Recycling and Renewable Energy Centre.
- Limitations to data methods: absence of interviews from national government representatives. Care was taken to avoid overgeneralisations.

Finding 1. Local government is taking action to lead low carbon urban transitions

Policy and Strategy

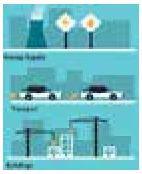
- **GCC alignment with Scottish Government:** Committed to the implementation of climate change policy, e.g. Climate Change Strategy and Action Plan, 2010; Energy and Carbon Masterplan, 2014; Glasgow City Centre Transport Strategy 2014-2024.
- Glasgow City Council Climate Change Strategy is aligned with targets committed by the Scottish Government for 42% reduction in CO2 emissions in Scotland by 2020.

Energy Efficiency

- **Management of Council's Estate:** 30% reduction target of CO2 by 2030, of which 9% was achieved by July 2013.
- **LED Street-lighting:** Major programme to replace 72,000 sodium street lamps to LED lamps by 2018.
- **Provision of District Heating:** Installation of district heating in new housing scheme 'The Village' in the East End.
- **Provision of Internal Energy Services Company:** Set up of council-owned energy services company to manage emissions from Council estate.

Sustainable Transport

- **Provision of Cycling and Walking Infrastructure:** Introduced an integrated network of bike lanes and avenues.
- **Implementation of Council Staff Travel Plan:** Subsidised low cost public transport tickets and cycle-to-work scheme.
- **Implementation of City Centre Speed-Controlled Zone:** 65 mandatory 20mph speed restriction zones in city



Finding 2. Challenges faced by local government when implementing transitions

Privatisation and Deregulation

- **Transport Network:** GCC has limited control over transport infrastructure, which makes it difficult to control pricing, service schedules, frequency and rolling stock
- **Housing Sector:** Lack of control of 81,400 social housing which were transferred In 1997.

Counterproductive Local Government Policies

- **Electric Vehicle Parking Charges:** Parking charges for EV discourages the use through profit-driven motives.
- **Subsidised Car Parking for Council Staff:** Scheme contradicts the Staff Travel Plan by encouraging staff use of cars

Lack of Long-Term Strategic Planning

- **Carbon Lock-In:** City Deal Infrastructure schemes equating to £1 billion received criticism for being very carbon-heavy due to short-termism and political inertia.

Complexity of Public Funding

- **Lack of spending, very competitive and limited funds:** Result of competing prioritisation and political inertia on a national and local government level, and wider neoliberal, market-based and centralised financial institutions.

"Some of [the low carbon projects] are not expensive, but are seen as politically challenging"

Finding 3: The formation of multi-actor networks to facilitate low carbon transitions

Public-Private Collaboration: Glasgow Recycling and Renewable Energy Centre: £154 million investment between GCC and Viridor. Treats up to 200,000 tonnes per annum of Glasgow's municipal waste. Diverts 90% of green bin residual waste away from landfill. Sparked by an increase in landfill tax in 2016.

Public-Social Enterprise Collaboration: Co-Wheels : Co-Wheels provide low emission, hybrid and electric car fleets on a pay-as-you-go service. GCC provide the space and parking bays for this initiative. Minimal risk and cost of £25,000 per annum.

Public-Third Sector Collaboration: Green Business Network: Set up with Glasgow Chamber of Commerce. Comprises approx. 100 businesses and small-medium enterprises to share experience, knowledge and expertise of low carbon transitions.

Finding 4: Challenges faced by multi-actor networks when facilitating transitions

Absence of trust: Lack of trust between the public and private sector can cause tensions implementing city-wide initiatives.

"It just can't be the public sector talking at the private sector, or vice versa. Rather, it needs to be collaborative joint decision-making, and we're just not at that stage yet"

Prevailing unequal power relations: Collaboration on a wider scale still demonstrates unequal dynamics of power relations, with elite groups dominating power and influence.

Complexities of engagement with multi-stakeholder partnerships: Delivery of large-scale projects can be extremely complicated, time-consuming, fragile and costly due to difficulties negotiating contracts, allocating risk, managing finance and procurement

Uneven balance of small-medium enterprises: Fewer involvement of local SMEs due to lack of resources and time. This can lead to an uneven distribution of political power for larger corporations and public bodies.

Reliance on economic priorities: Risk of neglecting or overlooking environmental and social priorities in the pursuit of maximising profitability.

Summary

- **Political will from local government**: e.g. policy, sustainable transport and energy efficiency.
- **Challenges thwarting local government's progress of implementation**: e.g. privatisation and deregulation, counterproductive council policies, absence of strategic planning and complexities of public sector funding for low carbon projects
- **Clear dependency placed on external actors:** new networks established with third sector and private enterprises.
- **Barriers still remain with regard to these networks:** e.g. lack of trust, unequal power relations, complexities of multi-stakeholder partnerships, difficulties engaging small-medium enterprises and dominance of economic development over environment and social priorities.

Recommendations

- **Devolution of powers** from national to local government e.g. planning
- **Long-term strategic cross-sectoral plans:** Cities to set out of how they wish to use enhanced powers and controls for low carbon transitions
- **Re-regulation** of buses in cities
- **Greater collaboration** between public bodies and city councils during key decision-making
- **Cities** should participate on equal standing with government agencies
- **Large-scale review** of low carbon funding

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Overarching Themes
Developed city contexts
Multi-Actor Governance of sustainable transitions
Challenges and barriers of implementation

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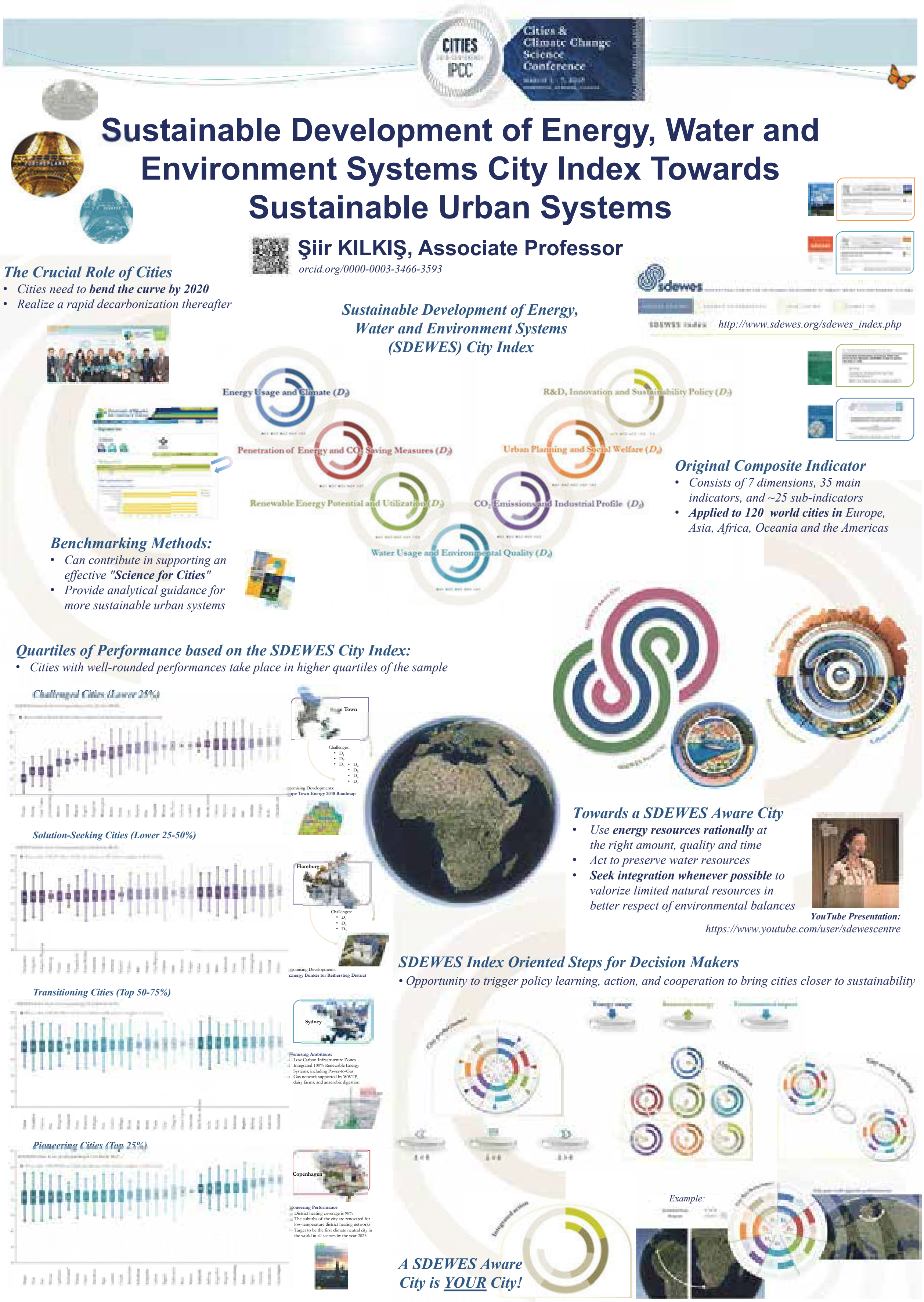

CITIES IPCC
Cities & Climate Change Science Conference
Sustainable Development of Energy, Water and Environment Systems City Index Towards Sustainable Urban Systems
Şiir KILKIŞ, Associate Professor
orcid.org/0000-0003-3466-3593
The Crucial Role of Cities
• Cities need to bend the curve by 2020
• Realize a rapid decarbonization thereafter
Sustainable Development of Energy, Water and Environment Systems (SDEWES) City Index
sdewes
http://www.sdewes.org/sdewes_index.php
Energy Usage and Climate (D_1)
Penetration of Energy and CO_2 Saving Measures (D_2)
Renewable Energy Potential and Utilization (D_3)
Water Usage and Environmental Quality (D_4)
CO_2 Emissions and Industrial Profile (D_5)
Urban Planning and Social Welfare (D_6)
R&D, Innovation and Sustainability Policy (D_7)
Original Composite Indicator
• Consists of 7 dimensions, 35 main indicators, and ~25 sub-indicators
• Applied to 120 world cities in Europe, Asia, Africa, Oceania and the Americas
Benchmarking Methods:
• Can contribute in supporting an effective "Science for Cities"
• Provide analytical guidance for more sustainable urban systems
Quartiles of Performance based on the SDEWES City Index:
• Cities with well-rounded performances take place in higher quartiles of the sample
Challenged Cities (Lower 25%)
Solution-Seeking Cities (Lower 25-50%)
Transitioning Cities (Top 50-75%)
Pioneering Cities (Top 25%)
Cape Town
Hamburg
Sydney
Copenhagen
Towards a SDEWES Aware City
• Use energy resources rationally at the right amount, quality and time
• Act to preserve water resources
• Seek integration whenever possible to valorize limited natural resources in better respect of environmental balances
YouTube Presentation:
https://www.youtube.com/user/sdewescentre
SDEWES Index Oriented Steps for Decision Makers
• Opportunity to trigger policy learning, action, and cooperation to bring cities closer to sustainability
Example:
A SDEWES Aware City is YOUR City!

EXCHANGING LESSONS

JOINT LEARNING & SHARING TO ADVANCE CLIMATE CHANGE PLANNING

DANIELLE KOLEYAK

LOCAL GOVERNMENT

- Cities need multiple inputs in order to have effective evidence for climate change adaptation planning and decision making.
- Cities have a role in funding and participating in climate change research. There are joint knowledge production approaches cities can take to support and integrate science into climate change decision making.
- Cities have data that if made open and available to practitioners, researchers and citizens could further research and understanding of local climate change issues and impacts.

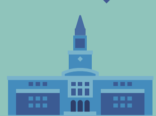
3 COMMON CHALLENGES

FACED BY LOCAL GOVERNMENTS IN ADAPTING TO CLIMATE CHANGE:

CHALLENGE:
TRANSLATING SCIENTIFIC KNOWLEDGE INTO MEANINGFUL ACTIONS AT A LOCAL LEVEL
(Cockburn et al. 2016)

CHALLENGE:
UNDERSTANDING HOW IMPACTS WILL BE FELT LOCALLY AND HOW LOCAL SYSTEMS WILL RESPOND TO THESE IMPACTS

CHALLENGE:
COMPETING PRIORITIES AND LACK OF INTERNAL RESOURCES WHILE BEING AT THE FOREFRONT OF ADDRESSING CLIMATE IMPACTS
(Nordgren et al. 2015).



PARTNER:

UNIVERSITIES

& OTHER ACADEMIC INSTITUTIONS

- Associated with this challenge is the sometimes disconnected research agenda of the scientific community with specific research needs of practitioners to understand local phenomenon and make evidence-based decisions (Ryers et al. 2010).
- Innovative partnerships with local academic institutions can be an effective way for practitioners to work with the research community to not only conduct specific and local research, but also to help develop the research questions and topics.
- One successful example from the City of Edmonton is the partnership with the University of Alberta on a program called "Sustainability Scholars". This program allows City of Edmonton staff to engage graduate students on specific research questions.
  - This allows City of Edmonton staff to obtain research support on specific important topics to make more informed decisions, while simultaneously helping graduate students get experience working with practitioners and policy makers.
  - This program fosters joint knowledge production via collaborative research between urban practitioners and the academic community.
- Another successful example from the City of Edmonton in engaging with academic and research institutions is through the Open Science program.
  - This program is a collaborative partnership between the city and academic communities to help develop innovative solutions to specific municipal challenges and engage the research community to help develop practical solutions to current issues in the City.
  - This program is delivered by the City of Edmonton's Open Data and Analytics Center of Excellence teams.

PARTNER:

CITIZENS

- Typically, municipal staff working on climate change adaptation do not have the capacity to fill these specific localized research gaps.
- A field, that is not emerging but is recently gaining more momentum is generating localized data by crowdsourcing large quantities of data through citizen science – a forum to enlist members of the public in data collection activities. Citizen science has been successful in advancing knowledge and information (Bonney et al. 2009, Wang et al. 2015).
- While crowdsourced data is often viewed to not be as rigorous as traditional scientific data collection methods, it is useful for generating local data in a cost-effective manner, and can help identify the need for further scientific research. In addition, using volunteers in citizen science allows more data to be gathered over a longer period of time than would be possible with traditional scientific research. Data gathered by citizen science can be reliable and valid, particularly if the research is designed from the outset to have citizen scientists be the data collectors (Cohn 2008, Wang et al. 2015). Citizen science gets members of the public interacting with and engaged in their environment, potentially raising awareness and action on environmental concerns (Cohn 2008, Wang et al. 2015).
- The City of Edmonton has partnered with Edmonton Public Libraries to include Airbeam Kits in circulation at the library. Citizens can check-out the kits, which contain a handheld Airbeam, instruction manual, and books on air quality. The Airbeam measures concentrations of fine particulate matter (PM2.5) in the outdoor ambient environment, mapping the readings geospatially on an open source platform. This data can be used to identify "hotspots" of PM2.5 that might require further investigation. This program is a cost-effective way to generate localized air quality information, while at the same time engaging citizens to become more informed and aware of air quality.
- Open data practices can also contribute to citizen science and can help close data gaps through the use of citizen science (Lisjak et al. 2017). Edmonton's Open Data Portal (and associated policies and initiatives) provide access to anyone to explore data for themselves. This can help to generate local knowledge and additional trends on specific datasets, beyond what the data may have originally been collected for.

PARTNER:

SUBJECT MATTER

EXPERTS

- Urban policy and decision makers can utilize urban practitioners and subject matter experts external to the local government to provide support for conducting research or developing tools to enable more informed climate change adaptation planning.
- During the City of Edmonton's first iteration of assessing climate risks and vulnerabilities, one challenge identified was the inability to quantify the assessment. Instead, the results relied on qualitative information, making it challenging for stakeholders to feel confident in their assessment.
- Moving into the second iteration of assessing the risks and vulnerabilities of Edmonton's changing climate, significant efforts by climate change adaptation specialists contracted by the City of Edmonton have been undertaken to develop quantifiable indicators for assessing the consequence of climate related risks. For example, when assessing climate change impacts on health and safety, DALY (disability-adjusted life year) indices were developed for different climate risks, enabling subject matter experts to specifically identify what a changing climate means for Edmonton.
  - This specific approach and method has not been used before. By encouraging and requesting that this approach be used for the City of Edmonton's climate change adaptation planning, a methodology is being developed that can be utilized by other local governments in the future.
  - Developing these quantifiable indicators not only provides more confidence and robustness to the assessment, but it has also helped to identify prominent data gaps and point to where specific further monitoring or research is needed, at the local level.
- Another way the City of Edmonton is leveraging the practitioner community is by conducting specific applied research. Partnering with the Miistakis Institute (a not-for-profit environmental research group based out of Calgary, Alberta), research is currently being undertaken to quantify the environmental benefits a critical mass of green roofs could have in Edmonton, factoring in Edmonton's current climate reality and projected climate change scenarios.
  - This research has potential to be seminal for climates like Edmonton's, and can help to build practitioner expertise in this field as well as provide guidance for other municipalities interested in green roof science and policy.

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CHANGE FOR CLIMATE

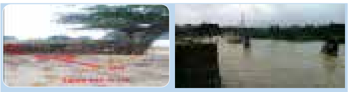
Edmonton

REGIONAL COOPERATION, MARINE SPATIAL PLANNING AND THE PROTECTION OF COASTAL CITIES AGAINST CLIMATE CHANGE: THE INTERESTS OF THE SUB-REGION OF THE GULF OF GUINEA AND ITS LONG CHAIN OF COASTAL CITIES

Kong Mukwele Sheila

I- GENERAL INTRODUCTION: PROBLEM STATEMENT

1- Coastal cities are known to be the most populated and the hub to the economic growth of their nations. Majority are port-cities with ongoing heavy maritime economic activities;



Source: Dr. ONGUENE, Oceanographer and Lecturer at the University of Douala, Cameroon. Images showing impacts of climate change in Kribi and Douala, two Cameroon's coastal cities.

3- The International Marine Environmental Law, is establishing through the international community legal climate/ocean action plans (e.g. Marine Spatial Planning) to be implemented at the national level;

4- However, the transboundary nature of the coastal environment and the challenges thereto, is an impediment to an effective Marine Spatial Planning (MSP) by any individual State.

II- CHALLENGES OF COASTAL CITIES OF THE GULF OF GUINEA (CCGG)

Source: http://onesharedocean.org/LME_28_Guinea_Current

1- CCGG contribute to the vitality of national and regional economies, and are home to marine ecosystem services such as fisheries, tourism and maritime transportation;

2- With 31 percent of its population living along the coastline, and generating 56% of total GDP (http://foreignpolicy.com/2016/10/21/west-africa-is-being-swallowed-by-the-sea-climate-change-ghana-benin/), CCGG are expected to experience Sea levels faster than the global average (West African Economic and Monetary Union, 2014).

4- Stressors such as the fast growing population (10 million/year : State of the World's Cities Reports, 2010/11) and poor coastal urban planning are causing great concern to their sustainability.

http://strangesounds.org/wp-content/uploads/2015/08/coastal-erosion-senegal-3.jpg

http://foreignpolicy.com/2016/10/21/west-africa-is-being-swallowed-by-the-sea-climate-change-ghana-benin/

The stressors are magnified by the impacts of climate change (CC) and ocean acidification…

- Sea level rise leading to overtopping and the destruction of low barrier beaches that limits coastal lagoons of cities such as Douala, Cotonou, Lagos and Dakar;
- Changes in precipitations which affect the rivers feeding these lagoons and risks of flooding for CCGG;
- These changes alter the physiology of fish species, reduce calcification rates in calcifying organisms and cause dramatic changes in the food chains and webs.
- resulting ripple effect affect the livelihoods that depend on all the ecosystem services that this area provides.

III- RESEARCH GAPS

1- Lack of acknowledgment and uses of MSP in existing national and local marine frameworks:

- The importance of MSP is still to be fully considered in actions towards the protection of coastal cities, particularly those of the Gulf of Guinea, against climate change impacts.
- The strategic role that MSP plays in the implementation of the 17 SDGs (**SDG 14 in particular**) is still absent in the decision-makers' policy and regulatory instruments of our coastal cities.

Source: World Ocean Council, "International Ocean Governance: Marine Planning Brief", International Business Alliance for Cooperate Ocean Responsibility, November 2014.

2- CCGG need to cooperate at a regional level for more effectiveness in fight against climate change and ocean acidification:

- Effective implementation of MSP as a tool for the protection of the chain of CCGG will require collaborative efforts at the sub-regional level.
- For the protection of the cities from climate change and the implementation of SDG14, the strengthening of existing marine legal and institutional frameworks as well as the creation of multidimensional and multisector platforms of cooperation whereby all concerned stakeholders are involved becomes key.

Source: Kobenan Kouassi ADJOUMANI et al., «Protection de la biodiversité marine enjeu locale ou global», Ministère des ressources animales et halieutiques, République de Côte d'Ivoire, OCEANPOLIS, Brest, France, p.5.

IV- METHODOLOGY

This work is carried basically through the inductive and deductive methods.

The pressure of urbanisation, rapid and vast growth of their populations, and alarming impacts of CCGG are at high risks of more foreseen and unforeseen outbreak of crisis.

\+

MSP has emerged as a major tool in the 21st century in the fight against potential impacts of CC and the associated rising sea levels in coastal areas, and other related consequences such as insecurity

\+

The complexity of ocean governance, even through MSP requires collective efforts for it to be efficient.

→ The protection of coastal cities using MSP would be effectively attained only through a common regional multisector and cross-boarder stakeholder involvement.

Source: Quartz Africa, "(DON'T) SEND DOWN THE RAIN: It's only just started, flooding is going to get a lot worse in Nigeria", https://qz.com/1054825/climate-change-in-nigeria-floods-in-lagos-abuja-niger-delta-are-going-to-get-a-lot-worse/

V- RESULTS

1- THE IMPORTANCE OF MARINE SPLATIAL PLANNING TO CCGG

With the intensification of spatial squeeze in CCGG due to present and future impacts of CC, MSP, because of its integrated nature is proving to be the sustainable tool that these coastal cities would benefit from for obvious reasons:

MSP will enable CCGG and their respective national governments to develop and implement an overall coordinated management plan based on ecosystem approach, while enhancing in the process the different activities, uses and services of their individual and common coastal zone;

MSP is a framework for marine management, that allows all marine interests and stakeholders to be given due consideration, while solving the problem of overlapping of competence;

MSP enables national and local decision-makers to have a holistic view which will take into account all aspects and all sectors of the governance of their coast, thus create a platform of avoidance of conflicts of all kinds ("human-human conflicts or human-environment conflicts);

MSP will enable these cities to effectively implement their rights and duties towards the sustainable exploitation and protection of their coastal areas as reflected in important global conventions, the United Nations Convention on the Law of the Sea and the Convention on Biological Diversity, and the Paris Agreement.

2- THE STRATEGIC ROLE OF REGIONAL COOPERATION IN THE USE OF MSP ON THE STUDY AREA

The complexity of the coastal environment of these cities, requires regional cooperation, as recommended by the United Nations Convention on the Law of the Sea (UNCLOS):

The good governance of the coastal environment cannot be achieved by individual efforts of coastal cities or States, but rather by collective regional actions;

The regional level of governance has proven to be a strategic lever for the conservation and sustainable use of the ocean, often taking action "closer, further and faster" than institutions at the international or national level;

Regional cooperation will enhance the sustainability of CCGG by creating a platform of cooperation, coordination and harmonisation of all frameworks of all sectors and scales (e.g.: governments and academia);

Regional cooperation offers the possibility for these cities to use the International Law principle of "mutual supportiveness" that is of key importance in the fight against CC and the guarantee of sustainable development;

Hence, effective integrated marine action plan against climate change, such as MSP, requires cooperative efforts, because in the words of Albert Salman, Director General of Coastal & Marine Union – EUCC, "the more partners the better".

My contact

VI- RECOMMENDATIONS

For the effective implementation of the found results of this study, the following policy recommendations would be useful:

- **The establishment of strengthened collaboration platforms, which will involve all stakeholders: a "public-private partnership" regional cooperation that gives the frontline to regional sea bodies such at the Abidjan Convention's Executive Secretariat;**
- **The creation of a regional consultative body for CCGG, wherein exchange of knowledge and monitoring of the MSP measures shall be carried out;**
- **The creation of strategic regional partnerships between local/national coastal governments and universities and research institutes would certainly help in attaining sustainable development, since academia are hubs of development and innovation ;**

VII- REFERENCE

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ARE CITIES REALLY MORE ENERGY EFFICIENT?

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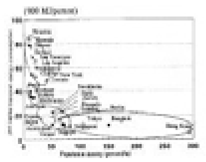
UNIVERSITY OF TORONTO

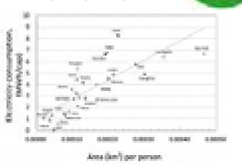
FOUR COMPETING ANSWERS

POPULATION DENSITY

Existing studies on global cities have demonstrated strong correlations between population density and lower energy consumption per capita.



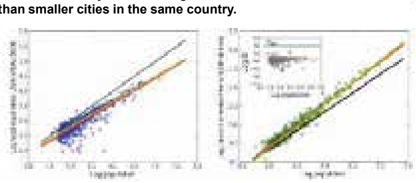
Variation in annual transportation energy consumption and population density between several global cities (Newman and Kenworthy, 1991).



Electricity consumption in megacities is strongly correlated with urbanized area per person (Figure S5 from Kennedy *et al.*, 2015).

URBAN SCALING THEORY

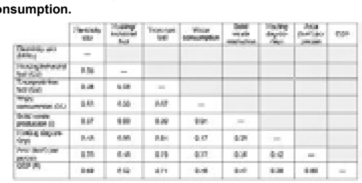
Urban scaling theory shows that total energy consumption and wasted energy increase with city size, i.e., larger cities use and waste more energy than smaller cities in the same country.



Sublinear scaling of road miles and superlinear scaling of GDP for U.S. cities (Figure 1 from Bettencourt, 2013). Total energy consumption and dissipation scale superlinearly.

WEALTH EFFECTS

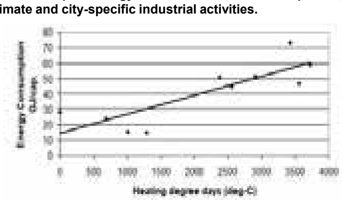
Existing studies on global megacities show that larger cities tend to be wealthier than smaller cities, and increased wealth leads to increased energy consumption.



Simple (univariate) correlation coefficients between urban metabolism parameters and driving factors in a study of the world's 27 megacities (Table S2 from Kennedy *et al*, 2015).

CLIMATE & INDUSTRIES

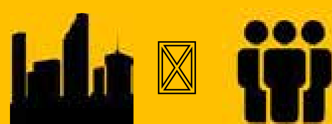
Other factors that impact energy use in cities are location-specific, such as climate and city-specific industrial activities.



Energy consumption from heating and industrial fuels increases with heating degree days, based on an 18°C base temperature (Figure 2 from Kennedy *et al.*, 2009).

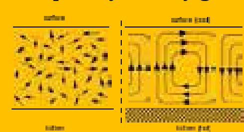
INTERPRETATIONS

Cities are more than the sum of their people



Urban living may be more energy efficient when it comes to meeting basic needs of individuals (i.e., density effects); however, the agglomeration effects of urban economies lead to even greater consumption in the city as a whole (i.e., scaling and wealth effects).

Cities are dissipative structures that build complexity as they grow



Formation of Bénard Cells

Cities are dissipative structures, similar to Bénard Cells or a tornado in a bottle. As cities become more efficient—by building transportation networks, for example—they transition to a higher order of complexity that drives even more economic activity, consuming more energy and making room for more people, who in turn consume more energy.

Urban energy needs will increase; low-carbon energy supply is a top priority

On their own, urbanization and efficiency may not actually help efforts to reduce our energy-related environmental footprint on the planet. Instead, we need strategies that can sustain potentially high energy use while reducing adverse impacts, such as a shift to low-carbon energy supplies.

References: Newman and Kenworthy, 1991, *Cities and automobile dependence: An international source book* | Kennedy *et al.*, 2015, *PNAS* 112(19): 5985-90 | Bettencourt, 2013, *Science* 340(6139): 1438-41 | Kennedy *et al.*, 2009, *Environ. Sci. Technol.* 43(19): 7297–302.

Spatial interpolation of summer air temperature in high-density cities: The impact of the urban environment in Hong Kong

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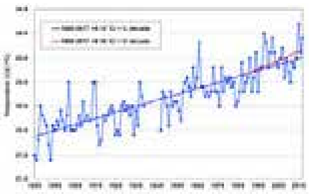
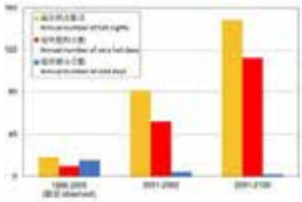
Background and Issues





Rising temperature under climate change and increasing frequency and magnitude of extreme hot weather. High-density urban environment and urban heat island further exacerbate the intense heat.

Need for spatially continuous temperature data to consider the urbanization effect. Spatial interpolation techniques are useful to supplement ground-level monitoring network.

Data and Methodology

Temperature data:
Hourly air temperature data from 40 ground-level stations operated by the Hong Kong Observatory.

Temperature metrics:
Average daytime temperature (07-18h)
Average night-time temperature (19-06h)
Average daily maximum temperature
Average daily minimum temperature

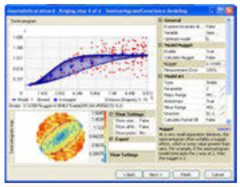
Meteorological Station Network in Hong Kong

Sky View Factor

Topography

Vegetation

Covariates: associated regionalized variables to spatially interpolate the sparse main attribute with abundant secondary information

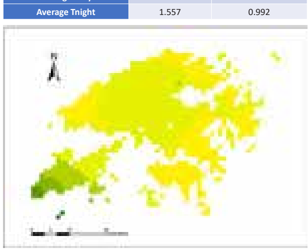


Kriging vs Cokriging

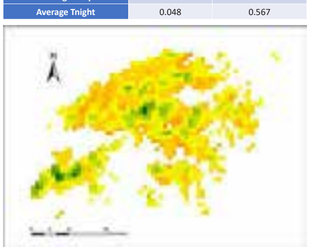
Performance of Kriging and Cokriging

Root Mean Sqaure Error	Kriging	Cokriging
Average Tmean	1.633	0.979
Average Tmax	1.810	1.074
Average Tmin	1.431	0.913
Average Tday	1.746	1.043
Average Tnight	1.557	0.992

R^2-value	Kriging	Cokriging
Aveage T	0.157	0.602
Average Tmax	0.018	0.605
Average Tmin	0.009	0.568
Average Tday	0.063	0.595
Average Tnight	0.048	0.567

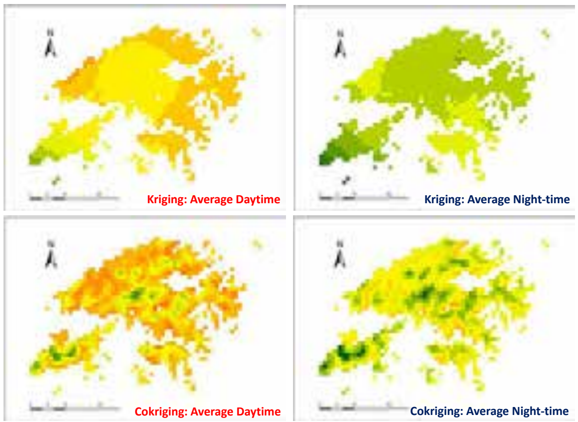


Kriging: Mean Temperature



Cokriging: Mean Temperature

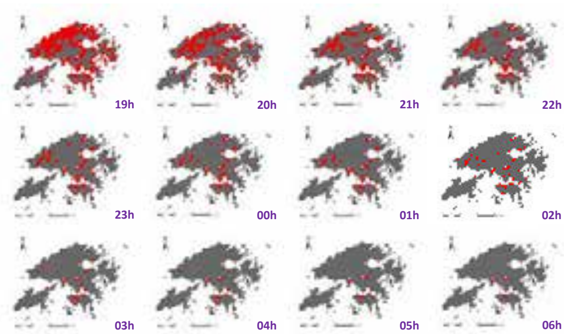
Spatial Variation of Temperature



Kriging: Average Daytime
Kriging: Average Night-time
Cokriging: Average Daytime
Cokriging: Average Night-time

Cokriging improves the spatial resolution by showing the variations in intra-urban temperature. The effect of urbanization becomes visible in average night-time temperature. Built-up areas exhibits higher temperature up to 29°C while the temperature of rural and mountain areas remains relatively lower.

Temporal Variation of Temperature



The temporal change of air temperature during night-time shows that temperature in urban areas can remain above 28°C (classified as Hot Night, an indicator of extreme hot weather used by the Hong Kong Observatory). High night-time temperature causes heat stroke in poorly ventilated residential dwellings and increases the need for air-conditioning. It also reduces the opportunities for human body to recover from daytime heat.

Implications and Further Work

Cokriging is capable of providing a spatially continuous dataset of temperature metrics with high accuracy. It helps to identify areas with potential heat stress, especially during night-time which has been largely ignored in terms of impact assessment. Applications include:

- Weather information services
  - Key meteorological stations need to be included in forecasting extreme hot weather
  - Warning of extreme hot weather may not be restricted to daytime when high temperature is always observed
- Health impact assessment
  - Public health risks can be associated with night-time temperature
  - Responses of social and community services need to consider night-time heat

Further work includes the comparison with hindcast data and hence informs the selection of reference stations for the heat stress information services with a view to better representing the potential impacts of extreme heat events.

Automatic Regional Weather Forecast in Hong Kong

Acknowledgement
This study is supported by General Research Fund, Research Grant Council, Hong Kong (Grant no.: 14611517). It also forms an integral part of the collaboration with the Hong Kong Observatory on enhancing the weather information services in Hong Kong.

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Hybrid modes of governing in Dar es Salaam and Nairobi:

Working the space between community and government for urban disaster risk management

Prof Mark Pelling and Dr Hayley Leck, King's College London

Urban Africa Risk Knowledge

Research Overview

This research seeks to understand urban scaled governance that can help build resilience to disaster risks and support transition in the risk-development nexus. This is explored through the lens of recent disaster events, specifically flooding in two case study cities as part of the ***Urban Africa: Risk Knowledge (Urban ARK)*** research programme: **Dar es Salaam, Tanzania and Nairobi, Kenya**.

Analysis focuses on how state and citizen actors interact cross the divide between national/city and local scales in disaster risk management and how this frames resilience questions.

This reveals new modes of governance, including collective and citizen action or new citizen-state relations that are forming contemporary African urban trajectories, blockages and opportunities for action.

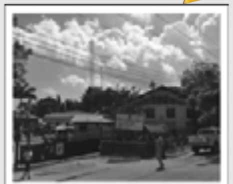
Core Focus Areas

○ Factors shaping the emergence and contribution of mediating or intermediary actors around urban development and risk.

○ Governance space between local community actors and organisations and local government/first level of political decision making – ***'the critical middle'***

○ Key influential actors operating in this space, how intermediaries negotiate this dynamic political space (and gain legitimacy) and the various entry points into that space (e.g. through NGOs, community groups, private sector etc).

•Gap in understanding:
What are the *implications* of emerging modes of governance for *urban risk reduction* and to what extent do they *reduce or exacerbate fragmentation*?

Critical middle of Urban DRR governance

Complexity of DRR in sub-Saharan Africa and more widely; customary institutions are simultaneously juxtaposed against and intertwined with 'formal' institutions, with widespread disconnection and fragmentation in governance, planning and other functions.

- **'Messy middle' (Mehta et al) adapted as the '*critical* middle' of urban disaster risk governance - the complex and vital middle governance space in urban contexts that straddles the interface between formal and informal actors and institutions, influencing at multiple scales and often in hybrid arrangements.**
- **Hybridity is a significant characteristic of the critical middle**

Emerging alternative hybrid governance arrangements for urban DRR can offer more inclusivity, considerable innovation and potential for transition towards risk-sensitive and transformative urban development.

- Innovation, new resources, insights, and knowledge to the urban DRR space,
BUT critical questions about power and scope of influence within broader political economic constraints and urban pressures.

Key considerations

Shifting risk governance landscape - Working the space between community and government – ***key are transformative individuals and institutions acting in networked alliances***

Drivers/triggers: *physical events, financial incentives, socio-political motives.*

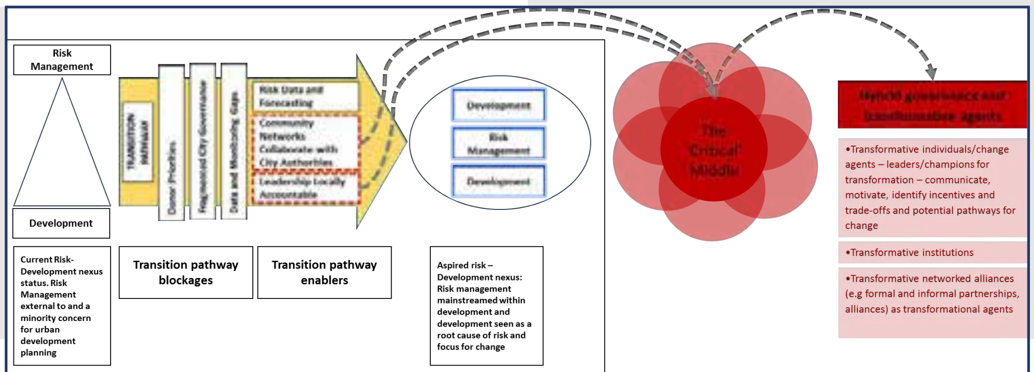
Strategies of influence: key factors for hybrid governance arrangements - credibility, accountability, legitimacy, inclusivity and longevity/sustainability. Influence through formal and informal structures and relations, role of trust,

Critique – whose interests? insiders/ outsiders, often funding and time bound/project based, possibility for more systemic influence within city-wide complex and uncoordinated DRR structure?

Policy and impact considerations: how to address fragmentation due to lack of communication+ complex nature of wider DRR governance structure, new financing structures for DRR through partnerships, new policy considerations for inseparability of formal-informal in DRR governance.

Policy messages

- Organised civil society – local government collaborations are important for addressing disaster risk but need to be better understood for their transformative potential and regarding issues of fragmentation.
- Local actors and collaborations that straddle the informal-formal interface of community members and local government in dealing with everyday experiences of risk and developmental challenges in the 'critical middle' space are central to addressing the disconnect between formal DRM structures & practical realities of DRM, especially in informal settlements .



The hybrid governance space between local communities and lowest level of government – the 'critical middle'- is key for supporting transition in the urban risk-development nexus.

Adapted from Pelling et al, 2017

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Mark Pelling

Effects of Urban Land-Use Regulations on Greenhouse Gas Emissions

Dr. Benjamin D. Leibowicz
Assistant Professor, Graduate Program in Operations Research and Industrial Engineering, The University of Texas at Austin

Overview

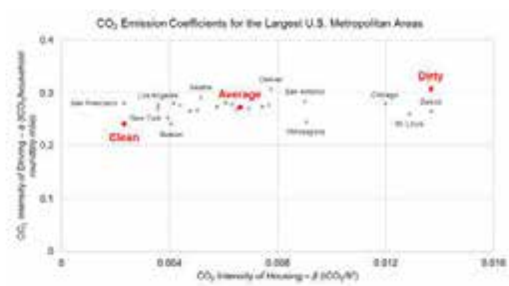
- This study is a **model-based exploration** of the **greenhouse gas (GHG) emissions** and **welfare** impacts of **urban land-use regulations**.
- Considers two types of regulation:
  1. **Floor area ratio (FAR) restriction**
  2. **Urban growth boundary (UGB)**
- Addresses three key questions:
  1. Under what circumstances will urban land-use regulations **reduce emissions**?
  2. When they do reduce emissions, what will be the **abatement cost** borne by consumers due to higher housing prices?
  3. What **factors** do these outcomes most critically depend on?

Literature Review

- More **compact urban forms** are associated with lower GHG emissions (Grubler et al., 2012).
  - In **transportation**, higher population densities tend to shorten commutes and enable public transit (Kennedy et al., 2011; Lohrey and Creutzig, 2016; Marshall, 2008).
  - In the **residential sector**, homes in denser cities are typically smaller and more likely to be part of multifamily buildings, which use energy more efficiently (Ewing and Rong, 2008; Kennedy et al., 2011).
- Efforts to **limit urban sprawl** could potentially make significant contributions to mitigating climate change (Hankey and Marshall, 2010; Marshall, 2008; Stone et al., 2009).
- However, land-use regulations often **raise real estate prices**, thus **shifting development** to relatively cheaper places that could have higher GHG emission intensities.
- "*Land-use restrictions, often allegedly implemented for environmental reasons, may be having the ironic effect of moving development from low emissions places, like California, to high emissions places, like Texas ... It is certainly possible that land-use restrictions are actually pushing people away from lower emission areas into higher emission areas. This topic seems to merit future research.*" (Glaeser and Kahn, 2010)

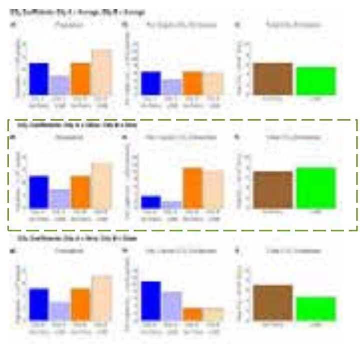
Methodology

- Extend the well-known **monocentric city model** (Alonso, 1964; Mills, 1967, 1972; Muth, 1969) to a context with **two cities** and regulation-induced, **inter-city migration**.
- The **urban spatial structure equilibrium** endogenously adjusts to the implementation of a land-use regulation, both within each city and across the two of them.
- For each resulting urban equilibrium, compute total and per-capita GHG emissions produced by transportation and housing.
- In cases where a regulation reduces emissions, estimate the GHG abatement cost by converting the change in household utility to monetary terms using **compensating and equivalent variation**.

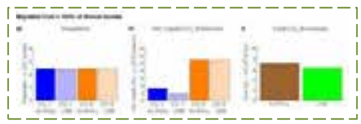


Results

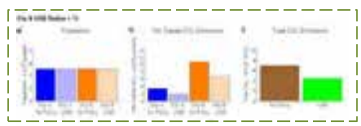
- A **UGB can increase emissions** if it is implemented in a relatively clean city and induces inter-city migration to a relatively dirty city.
- This occurs even though per-capita emissions decline in both cities.



- This outcome is less likely to occur if **migration is more costly**.



- Land-use regulation is more likely to reduce emissions if it is **universal**, rather than implemented in select cities.



- Even when UGBs reduce GHG emissions, they carry **high abatement costs** because consumers suffer from higher housing prices.

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Conclusions

- Cities with relatively low GHG emission intensities should be **cautious about using smart growth regulations for climate change mitigation**, since this approach can actually increase emissions by shifting development to more emission-intensive places.
- Even when they do reduce total emissions, smart growth controls are an **expensive** way of doing it. Based on most social cost of carbon estimates, climate change mitigation benefits only **justify a small fraction of the costs** they impose via higher housing prices.

Citation for the full article:
Leibowicz, B.D., 2017. Effects of urban land-use regulations on greenhouse gas emissions. *Cities* 70, 135–152.

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Benefits of explicit urban parameterization in regional climate modelling to study climate and city interactions

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*Regional climate models, driven by general circulation models, aim at simulating more accurately regional-scale climate evolutions, and also environmental impacts. But **most of RCMs do not include explicit modelling of urban areas**. Some of them do not represent cities; others are based on a simplified approach describing cities as rock covers with high roughness length.*

*In view of fine spatial resolutions reached today, **the relevance to take into account a specific representation of cities is investigated here**, with the aim of:*
>> Simulating more accurately the urban processes at the surface/atmosphere interface (especially urban heat islands)
>> Simulating the potential retroaction of local urban effects on regional-scale climate

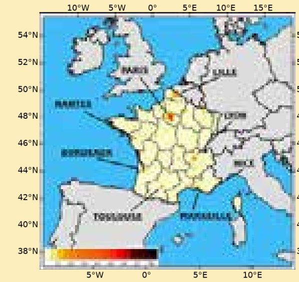


Fig 1 - Map of impervious cover fraction for the ALADIN-Climate modelling domain, and location of the eight largest French cities

1. General configuration for regional climate simulations

ALADIN-Climate regional climate simulations over France for past period have been performed with the following configuration:

- Model version: limited-area model ALADIN-Climate V6 (most recent version)
- Spatial domain: Metropolitan France (Fig 1)
- Horizontal resolution: 12 km
- Simulation period: 1980-2009
- Lateral boundary conditions provided by ERAinterim reanalyses (resolution of 80 km)

ALADIN is coupled to SURFEX land surface modelling system in which several surface models are implemented, especially:
- **ISBA** soil-vegetation-atmosphere transfer model for natural soils and vegetation
- **TEB** urban canopy model for urban areas (based on "urban canyon" concept, Fig 2)
>> Land surface covers and properties are defined using the **ECOCLIMAP v2 database** including urban covers

Simulations have been evaluated using long-term SAFRAN analyses at 8 km resolution, for incoming solar radiation, Tmin and Tmax, daily precipitation rate. The main defect of the model is the lack of cloudiness which tends to increase incoming solar radiation and results in Tmax overestimation

2. Sensitivity experiments for cities modelling

Three experiments have been performed to describe and model urban areas in SURFEX:

exp CITY Urban areas are explicitely modelled by activating TEB in SURFEX
>> At each grid cell, surface exchanges and near-surface temperature are computed with TEB for impervious covers and with ISBA for natural areas (Fig 2), and then averaged according to respective land cover fractions

exp ROCK Urban areas are modelled as rock covers with high roughness, that is the conventional approach in ALADIN-Climate

exp VEG Urban areas are replaced by local vegetation and modelled with ISBA

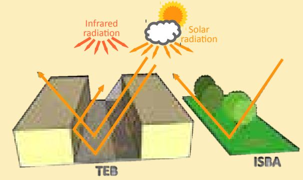


Fig 2 - Combination of TEB and ISBA models for grid cells composed of pervious and impervious covers

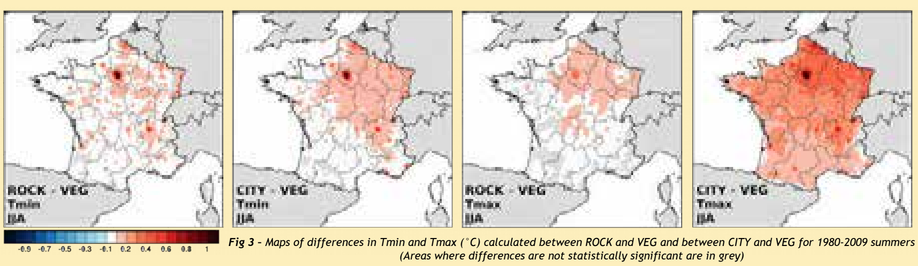


Fig 3 - Maps of differences in Tmin and Tmax (°C) calculated between ROCK and VEG and between CITY and VEG for 1980-2009 summers (Areas where differences are not statistically significant are in grey)

	JJA		DJF	
	ΔTmin	ΔTmax	ΔTmin	ΔTmax
ROCK-VEG	+1.3	+1.1	+0.4	-0.3
CITY-VEG	+1.5	+0.7	+1.3	+0.7

Tab 1 - Temperature anamalies between ROCK and VEG and between CITY and VEG, calculated for Paris grid cell in Tmin and Tmax, for summer and winter

3. Regional impact of urban areas

CITY and ROCK are each compared to VEG in order to quantify urban effects. No significant impact is noted for precipitation, but significant impacts are obtained for near-surface temperatures.

The comparison CITY vs VEG shows a systematic warming trend.
Locally over cities, increases in Tmin and Tmax are comparable in summer. They are more marked for Tmin than Tmax in winter (Fig 3 and Tab 1). The warming extends beyond the urban areas boundaries, especially in summer and for Tmax. This result illustrates the influence of cities on regional climate.

The urban effects are stronger in CITY (using the TEB model) than in ROCK, regarding (1) the temperature anomalies calculated versus VEG over urban areas, and (2) the spatial extend of urban signature on regional-scale temperature (Fig 3 and Tab 1).

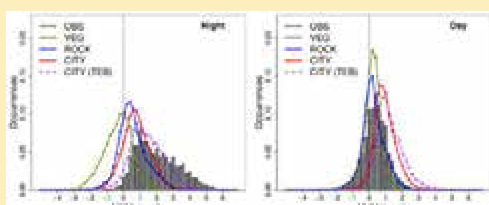


Fig 4 - Comparison of distributions of urban heat island intensities computed for nighttime (Tmin) and daytime (Tmax) from simulations (color lines) and observations (grey barrs)

4. Urban heat islands

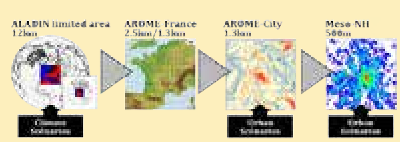
Temperature time series from one station in Paris and two in the countryside made possible to compute UHI intensities (UHI=T_{URB}-T_{RUR}) over 1980-2009, and evaluate the three experiments.

Nighttime UHIs are better simulated in CITY than in VEG or ROCK (Fig 4).
>> TEB simulates warmer urban temperatures, that gives higher (and more realistic) UHI's intensities
>> Results are still better by using the air temperature in the canyon simulated by TEB only (purple line, Fig 4)

Daytime UHIs are overestimated in CITY due to overestimation of incoming solar radiation by ALADIN, that amplifies surface warming and increases air temperature.

Conclusions and Perspectives

This work highlights the gain brought by a detailed urban parameterization for regional climate models, both for simulating more realistic nighttime UHI and for simulating regional impacts of cities.
Dynamical downscaling approaches are currently tested to reach kilometric and hectometric resolutions, for impacts studies in cities. For such applications, the French numerical weather prediction model AROME is now implemented in a climate mode for long-term simulations.



The work has been co-funded by Meteo France and Region Occitanie
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Carbon Emissions Assessment of Urban Transport A New Approach for 10 Major Vietnamese cities

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1. BACKGROUND

With rapid economic development, Vietnam is experiencing substantial growth in vehicle numbers and motorized mobility (Fig. 1). This is causing rapid increase in greenhouse gas (GHG) emissions and air pollution.

There is a need to better understand the effectiveness of transport measures so as devise policy measures to reduce GHG emissions. Quantifying the emissions is vital for this.

However, the databases and modelling tools for the quantification of traffic-related GHG emissions are not available in Vietnam.

This study offers a practical approach to quantify road transport sector energy consumption and GHG for 10 (5 major, 5 secondary) cities located in Southern Vietnam from 2014 to 2016 based road network traffic, estimated fuel consumption and emissions factors.

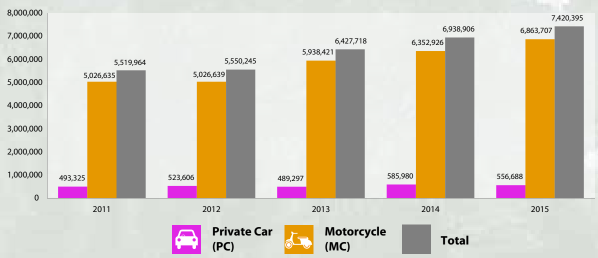


Figure 1. Vehicle population of Ho Chi Minh City (Source: Ho Chi Minh City Department of Transportation)

2. METHODS

Bottom-up approach:

- We use the bottom up approach to quantify emissions in the transport sector
- This approach provides more detailed data on GHG emissions by mode, vehicle type, trip purpose, fuel type, etc.

Data collection and emission calculations:

Three approaches are integrated in the research (Fig. 2 & Table 1):

1.International Vehicle Emissions (IVE) model
2.COPERT model, and
3.Country-specific emission factors (Lents et al., 2005; Ntziachristos et al., 2009; Ho, 2011)

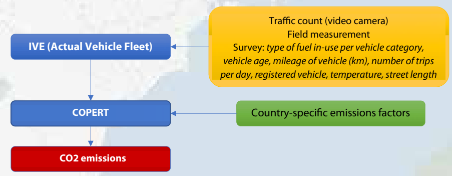


Figure 2. The integrated methodology for data collection and analysis

Table 1. The steps in collecting data and calculating emissions

#	Steps	Outcomes
1	Analyze vehicle registry data	Vehicle distribution by vehicle type and fuel type
2	Conduct parking lot surveys	Age of vehicle, vehicle mileage, and others
3	Conduct video surveys	Vehicle counts by type of vehicles
4	Calculate average annual daily traffic (AADT)	The average vehicles count per day on various types of roads during based on video survey counting
5	Multiply AADT on each road category by the length of roads	Daily vehicle kilometers traveled (VKT)
6	Divide VKT per year by the average kilometers traveled by different categories of vehicles	The number of vehicles on roads
7	COPERT	Exhaust emissions

3. RESULTS

Traffic volume, vehicle fleet, and fleet composition:

Motorcycle is found to be the most predominant vehicle type (47-66%), followed by heavy truck (28-48%), car (1-3%), and light truck (1-2%). Bus only contributes ~1%.

Despite the small numbers of private vehicles, they contribute to disproportionately greater GHG emissions. Public transport service remains limited in Vietnamese cities. Bus emissions is also related to the size of city, yet they are less carbon intensive if the occupancy is higher.

The major cities have a higher total transport sector CO2 emission than secondary cities. Severe congestion makes motorcycle a popular mode. In large cities such as Ho Chi Minh City (HCMC), there is higher motorcycle emissions than other cities.

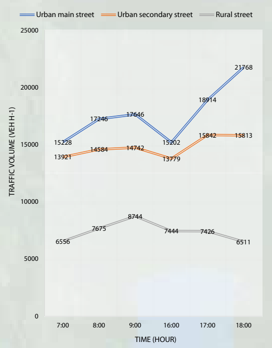


Figure 3. The hourly traffic volume in three kinds of street, vehicle h[-1] in one district in Ho Chi Minh City (a major city)

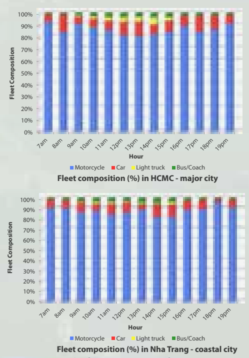


Figure. 4 The fleet composition of two major cities

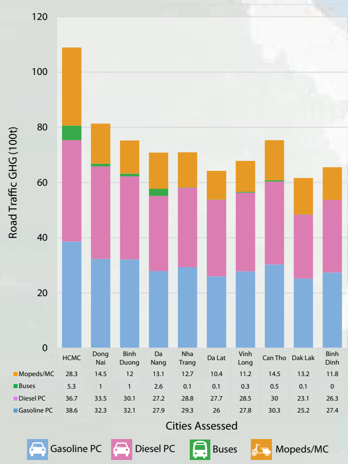
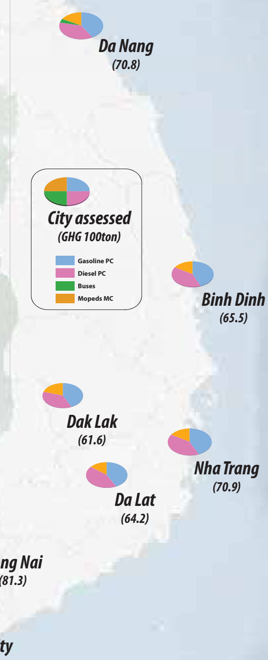


Figure. 5 The comparison of CO^2 of the 10 cities assessed (Unit: 100 ton)



4. DISCUSSION

Key contributions: This study presents a workable method for calculating emissions from on-road vehicles for cities with limited data or low quality data, which is a major issue for developing countries. The methodology of this study could be applicable to other similar cities in the global south and help develop better regional and local monitoring systems to help dealing with global climate change.

Further analysis would need to take account of vehicle trip occupancy for a more complete picture. More research needs to be done on motorcycle-dominated cities as the understanding of travel related emissions is comparatively limited.

Implications: While GHG emissions is Vietnam is low compared to other countries, it is rapidly growing. There is an urgent need for Vietnam to curb further motorization (both car and motorcycle) by better land-use planning and ambitious public transport provision. This is currently underway but capital project is costly. Improvement of built environment also helps to encourage walking and cycling.

Caution needs to be applied on resultant GHG reduction policies - governance and equity factors needs to be considered. This is another future research direction for IPCC.

Figure 6. Peak hour traffic in Ho Chi Minh City (Source: Le, T.P.L.)

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Ntziachristos L., Gkatzoflias D., Kouridis C., Samaras Z. (2009) 'COPERT: A European Road Transport Emission Inventory Model'. In: Athanasiadis I.N., Rizzoli A.E., Mitkas P.A., Gómez J.M. (eds) *Information Technologies in Environmental Engineering. Environmental Science and Engineering*. Springer, Berlin, Heidelberg

Brazilian Cities in Multilevel Governance of Climate Change

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Multilevel (?) Climate Governance in Brazil

Context

> 200 mi inhabitants, 84% in cities (2016)

9th Economy 2017 - GDP recovering (major recession 2014-2017)

Emissions from LULUCF: 73% of total - 7th largest emitter 2016

Energy : 19% of total – Scenario for Pre-salt emissions?

Federation – 3 equal powers Federal, State, Municipal

NDC - absolute GHG emissions reduction goals of 37% by 2025 and 43% by 2030, relative to 2005 levels

Pledge: 45% renewables (including hydroelectric power) in energy grid,

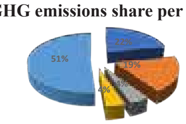
End illegal deforestation & restore 12 mi hectares of tropica forest in 15 years

Climate governance in Brazil

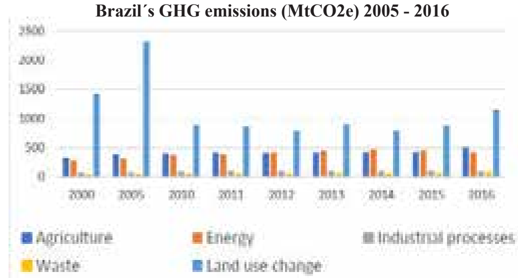
1988 Constitution + Climate Law (2009) + 12 sectorial plans: focus on LULUCF

Synergies with national (urban) policies: eg Sanitation (2007);Waste (2010); Urban Mobility (2012)

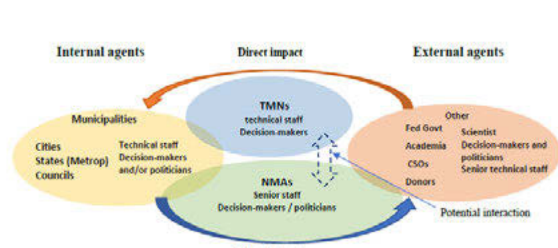
Brazil´s GHG emissions share per sector (%) in 2016



Brazil´s GHG emissions (MtCO2e) 2005 - 2016



Roles and interactions



Local climate action

Brazilian association municipal environmental departments (Anamma) Survey

By April 2017

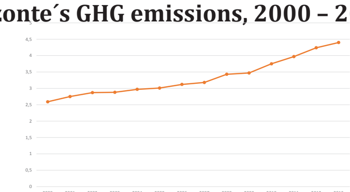
- 433 respondent municipalities (7.8% of total 5,570)
- 240 (55%) have some climate change activities: 10 capital cities + 1 metropolis+1 medium +2 large cities – CoM / ICLEI members
- 11 capital cities - GHG emission inventories +climate related policies are ICLEI members (estimated population of 33,326,765 inhabitants in 2016)
- 137 cities – waste management
- 128 reduce deforestation
- 156 improve urban mobility
- 44 incentivise renewable energies and/or energy efficiency
- 89 outreach and awareness building

CoM Brazilian cities and network membership in 2017

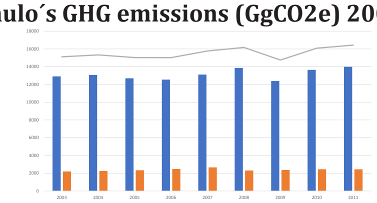
CoM signatories	Transnational municipal networks						National Municipal Associations					
	ICLEI	C40	UCLG	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Global membership	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]	[illegible]	[illegible]
Brazilian capital cities												
Belo Horizonte, MG												
São Paulo, SP												
Aracaju, Brasília, Curitiba, Fortaleza, Goiânia, Manaus, Natal, Porto Alegre, Recife, Rio de Janeiro, Salvador												
TOTAL 13	12	2	11	4	2	11	12	13	13	12	9	12
Other cities 21	19	2	12	8	2	13	1	21	16	[illegible]	5	7
Municipalities 34	31	4	23	12	4	24	13	34	29	12	14	19

Benchmarks

Belo Horizonte´s GHG emissions, 2000 – 2013 (tCO2e)



São Paulo´s GHG emissions (GgCO2e) 2003-2011



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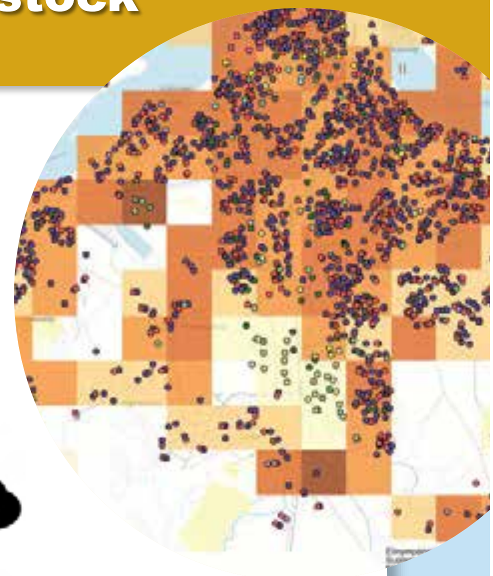
Unique and open map-based application for understanding the building stock and its emissions



I INTRODUCTION

Cities and the buildings within them require energy and material inputs to sustain human settlement. Energy production, especially the use of fossil fuels, causes environmental impacts on both local and global scale. Consequently, the energy consumption of buildings form a big part of the emitted greenhouse gas (GHG) emissions of cities. For climate change mitigation purposes, there is an evident need to understand energy consumption of buildings and the related emissions, and moreover, to disseminate the information. Local decision-makers, urban planners, the building industry, housing cooperatives, property managers and citizens would benefit from this type of information.

Fig. 1 Zoomed view of the provided building-specific information in LIITERI. Colored points represent buildings, and the color indicates the building type: e.g. blue for resiential buildings, yellow for office buildings , red for other types of buildings.

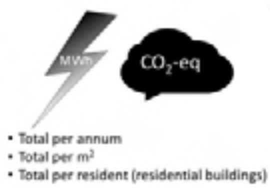


Fig. 2. Aggregated estimates of energy consumption and emissions available in the statistics of LIITERI-service.

II APPROACH

- Bottom-up physical modeling approach, which is based on modeling work done in Tampere University of Technology, is used to estimate and illustrate buildings' annual energy consumption and GHG emissions in Finland (Mattinen *et al.* 2014)
- Main input data fed into the model are from national building register that includes detailed characteristics of each building
- The model deals with physical characteristics of building types, specified through the model parameters
- Aggregate modeled energy consumption and emissions are publicly available in web application called LIITERI
- LIITERI employs Geographical Information System (GIS) and allows users to view (Fig 1)
  - Statistics up to a 250m grid resolution
  - Building-specific estimates
- The most detailed specific data are available for contract users

III RESULTS

- The application provides users with a better understanding of the current building stock's energy consumption and emissions

⇨ identification of hot spot areas that would require energy renovation or other measures

- Users can incorporate the energy and emission data with building-related data, numerous other map layers and statistics featured in the service; City-level results can be downloaded for further analyses

⇨ Allows rich analysis of the area at hand

⇨ Helps data-driven decision making

- The service takes into account data privacy issues, and is updated annually as the new building register data is available

⇨ gives detailed timely information on building stock level

⇨ enables to view changes in time series

IV FUTURE STEPS

- LIITERI is an example of a unique and publicly open information service, thus we expect to give inspiration to other regional and national level building stock modelers and data users how to disseminate scientific results
- In the future, new buildings should be (nearly) zero-energy buildings which means that the relevance of construction and end-of-life stage rise; at the same time demands for solutions within the circular economy grow in the building sector

⇨ information about the building materials will be incorporated, so that the whole life-cycle of the building and its environmental impacts can be examined by using the building register data

⇨ Inclusion of mobility emissions in the same service will be considered

Acknowledgement

The strategic research funding from the Strategic Research Council, Academy of Finland, grant for Beyond MALPE coordination: Integrative Envisioning (BeMInE, 303556) is gratefully acknowledged.

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Looking South: how can we read climate responses from Latin American global cities?

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University of Brasília (UNB)

How? Analytical Framework

- **Global Cities** → Global responses;
- Bridging the local and the global through transnational networks → C40 and ICLEI;
- Polycentric governance (Ostrom, 2010);
- Latin America context demands observing implementation → beyond the climate responses discourse

Legal responses: laws and decrees

Policies responses: mitigation and adaptation plans

Governance responses: local and global arrangements

Latin America Case Studies

Practical significance

- Second wave of municipal responses to climate change (Bulkeley; Betsill, 2013) → cities from the South;
- Contribute to improve transnational cities networks approach and policies towards Latin American cities;
- Transnational city networks can push cities to respond to the challenges posed by climate change but are they able to foster a transition to a low carbon development?

Climate responses + **Implementation**

Cities/ Responses 2005-2017	Legal	Policies	Governance	Implementation Results
São Paulo (SP)	- Decree n. 45.959 (6/6/2005) creates Municipal Committee about Climate Change and Sustainable Ecoeconomy; - Climate Law 14.933 (6/5/2009), establishes the PMMC; - Law 16,802 (January 18th 2018) modify Law 14,933 redefining new deadlines for the public transportation fleet to become cleaner.	- Municipal Climate Change Policy (PMMC): mandatory target to reduce 30% GHG emissions by 2012, should be revised every 5 years; - Guidelines for mitigation and adaptation plan of action of SP (2011).	Local: Municipal Committee about Climate Change and Sustainable Ecoeconomy Global: C40, ICLEI	GHG emissions increased – Missed mitigation target Climate law ignored, no new reduction goals, no new GHG emissions inventory (supposed to be published in 2015). Few projects on adaptation
Mexico City (CDMX)	- CDMX Mitigation and adaptation to Climate Change and Sustainable Law and its regulations (6/16/2011)	- 2000: start of climate change policy; - 2004: 1st Climate Action Strategy; - 2008-2012 CDMX Climate Action Program (PACCM); - 2014-2020 Local Climate Action Strategy (6/5/2014); - 2014-2020 CDMX Climate Action Program (PACCM); - PACCM Monitoring System; - 2015: CDMX vision on Climate Change to 2025; - 2016 CDMX Resilience Strategy; - Environmental Fund for Climate Change (2015).	Local: CDMX Inter-Institutional Commission on Climate Change (2010) Global: C40, ICLEI, [OECD], 100 Resilient Cities Rockefeller Foundation	GHG emissions decreased – Mitigation target accomplished Adaptation projects developed (100 Resilient Cities)
Buenos Aires (BA)	- Adaptation and Mitigation Climate Change Law 3.871 (9/1/2011)	- Climate Change Action Plan (PACC) 2010-2030 (12/2009): revised every 5 years; - Climate Change Action Plan 2016-2020 (12/2015).	Local: Climate Change Interministerial Team + BA EPA External Advisory Council (APrA) Global: C40, ICLEI, 100 Resilient Cities Rockefeller Foundation	GHG emissions decreased - Mitigation target accomplished Few adaptation projects developed (100 Resilient Cities)

Preliminary Results

•Intersections between municipal international and climate politics → Key role of city networks (ICLEI + C40) fostering the adoption of climate legal, policies and governance responses;
•Mitigation > adaptation: a North/international approach?
•Implementation: national and local features were more relevant than international drivers (Ryan, 2015);
•Inconsistent role in global climate governance due to variations in the levels of climate responses implementation.

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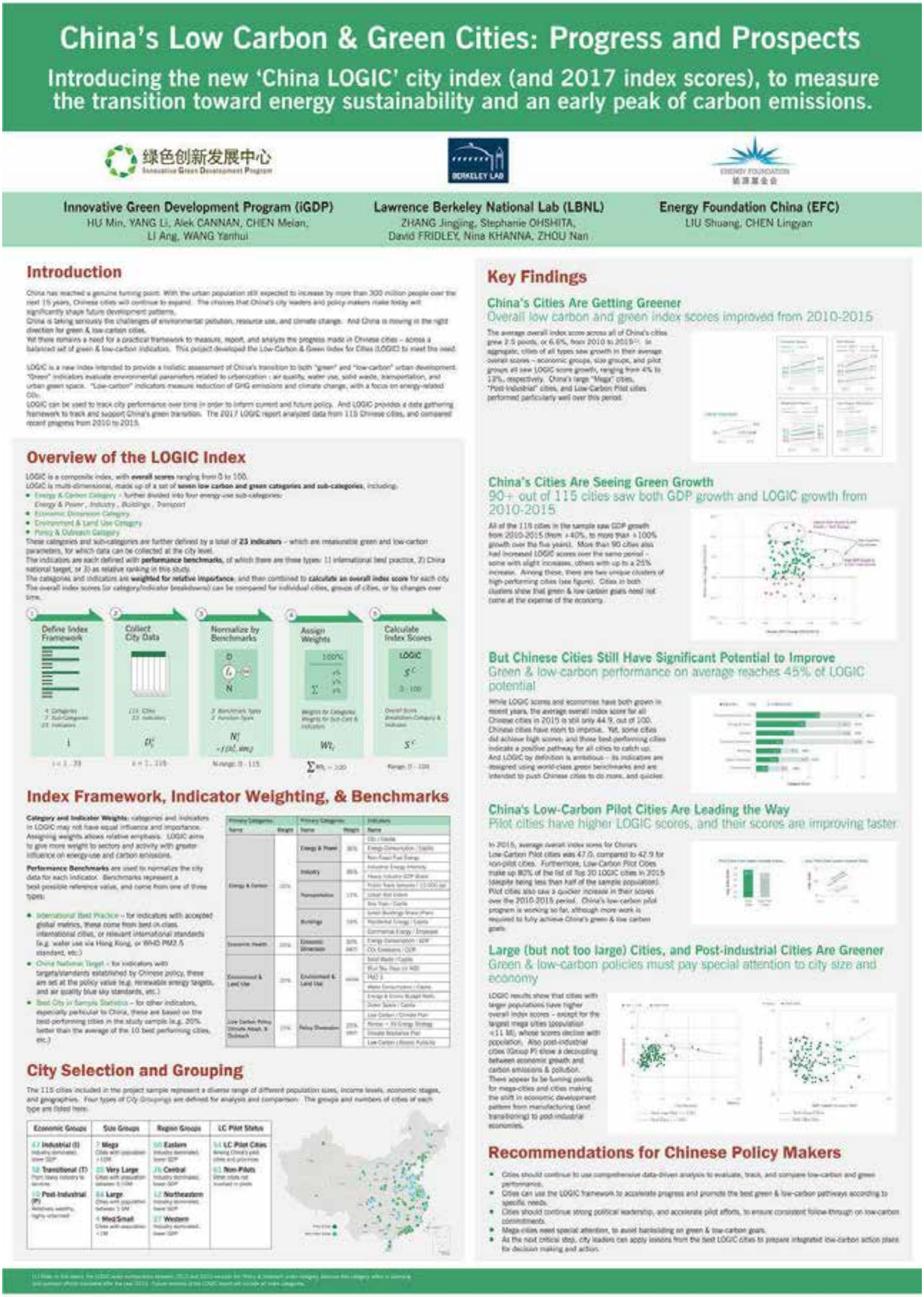
Funding: CAPES and FAPDF


China's Low Carbon & Green Cities: Progress and Prospects
Introducing the new 'China LOGIC' city index (and 2017 index scores), to measure the transition toward energy sustainability and an early peak of carbon emissions.
绿色创新发展中心
BERKELEY LAB
Innovative Green Development Program (iGDP)
HU Min, YANG Li, Alek CANNAN, CHEN Meian, LI Ang, WANG Yanhui
Lawrence Berkeley National Lab (LBNL)
ZHANG Jingjing, Stephanie OHSHITA, David FRIDLEY, Nina KHANNA, ZHOU Nan
Energy Foundation China (EFC)
LIU Shuang, CHEN Lingyan
Introduction
Overview of the LOGIC Index
Index Framework, Indicator Weighting, & Benchmarks
City Selection and Grouping
Key Findings
China's Cities Are Getting Greener
Overall low carbon and green index scores improved from 2010-2015
China's Cities Are Seeing Green Growth
90+ out of 115 cities saw both GDP growth and LOGIC growth from 2010-2015
But Chinese Cities Still Have Significant Potential to Improve
Green & low-carbon performance on average reaches 45% of LOGIC potential
China's Low-Carbon Pilot Cities Are Leading the Way
Pilot cities have higher LOGIC scores, and their scores are improving faster
Large (but not too large) Cities, and Post-industrial Cities Are Greener
Green & low-carbon policies must pay special attention to city size and economy
Recommendations for Chinese Policy Makers

Perceptions of vulnerability, tenure security and resettlement issues of urban informal communities in Papua New Guinea

Georgina Numbasa, University of Papua New Guinea and David Mitchell, RMIT University, Australia

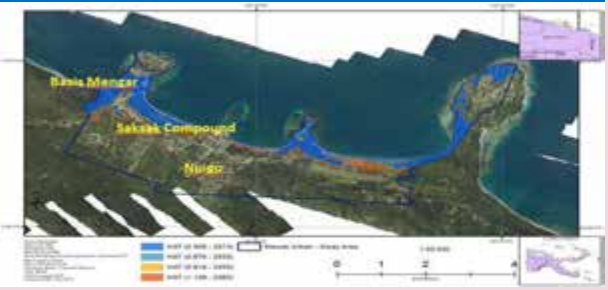
Background

This study is based on research conducted among three urban informal settlements in Wewak, northern Papua New Guinea (PNG). Wewak with a population of almost 30,000 is the fifth largest urban center in PNG and is the administrative and commercial centre for East Sepik Province. The case study settlements in Wewak were Basis Mengar, Nuigo and Saksak Compound. The questions were designed to gauge respondents' perceptions of:

- Climate risks, vulnerability and adaptive capacity
- Security of tenure
- Resettlement as an adaptation option

These communities have different land tenure arrangements and varying climate related risks.

Sea Level Rise – Inundation Modelling for Wewak, ESP, PNG

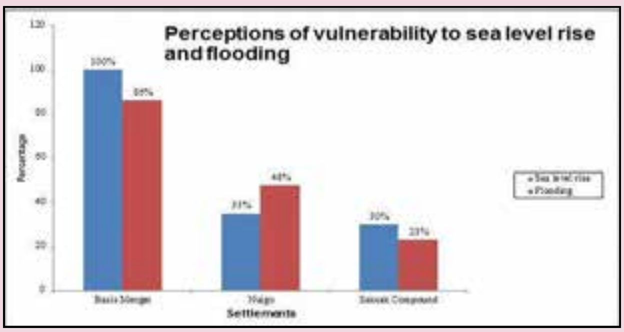


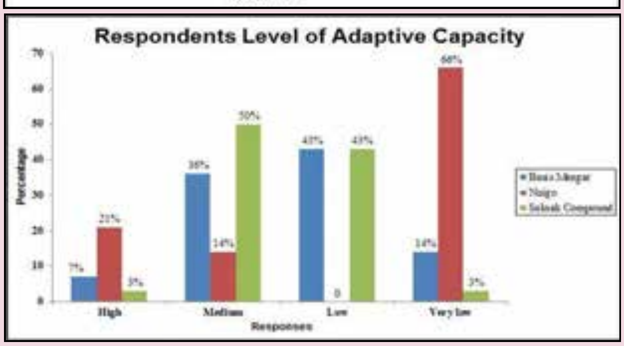
Perceptions of Climate Risk, Vulnerability and Adaptive Capacity

The respondents' perceptions of risk posed by climate change, beliefs on vulnerability and level of adaptive capacity vary between communities though within the same locality.

Major climate risk perceived by respondents in each Settlement

Climate Risk	Basis Mengar	Nuigo	Saksak Compound
Storm surge and sea level rise	25%	24%	0
Coastal erosion	75%	21%	0
Flooding	0	0	3%
Strong winds	0	0	0
Drought	0	55%	97%





Each settlement's perception of climate risk, vulnerability and adaptive capacity differ though within the same locality. Factors influencing their perceptions:

- Direct locations to perceived risk
- Tenure security
- Coping strategies
- Livelihood options
- Connections to place of origin

Perceptions of Security of Tenure

A key factor in their perceptions of tenure security was whether they thought the government would protect their rights to land.

Responses on Land Tenure Security

	Basis Mengar (Customary Land)	Nuigo (State Land)	Saksak Compound Freehold Land
How long have you been living in this settlement?	More than 20 years 86%	More than 20 years 90%	More than 20 years 53%
How did you gain access to this land?	Customary arrangements 82%	Informal arrangements 83%	Informal Arrangements 100%
How secure is your tenure?	Less secure 79%	Very secure 96%	Less secure 100%
Are you vulnerable to eviction or land grabbing?	Yes 75%	No 90%	Yes 67%
Are your property rights recognised by others?	Yes 61%	No 55%	No 63%
Does the government protect your access to land?	No 92%	Yes 66%	No 100%

Resettlement Priorities

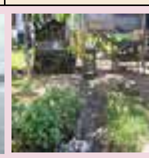
The question of resettlement was asked as an adaptation option.

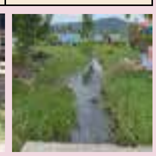
Resettlement as an Adaptation Option

	Basis Mengar	Nuigo	Saksak Compound
Should your household be resettled?	No 61%	No 63%	Yes 77%
Would resettlement affect your tenure and livelihoods?	Yes 58%	Yes 52%	Yes 70%
Do you have land in other areas where you could resettled to?	Yes 64%	Yes 66%	Yes 77%


Wewak Beachfront


Basis Mengar Settlement


Nuigo Settlement


Saksak Compound Settlement

- Resettlement would affect their tenure and livelihoods
- Determining factor in resettlement is tenure security than climate change risk

Recommendations

- More emphasis on case by case study of climate risk, vulnerability, adaptive capacity, tenure security and resettlement options
- More research on the perception of host communities to resettlement
- Explore past adaptation strategies in indigenous communities
- More research on rural urban linkages
- More collaboration between government and land owning groups
- Case by case study on community's adaptation strategies
- More collaboration between academia, research and policy

HUNG JURY: A CASE FOR NON-MOTORIZED TRANSPORT IN NAIROBI

Edna Odhiambo, Tutorial Fellow, University of Nairobi, School of Law

INTRODUCTION

Sustainable transport in rapidly growing cities like Nairobi is a key strategy towards addressing increasing greenhouse gas emissions (GHG). NMT is a low-carbon mobility option with co-benefits such as:

- Increasing accessibility
- Creating livelihoods
- Improved quality of life.

I argue that, despite the Kenyan Nationally Determined Contributions under the Paris Agreement making mention of low-carbon transport, regulatory regimes have not prioritized NMT as a fundamental component of sustainable mobility. I further assert that limited autonomy in African cites and lack of a localized approach towards transport policy will continue to hamper the shift to low-carbon mobility.

The aims of this study are to:

- Prioritize NMT as a climate mitigation strategy
- Improve existing NMT infrastructure
- Increase investment in NMT infrastructure
- Promote greater autonomy of counties in directing sustainable infrastructure

METHOD

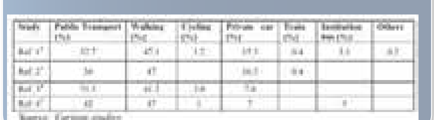
The study is based in Nairobi, the capital city of Kenya with four million inhabitants and largely depicts the realities of African megacities. The data was derived from two major road corridors (Juja and Jogoo) and one major street (Luthuli) located in the Central Business District. Primary methods such as observation, photographs and interviews with county officials were undertaken. Additionally, secondary data documented in the Nairobi NMT policy was used.

I restrict my analysis of desktop review to the transport, climate change, urban planning, land-use, and finance regimes in addition to sustainable transport literature in Africa.

RESULTS

NMT is considered insignificant in the reduction of GHG emissions from the transport sector whilst BRT and LRT have been prioritized as key to mitigating emissions.

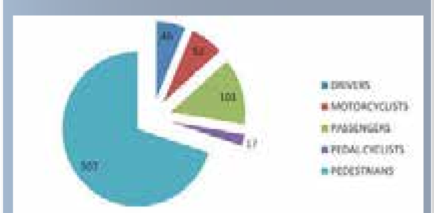
NMT is the most popular means of transport not by choice but for the low-income residents who cannot afford public transport and private vehicles.



Study	Public Transport (%)	Walking (%)	Cycling (%)	Private car (%)	Train (%)	[illegible] (%)	Others
Ref 1	[illegible]	[illegible]	1.2	[illegible]	0.4	1.1	[illegible]
Ref 2	36	47		[illegible]	0.4		
Ref 3	[illegible]	[illegible]	[illegible]	[illegible]			
Ref 4	42	47	1	7		3	

Source: Various studies

NMT users account for highest percentage of fatalities in road carnages making NMT the most unsafe means of transport.



NMT infrastructure is inadequate, and the existing infrastructure is in a dire state due to encroachment, lack of maintenance, competing road users, and vandalism.

Poorly maintained infrastructure:

Competing users:

Encroachment of NMT spaces

- With increased income, residents opt to purchase vehicles and according to the government, less users of NMT is an indicator of 'development'.
- Africa is on an unsustainable path focusing on improvements to connectivity through heavy infrastructure investments.
- Foreign input has influenced car ownership; an approach that has not worked well in developing cities where population densities are much higher than those in the West.
- Administrative and fiscal decentralization in Sub-Saharan cities remain weak, thus undermining the authority of local governments to advance sustainable infrastructure.

CONCLUSION AND RECOMMENDATIONS

My analysis reveals that NMT has been neglected as a climate mitigation strategy and there are conflicting approaches and attitudes from the county and national governments on integrated transport planning. I recommend the following proposals:

- Unpack development
- Optimization of bus rapid transits and light rails
- Localized Avoid Shift Improve (LASI)
- Behavioural change and creating awareness

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How perceptions of Climate Change and an identity as a *water-sensitive city* shift future resource patterns in the city of Cape Town

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Researching a *Moving Target – Cape Town's Water Crisis*

This research project entails a few approaches: an industrial ecology inquiry which seeks to quantify water flows in Cape Town and identify socio-technical intervention points; a political ecology lens which examines the governance systems which direct these flows; and a systems dynamics approach which examines scenarios at temporal levels. Researching a crisis faces the challenge of locating a moving target and discussing how rapid changes affect the emergence of systemic outcomes. This study presents visual description of the industrial ecology inquiry and offers a succinct narrative account of Cape Town's Water Crisis.

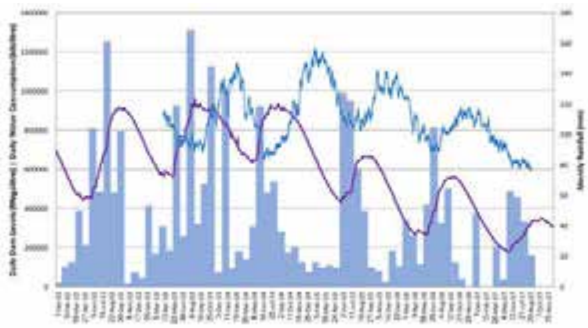

Figure 1 – Water levels at the six dams which service Cape Town (purple line), daily consumption (blue line) and monthly rainfall (blue bars). The highest dam levels are reached ±2 months following the highest rainfall months (June-August) and preceding the peak consumption months (December-February). Consumption data (even aggregate levels) are not advertised openly by the City.

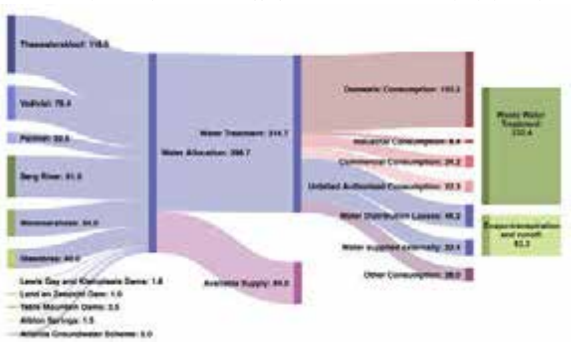

Figure 2 - Flows of Water through Cape Town pre-crisis (2014) – units are Million kilolitres. The largest consumers of water are the domestic sector, which has shown an immense reduction in daily consumption due to behavioural interventions, and water losses, which have been addressed through widespread repairs by the city. Source: (Currie et al. 2017)

Figure 3 - Photo of Theewaterskloof Dam 21 August 2017 – Dam Level 25.3% capacity

Becoming a Water Sensitive City

The city of Cape Town is currently experiencing its worst water crisis in a century. Since 2014, reduced rainfall and consistent consumption has resulted in lowered dam levels (Figure 1). **Population growth and lifestyle improvements are expected to add to the city's water demand, compounding a response to a short-term crisis with the need for long term planning**. Water restrictions were belatedly enacted in late 2016 aiming to bring consumption down from an annual peak of 1100 megalitres per day to 500 megalitres per day. As winter rainfall failed to deliver, more severe measures were implemented to attempt to reduce consumption below a stubborn 620 megalitres in September 2017. Such measures targeted **behavioural change** through widespread visual messaging throughout the city and on municipal bills, increased step tariffs, and fines for negligent users. **Technical measures** were also applied such as network repairs, reduction in network pressure to reduce leakage, and water-management devices for negligent users who have refused to lower their consumption despite the fines. Behaviour change may have been more effective in households where residents feel ownership over the resource, while technical interventions may have been more effective in commercial sectors. The city's short term augmentation plan aimed to produce 500 megalitres per day by early 2018, to match the 500 megalitre consumption target, a feat which would allay the crisis.

However, in January 2018 it became apparent that new augmentation would potentially only begin in June 2018, resulting in political declaration that ***Day Zero* – the day on which the municipality would shut down the water reticulation system across the city, excepting strategic or vulnerable areas, and implement a disaster management plan – was now a likely reality**. An online dashboard reveals the shifting dates of Day Zero (May 12, April 20, April 12, May 9, June 12), determined weekly as Cape Town conserved or consumed more water. The governing political party began a messaging campaign treating the water crisis as an enemy to be defeated **(#defeatdayzero)**, rather than a crisis to be ameliorated. The new level of panic this inspired may have led to the observed reduction in consumption to a daily 505 megalitres, while others identify the halt of agricultural use of municipal water as the key contributor to a delayed Day Zero. As of late February, the sense is that Day Zero will not occur in 2018, as rains and new augmentation give brief calm to the crisis. This brief respite may give the City of Cape Town time to prepare more appropriate disaster management systems (currently imagining to service a city of 4 million using 200 water distribution points).

A significant impact of the crisis is that resident and municipal **perceptions of Cape Town as a *water-scarce city* are likely to remain** for an extended period, and galvanise widespread water-sensitive practices, which will improve long term water security. Duly, we expect to see a number of **shifts in the way water infrastructure is developed** and the resource is distributed, namely (i) shifts from overconsumption behaviours to those based on **conservation of limited resource**, (ii) moving from single water source (surface water from mountain catchments) to **multiple water sources** (groundwater, desalination and wastewater reuse), (iii) shifts from centralised infrastructure systems to **decentralised systems**, (iv) water management solely as state responsibility **to multi-stakeholder responsibility**, (v) hard urban design to **eco-design which absorbs and captures water**. These shifts towards more diverse systems suggest greater resilience of the city's water infrastructure

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Initial estimates of anthropogenic heat emissions for the City of Durban

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1. INTRODUCTION

Cities in South Africa are key hotspots for regional emissions and climate change impacts including the urban heat island effect. Anthropogenic Heat (AH) emission is an important driver of warming in urban areas. The implementation of mitigation measures within urban sectors such as transport, industry, community and local government can have co-benefits for ameliorating the urban heat island effect and improving air quality. Characterizing atmospheric emissions is a first step for the generation of empirical evidence to identify policy measures that are most likely to simultaneously meet development needs that allow for societal wellbeing and economic growth whilst living within environmental thresholds.

This study provides an initial estimate of AH emissions for Durban for 2011. A top down emission model was developed to quantify the AH emissions using municipality energy consumption statistics.

2. METHODOLOGY

AH emissions were quantified from energy consumption data from the eThekwini (Durban) Greenhouse Gas Emission Inventory. AH emissions were quantified for the commercial, residential, industrial, traffic and human metabolic sectors. These sectors have been acknowledged to be the primary sources of AH emissions related to buildings, transport and population (Iamarino et al. 2012).

Equation 1 is proposed to quantify the anthropogenic heat emissions from fuel combustion ($Q_{(f)}$) and was adapted from Quah and Roth (2012). The equation was applied for the quantification of AH emissions from buildings and traffic.

$$Q_{(f)(h)} = \sum_k C_k (h) \times NHC_k / A \quad [\mathrm{W.m^{-2}}] \quad (1)$$

Where k indicates fuel type, and C_k is the mean hourly consumption of fuel type k at hour (h), NHC_k is the net heat of combustion factor for fuel type k and A is the size of the source emission area (m^2). The source emission area for traffic was the total surface area covered by roads. The source emission area for buildings was the surface area covered by urban land uses such as industrial, commercial and residential. The net heat of combustion factor is also known as the net calorific value and the information is acquired from the South Africa Department of Energy (DoE, 2010).

Equation 2 is proposed to quantify anthropogenic heat emissions from buildings due to electricity consumption ($Q_{B\,(e)}$) and is modified from Quah and Roth (2012).

$$Q_{B\,(e)\,(h)} = \sum E(h) / A \quad [\mathrm{W.m^{-2}}] \quad (2)$$

Where E is the mean electricity consumption at hour (h) in Watts, and A is the size of the source emission area (m^2). It is assumed that all energy consumed by all buildings is released into the environment after use (Iamarino et al. 2012).

AH emissions from human metabolism (Q_M) were quantified using the formulae adapted from Allen et al. (2011) indicated in Equation 3.

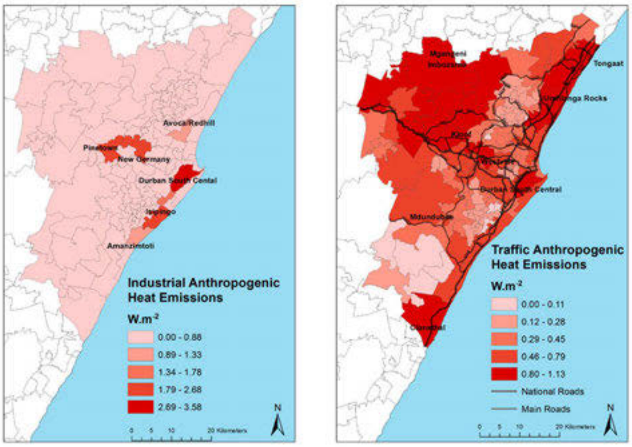
$$Q_M = \frac{PH_M}{A} \quad [\mathrm{W.m^{-2}}] \quad (3)$$

Where the human population is indicated by P. The area of the domain is A in m^2 and the metabolic heat rate is indicated by H_M which is acquired from Sailor et al. (2015). Human population data were collected from Statistics South Africa.

Spatial disaggregation of the AH emissions were achieved by adapting the methodology of Lee et al. (2009) indicated in Equation 4.

$$Q_i = \sum(Q_i . LUF_i) \quad (4)$$

Where Q_i is the mean AH emission, LUF is the land use area fraction of sectors i including residential, industrial and industrial land uses. The South African national land cover data for 2013 to 2014 is used to identify sectoral land uses. The road data was provided by eThekwini Municipality.



a b

Figure 1: Anthropogenic heat emissions of Durban for a. traffic and b. industry

3. Results and Discussion

The total hourly averaged AH emission for Durban is 77 W.m^{-2} for 2011. The primary contributors to the total AH emission is traffic and industry. The spatial distribution of the AH emissions from these sectors are indicated in Figure 1. As indicated in Figure 2, total AH emissions are composed by 56.3% traffic, 31.1% industry, 10.7% commercial and the remainder by human metabolism and residential.

The objective to compiling AH emission maps were to identify key emission hotspots. The spatial distribution of the total AH emissions are indicated in Figure 3. The maximum emission intensity ranges between 3.25 and 4.56 W.m^{-2} with areas of the highest emission intensity located in the Durban South region which is an industrial agglomeration in proximity to the main roads that occur in the city. Other areas with relatively greater AH emissions also were found to be located in largely industrial areas with a high surface area of roads. These areas include Isipingo, Tongaat, Cato Ridge/Hammarsdale and Pinetown. Additionally the areas of Durban North and Umhlanga Rocks are major transport regions which are key commercial and light industrial centres.

Efforts to reduce anthropogenic heat emissions, will contribute to urban heat island mitigation and the road transport and industrial sector should be prioritised.

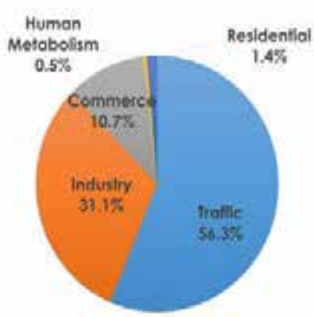


Figure 2: Sectoral contributions to the anthropogenic heat emissions of Durban.

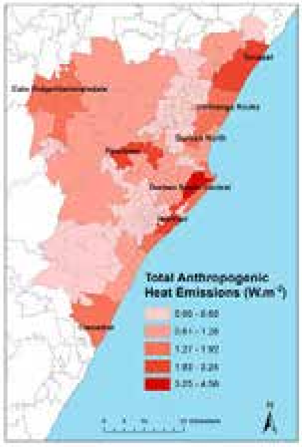


Figure 3: Total anthropogenic heat emissions of Durban .

4. Conclusion

This is one of the first studies to quantify AH emissions for a South African city. AH emissions are essential factors in city-scale atmospheric circulation and surface temperature and as such this type of analysis ultimately will improve our ability to quantify these emissions in South African cities at a temporal and spatial scale that can support urban climate assessments. Future work will include the comparison of the AH emission estimates quantified in this study to other modelled estimates for Durban completed at a global scale.

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The following organisations are acknowledged as data providers:

eThekwini Municipality for the provision of energy and road data
South African Department of Environmental Affairs for the provision of the national land cover data
Statistics South Africa for the provision of human population statistics from the 2011 Census.

Plenary Summaries
Parallel sessions summaries
Conference Posters
References
Annexes

Local Action Plan for Disaster Risk Reduction in Santa Maria River Watershed

Alberto Pascual Q

FUNDACIÓN CoMunidad®

CONTEXT

Santa Maria River Watershed

The Santa Maria River Watershed is a priority for Panama because it provides water to more than 200,000 people in three provinces: Veraguas, Coclé, Herrera and one indigenous region Ngäbe-Buglé, include a total of twelve municipalities in the country.

Upstream-Downstream

MANAGEMENT

The priorities are actions in the upper, middle and lower part and linked:
1. Safeguard Natural Buffers to Enhance Ecosystems' Protective Functions
2. Increase Infrastructure Resilience
3. Ensure Effective Disaster Response

Adaption and Mitigation

Upper Part
- Santa Fe National Park
- Forested Reserve La Yeguada

Lower Part
- Sarigua National Park
- Mangrove Cenegon
- Swamp The Macanas

CHALLENGE

Climate Change has affected climatic variability, generating drought and intensifying flooding in the settlements located at the margins of the watershed and the cities of the interior of the country grew in population and infrastructures. In the Santa Maria Watershed, they settled development pole, for this reason increasing the water demand for domestic, industrial and agricultural use. This rapid growth has significantly increased pressure on the natural resources of the watershed.

We work with all governmental institutions working in the watershed, policy decision-makers, users of the watershed and representatives of local populations, the project has the validation of all key stakeholders

African urban development pathways in the context of 1.5 and 2 degrees

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Introduction

- There is increasing evidence that climate change has significant impacts on cities, both on the physical environment and on city residents. On the African continent, cities are units of particular risk as rural to urban migration increases, and urban population growth outpaces service delivery, housing and infrastructure provision
- There has been little detailed work on understanding the timing and magnitude of these impacts; long-term development plans and visions seldom consider climate change impacts in detail
- While climate scientists have modelled what a 1.5 and 2 degree increase in global average temperature is likely to look like, there has not been much work on downscaling these climate change projections to the city scale
- However, cities need to understand what a 1.5 or 2 degree temperature increase might look like in their specific case, as this could translate to greater (or lesser) temperature increases at the specific city scale
- Thus, better understanding of the extent of temperature increases at the city scale could help prioritize adaptation responses by cities
- This understanding should be better integrated in city level development planning in order to transition to more resilient trajectories sooner rather than later, and avoid the problems of lock-in to unsustainable urban development trajectories

The case of Dar es Salaam

Research suggests that in Dar es Salaam city actors are heavily focused upon urban flooding. While this constitutes an important urban risk, it is potentially inaccurately framed as a climate change risk. Projections of rainfall changes are highly uncertain and are strongly dominated by natural variability prior to mid-century. By contrast, climate projections for Dar reveal that the strongest climate signal in this location is for future temperature increase (refer to Table 1 for details). Warming of 1.5 °C globally could mean up to 2 °C locally in Dar, and up to a 400% increase in hot nights annually. In fact, regardless of the uncertainty in the projections, an impactful increase in hot nights is observed for the city.

Among the potential impacts of rising temperatures are those on health and well-being outcomes: heat is likely to become an important aggravator of many existing health risks. Some examples of the impacts of an increase in temperature on health are: increases in heat related illnesses (e.g. fatal heat stroke, dehydration); increases in infectious diseases (e.g. cholera, salmonella); increases in vector-borne diseases (e.g. dengue, possibly malaria); increased morbidity and mortality related to non-communicable diseases (e.g. cardiovascular disease, cerebrovascular disease, respiratory disease); increased mental illness and decreased wellbeing. Examples of impacts on well-being consist of decreases in work productivity, or potential increases in crime and violence.

Figure A. Local residents find shade in the Vingunguti informal settlement of Dar es Salaam, where poor housing structures and a lack of trees and planned shading lead to high exposure to heat .

Figure B. Many residents in Dar have limited access to, and cannot afford, adequate health care such as is offered by private health care facilities (pictured above).

Global warming	Warming in Dar es Salaam	Hot days	Hot nights
1.5 °C	A global warming of 1.5 °C translates to an increase of between 0.36 - 2.0 °C in Dar	Increase in hot days from a baseline of 40/year to between 50 - 100/year	Increase from a baseline of 40/year to between 60 - 160/year
2 °C	Between 0.8C - 2.5 °C	Increase from a baseline of 40/year to between 60 - 150/year	Increase from a baseline of 40/year to between 75 - 200/year

Table 1. Climate projections for temperature for Dar es Salaam under global warming scenarios of 1.5 and 2 °C respectively. Hot days in Dar es Salaam are defined as days where the hottest day-time temperature is above the 90th percentile (i.e. more than 34.6 °C) and hot nights are defined as nights where the lowest night-time temperature is above the 90th percentile (i.e. more than 24.5 °C).

Research demonstrates that city actors (e.g. local and higher levels of government, the private, public and NGO health sectors) are currently under-privileging responses to the potential impacts of temperature increases. At the same time, residents have high current vulnerability to a wide range of potential negative health and well-being impacts from heat, mediated through high exposure and sensitivity to heat coupled with low capacity to adapt (Figures A and B).

Numerous policy and practice interventions at multiple scales are required that could increase the resilience of local Dar communities to the impacts of rising temperatures. Some examples consist of: further research/monitoring (e.g. the development of appropriate heat thresholds, mapping of high-risk areas of the city vulnerable to heat impacts, increased disease surveillance and data collection); spatial/building planning and design strategies (e.g. public access to potable water, increased availability and access to cool spaces, city greening campaigns, green or white roofs); health sector strategies (e.g. capacity-building of health sector staff, heat-focused examination procedures, keeping health facilities cool).

Take-home messages

- 1.5 and 2 degree increases in global temperature could manifest at the city scale as either greater or lesser temperature increases
- Now is the time to shift city development trajectories to cope with future impacts, as lock-in makes path-switching in the future harder
- There is a lack of exploration around how current city development trajectories are going to be impacted by future climate impacts, and many cities still do not have the data and understanding of the impacts of temperature and precipitation changes on many sectors
- In some cases the time horizons of decision-making are out of step with the time horizons of climate change impacts e.g. in the case of preparing for extreme drought situations (such as the City of Cape Town is currently experiencing)
- In some cases decision-making does not yet consider potential future climate change impacts e.g. the impacts of heat on health, as the case of Dar highlights
    - Furthermore, there is a great lack of understanding and research still on what consequences, exactly, a rise on temperature will have on health outcomes e.g. there is a lack of attribution data
- Nonlinear response to climate variables requires more understanding of the thresholds at which impacts become difficult to manage
    - e.g.. Malaria has a non-linear response to temperature: an increase in temperature is likely to result in an increase in Malaria, but after certain temperature thresholds are reached, Malaria can decrease

Urban Africa Risk Knowledge
UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD
CSAG CLIMATE SYSTEM ANALYSIS GROUP
ACDI African Climate & Development Initiative
UKaid
Department for International Development
ESRC Economic & Social Research Council

ENVIRONMENT, CLIMATE CHANGE AND HEALTH IN A URBAN PLANNING: A MODELING APPROACH FOR NEW YORK CITY

Fabrice Casciani (EDF - presenting)
Dr D. Jack (Department of Environmental Health Sciences, Columbia University.), Dr A. Pasanisi (EIFER – EDF), Dr S. Thiriot (EDF), C. Payre (EIFER)
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ENVIRONMENT, CLIMATE AND HEALTH IN URBAN PROJECTS

Main drivers to be included in urban planning

- Mobility
- Energy consumption and production
- Urban morphology
- Land use
- Climate and environment
- Health

Main outputs

- Quality of life
- Environmental quality
- CO_2
- Cost of operation
- Attractiveness

CASE STUDY

New York City (southern Manhattan)

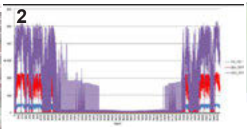
- Evaluate the impact of energy production and traffic
- Scenarios based on urban policies for mobility and energy
- A focus on air quality

Collaboration between: Columbia University - Mailman School of Public Health, EDF (France), and EIFER (Germany) with the participation of the Ecole Centrale de Lyon

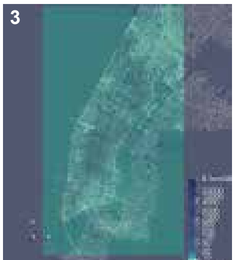
1

Emission of energy systems in Lower Manhattan
Large red dots: generating stations
Smaller dots: residential boilers

2



3



O_3 concentration
03/15/2010 5PM (ug/m^3)
for reference

1. Urban planning

Definition of the current situation | Scenarios of city's evolution: buildings, transport network, and energy production system

2. Emissions of the systems

Determination of the emissions of pollutants for each system (energy production units, street)

3. Dispersion

Modelling the dispersion of pollutants in the city, including emissions coming from other sources in the city
(with software SIRANE©)

4. Assessment of impacts *(ongoing)*

Health: Mortality and morbidity, with a focus on vulnerable people | Environmental impacts: climate change, biodiversity

SOLUTION

A method, for diagnostic and prospective analysis

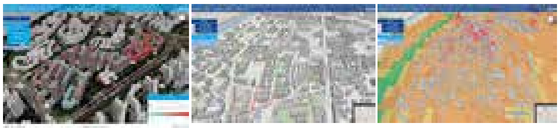
- Prospective scenarios
- Simulations
- Modular, replicable and adaptable to client's needs

For all actors

- Stakeholders, citizens, scientists, etc.
- Possibility to test scenarios and compare consequences

WHAT NEXT?

- Health impact assessment
- Include climate change scenarios
- Adding other environmental stressors (noise, urban heat islands)
- A decision support tool with a systemic view



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Seasonal-based analysis of diurnal cycles of urban climatological characteristics using multi-site measurements

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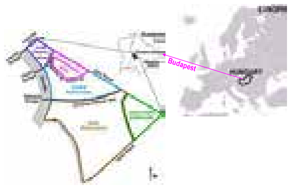
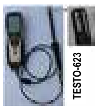
ABSTRACT

The concentrated presence and activities of people substantially modify the natural environment: (i) Emitted air pollutants may result in urban smog events due to the lack of efficient air circulation. (ii) The radiation characteristics of artificial covers lead to an enhanced heat emission, and thus, the urban heat island effect. (iii) The vertical extent and density of buildings modify the local circulation. All these fundamentally influence the everyday lives of city dwellers resulting in several health issues and implying the necessity for complex urban planning. In order to address the possible raising issues, and cope with climate change impacts in cities, local governments evidently have special roles.

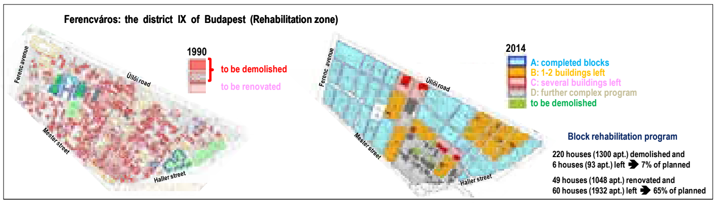
For instance, the local government of the southern central located district (district IX) of Budapest, Hungary, has already initiated and completed several urban renewal programs since the 1990s with the ultimate goal of improving the urban environment for the local city dwellers. For this purpose, green areas with vegetation cover were increased within the district, especially, in the so-called rehabilitation area where the inner parts of old house blocks were completely demolished in order to create common green areas inside the renovated and newly built blocks. The presented research focuses on this renewed, renovated part of the district where we started a multi-site climatological measuring program in 2015. The measuring sites are located along a pre-defined walking path with different characteristical points of the district, such as green parks, narrow streets, paved squares, and wider roads with busy city traffic. In order to analyse the urban climatological characteristics, temperature and humidity measurements are compared to the hourly recorded data of the Budapest synoptic station located in the southeastern suburb area of the city. On the basis of the first year's experiences of the measurements, we extended the measuring period for at least 24 hours (and extended to 3 days during summer measuring campaigns), thus, the full diurnal cycles of air temperature and humidity can be analysed from recorded continuous measurements. The local government can use this new climate information to monitor the urban environment, and further adapt to future climatic change.

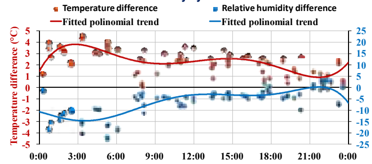


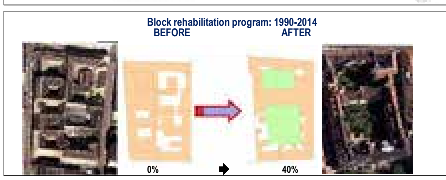


– Measuring air temperature and relative humidity along a walking path consisting 23 measuring points (for the whole path 2-2.5 hr is needed)
– Involvement of BSc/MSc-level students
– Start of the measurement program: 20.03.2015
24-hr continuous measurements started: 03.06.2016
Altogether 65 days with measurements (>700 hrs)

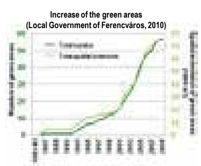
Public transportation centre (buses, trams)
Traffic (10 min): 215 + 104
Buildings height: ~30 m
Vegetation: ~10%

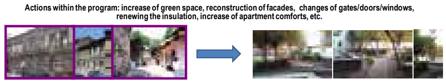




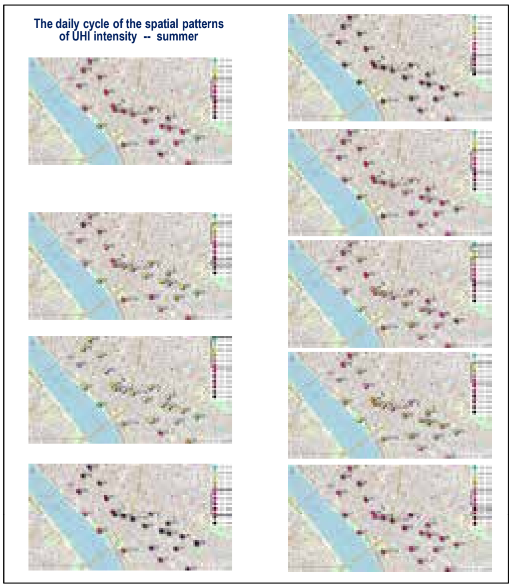


Actions within the program: increase of green space, reconstruction of facades, changes of gates/doors/windows, renewing the insulation, increase of apartment comforts, etc.



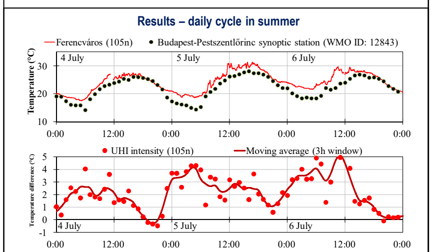


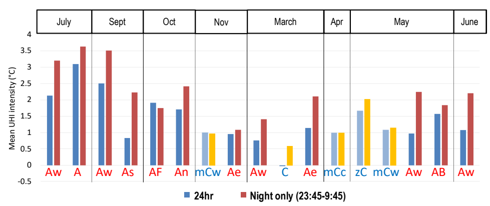
Rehabilitation program in the middle district region:
– Continuous program from the late 1980s
– Block renovation: introducing inner green space surrounded by renovated house blocks



Measuring point no. 105n - passage
Buildings height: ~20 m
Vegetation: ~60%

Synoptic situation during the summer campaign in 2016:
anticyclonic circulation over the Carpathian basin
-- SLP > 1020 hPa (indicated by M)
-- clear sky



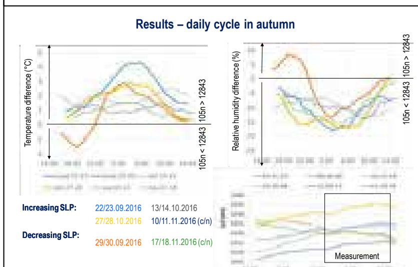


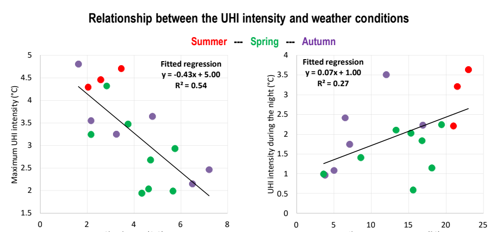
Summary

UHI dependence on macrosynoptic situation (Péczely types) in different months

A: anticyclonic
C: cyclonic

Measurements from station 105n





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PIK Potsdam Institute for Climate Impact Research

Paisajes Sostenibles para la Amazonia

Regionalization of urban food systems and its climate benefits

Global urban food transport emission would reduce by half or more by regionalization of food systems. To enable regionalized food systems would additionally require closing yield gaps, food waste reduction, and a shift towards diversified farming.

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INTRODUCTION

A global challenge is to sustainably nourish the growing population. By 2050 the share of urban population may grow up to 70%. Thus, sustainable urban food systems based on regionalization is a potential solution to address the global challenge. Regionalization of the food systems also contribute to lower carbon emissions from food transport by reducing food-miles. However, this requires an understanding of interdependency between hinterlands and urban areas in food production and consumption, which we consider as urban foodshed.

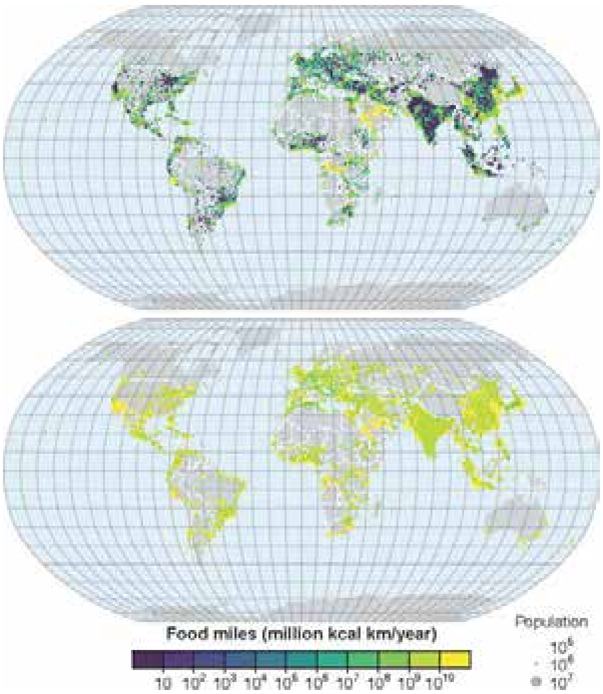

Fig. 1 Net food distance also called as food-miles under regionalized (top) and globalized (bottom) food systems in 2010. The bubble's size depicts UAU's population. Food-miles are estimated by summing up the product of distance and food amount transported from each arbitrary or peripheral area (pixel) to fulfill the UAU 's food demand. Under regionalized food systems , food-miles are generally larger for big UAUs than for small UAUs. The food-miles are mostly greater under globalized than regionalized systems.

METHOD AND DATA

We analyze foodshed and food-miles of 7000 urban administrative units (UAUs) globally and estimate carbon emissions related to food transport for 2010 by applying two methods:

i. regionalized food systems where the food demands are met from peripheral areas
ii. extreme globalized food systems where UAUs' food demands are met from arbitrary sites

Food systems	Regionalized	Globalized
Baseline	0.150	1.872
Food waste	0.103	1.748
Yield gap	0.089	1.869
Food waste & Yield gap	0.061	1.745
Food groups	0.287	1.738

Tab. 1 Emissions due to urban food transport (GT CO_2/yr) under regionalized and globalized food systems in 2010 considering: i) demand and production of total calories (baseline), ii) halving food waste (food waste), iii) closing yield gaps by 75% of potential yields (yield gap), iv) combination of (ii) and (ii) (food waste & yield gap), v) demand and production of the eight major food product categories (food groups). In 2010, the urban food transport emissions were 0.34 GT CO_2/yr.

RESULTS

Regionalized urban food systems would halve the current carbon emissions from food transport. However, for this regionalization to occur would require restructuring of the current food system, especially through diversifying cropping to produce a variety of products and shifting diets towards more local and season products. Food miles and associated transport emissions are lower for most UAUs under regionalized rather than under globalized systems. Food waste reduction and closing yield gaps would also result in lower estimates.

By 2050, the emissions due to urban food transport may respectively increase to 0.25–0.92 GT CO_2/yr and 2.20–3.00 GT CO_2/yr under regionalized and globalized food systems. The transport emissions are higher under scenarios that only consider increase in food consumption, compared to ones that account for food demand management, such as reducing food waste and improving feed conversion efficiencies.

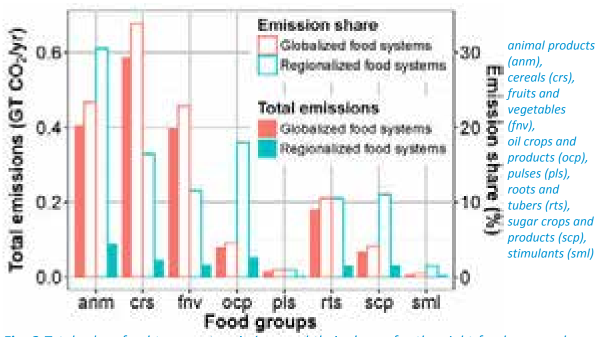

Fig. 2 Total urban food transport emissions and their shares for the eight food groups, based on demand in 2010 and modeled globalized or regionalized food systems.

DISCUSSION

To limit global warming to well below 2°C as agreed at Paris, countries need to follow a deep decarbonization pathway that decreases the global emissions to 5 GT CO_2/yr by 2050. Regionalized food systems would be an important component of such decarbonization pathway as regionalization has the potential to reduce food transport emissions. Conversely, increasing globalization would increase the emissions considerably. Regionalized food systems also reconnect producers and consumers, leading to responsible production and consumption, strengthening regional economies, and closing nutrient loops.

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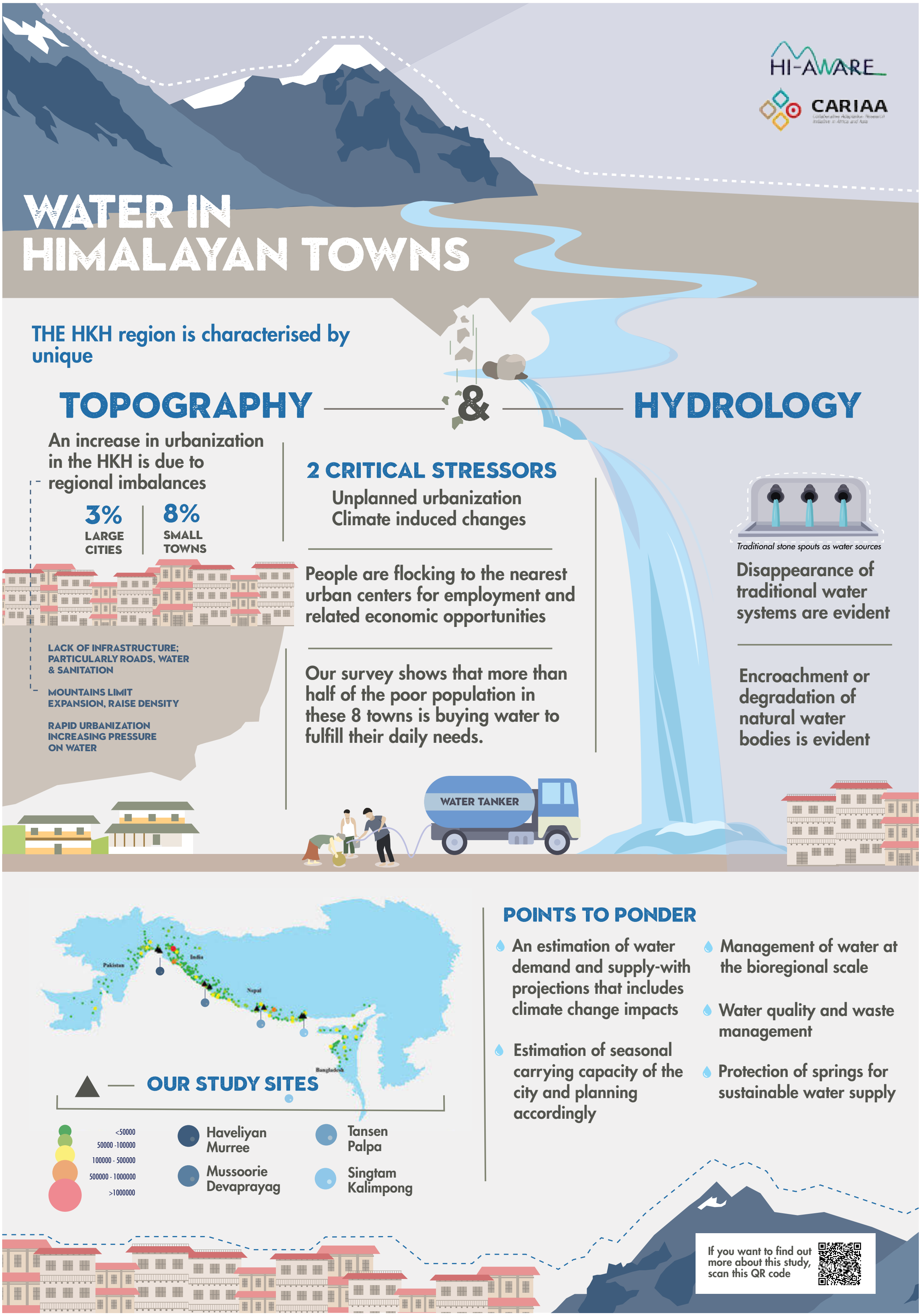
HI-AWARE
CARIAA
Collaborative Adaptation Research Initiative in Africa and Asia
WATER IN HIMALAYAN TOWNS
THE HKH region is characterised by unique
TOPOGRAPHY
&
HYDROLOGY
An increase in urbanization in the HKH is due to regional imbalances
3% LARGE CITIES
8% SMALL TOWNS
LACK OF INFRASTRUCTURE; PARTICULARLY ROADS, WATER & SANITATION
MOUNTAINS LIMIT EXPANSION, RAISE DENSITY
RAPID URBANIZATION INCREASING PRESSURE ON WATER
2 CRITICAL STRESSORS
Unplanned urbanization
Climate induced changes
People are flocking to the nearest urban centers for employment and related economic opportunities
Our survey shows that more than half of the poor population in these 8 towns is buying water to fulfill their daily needs.
WATER TANKER
Traditional stone spouts as water sources
Disappearance of traditional water systems are evident
Encroachment or degradation of natural water bodies is evident
Pakistan
India
Nepal
Bangladesh
OUR STUDY SITES
<50000
50000 -100000
100000 - 500000
500000 - 1000000
>1000000
Haveliyan Murree
Mussoorie Devaprayag
Tansen Palpa
Singtam Kalimpong
POINTS TO PONDER
An estimation of water demand and supply-with projections that includes climate change impacts
Estimation of seasonal carrying capacity of the city and planning accordingly
Management of water at the bioregional scale
Water quality and waste management
Protection of springs for sustainable water supply
If you want to find out more about this study, scan this QR code

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Mainstreaming Climate Change Adaptation in Urban Planning: Proposed Synopsis for Oman

Elnazir Ramadan ,Sultan Qaboos University ,Oman

جامعة السلطان قابوس
Sultan Qaboos University

BACKGROUND

The effects of climate change witnessed especially the rise of temperature, frequency and intensity of extreme phenomena, which have been taking place in the past few years, tend to deepen and therefore they have become a matter of interest to governments and the international community. The results of scientific research clearly indicate that phenomena caused by climate change are a threat to the social and economic development of many countries in the world, including Sultanate of Oman. Sultanate of Oman encompasses about 310 thousand square kilometers geographical area consisting of three major regions: coastal zones (3%) which serves as main agricultural areas; mountain ranges (15%) where peaks can reach up to 3,075 meters; and interior plains (82%) which consists of low-elevation desert areas

Observed and foreseen climate changes have a very negative impacts on urban areas, tourism (coastal zones) and infrastructure in Sultanate of Oman. Apart from the obvious impact of a sea level rise, negative phenomena include most of all, an increased frequency and intensity of extreme events. With climate change, low-lying coastal areas are vulnerable to sea level rise and storm surges associated with extreme weather events. In addition, flash flooding magnitude and frequency could increase in the future. Oman's development plans for urban areas and infrastructure should be re-evaluated to account for these risks.

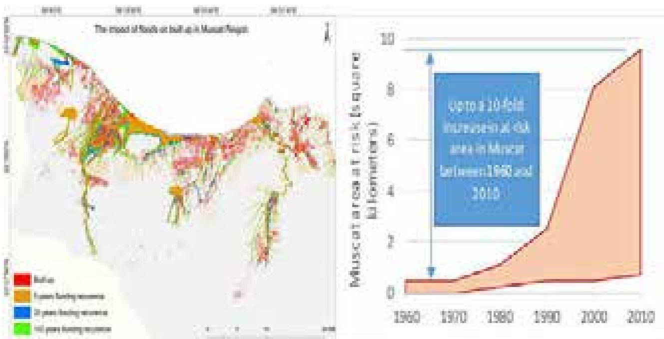
PURPOSE

The study concentrates on the vulnerability of urban environments in the Sultanate of Oman to primary and secondary impacts of climate change. Cities and their population are increasing in a high rate in Oman. Climate change impacts reduction has drawn the attention of both national and international authorities. Serious efforts on mitigation side are going on at the international level. Adaptation to climate change is similarly important due to the high numbers of population living in vulnerable cities of developing nations. Climate change rises the frequency of extreme events as well as brings changes in temperature and rainfall intensities. This puts more pressures on infrastructures planning institutions, and creates a need for adaptation on city level to both present and expected climate change events. Therefore, it highly important to incorporate adaptation agenda in the frameworks of cities administrations

MATERIALS AND METHODS

The Study used existing urban land cover maps and flooding risk maps and employed GIS analysis to identify the amount of urban expansion in flood prone zones in Oman. This study shows that even without climate change the majority of the urban centers in Oman are exposed to the risk of flooding due to their geographical context. attempt in Oman to integrate climate change adaptation into urban development polices and look for challenges that faces this integration. Given the above facts, Sultanate of Oman is highly aware that climate change is a multidimensional and complex challenge which poses serious environmental and socio-economic consequences and represent key threat facing future generations.

Urban expansion in Omani cities has typically not accounted well for even historical risks of flooding, much less the greater flooding risks that will accompany climate change. Today, the impact of floods in the built up area of Sohar Wilayat, Saham, Al-Khaburah, As-Suwayq and Muscat can wreak havoc on transportation and power systems. These risks have increased substantially over the past 50 years. Currently in Muscat, for example, built up areas are situated in close proximity to recurring flooding episodes (left plot below). This pattern has yielded a nearly 10-fold increase in the urban area at-risk across all sectors of the economy (right plot below



ADAPTATION STRATEGY

It aimed at covering all provinces of entire country with an effective system of spatial planning to ensure an appropriate and sustainable use of areas, taking into account information technology (IT) tools such as Geoportal. In addition, in the construction sector, it will be necessary to take into account a potential impact of extreme events caused by climate change. With regard to coastal areas vulnerability, primary objective should be to strengthen monitoring of the flood protection system and prevention of degradation of shorelines as well as the development of coastal zone monitoring. Following are some of adaptation strategies that can be considered toward sustainable development

- Updating flash flooding map
- Develop an early flood warning system
- Support ongoing collection and analysis of sea level rise, storm surge, and tidal data by existing institutions
- Consider any possible legal issues associated with the protection of coastal zone (buffer)
- Enact planning laws that prevent new-construction in vulnerable zones
- Review national building and design codes to promote resiliency of communities, to mitigate storm and flood damage.

CONCLUSIONS

Effective adaptive responses rely on good knowledge of anticipated changes. Therefore, a high priority for research must be the generation of more reliable projections of likely climatic changes at the regional and local levels. Profound Climate policy is firmly a cross-sectoral and whole-of-government activity; however, such "mainstreaming" or climate policy integration has yet to be developed sufficiently in policy practice in case of Sultanate of Oman. Climate change in both its mitigation and adaptation dimensions considered as the matter . To cope with uncertainty in projected climate but the certainty of ongoing technological, cultural and institutional change, there is a need to use an active adaptive management approach for adaptation. This requires directed change in management or policy that is monitored, analyzed iteratively and effectively adjust to ongoing climate changes

CITIES 2018 · CONFERENCE IPCC

Are European Cities Prepared for Climate Change? Evidence and Gaps from Local Climate Action Plans in 885 Cities in EU-28

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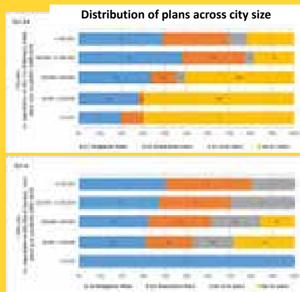
Second Assessment of Local Climate Action Plans (LCAPs) in 885 Urban Audit core cities, EU-28, January 2016

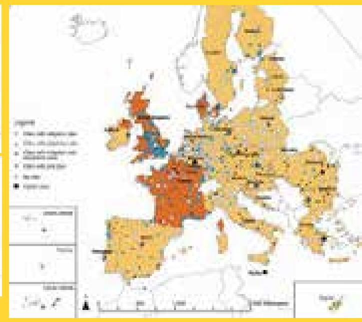
AIM: Develop a typology of LCAPs

	Integration with or placement within the existing local policy documents					
Spatial dimension	Comprehensive and stand-alone (A)	Main-streamed and inclusive (B)	Partial sources and sectoral impacts (C)	Operational (D)	Related (E)	Areal (F)
Autonomous (1)	A-1 Autonomous LCAPs	B – Climate action in sustainability plan, resilience plan, development/ master plan, core strategy	C – LCAP addressing particular sectors (e.g. energy) or particular impacts (e.g. heat, flooding)	D – LCAP for parts of municipal operations, such as universities, schools, etc., e.g. carbon management plan in the UK	E – Plan with relevance to the climate issue, e.g. municipal emergency plan, disaster risk reduction plan, civil protection plan	F – LCAP for parts of a city/ urban area.
National regulation (2)	A-2 Legally required LCAP					
Internationally induced (3)	A-3 International climate networks, such as Covenant of Mayors, Compact of Mayors, e.g. SEAP, SECAP					

Goes along with a substantial degree of harmonization, following national & organization's guidelines

AIM: Document state of adaptation and mitigation planning, e.g. across city size, country and region





Evidence and Gaps - Analysis 2016

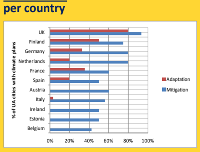
- Type A-Plans: **66% of cities have mitigation (MITI) LCAP, 25% adaptation (ADA) LCAP, 16% ADA+MITI joint LCAP, 30% without Type-A LCAP. Most plans in DK, GER, FI**
- About 70% of the cities >1 mio. inhabitants have A1 or A2 MITI or ADA plan. **National legislation, city size and international networks influence the development of LCAPs**
- ADA+MITI integration mostly in countries with **national climate legislation; DK, FR, SL & UK**
- **Difference between non/obligatory LCAPs: *2 for MITI, *5 for ADA + "threshold effect"**

Number of mitigation, adaptation and joint plans of Type A1, A2, and A3 across EU-28

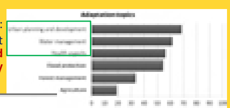
	UA Cities	Mitigation plans		Adaptation plans		Joint plans		No plans	
	#	#	%	#	%	#	%	#	%
A1 - 24 countries	612	223	36.4	69	11.3	18	2.9	370	60.5
A2 - 4 countries	273	174	63.7	150	54.9	121	44.3	88	32.2
A3, in cities w/o A1 or A2 – 28 countries	885	188	21.2	3	0.3	3	0.3	697	78.6
A3, in cities with A1 or A2 – 28 countries	885	343	38.8	103	11.6	10	1.1	552	62.4
All cities with A1, A2 or A3	**885**	**585**	**66.1**	**222**	**25.1**	**142**	**16.0**	**263**	**29.7**

First Assessment of LCAPs in 200 Urban Audit core cities, EU-11, January 2013

AIMS: Document state of ADA + MITI planning; Reveal insights of content & Barriers of LCAPs



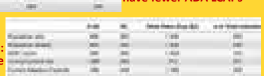
Distribution of cities with LCAP per country



ADA **LCAP Sectors**: Urban planning largest category; **ADA organized more holistically**

MITI **LCAP Sectors**: Energy & Renewables; **MITI rather sectorally organized**

"Barriers" ADA: Cities at the coast & of high future impacts have fewer ADA LCAPs



Barrier MITI: Unemployment rate

Methods: Desktop research & Content analysis

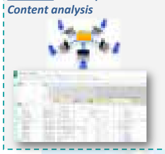
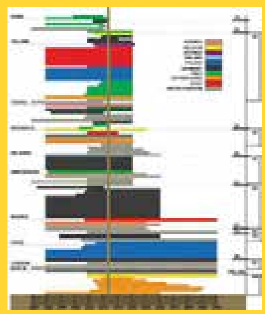


Figure: Urban Audit (UA) core cities (entire sample) & resident pop. (1/1/2012). UA cities are a balanced and regionally representative sample, i.e. geographically dispersed and varying in size per country, incl. cities <50,000 inhabitants. Source: Eurostat (2015)

AIMS: Calculate carbon reduction potential; Estimate contribution towards 2°C



„Carbon tree"
- Line: 1 emission target/plan/city
- Color: Country of plan
- X-axis: Time line from base year to target year of reduction target; „stem" = 2012
- Y-axis: height of reduction target (%)

Carbon reduction potential

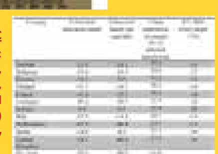
→ Found: 20% reduction by 2020 (EU goal) adopted by many

→ Needed: „healthy", pyramid shaped tree

Contribution towards 2°C

→ EU-11 Commitment: 37% emission reduction, exceeding the 20% target, but missing the 2°C goal (i.e. ~80% reduction)

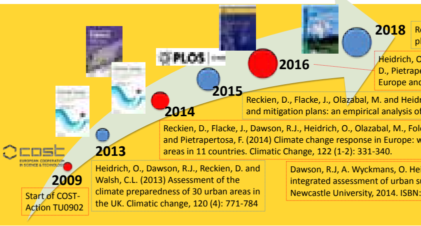
→ There is huge variability



Evidence and Gaps - Analysis 2013

- **65% of cities have mitigation (MITI) LCAP, 29% adaptation (ADA) LCAP, 22% ADA+MITI joint LCAP, 35% without LCAP**
- **LCAPs correlate with size & economic strength of a city; cities at the coast & of high future impacts have less LCAPs**
- **EU-11 Commitment: 37% emission reduction, exceeding the 20% target, but missing the 2°C goal**
- **No evidence on implementation success and ADA+MITI effectiveness or achievements yet**

Scientific impact and the way forward



Start of COST-Action TU0902

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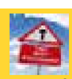
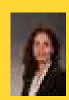


Analysis 2018

- Assessment of B, C, D and E-Type LCAPs in the 885 UA Cities in EU-28
- Content analysis of A1- and A2-Type LCAPs, re:
  - New mitigation targets,
  - Adaptation monitoring and effectiveness,
  - Use of green and blue infrastructure,
  - Health implications, a.o.



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Why Cities May Be the Most Appropriate Level of Government at Which to Pursue Climate Science–Policy Partnerships

Garrett Ward Richards, University of Saskatchewan

Abstract

The urgency of climate change demands that we think strategically about the uptake of scientific knowledge by policy makers and, more broadly, the very relationship between science and public policy. Literature from the fields of political science and STS (science, technology, and society) tells us scientific knowledge is unlikely to influence policy decisions, at least not in any direct or immediate way, unless policy makers are involved in producing or requesting that knowledge. Consequently, science–policy partnerships (SPPs), which bring together researchers and policy makers (usually civil servants rather than politicians) for direct and regular co-productive exchanges, are a possible way forward, potentially improving mechanisms of uptake for evidence-informed policy. My research uses a social scientific and qualitative lens to examine existing cases of climate SPPs in Canada (with a particular focus on the province of British Columbia), including research organizations such as the Pacific Climate Impacts Consortium (PCIC) and the Pacific Institute for Climate Solutions (PICS) as participants. Findings demonstrate the possible benefits of SPPs for both science and policy, the factors that must be considered and understood in order to establish new SPPs, and the institutional design principles that may improve the effectiveness of SPPs. Most importantly, my research suggests that SPPs may be easiest to establish and most productive at the municipal or local level of government (i.e. rather than the regional or national level), which implicates cities as a crucial site for co-productive action on climate change.

What Is a Science–Policy Partnership?

"A science–policy partnerships (SPP) is any lasting, regular, collegial interaction between a specific ministry, branch, or agency within government and a specific department, research group, or institute within academia. They can be as simple as **informal monthly meetings** to exchange information about current policy priorities and contemporary research in a given field. For the sake of simplicity and focus, this definition sees university-based groups as the likely research partner, but similar arrangements may be possible with research organizations outside of academia (although think tanks and private research groups may bring their own complications)." (Richards 2017, p. 167)

Examples of SPPs for Climate Change → Pacific Institute for Climate Solutions + BC Provincial Government; Pacific Climate Impacts Consortium + BC Municipalities

SPPs are particularly important because they challenge how we think about the policy process. Academics tend to assume (even if just on an intuitive level) that policymakers will respond to their findings and recommendations. While policymakers do tend to agree that academic research is important, it very rarely has a direct and noticeable influence on policy decisions (Weiss 1977). An effective SPP accepts the reality that scientists and policymakers have **different priorities**. Instead, it focuses on cultivating the science–policy relationship itself, with an emphasis on learning, feedback, joint projects, and sharing resources (Richards 2017).

My Research: Climate SPP Case Studies in British Columbia

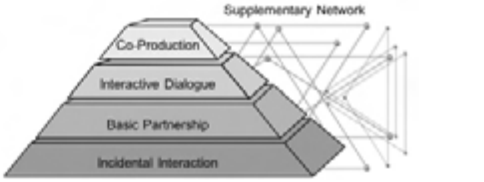
Question - What explains the success or failure of a climate SPP?

Hypothesis - Institutional design characteristics are an important factor.

Methods - Elite interviews with science and policy partners from cases of climate SPPs at each level of government.

Key findings include…

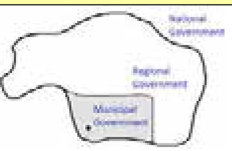
- While institutional design characteristics (e.g. informality, feedback, facilitation) can contribute to the success of a SPP to some degree, they are not nearly as important as **external factors like political will**.
- Climate SPPs can be classified into a framework that I call the Science–Policy Relationship Hierarchy (SPRHi) model. The science and policy partners must first form a basic partnership based on trust and credibility before they can engage in a more interactive dialogue. From there, moving to the ideal of true **co-production** (i.e. mutual influence) without violating the initial foundation of trust requires particularly high political interest in climate change or the involvement of particularly proficient individuals.



- The only case to come close to the co-productive ideal was the municipal-level case between the Pacific Climate Impacts Consortium (PCIC) and various cities in BC.
- In this case, the science partner was extremely open to **feedback** from users, which continually improved the quality of information and tools provided to partner cities.
  - One **success story** involved the municipality of Castlegar. Based on information from PCIC, they were able to identify flooding as a vulnerability and inexpensively increased their frequency of culvert maintenance (as well as requiring new neighbourhoods to have larger culverts). Within a year, a major precipitation event did occur, and the low-cost solution paid off immensely.
- While there are many factors in this case that help to explain its success, the fact that it manifested at a low level of government (i.e. the municipal level) may have been important. Indeed, some interviewees suggested that science–policy connections are easier to establish and maintain at the municipal level.

An important theme for this research was to identify causes that can be manipulated. Scientists cannot easily change the amount of political interest in climate change, but they *can* choose which governments to engage with.

What Is Multi-Level Governance?



A country's constitution often specifies which policy sectors fall under the jurisdiction of which level of government (e.g. Canada's federal government has law-making authority for foreign affairs and commerce, while provincial governments are responsible for natural resources and municipalities). However, the environment is still a relatively new sector, and it is not always clear which section should have authority, not to mention that climate change itself cuts across many sectors. In such situations, we must turn to multi-level governance (MLG). This can mean specifying new, distinct responsibilities for each jurisdiction to avoid overlap, or it can mean accepting complexity and having the levels deliberately work together to address an inter-jurisdictional issue (Hooghe & Marks 2003). Obviously, climate change action can take place at any level of government. Still, even under a collaborative governance model, we must ask how the ease and effectiveness of climate actions vary across the different levels. What role should municipalities play?

Are Cities the Most Important Sites for Climate SPPs?

Maybe! The interview data from my research suggests the following possibilities:

a. Cities tend to have jurisdiction over **adaptation** measures (e.g. civil infrastructure) for many of the most immediate and on-the-ground impacts of climate change (e.g. flooding), so they may be particularly interested in climate science.
b. Because there are a large number of municipal governments in any given region, and a lot of variability among them, chances are good that a few will be interested in climate SPPs (perhaps leading to further connections with others).
c. Institutions for municipal governance are "smaller" and less formalized than those for regional or national governance, and their more permeable boundaries make it easier for science organizations to interact with them.
d. Cities usually have less capacity to employ their own government scientists, which means they may have more to gain and learn from partnering with academic scientists.
e. Lower levels of government are not as likely to have any authority (perceived or actual) over science organizations with whom they might partner, avoiding a complicating **power dynamic**.
f. Cities are usually under less public scrutiny than higher levels of government, which means they are freer to pursue policy initiatives supported by **evidence** from scientists without being constrained by public opinion.

Conclusion: Research Gaps to Consider

1. How do the ease and effectiveness of climate science–policy partnerships vary across different levels of government (e.g. municipal, regional, national)?

   Possible answer: For the reasons above, cities may be the most appropriate site (although the potential impact of SPPs will be less than at higher government levels)

2. What principles for effective climate science–policy partnerships can we learn from successful municipal-level cases?

   Possible answer: The policymakers I interviewed reported credibility, informality, and a focus on users as key ingredients in a successful municipal-level SPP

3. Information on science–policy–practice linkages should draw on the expertise and experience of actual policymakers and practitioners, not just academics.

   Possible answer: We cannot yet know what answers this consideration might bring, but it is critical not to be over-reliant on existing academic procedures and research

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REALISING JUST CITIES

MISTRA URBAN FUTURES

ENGAGEMENT AND CO-PRODUCTION OF KNOWLEDGE

Author: Jan Riise, Engagement Manager, Mistra Urban Futures

The Sustainable Development Goals (2015) and the New Urban Agenda (2016) emphasise the need for collaborative participation and engagement by cities, science and citizens – thus forming a framework for Mistra Urban Futures.

GLOBAL CHALLENGES - LOCAL ACTIONS

Challenges in urban areas such as poverty, social polarisation, unsustainable lifestyles, climate change, lack of resources efficiency, financial instability and urban sprawl are complex and sometimes even conflicting. No single actor has the capacity or power to grasp or address these challenges alone. They engage a variety of actors, decision-making levels, disciplines and sectors. They are global challenges requiring local actions. Mistra Urban Futures brings researchers and practitioners together to co-create and co-coproduce knowledge to enable sustainable urban futures.

CO-PRODUCTION

Co-production has emerged as a rewarding approach for addressing the complex problems of sustainable urban development. It refers to collaboratively based processes where different actors and interest groups come together with researchers to share and create knowledge that can be used to address sustainabilty challenges.

IMPLEMENTING THE SOLUTIONS

Bringing together the 'what' of new knowledge with the 'how' of implementation, the co-production approach adds the local context and the inclusion of stakeholders. This enables crucial knowledge transfer to many different actors in the city.

ENGAGEMENT

Public engagement in science is a two-way communication, where decisions are transparent and participation in the process of decision and policy-making is meaningful. The engagement process provides the tools for such participation to be productive for all involved, thus contributing to useful results and legitimacy.

IMPACT – MORE THAN BIBLIOMETRICS

Looking at societal impact in three dimensions:
- first order: reports, plans, capacity building
- second: new policies, organisational changes
- third: transformed social practices

through long-term commitment to follow-up and analysis of outcome and impact logic

Suggested reading:
'Rethinking Sustainable Cities' David Simon (ed) (2016)
Summaries available in English, Swedish, Spanish and Hindi
'Co-production in Action', Palmer & Walasek (eds) (2016)
Open Access - www.mistraurbanfutures.org

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Mistra Urban Futures is a transdisciplinary research centre located at Chalmers University of Technology in Gothenburg, Sweden, and local platforms in Skåne, Stockholm, Sheffield-Greater Manchester, Kisumu and Cape Town. Partners in Shimla and Buenos Aires.

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Photos: Mistra Urban Futures, Lanski/Shutterstock (bike lane) and William Perugine/Shutterstock (bikers in Copenhagen)

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CSIR
our future through science

What to adapt for?

Climate change risk profiles for South African cities

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WHAT TO ADAPT FOR?

- Climate change adaptation has increasingly been included in national policies because of the far-reaching effects climatic changes have on places and people.
- To build resilient settlements, national policies need to be translated into context-specific climate change adaptation measures that are integrated into local spatial planning and land use management practices.
- Urban planning plays a critical role in anticipating change and to plan for and adapt to these anticipated changes. Urban planning and adaptation have in common that they both intervene in space, promote change and transformation, and are concerned with the future.
- Many municipalities in South Africa, as in many other countries, do not have the capacity or the resources to develop adaptation strategies. Furthermore, the lack of scientifically-backed risk and vulnerability assessments weaken the urgency to prioritise and act.
- This project attempts to address the barriers experienced by local governments by developing detailed risk and vulnerability profiles based on climate change projections, and then linking adaptation options to these.

AIM OF THE GREEN BOOK RISK PROFILES

- The Green Book project was conceptualised to propose adaptation options linked to the climate change risk profile of every settlement in South Africa.
- Compiling the risk profiles has advanced our scientific understanding of climate change and its impacts, the geographical location and exposure of settlements to future hazards, and future settlement vulnerability.

The risk profiles and adaptation options aim to:
- Assist municipalities to adapt urban planning and development practices in line with local and global climate change commitments, objectives and goals;
- Influence policy development at the urban planning/climate change adaptation nexus; and
- Identify priorities for mainstreaming climate change adaptation into development planning.

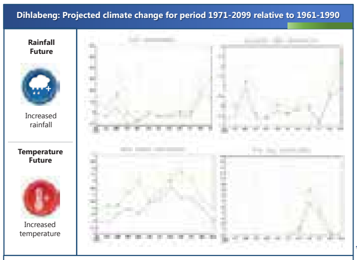
- The team consists of approximately 50 researchers from disciplines such as urban planning, geo-informatics, geography, climatology, ecology, hydrology, anthropology, architecture, disaster risk reduction, economics, statistics, and botany.
- This research is funded by the IDRC and the CSIR (2016-2019). Our two partners include the National Disaster Management Centre (NDMC) and the African Institute for Inclusive Growth (AIIG).

THE SCIENCE BEHIND THE RISK PROFILES

The risk profiles are made up of:
- Climate change projections downscaled to 8x8 km over South Africa.
- The impact of climate change on key sectors such as water resources, agriculture and the economy.
- A geographical analysis of the exposure to hydro-meteorological hazards (flooding, coastal flooding, drought, wild fires) for all settlements in the country for a 2030 and 2050 future.
- Socio-economic vulnerability indicators and settlement growth modelling (also for a 2030 and 2050 future), as well as the coping capacity of municipalities and their residents.

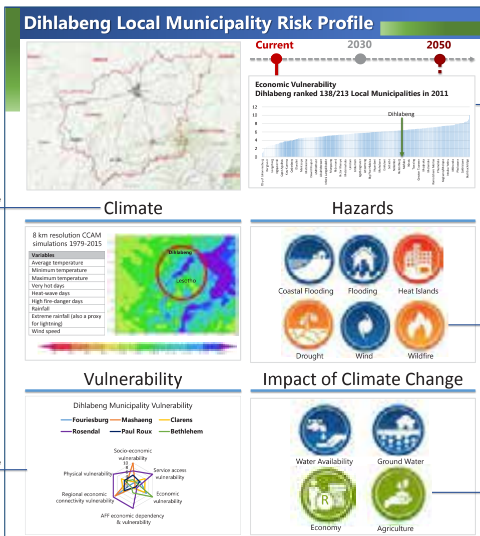
- The profiles not only consider the current static risk of settlements but are forward looking (2030/2050) to include population growth projections, hazard footprints and the impacts of climate change on key resources.
- As a final step in the project, local planning adaptation options are linked to each risk profile, to be integrated into local planning practices by municipalities.
- This poster features the scientific evidence underpinning local adaptation.

Dihlabeng: Projected climate change for period 1971-2099 relative to 1961-1990



Climate projections based on RCP 4.5 and RCP 8.5 scenarios and six downscaled GCM's.

Dihlabeng Local Municipality Risk Profile



Vulnerability indices for 213 local municipalities showing 2011 trend relative to 1996

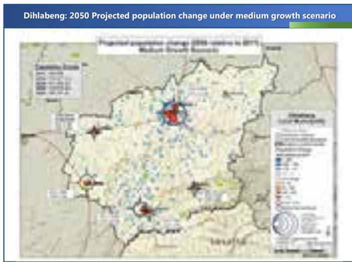
MUNICIPALITY	Socio-Economic Vulnerability Index	Trend	Economic Vulnerability Index	Trend	Physical Vulnerability Index	Trend	Environmental Vulnerability Index	Trend
City of Cape Town	1.19	↗	1.31	↗	4.25	→	4.57	→
City of Johannesburg	1.10	↘	1.00	↘	3.73	→	1.28	→
City of Matlosana	3.22	↘	7.25	↗	3.45	→	1.03	→
City of Mbombela	3.53	↘	5.32	↗	1.96	→	2.97	→
City of Tshwane	1.00	↘	2.74	↘	4.00	→	1.66	→
Dihlabeng	3.61	↘	6.27	↗	3.87	→	1.31	→
Dikgatlong	6.44	↘	7.37	↘	4.02	→	1.00	→
Nelson Mandela Bay	2.66	↘	5.70	↗	2.83	→	1.17	→
↓								
213 Local Municipalities	-		-		-		-	

Multi-criteria analysis for composite indicator development, profiling vulnerable local municipalities.

Dihlabeng: Increase in very high fire danger days by 2050

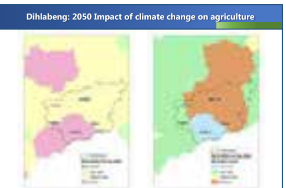
Fire hazard model based on fire regimes, using high fire danger days from climate projection outputs.

Dihlabeng: 2050 Projected population change under medium growth scenario



Projecting population changes on a local level using new population potential disaggregation model in combination with demographic modelling.

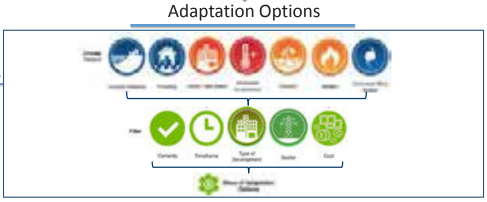
Dihlabeng: 2050 Impact of climate change on agriculture



Climate Narrative	Impacts on Sector 1	Impacts on Sector 2	Impacts on Sector 3
	Wheat	Maize	Potatoes
Projected warmer & wetter future	Increase in yield, but under RCP 8.5 can decline in far future due to significant temperature increase.	Increase in yield, but under RCP 8.5 can decline in far future due to significant temperature increase.	Increase in yield, but under RCP 8.5 tuber yield can decline in far future due to significant temperature increase.

Risk screening the impact of projected climate change on agriculture and local level commodity farming using crop and livestock modelling.

Adaptation Options



Dihlabeng: Adaption options for wildfire

Hazard: Wildfire

Option: Establishment and maintenance of fire breaks
Aim: Prevent the spread of fire and provide general protection for infrastructure and housing
Cost: Depends on the method (e.g. burning versus herbicide application), size of firebreak, topography and type of vegetation etc.
Low regrets (clear delineation of land to be used as firebreaks
Co-benefits: Support disaster risk management

Example

IDRC CRDI

Space Heating Electrification as a Tool for Urban Decarbonization

Sven Scholtysik, Bryson Robertson, Peter Wild, Andrew Rowe
Department of Mechanical Engineering, University of Victoria, Canada

Introduction

- 80% of Canadians live in urban areas.
- Secondary energy use in Canada is largely based on space and water heating and is a major contributor to urban GHG emissions.

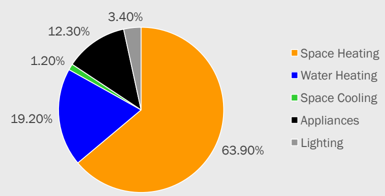


Figure 1: Share of applications of secondary energy use of Canadian residential sector in 2014 [1].

Urban Electrification

- Heating demand shows seasonal and hourly variation.
- Electrification and building envelope improvements are able to change the demand for electricity, capacity and flexibility.
- The choice of electrification technologies influences this demand.
- Demand changes can influence the buildout of the future electricity generation system.
- System response depends upon
  - how fast changes happen,
  - technology use,
  - level and development of technology and resource prices (CAPEX, fixed, variable),
  - life time of technologies,
  - residual capacities ,
  - policy.
- Techno-economic optimization is a helpful tool to determine system response

How Do We Heat Our Homes?

- Energy sources used for space heating differ from province to province.
- All Canadian provinces feature a significant potential for electrification.
- Electrification is possible through different technologies (e.g. baseboard heaters, ground source heat pumps, air source heat pumps, etc.).

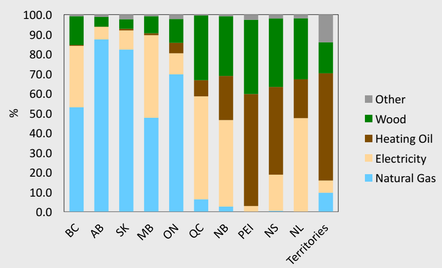


Figure 2: Share of energy sources used for space heating in 2013 [2].

Model Architecture

- An OSeMOSYS based, technologically explicit linear programming model is used in this research.
- Objective function is NPC minimization under consideration of decarbonization targets.

Figure 3: OSeMOSYS model of an electricity system with a dedicated heating and thermal comfort demand.

Results

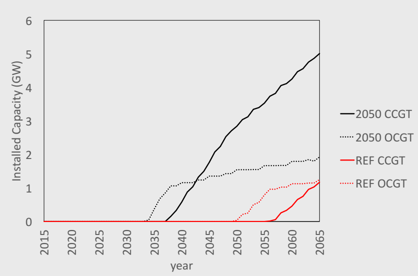


Figure 4: Installed capacity of natural gas based electricity generation technologies in British Columbia, REF vs. 2050 scenario.

- British Columbia, carbon tax of \$50/t CO_2 emitted, 18% reserve margin, 6% discount rate, no interconnections, two scenarios:
  - 2050: 100% of space heating demand electrified by 2050
  - REF: no further electrification prescribed.
- Preliminary results for BC show that prescribing an electrified heating system that is serviced by resistance heating can lead to significant electricity and capacity demand increases.
- Capacity demand is met by investment in natural gas based electricity generation technologies (OCGT/CCGT – open/combined cycle gas turbines) due to favourable pricing assumptions [3].
- Electrification can act as a tool for decarbonization if the underlying electricity generation system is based on low or no carbon technologies.
- Heat pumps can be a more economical alternative to resistance heating from a systems perspective.

For more information about our current research visit: www.uvic.ca/research/centres/iesvic/

Contact: Sven Scholtysik (sscholtysik@uvic.ca)
Institute for Integrated Energy Systems (IESVic)
Department of Mechanical Engineering, University of Victoria, Canada

References:
[1] Natural Resources Canada, "Residential Sector Table 2 Secondary Energy Use and GHG Emissions by End Use", NRCan, 2017.
[2] Natural Resources Canada, "Residential Sector Table 5: Space Heating Secondary Energy Use and GHG Emissions by Energy Source", NRCan, 2017.
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The Heating and Cooling Gap in Southern European cities: A Challenge for Climate Mitigation

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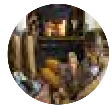
Questions

- What is the **energy performance gap** for space heating and cooling in Portuguese dwellings, at very high spatial scale?
- How do **climatization patterns** affect the gap?
- What is the impact of **bridging the energy gap on CO_2 emissions**?

Context

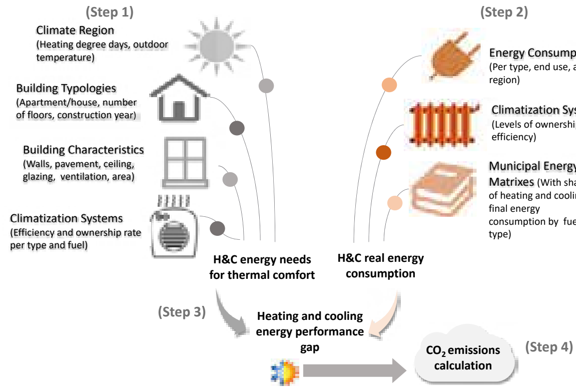
- People spend about 90% of their time inside buildings [1], mostly in their own homes.
- In European Union, low income households, poor building construction and high energy costs: **50 to 125 million people are not able to ensure indoor thermal comfort (heating & cooling, H&C) in their households** [2]. Thermal comfort affects people's health, welfare and ability to function.
- **Heatwaves** put in risk populations' health [3,4,5], and require increasing energy need for cooling. Future climate change scenarios carry an increase in the number and intensity of heat waves for this region [5,6].
- **Portugal is a good case study:**
  - located at Southern Europe, targeted as one of the **most likely climate impacted regions** [7].
  - **ageing building stock with low energy performance, decentralized low efficiency climatization systems** and **low rates of climatization systems**, mainly cooling.
  - **high levels of energy poverty** [8,9]: 24% of the population are unable to keep their homes warm during winter, whilst during summer, 36% cannot keep their homes cool [10]. Most residential buildings rely solely on natural ventilation for cooling [4].



Methodology

Energy performance gap acts as a proxy for thermal comfort and energy efficiency assessment.

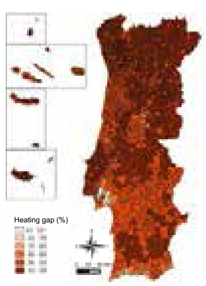
- *Step 1* – **Nominal final energy** needs for space H&C estimated from **191 different building typologies** (e.g. buildings' area, walls types, bearing structure). **Geographical explicitness:** 18 different climatic regions, and all **3092 Portuguese civil parishes** (administrative territorial units smaller than a city).
- *Step 2* – **Real energy consumption** for H&C estimated from climatization systems ownership data, municipal statistics on energy consumption and data from energy matrixes per type of end use for different Portuguese geographic regions.
- *Step 3* – **Energy performance gap (%)** estimated from the difference between **Nominal** and **Real** final energy consumption. Alternative **Conservative case** assessed, assuming more realistic regional average cooled/heated areas and climatization equipment operating hours.
- *Step 4* – **CO_2 emissions related to energy consumption increase** for bridging the performance gap are computed for both cases and compared to current energy consumption associated emissions.



Results

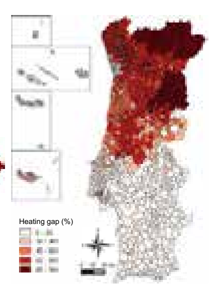
Real case: 600 kWh per capita; **Nominal case:** 7415 kWh per capita; **Conservative case:** 1375 kWh per capita

Heating Gap: Nominal case
[24h/day & 100% area]

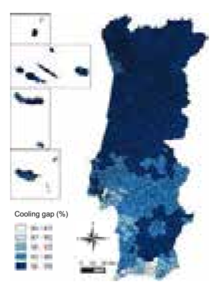


- 20% of spatial units with no gap.
- Average national heating gap reduced from **93% to 52%.**

Heating Gap: Conservative case
[11h/day & 50% area]

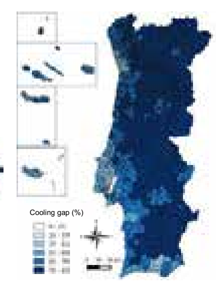


Cooling Gap: Nominal case
[24h/day & 100% area]

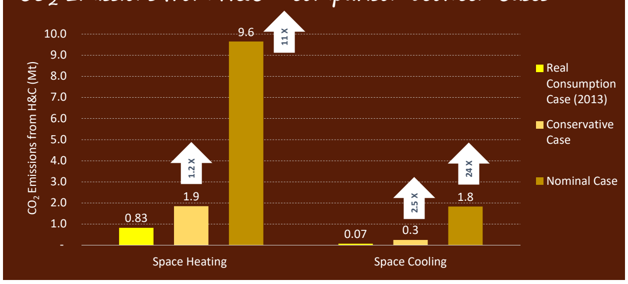


- No cooling gaps are offset.
- Average national cooling gap reduced from **97% to 76%.**

Cooling Gap: Conservative case
[10h/day & 38% area]



CO_2 Emissions from H&C – comparison between Cases



Discussion and Conclusions

- Energy performance gap results from behavioral climatization patterns, occupants' habits and schedules, **without jeopardizing indoor thermal comfort, and** also from **energy poverty levels** of population groups.
- The potential increase of energy consumption (and emissions) for adequate indoor thermal comfort, red flags a **problem for climate mitigation goals.**
- **Energy efficiency increase in both buildings and equipment and the increased use of passive measures (shading and insulation)** for southern European countries are key to reduce energy needs.
- Thermal comfort requires investment in **local renewable energy sources** to prevent impacts on CO_2 emissions.
- Results combined with socio economic data of the building occupants can be further developed to track **vulnerable consumers** and to support national and local energy efficiency policies and instruments.

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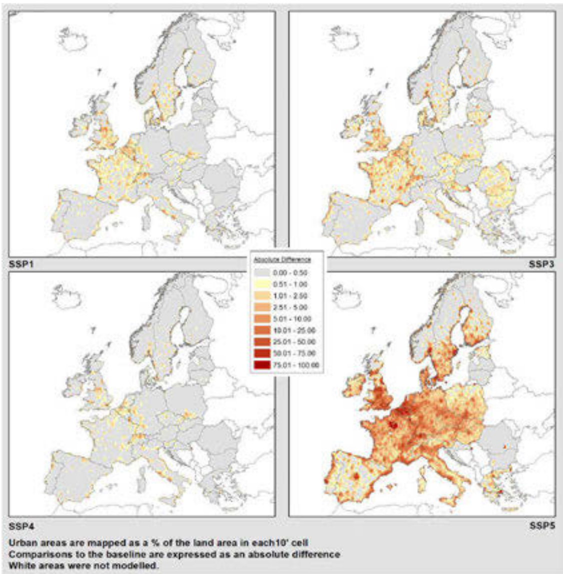
Population driven urbanisation

Utilising the SSP framework

Fig 1. The projected change, from baseline, in artificial surface extent (as a percentage of the 10' cell land area) by 2100 under four different socioeconomic scenarios. Darker colours are associated with greater artificial surface expansion



We modelled (i) population structure and dynamics, and (ii) changing values and preferences driving urban land use across Europe up to 2100 with a regional urban growth model.

Fig 2. Adaptation and mitigation challenges of the different SSPs (adapted from O'Neill et al., 2015)

Artificial surfaces cover approximately 4% of European land surfaces. Despite their restricted extent, they are home to nearly three quarters of the European (EU-28) population, account for ~80% of European energy use and emit ~69% of Europe's CO_2.

Key factors driving future urban form:

(i) a changing population and demographic structure
(ii) changing cultural/societal values, living standards & preferences
(iii) environmental and social policy
(iv) regulatory frameworks.

RECOMMENDATIONS

1) Quantification & foresight on preferences and age structure for development of the urban & built environment

2) Forward-looking spatially explicit socioeconomic indicators

We witness the effects that

(i) baseline (2010) year differences in age structure have on future regional change
(ii) SSP-specific demographic assumptions on fertility and
(iii) scenario specific societal preferences have on intra-European development.

The results provide a discussion point on the importance of population structure & development of (age specific) living preferences in driving future artificial surface demand, i.e. urbanisation.

Research Gap

1) Quantified data & foresight of the influence of preferences and age structure on the development of the urban and built environment

- Key factors driving the form of future urban areas include (i) a changing population and demographic structure, (ii) changing cultural/societal values and living standards, (iii) environmental and social policy, and (iv) regulatory frameworks. Taking into account population structure (demographics) and changing preferences clearly impacts the extent of required artificial surfaces.

2) Forward-looking spatially explicit socioeconomic indicators

- In the face of severe adaptation needs and locally varying capacities, there is a huge demand to address spatially explicit socioeconomics. To inform current and longer-term climate adaptation, we will need forward-looking information the key issues: demographics, income, education etc. that pave the way to quantifying overall vulnerability and adaptive capacity inherent in local communities.

Terama, E. et al. 2017. Modelling population structure in the context of urban land use change in Europe, Regional Environmental Change. https://link.springer.com/article/10.1007/s10113-017-1194-5

IMPRESSIONS BEMINE

IMPRESSIONS, FP7
BEMINE, Strategic Research Council of Finland
06 Mar 2018

Assessing Future climate change Urban Inundation Risk under Deep Uncertainties: Using RDM Theory in Central Shanghai

Zhan Tian, Hengzhi Hu, Laixiang Sun
(Shanghai Climate Center)

1 Introduction

▶Background: Climate change induced hazard leading to an increasing risk of urban flooding and inundation in mega-cities. Previous studies seldom consider either the large numbers of scenarios to reduce the deep uncertainties under climate change background, or quantitatively evaluating adaptation solutions in plausible futures. The Robust Decision Making (RDM) provides a systematic, quantitative decision support methodology for developing robust and flexible plans under conditions of deep uncertainty (Lempert et al. 2003; Hallegatte et al. 2012).

▶Data: The study choose the approximately 670km² region within the inner ring as the study area，use strong convection rainstorm event during 17-19PM Sep13th, 2013 as the case of study. Deal with the process of Shanghai station daily rainfall data.

▶Methodology: This study organized the indicators into an "XLRM" metric; selected three factors to build the future rainstorm scenarios; used SCS-based flooding model to simulate inundation of downtown in various future scenarios; built the depth-damage curve and exposure value; evaluated future flood risk using ArcGIS raster calculator; quantified adaptation strategy based on the potential risk reduction rate.

2 Results

2.1 XLRM Metric Analysis

Table1. RDM XLRM Key Elements

Uncertainties, X	Policy Levers, L
▶future precipitation ▶rain island spatial pattern ▶decrease of drainage systems capability	▶current protection ▶urban green area ▶drainage improve ▶deep tunnel construction
Relationships, R	**Measures, M**
▶ shanghai urban inundation model ▶risk assessment model	▶potential economic loss reduction rate

▶ "XLRM" metric based on RDM bulit a framework, including uncertainties (X)、policy levers(L, we defined the capacity of the deep tunnel into three levels - 30%, 50% and 70%)、Relationships(R) and Measures(M).

2.2 Inundation Simulation

▶ The 100 future rainstorm scenarios were equal likely sampled by the three uncertain factors using Latin Hyper Cube Sampling method. The simulated results show significant difference in terms of inundation area and depth among the scenarios(Fig. 1)

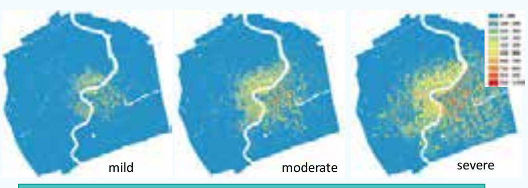


Fig.1. Comparison of Inundation area and depth

▶Severe inundation is mainly at high density region in terms of population and properties along Huangpu river and Suzhou creek. The depth of the extreme case is as high as 1.42m which is 0.75m higher than the maximum depth happened in Sep 13th, and the inundated area increased by 62% based on the current infrastructure.

2.3 Scenario Correlation Analysis

▶The change range of the uncertain factors and their mechanism of action cause significant different of inundation. We conducted the correlation analysis to find out the dominate uncertain factors.(Fig. 2)

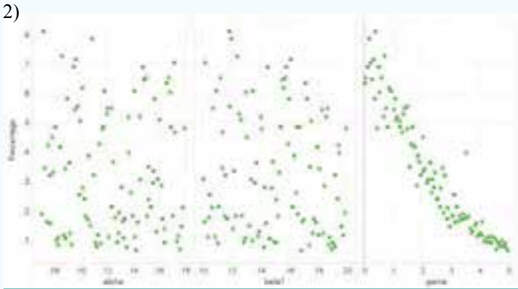


Fig.2. Correlation Analysis of Three Uncertainty Factors and Average Inundation Depth

▶Drainage capacity decrease has significant correlation with average inundation depth, and has relative strong correlation in terms of the inundation depth and area, while other two factors have weak correlation with average inundation depth.

▶Average inundation depth below 75%, 50% and 25% - occurs when drainage capacity below 0.16

2.4 Risk Reduction

▶The solutions were applied into the scenarios to compare the performance in reducing the inundation risk. (Fig.3)

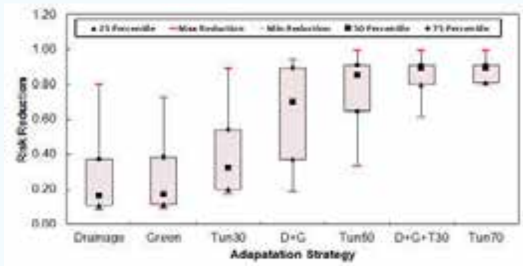


Fig.3. Potential risk reduction rate

▶Increase of drainage capacity can reduce the maximum inundation from 6% to 31%, the average inundation from 7mm to 19mm, But the solutions such as green area, deep tunnel and other combinations all improve the results compared to the increase of drainage capacity, which are able to minimize both the inundation depth and area among moderate futures and mild futures (up to 99% reduction rate), even in extreme cases(e.g. Tun70, 95% reduction rate in future 11).

3 Conclusion

▶The increase of future rain and urban rain island effect would have small impact on the inundation due to the improved protection drainage standard and the implementation of sponge city. The situation that decrease of drainage capacity induce by the potential compound flood hazards such as rainstorm storm surge and astronomical high tide will strongly threaten the central city causing severe inundation.

▶The combination of solutions - Drainage+ green + tunnel 30% (D+G+Tun30) not only has a better practically integration effect in reducing urban inundation, but also able to improve the local air quality and micro-climate in correspondence to the idea of sponge city.

Cities and Climate Change Conference

Edmonton, Alberta Canada, 5 - 7 March 2018

Model of Adaptive Urban Governance for Climate Change Management

Banner Presenter
Amos Tindyebwa
Foundation For Oil And Energy
Governance Initiatives, UGANDA
Email : info@foegi.org

Focusing research for evidence based collaborating efforts and working with city governments and urban residents to identify, understand and reduce vulnerability and risks.

FOUNDATION FOR OIL AND ENERGY GOVERNANCE INITIATIVES, EAST AFRICA (FOEGI UGANDA)

Cities & Climate Change Science Conference @ Edmonton Shaw conference centre 2018.3.5-7

Investigation of summertime thermal environment in downtown Tokyo - Airborne remote sensing, field observations, and numerical simulations -

Nobumitsu Tsunematsu (Tokyo Metropolitan Research Institute for Environmental Protection, Japan), Tsuyoshi Honjo (Chiba University), Arata Ichihashi (TMRIEP), Ko Nakajima (Tokyo Metropolitan University / TMRIEP), Yoshiki Yamagata (National Institute for Environmental Studies), Daisuke Murakami (Institute of Statistical Mathematics)

Abstract This study investigated spatiotemporal changes in amounts of thermal infrared (TIR) energy emitted from urban surfaces in downtown Tokyo, using 2 m spatial resolution data obtained from airborne TIR measurements at midday on the four different hot summer days: Aug. 7, 2007, Aug. 19, 2013, Aug. 19, 2014, and Aug. 19, 2015. Detailed land use data were also used for analyses of relationship between amounts of TIR energy and land use variations. The results showed significantly large amounts of TIR energy in high density wooden residential areas, whereas amounts of TIR energy in areas with office and commercial buildings were relatively small. Concerning the areas with office and commercial buildings, we found that amounts of TIR energy in many parts of urban renewal areas had clearly decreased between 2007 and 2013.In the renewal areas, many green surfaces have been provided in public open spaces. This would be one of the main causes of the decreases in amounts of TIR energy. Creation of public open spaces has been promoted by an incentive-based policy that offers an increase in the floor area ratio as a reward for constructing public spaces. These results strongly indicate that some governmental measures like the incentive system enacted for the areas with office and commercial buildings are required to reduce radiant heat in the high density residential areas. The maximum occurrence frequency of heat strokes tends to be recorded in residential areas and at midday. This study also investigated characteristics of thermal environment in high density residential areas located in downtown Tokyo, using data from meteorological measurements performed at about fifteen single-family detached houses in the period from July to Sep. (2016 and 2017) and numerical simulations. The results indicated that 1) decreases of air temperatures and water vapor amounts in indoor spaces in the afternoon, 2) improvement of radiative environment on houses, and 3) increases of wind velocities would be effective measures for reducing the number of heat stroke patients in high density residential areas. Further investigations and quantitative analyses are needed to consider adaptation and mitigation strategies that can improve the thermal environment.

Remote sensing of midday ↑ TIR energy in downtown Tokyo

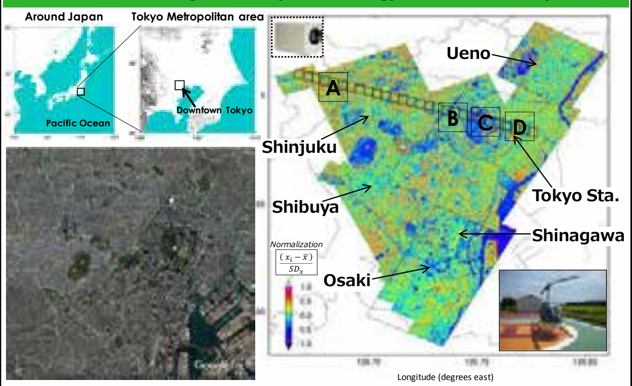


Fig. Upward TIR energy in downtown Tokyo on hot summer days (Aug. 19, 2013, 2014, and 2015) measured at around midday. Results of the measurements were normalized. About 2 m resolution (4 m for areas enclosed by dotted lines).

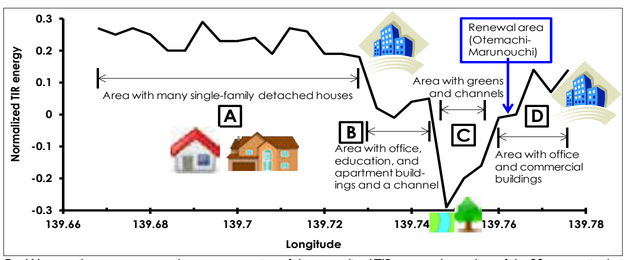
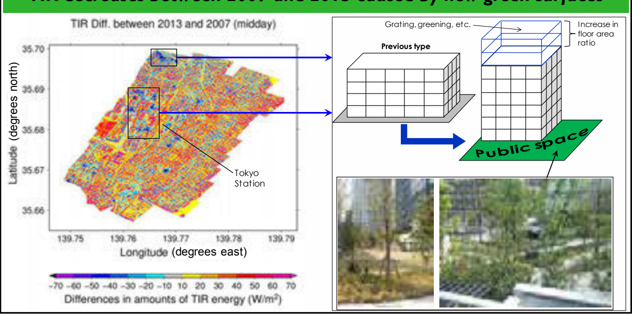


Fig. West-northwest to east-southeast cross section of the normalized TIR energy along a line of the 28 squares in the above fig.. The marks A, B, C, and D correspond to those in the above fig. (from Tsunematsu et al., 2016, Urban Climate)

TIR decreases between 2007 and 2013 caused by new green surfaces



Occurrence frequencies of heat strokes in downtown Tokyo

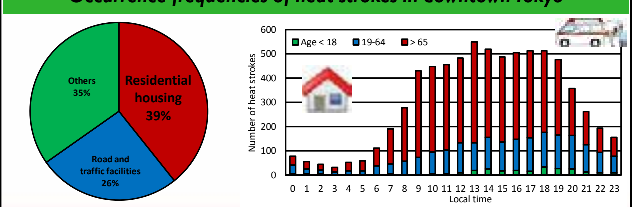


Fig. Occurrence frequencies of heat stroke patients in downtown Tokyo in 2010-2015 for places (the pie chart) and for time & ages for residential housing (the column chart). The analyzed data were provided by the Tokyo Fire Department.

Observations of thermal environment in high density residential areas

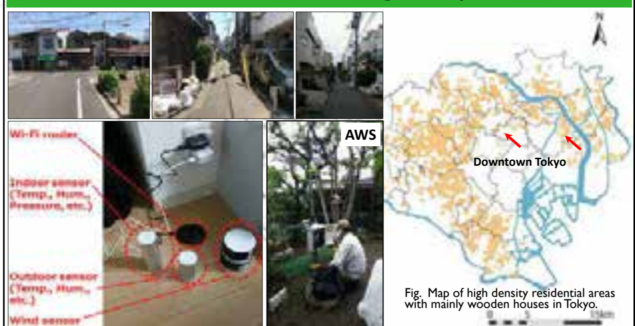


Fig. Map of high density residential areas with mainly wooden houses in Tokyo.

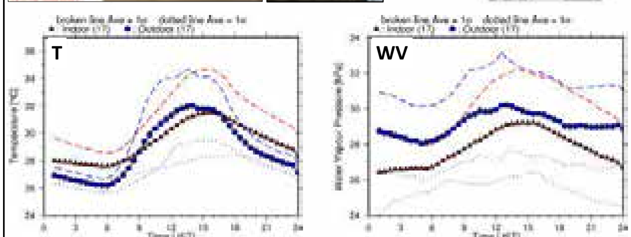


Fig. Diurnal variations in outdoor & indoor air temperatures (the left panel) and water vapor pressures (right) averaged for data from each sensor installed at 17 single-family detached houses in the periods from Aug. 1 to 31, 2016 and 2017.

Simulations of thermal environment in high density residential areas

- Thermal fluid model (FlowDesigner2018) including calculations of solar radiation & TIR.
- Initial time: 0900 LST on Aug. 28., 2017.
- Initial and boundary conditions: meteorological data from Japan Meteorological Agency.
- Mesh size: about 1.5 m (x: 203, y: 343, z: 33).
- Turbulence model: modified Launder-Kato model (Launder and Kato., 1993).
- Outdoor unit exhaust: 40 °C and 50 m³/min.

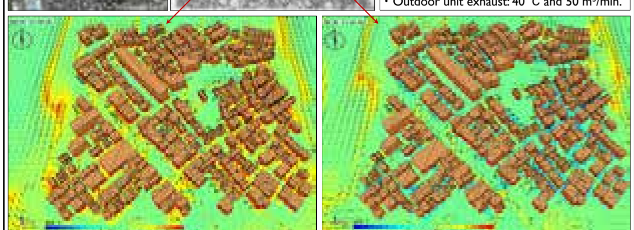


Fig. Simulated air temperatures at a height of about 4 m at 1300 LST Aug. 28 for the case of no measures for exhaust heat from air-conditioning outdoor units (the left panel) and for the case of dry mist-equipped outdoor units (right).

Summary

- Relatively small amounts of midday TIR energy in areas with office and commercial buildings due to increases in green surfaces provided mainly in public open spaces in renewal areas, which were promoted by an incentive-based policy enacted by Tokyo metropolitan government.
- Large amounts of midday TIR in high density residential areas with many wooden houses.
- 1) Decreases in air temp. & water vapor in indoor spaces in the afternoon, 2) improvement of radiative environment on houses, and 3) increases in wind velocities could be effective measures for reducing the number of heat stroke patients in high density residential areas.
- Measures for air-conditioning outdoor units such as installation of dry mist systems could be effective in improving thermal environment in outdoor spaces in high density residential areas.

Acknowledgements: This study was performed as a research project funded by Bureau of Environment of Tokyo Metropolitan Government. Also, this study was performed as part of JSPS KAKENHI (Grant-in-Aid for Scientific Research (B); JP17H01926).

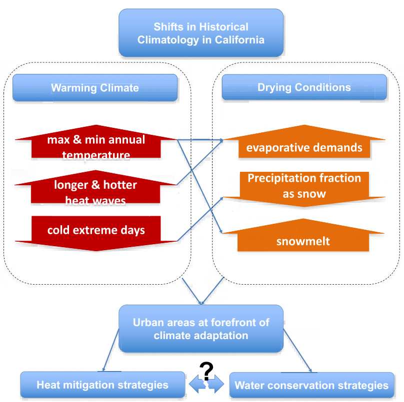
Plenary Summaries
Parallel sessions summaries
Conference Posters
References
Annexes

Water Conservation Benefits of Urban Heat Mitigation

Pouya Vahmani and Andrew D. Jones

INTRODUCTION AND OBJECTIVES

Scientific Imperative

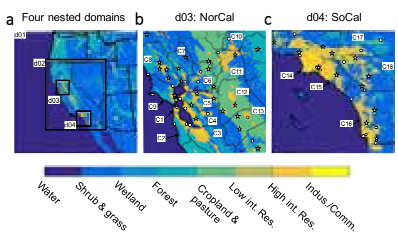


Study goal:
- To assess the benefits of widespread deployment of cool roofs, a heat mitigation measure, from a water conservation point of view as well as the climatic consequences of outdoor water conservation measures.

Overarching project goals:
- Understand how climate change will affect urban microclimate extremes.
- Evaluate adaptation strategies to reduce risks to water and energy systems.
- Understand trade-offs among adaptation and mitigation strategies.
- Link this research with decision-makers and analysts concerned with the impacts of climate variability and change on urban infrastructure, water, energy, and health systems.

APPROACH

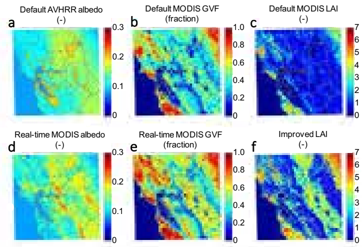
Regional climate modeling framework (WRF)



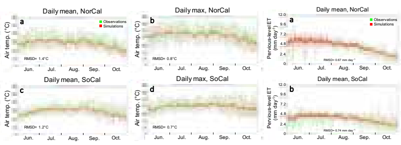
Description of the Modeling System
- Weather research and forecasting model coupled to an urban canopy model (**WRF-UCM**)
- 4 nested domains with horizontal resolutions of **13.5 km, 4.5 km, 1.5 km, 1.5 km**
- Simulation period: **June-October** of **2001-2015**
- Enforced with satellite-based observations of land surface physical characteristics
- Incorporated urban irrigation module
- Incorporated land cover/use and urban fraction, based on the very high-resolution (30 m) NLCD data
- Incorporated boundary and initial conditions, based on the NARR dataset
- Incorporated an urban morphology dataset, based on the National Urban Database and Access Portal Tool (NUDAPT)

APPROACH, CON'T

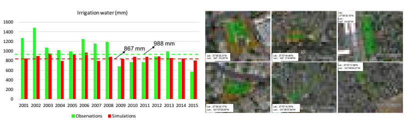
Model Improvement
- Realistic, real-time, and domain specific land/sea surface physical characteristics are included to improve the fidelity of the predicted signals.



Model Validation
- The improved modeling framework reproduces daily mean and max air temperatures (RMSD of <1.4 °C) and evapotranspiration (ET) variabilities with ensuring accuracy (RMSD of 0.74 mm day^{-1}).

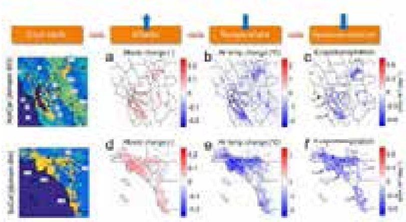


- Irrigation water measurements from 6 parks are used to validate the urban irrigation scheme in WRF-UCM.

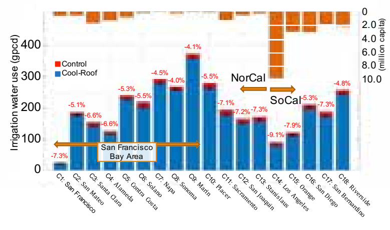


RESULTS

Impact of cool roofs on air temperature and evapotranspiration
- Air temperature and evapotranspiration are reduced by up to **1.5ºC** and **18%**, respectfully.

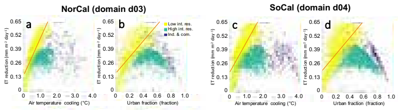


Impact of cool roofs on outdoor water use
- Irrigation water is reduced by up to **9%** as a result of cool roofs implementation across 18 studied counties.

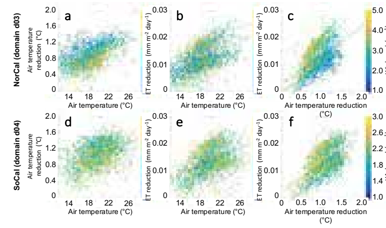


RESULTS, CON'T

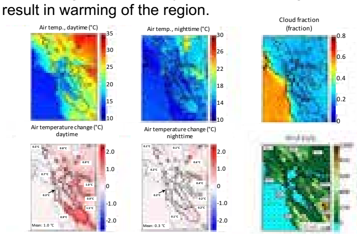
Impacts of cool roofs: spatial variations
- Urban density (urban type) and urban fraction (impervious fraction) play an important role in effectiveness of cool roofs in reducing air temperature and evaporative water demand.



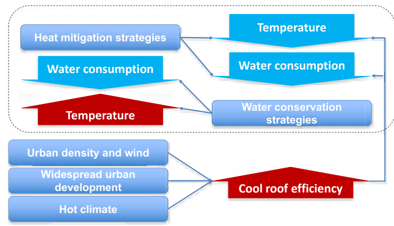
Impacts of cool roofs: daily variations
- Cool roofs are most effective during the hottest days of the year and there is strong positive correlation between air temperature change and evaporative water demand change.



Climatic consequences of outdoor water conservation strategies
- The strategies that directly reduce urban irrigation can result in warming of the region.



SUMMARY AND NEXT STEPS



Next steps
- How will future climate enhance water demand in both urban and agricultural regions?
- How effective are proposed adaptation strategies for countering climate change induced water and energy demand increases?
- How will the role of fog and sea breeze in CA coastal cities change in response to large-scale climate forcing?

ACKNOWLEDGMENTS

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Vahmani, P., A. D., Jones (2017), Water conservation benefits of urban heat mitigation, Nature Communications, doi:10.1038/s41467-017-01346-1.

Vahmani, P., A. D., **Jones** (2017), **Water conservation benefits of urban heat mitigation**, *Nature Communications*, doi:10.1038/s41467-017-01346-1.

Designing a Space-Based Decision Support System (DSS) for Climate Resilient Coastal Cities: Zamboanga City

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Abstract

This DSS enabled the generation of integrated risk maps as compounding effects of hazards, exposures and vulnerabilities (HEVRs). For this, we considered a network relationship of variables. The participative formulation of CCA-DRRM options and their cost-benefit analyses then ensued. Zamboanga City is the study area, being one of the major cities in southwestern Philippines experiencing rapid urbanization. It is also prone to disasters, like the "super El Niño" in 2015-2016, which significantly reduced water supply. Roughly 40% of its population are poor and it is surrounded by internal armed conflict. Next steps proposed after risk overlays are risk indexing as well as criteria-based and hybrid risk mapping. It is highly recommended to develop a planning calque by which to reconcile complex paradigms of sustainable development (i.e. Resilience, inclusiveness, security as well as equity with growth - RISE) and competing demands on vital resources.

Research Questions

Research Components	Research Questions
1. Climate Modelling, Downscaling and Analysis of Rainfall and Temperature including Drought	What are the historical climate scenarios and their hydrological implications (i.e. Too much and/or too little water)?
2. Hydro-Meteorological, Seismic and Volcanic Hazard Mapping and Assessment	What are the susceptibility to hydro-meteorological, seismic and volcanic hazards? What are the existing the future implications of hydro-meteorological, seismic and volcanic hazards?
3. Multi-Temporal RS-GIS-Based Exposure and Vulnerability Mapping	What are the historical and projected exposures to multi-hazard scenarios? What are the vulnerabilities (i.e. Susceptibility, coping capacities and adaptive capacities; poverty levels) of exposed population/ communities/ stakeholders?
4. Integrated Risk Overlays, Parametric Water Demand and Water Availability Analysis as well as Food Demand and Availability Analysis	What are the historical and projected risks to water and food availability considering the confluence of multi-hazards, exposures and vulnerabilities? What are the existing and projected population and land cover scenarios as well as their implications on corresponding water and food demand vs supply/ availability? What is the picture of future water and food balance (i.e. Availability vs demand) and health?
5. Assessment of the Competition/ Conflicts in Water and Food Allocation and Related Health Impacts due to Population Growth, Densification, Land Cover Changes and Urbanization	What are the competing demands for water and food attributed to population growth, densification, future land cover change scenarios and urbanization?
6. Impacts of Climate Scenarios, Hydro-Meteorological, Seismic and Volcanic Hazards, Land Cover Changes and Urbanization on the Watershed	What are the possible future impacts of multi-hazard scenarios on population growth, densification, land cover changes and urbanization and vice versa?
7. Presentation and Cross-Sectoral Validation of the DSS, Formulation of Strategic CCA-DRRM Options with their Relative Weighting and Mainstreaming Pathways as well as Subsequent Cost-Benefit Analysis	What are the strategic CCA-DRRM options towards urban watershed resilience? What are the relative weights of CCA-DRRM options? What are the CCA-DRRM vertical and horizontal mainstreaming pathways? What are the costs-benefits of CCA-DRRM options? What are the sectoral priorities in space and time?

Analytical Framework

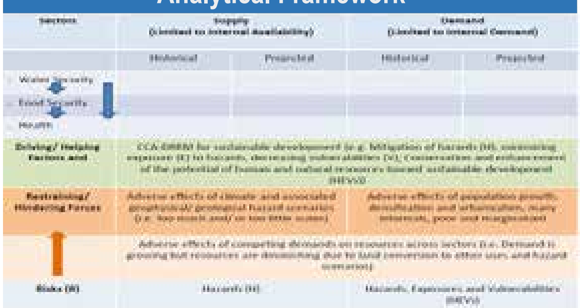

Figure 1. Analytical Framework

Methods and Materials

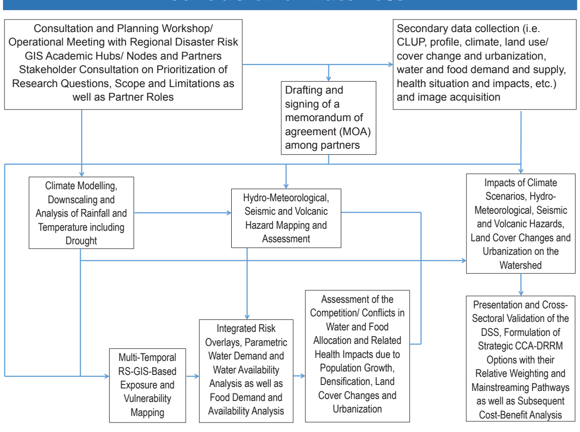

Figure 2. Interrelationship of Project Research Components

Results

Sample HEVR Overlay

- Lesser rainfall (3% and 6% drop in near- and mid-future, respectively) are observed especially over the urban areas.
- Less rainfall means lower groundwater recharge and lower water level in the Tumaga River, the main source of water in the city.
- Drier climate can also lessen agricultural and production especially in southern Zamboanga City.

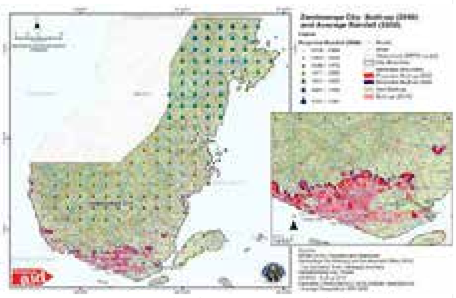

Figure 3. Projected Built-up (2050) and Average Annual Rainfall (2050)

Water Security

- Increased population (up to 1.3 million by 2050) leads to greater water demand (2.78 MCM per month by 2050).
- Insufficient water supply and poor water quality is already experienced in several barangays.
- Top CCA-DRRM options are STP (Septage Treatment Plant) and reclaimed water and closed forest and dam. Priority barangays are highlighted in Figure 4.

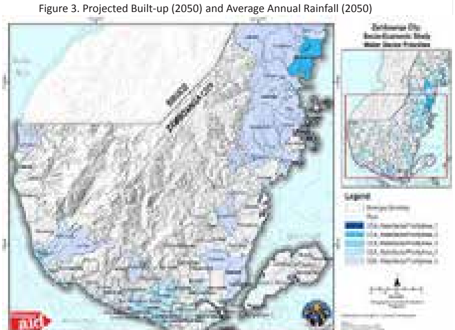

Figure 4. Water Sector Priorities based on Socio-Economic Study

Food Security

- People are consuming more water-intensive and drought-sensitive crops.
- Water shortages and intermittent power outage impact food manufacturing process negatively.
- Rapid conversion of land to urban uses significantly reduces food production.
- Top CCA-DRRM options are seaweed drying facility and multi-species hatchery. Priority barangays are highlighted in Figure 5.

Figure 5. Food Sector Priorities based on Socio-Economic Study

Related Health Needs

- The outbreak of Acute Gastroenteritis was due to water shortage in 2015-2016 El Niño.
- Wells in areas susceptible to flood events may be contaminated.
- Cases of parasitism were also high from 2015-2016.
- Top CCA-DRRM options are promotive/ preventive and curative/ rehabilitative measures.

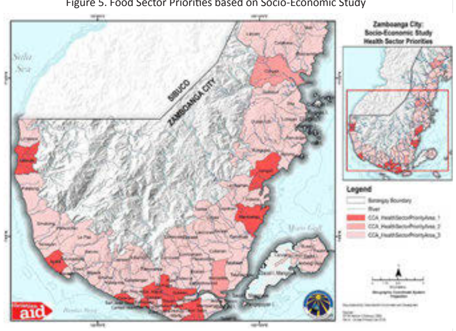

Figure 6. Health Sector Priorities based on Socio-Economic Study

Further studies

Figure 7. Water-Food-Energy-Human Security-Health Nexus

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Modeling urban expansion
across a panel of diverse cities

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C.I.R.E.D.

1. Context and main ideas

The spatial structure of cities plays a key role on their energy consumption levels and on their vulnerabilities to environmental hazards.

The type of urban growth that cities will experience in the next decades will therefore have major implications for climate change mitigation and adaptation.

Objective

In our work, we study and model the mechanisms driving the urban expansion of cities. We analyze economic, environmental and social consequences of policies aiming at impacting urban sprawl.

Approach

Urban shape is the result of 2 forces :

- State decisions : Land-use constraints, zoning, urbanism policies. . .
- Aggregation of multiple individual decisions taken by the inhabitants, and often reflected in a land market (these decisions can be influenced by policies, e.g. transport policies).

The second force (the market) can be analyzed through ***economic models***. We use such a model to simulate prospective scenarios of city growth and to assess the consequences of various policies.

2. Model (NEDUM-2D)

Transport, land planning policies and real estate prices each interact wit each other. Each of them impacts residential location choices of city inhabitants, which themselves act on land prices, and on transport demand.

Transport

Land planning ⟷ Land prices

Using only the most fundamental economic principles from urban economics literature, NEDUM-2D model enables to model these interactions and to build scenarios on city conceivable future evolutions.

It uses as inputs scenarios on the city's future demography, transport system and land use constraints.

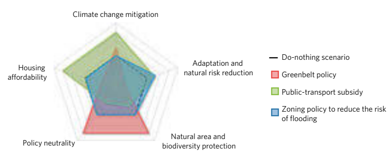
This model is by nature an idealization of reality, but implementations on several cities on different continents have shown that it reproduces faithfully main characteristics of inhabitants residential choices, buildings construction and real estate prices across an urban area.

3. Applications

Scenarios on cities future spatial expansion [6,8]

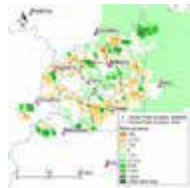
Example of a scenario for Paris metropolitan area expansion between 2010 and 2100 [8]

Analysis of the trade-offs and synergies between mitigation and adaptation policies at city scale [1]



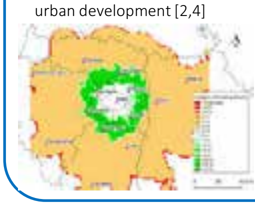
Example of analysis in Paris metropolitan area[1]

Consequences of new transport infrastructures on urban development [9]



Simulated impact of Grand Paris express metro line construction on rents

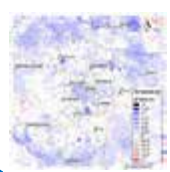
Taxation, building constraints and land planning policies consequences on real estate prices and urban development [2,4]



Example: simulation of potential impacts on population density of a novel construction tax in Paris region.

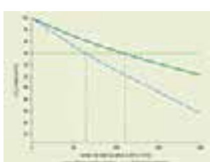
Main cities studied using NEDUM-2D model

Implications of city growth scenarios in terms of greenhouse gases emissions, air pollution and natural hazards vulnerability [5,6,7]



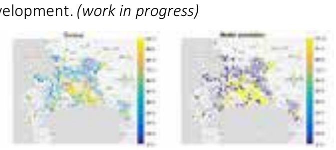
Example: simulation of air temperature change in case of heat wave, in a simulated scenario in which Paris region becomes less compact [5]

Analysis of the consequences of delays in the implementation of emission reduction at city scale [3]



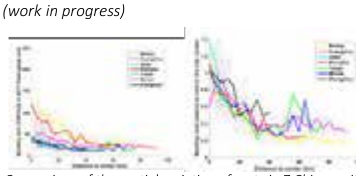
Relative impacts of carbon taxes on commuting-related emission levels in Paris region in 2020 for scenarios with and without public transport [3]

Consequences of transport, land planning and economics policies on income repartition and slum development. *(work in progress)*



Simulation of the share of the households earning less than the median income in Cape Town, South Africa

Comparison of the spatial configurations of cities, and of the link with transport/land planning policies. *(work in progress)*



Comparison of the spatial variation of rents in 7 Chinese cities

4. Summary

- Economic-based urban expansion models can inform decision making, and derive prospective scenarios about cities future expansion/structure modification
- Such models can be coupled with environmental modules (flooding-prone zones, urban micro-climate, air pollution emission and dispersion…)
- The model we have developed, NEDUM2D, is able to dynamically assess variations in real estate prices associated with public investments or changes of urban planning regulations.
- This model is relatively easy to calibrate, and is based on robust and verifiable assumptions : it allows the user to easily understand the mechanisms involved and to understand clearly the uncertainty and the validity of the results obtained.

5. References

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URBAN EMISSIONS IN UGANDAN CITIES

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COUNTRY PROFILE [1]

- **Location**: East Africa. Land locked
- **Population**: 35.6 million (2015), growing at 3.4% per annum
- **Capital city**: Kampala (31% of total urban population)
- **Electricity:** 84% from hydropower dams along River Nile and its tributaries

Figure: Map of Uganda showing major urban centres

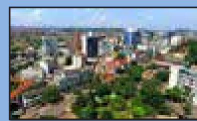


Figure: Skyline of Kampala (Photo Credit: Uganda Safaris Tours)

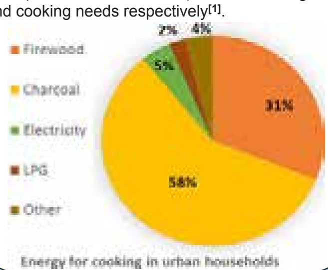
UGANDA'S URBAN CENTRES [1] [2]

- 7 million dwellers (20% of the total population)
- 21 million will live in urban areas by 2040
- Contribute 70% of non-agricultural GDP
- 40% of urban population connected to electricity grid

1. SOURCES OF EMISSIONS

Household Energy

Majority of Uganda's urban households rely on petroleum products (kerosene) and solid biomass fuels (charcoal and firewood) to meet their lighting and cooking needs respectively[1].



Transport

16+ year old second hand cars are imported into Uganda, and then driven for another 20+ years. Toxic fuels with unhealthy levels of sulfur and benzene are also imported and used[3].

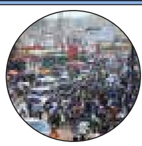
Image: The New Vision

Municipal Waste

Kampala city alone generates 1,500 tons of waste daily, and only 40% of this is collected and suitably disposed of by the city council[5]. The rest is burned in backyards, left to rot in the streets, or dumped in water and sewer channels.

Image: Sanitation Crisis in Unsewered Slum Areas (SCUSA)

2. DRIVERS, IMPACTS AND VULNERABILITIES

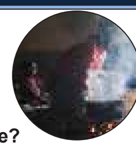


Key Drivers

- Increasing rural-to-urban migration
- Rapid population growth
- Costly and unreliable electricity supply
- Deficient social service provision
- Crippled and poorly planned infrastructures
- Lack of/slack policy measures

Impacts

- Indoor and outdoor pollution
- Respiratory ailments
- Premature deaths
- Loss of forest/tree cover
- Waste run-off into water bodies and drainages
- Urban heat islands. Flooding in wet seasons



Who is Vulnerable?

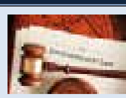
- Women and children - more involved in domestic chores
- Persons with heart and/or lung conditions
- Young children with underdeveloped lungs
- The urban poor in slums or low income neighborhoods
- Water bodies and their ecosystems
- Forests, trees and their ecosystems
- Drainage channels and related infrastructure

3. KNOWLEDGE GAPS AND OPPORTUNITIES FOR INTERVENTION

Opportunities

Waste Management

- Collection and separation
- Transportation
- Processing and treatment
- Waste to energy



Policy and Regulation

- Policy enforcement on: plastics, old vehicles, waste disposal
- Protecting forests, lakes, wetlands
- Sustainability incentives

Infrastructure Development

- Public Private Partnerships
- Inclusive transport systems
- Duly planned housing, social centers, road networks, water and sewerage structures

Energy Provision

- Sustainable
- Reliable
- Affordable
- Diverse

Knowledge Gaps

- What steps should be taken to bridge the gap between environmental policies and their enforcement in cities?
- Can the fairly new concept of Micro Cities be feasibly applied to the planning, expansion, and development of Uganda's urban centers?
- How best can Uganda's vast energy resources be leveraged to build a diverse, sustainable, and decentralized energy portfolio for its expanding cities?
- What lessons can be learned from rural-to-urban migration patterns and slum ecosystems to inform inclusive social service provision?

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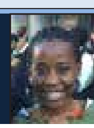

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Urban landscape smoked polluted atmosphere from emissions of plants and factories, view of pipes with smoke and residential apartment buildings timelapse © Shutterstock

Annexes

Annex 1

EXTENDED VERSION: GLOBAL RESEARCH AND ACTION AGENDA ON CITIES AND CLIMATE CHANGE SCIENCE

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

Laying the foundation

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

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

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

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

To build the *Global Research and Action Agenda on Cities and Climate Change Science*, the SSC (see full list Annex D), with support from co-sponsoring organisations, compiled and synthesised input from all conference plenaries, parallel sessions, posters, pre-conference commissioned papers, and discussions during the conference, regarding knowledge gaps and key recommendations.[60] This information was synthesised to shape this Research and Action Agenda by the SSC, with contributions from co-sponsoring organisations and external experts (see authors list, Annex A), who represented diverse disciplines, perspectives, and areas of expertise. Examples used throughout this agenda were discussed at the Conference and are meant to be illustrative. In no way are they meant to be prescriptive or representative of all examples or best practices in the field.

The Conference and the resulting Research and Action Agenda can be considered steps in a longer journey to explore the opportunities offered by evidence-based knowledge in helping address challenges associated with climate change in urban areas. Experience from cities with diverse and distinct characteristics including size (small,

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

medium, large and mega cities), growth patterns (rapidly expanding, sprawling, or stagnating), geography (coastal, dryland, highland, etc.) and contexts (Global North, Global South, high income, high inequality, etc.) were represented at the Conference. The Research and Action Agenda is meant to be applicable across these variations, however it is clear that some aspects may be more relevant for certain cities and countries. Note that the agenda enriched and expanded on the six research priorities identified by Bai et al. (2018) in the course of preparation for the Conference.

This document aims to serve and support national governments, local and municipal authorities[1], researchers and scientists, the planning and design communities, private sector enterprises, international organisations (including international cooperation and development banks) and civil society including indigenous peoples, in developing blueprints and action plans for developing new evidence-based research and knowledge that supports effective climate action strategies in cities. This document signposts key issues that will require research to help guide effective policy development for climate action in cities.
This ambitious agenda attempts to be holistic, inclusive, responsive and solution oriented. It seeks to enable co-design and co-production of knowledge, to encourage system-based approaches, and to highlight the importance of urban processes in facilitating a global climate change response.

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

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

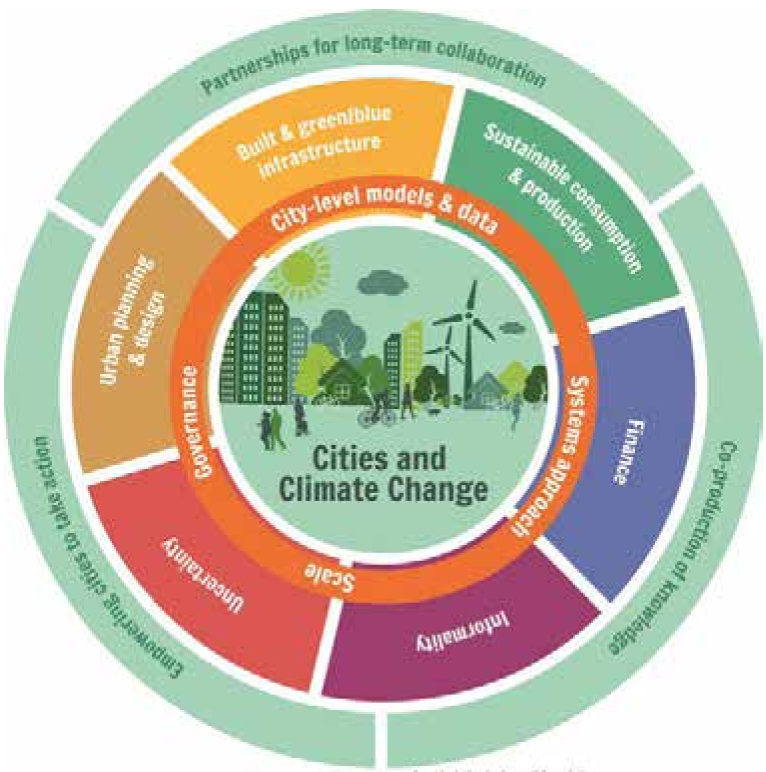

Figure 2: Pathways for climate adaptation and mitigation in cities

1. Crosscutting knowledge gaps

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

1.1. Systems Approach

Taking a systems approach to explore solutions for cities is particularly important for climate change mitigation and adaptation strategies. A systems approach recognises the interaction and interdependent nature of cities within their regions and countries. Cities are open, complex, self-organising, adaptive and evolving formations that are embedded in broader social, ecological, economic, technical, institutional and governing structures.

A systems approach allows various (possibly conflicting) issues to be addressed simultaneously, can help to create more balanced solutions, for example, by combining a climate change perspective (both adaptation and mitigation) with human, ecological, biodiversity and economic development factors, avoiding unsustainable development scenarios while meeting the needs of the disadvantaged. Traditionally, much urban research and action has taken place in various silos (either adaptation or mitigation, or limited to specific sectors, academic disciplines or policy-making units). As a result, many systemic opportunities and risks have been overlooked. Research identifying synergies and trade-offs between adaptation and mitigation in urban areas in different regions could create valuable precedents for urban areas seeking to create climate change agendas.

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

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

New methods need to be developed to incorporate integrative measures of valuation, bringing together quantitative, relational, distributional, behavioural and economic values[61] to assess synergies, trade-offs and co-benefits and potential maladaptation between interventions the respond to climatic and non-climatic hazards. A core challenge facing decision-makers is identifying and prioritising climate change interventions in specific contexts. Calculating costs, co-benefits and trade-offs is often difficult, because many components have no clear monetary value. The total and true 'value' of an action or intervention could be derived by, for example, assessing reduced mortality and morbidity, reduced energy consumption, protected biodiversity or infrastructure, the various benefits of nature-based solutions, socio-cultural well-being, cleaner air, etc. (e.g., Hallegatte et al. 2013; Masson et al. 2014; Lemonsu et al. 2015)). New systems-based valuation approaches need to provide and compare valuation of adaptation and mitigation actions, between various systems and regions, and within specific national contexts. Research in this direction could strengthen contributions to climate change action in urban areas.

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

Advancements in action-oriented research are needed, focusing on multiple impacts, assessing how uncertainty can be reduced, providing options for transformative climate action plans, and highlighting co-benefits for achieving the SDGs and other global agendas, within the context of rapid urbanisation. Rapidly growing and developing urban areas stand to reap long-term rewards from investing early in a systems approach when designing mitigation and adaptation strategies. Within a broader development framework, synergies and co-benefits of systems-based solutions for urban areas can help achieve many SDGs.

Research is needed on how different SDGs and their targets interact and interface with other global agendas, in terms of possible co-benefits and trade-offs. Integrating and comparing targets pertaining to cities under different SDGs could allow for the development of possible optimal solutions to meet mitigation and adaptation targets within other global agendas (Sanchez Rodriguez et al. 2018). Further research using a systems approach is also needed that identifies maladaptive and mal-mitigative pathways and demonstrates possible alternatives. Considering climate change within a systems approach can also help avert compounded and aggregated risks of climate and non-climate hazards in cities. A systems approach is key in delivering the climate change agenda as well as the UN's New Urban Agenda, the SDGs (Bai et al. 2016) and the Sendai Framework for Disaster Risk Reduction.

1.2. Governance and Institutions

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

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

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

Knowledge is needed on different forms of governance, including multilevel governance, that can best support climate action across a highly uneven institutional landscape. Existing evidence points to the importance of building governance capacity. Different institutions and actors have highly uneven access to the knowledge, resources and power required to engage with the climate change challenge. Cities in the Global South experience a significant deficit in governance capacity compared to those in the Global North, with small and mid-size cities having even more asymmetrical governance capacities compared to large cities or capital cities in the same country. Multilevel governance arrangements for political and financial decision-making, long-term continuity and inter-municipal collaborations, as well as joint efforts between research institutions, decision-makers, practitioners and transnational city networks, are all potentially key factors. More evidence is needed to understand the impacts and effectiveness of different forms of governance, to solve tensions and reduce trade-offs, negotiate business practice and information use and create enabling conditions for effective city-based action.

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

1.3. Scale

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

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

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

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

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

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

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

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

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

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

Future climate scenarios need to incorporate transdisciplinary approaches that integrate sociological, economic, climatic and ecological features applicable at the city scale (and that are informed by a range of expertise including indigenous knowledge and local knowledge), is crucial for scientific advancement. Scenarios often rely on many assumptions related to social factors such as urbanisation, demography, economics and innovation. For example, at the global scale, the Shared Socio-Economic Pathways were developed to encompass a plausible range of qualitative narratives regarding demographics, urbanisation, human development, economy and lifestyle, policies and institutions, technology, environment and natural resources (O'Neill et al. 2014). Further research is needed focusing on new modelling methods that allow for assumptions and starting parameters to be scalable, based on actual local data. This would reduce the uncertainty in future scenarios and would make outputs more relevant and reliable in informing local city action, especially if climate and socio-climate metrics were to be monitored and modelled continuously at the city scale.

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

2. Key topical knowledge gaps

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

2.1. Informality

The way in which informal settlements[4] and the informal economy operate, and the ways in which governments respond to these, have significant implications for adaptation and mitigation. Informal settlements are urban settlements or neighbourhoods that have developed outside formal systems regarding land ownership, land tenure and a range of regulations related to planning and land use, built structures, health and safety. Informal settlements do not always occupy land illegally, but rather informality may arise from subsequent sub-divisions or sublets, which do not meet formal standards.

Climate change often affects the inhabitants of informal settlements most severely – the poorest, most vulnerable and marginalised populations in the city, generally with low per capita carbon footprints. Furthermore, differences in the capacity to mitigate carbon emissions and risks while adapting to both rapid and slow onset events (e.g., floods and droughts) depend on differences in socioeconomic status, which in turn can be exacerbated by growing levels of social inequality. More research is needed to understand informality in the context of climate change given the scale of the issue. The population living in informal settlements globally was estimated to be between 881 million and one billion in t2014 (UN Habitat 2017). A possible tripling in the informal population is foreseen (see http://mirror.unhabitat.org/content.asp?typeid=19&catid=10&cid=928) in the coming years given the high rate of informality in Africa and Asia and that 90% of the urban population growth up to 2050 is expected to happen in these two continents (UN DESA 2014).

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

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

Further research could investigate the relationship between climate change and the informal economy to understand how to increase adaptive capacity of informal sectors and how to scale-up low-carbon and climate resilient solutions from and for the informal sector. People whose livelihoods rely on the informal economy can be more vulnerable to climatic changes – for instance higher temperatures and extreme events – due to the lack of a regulatory framework and reliance on casual and intermittent employment.

Developing knowledge and strategies for increasing adaptive capacity of informal businesses would reduce vulnerability. While some areas of the informal economy need low-carbon solutions to sustainably scale up business (such as sustainable energy to replace generators or reliance on biofuels), there are other sectors where current activity is already low-carbon in nature (e.g. waste pickers) and could be scaled-up to citywide level as part of a broader low-carbon strategy. For example, around the world, informal recycling businesses showcase positive environmental outcomes, which can be starting points for more expansive recycling initiatives (Delgado-Ramos and Guibrunet 2017; Botello-Álvarez et al. 2018). These activities could become more efficient through city-level adaptation and mitigation programmes and be integrated as an aspect of a citywide low-carbon transition.

2.2. Urban Planning and Design

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

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

It will be increasingly important for both researchers and decision-makers to understand how urban micro-climates integrate into urban planning and design to simultaneously improve urban environmental outcomes, reduce risk and address the need to adapt to, and mitigate, climate change. From enhancing ventilation, increasing vegetation cover, maximising green and ecological infrastructure, to using strategic shading, understanding the configuration of the micro-climate of an urban district is increasingly important for both researchers and decision-makers to develop responses to guide urban planning to address climate mitigation and adaptation challenges. In addition, the vast majority of our current understanding of heat risk in cities comes from studies in the United States, Europe and Australia, but cities in the Global South are unique in their climates, vulnerabilities and exposures.

Foundational and actionable research on the best ways to define heat waves (e.g., determining relevant indices or variables), what thresholds are considered dangerous in different cities and how heat interacts with the built environment (e.g., corrugated metal roofs in slums) would provide important insight for adaptation and mitigation needs in the context of specific cities. The complexity of understanding and managing a city's micro-climate, both in urban areas in the Global South and Global North, calls for further research and the development of new methodologies for urban planning for mitigating of and adapting to climate change.

It will be important to explore the role of urban and spatial planning in reducing vulnerability and enhancing adaptation to climate change for both formal and informal settlements. Urban form and structure play a prominent role in shaping vulnerability, but informal settlements are often not considered in planning strategies. Encouraging research on how planning approaches can become inclusive of informal settlements for climate change adaptation would make a key contribution to reduce negative impacts of current and future urban growth. Further research is also needed to assess underlying causes of social vulnerability to climate change, particularly in small- and medium-sized urban areas in the Global South.

The implications of exploring urban planning in reducing vulnerability could contribute many positive impacts, especially in towns and cities with high levels of informality, where planning and action cannot take place because of a lack of knowledge around risk awareness, threshold identification, forecast products and actionable guidance from the planning community. Accounting for predicted future population growth and land consumption while considering vulnerability and risk, could compliment vulnerability assessments of urban areas further enhancing the capacity of the planning community to address risks associated with climate change.

In planning for future urban expansion, there is a need to document and quantify the impacts of climate change on human health, and to map the full range of health co-benefits of adaptation and mitigation. Climate change presents complex threats for human health, both direct and mediated by natural and human systems. In cities, these threats are often amplified by high population density and vulnerability, systemic interdependencies, and by risk of flooding and inundation in coastal and low-lying areas.

Urban planning and design can help address these threats especially where buildings, transport and infrastructures are yet to be built, or where informal and vulnerable areas are earmarked for upgrading or retrofitting. Health co-benefits of climate action can be immediately relevant and a potentially powerful motivator for investing in climate action. To support transformative change, there is an urgent need for detailed local information on the impacts of climate change on human health and potential co-benefits (for instance improved air quality, resilience to temperature extremes, reduced rate of death, injury or propagation of communicable disease due to climate disasters, avoiding system breakdowns with their downstream effects on food, water and energy security) which can be considered in future urban planning.

2.3. Built and Blue and Green Infrastructure

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

Further exploration is needed on low-carbon and environmentally-friendly infrastructure options that go beyond traditionally dominant grey infrastructure[6] for transformational climate solutions in developed and rapidly developing urban areas. Urban development remains dominated by grey infrastructure – buildings, roads and associated infrastructure. The way urban areas are designed, planned and maintained significantly affects urban emission levels (Seto et al. 2014). While there have been promising technological developments, more research is needed on low-carbon construction techniques, affordable low-carbon building materials, carbon storage in infrastructure, bioclimatic designed infrastructure, novel mobility paradigms and more environmentally-friendly planning and design, including blue/green infrastructure[7]. With the potential to reduce energy needs, high-carbon materials consumption and urban heat island effect and to increase urban resilience, these options could make a significant impact on rates of future global emissions. These effects also need to be better captured in emission scenarios.

Further research is needed to understand the co-benefits of blue/green infrastructure and ecosystem-based adaptation, and how mitigation projects could support decision-making in terms of future infrastructure priorities to address climate change in cities. Blue/green infrastructure such as open spaces, parks, indigenous biodiversity and bodies of water have a wide array of economic, social and environmental benefits, including, greatly improving urban form, and enhancing the effectiveness and/or reducing demand on other infrastructure sectors.

Further research is needed on how to maximise their potential to improve the health and wellbeing of urban residents (Chu et al. 2004; Bowen and Lynch 2017) mitigate climate change through carbon sequestration (Liu et al. 2016; Pennino et al. 2016; Zuñiga-Teran 2017; Chenoweth et al. 2018; Bartesaghi Koc et al. 2017) and passively modulate the urban micro-climate. It will also be necessary to understand how blue/green infrastructure itself is vulnerable to future climate change, including increases in temperature, changes in precipitation patterns and more frequent and intense weather events (e.g., ice storms, hurricanes), with the goal of enhancing resilience and reducing maintenance costs of the blue/green infrastructure solutions. Study and development of innovative financial solutions for incorporating blue/green infrastructure is also crucial for cities, especially those that make these solutions affordable for cities in the Global South. Research on the cultural value of these ecosystem services is also key to a better understanding of their utilisation by urban inhabitants, particularly in the Global South, and will imply close collaboration with social sciences and humanities.

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

2.4. Sustainable Consumption and Production

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

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

In the Global South, although the above is desirable, most of the short and mid-term opportunities are to be found in updating obsolete means of production and increasing production capabilities with cleaner technologies. In the mid- and long-term, opportunities for Global South cities lie in moving their main economic structure towards low-carbon, sustainable and more knowledge-intensive options. This transition is of high importance as this is where most future population growth is expected. These cities represent a major opportunity to avoid repeating the high consumption and emission developmental pathways and subsequent high carbon lock-in of industrialised countries, and to be at the forefront of innovation. In any Global South transition, North-South and South-South cooperation seems to be crucial.

Research is required to better understand potential pathways for social change that promote lifestyles and cultures which are less resource intensive and that increase adaptive capacity and well-being. It is through consumption that people navigate their way in the world, create identity, express status and symbolically communicate with others. Yet these activities inflict a heavy burden often have in terms of energy and materials utilisation. High consumption patterns are particularly salient in the lives of urban populations, and especially prominent in the Global North, and need to be considered in meaningful climate-response programmes.

Further studies could explore how diverse ways of organising community life – both the physical form and social relations – affect consumption as measured by GHG emissions, influence adaptive capacity and destabilise the long-standing connection between fossil fuels and urban development while ensuring urban liveability. Another aspect of this research would be to understand better the role of incentives, privileging investments, technological innovations, law, taxation, education and urban governance in influencing decisions made by people and communities, which orient choices towards reduced carbon and energy use, and towards more sustainable consumption. Research focusing on the transfer and adoption of consumption patterns in the Global North to cities in the Global South is also relevant for climate change agendas.

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

2.5. Finance

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

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

Further research is needed to explore how public budgets can be strategically used, including to crowd in private investment, to address the shortfall in sustainable urban infrastructure investment. Bankability and creditworthiness are prerequisites for private investors, who require either a sufficient return on investment based on project income flows or low-risk government debt repayments. Governments and development agencies play a role in structuring and packaging urban infrastructure projects, using domestic and international public finance strategically to attract investment and lower the cost of capital (Floater et al. 2017). Cities could benefit from targeted research on how to strengthen the coherence and effectiveness of demand-side institutions (the project implementers) and the effectiveness of project preparation facilities.

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

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

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

2.6. Uncertainty

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

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

Further research is needed to evaluate the ‘fit-for-purpose’ attributes of models and to provide guidelines for simplified approaches that would strengthen the evaluation of the confidence in projections and the associated uncertainties. Examples of such uncertainties include whether the sets of projections used in city scale models encompass the full range of relevant drivers (e.g., land use and aerosols at the regional scale, and greenhouse gases at the global scale), whether the methodologies encompass the full range of plausible climate variations on the near and long term, whether they include low probability, high risk, poorly known events (e.g., compound extreme events), and whether non-linear behaviours and risks of thresholds and abrupt shifts are accounted for. Developing simplified approaches that can be adapted to different city contexts, and that are informed by exhaustive assessments of sources of uncertainties and limits of complex modelling approaches is needed to account for the full spectrum of uncertainty to inform decision making.

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

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

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

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

3.1. Knowledge Co-Design and Co-Production

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

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

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

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

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

3.2. Empowering Cities to Take Action

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

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

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

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

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

Fostering mutual understanding, through advancing co-production and co-generation of knowledge and further empowering cities to take action. Climate change action has tended to occur in silos, not only within the three communities, but also in the sectors and fields within them (e.g.; natural, social sciences and humanities). A first step towards fruitful and holistic collaboration would be to raise awareness of the personal competencies required to work across silos.

Such competencies might include for example the ability to understand and navigate differences in organisational culture, ethical and normative issues, the ability to translate between different knowledge schemes, the necessary self-awareness to recognise gaps in capacity and the willingness to develop lacking capacities actively, by involving different perspectives.

The recognition of the different level of detail needed and the different priorities of the three communities (e.g., different information needs of high level government officials looking to create new policy and practitioners implementing solutions on the ground) by all collaborating actors would facilitate dialogue. Identifying common ground on issues relating to mitigation and adaptation, and on how science and policy needs can best be aligned, would allow for cross community benefits to emerge on an ongoing basis.

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

Close interactions between cities and the scientific community can be fostered by providing opportunities for researchers to work in municipal and local authorities, and opportunities for practitioners and decision-makers to invest time in research projects. This could be facilitated by grants and fellowships for PhD or master students from both social and natural sciences and humanities to conduct research in local and municipal authorities' offices or to work as part of collaborative research projects. Another approach could be a chief scientist or a scientific advisory panel supporting a city on climate change issues (Bai et al. 2018). This would help the research community better understand city opportunities, challenges and constraints (e.g., timelines, priorities).

Another option would be to have urban practitioners and decision-makers take a larger role in research projects or in the development of climate centres in research institutes to ensure they are better aligned with city challenges. Establishing living laboratories[10] could also facilitate this and increase understanding between disciplines and departments. These approaches would facilitate a deeper understanding of the processes in cities and the development of solutions based on scientific evidence.

Catalysing collaboration and knowledge production

Building on existing knowledge and action, the Conference and this *Global Research and Action Agenda on Cities and Climate Change Science* are two steps in a journey towards generating greater knowledge in support of practice and decision-making to address climate change challenges and opportunities in urban areas. The following are examples of forward-thinking initiatives that have recently emerged to continue this journey: (1) The Science we Need for the Cities we Want, signed by most of the Conference organising partners as well as Urban Climate Change Research Network (UCCRN) at the end of the Conference, and now signed by 24 organisations,62; (2) the Edmonton Declaration, which calls on cities to support evidence-based decision-making and action to address climate change in cities; (3) a national gathering of science, policy and practice in Mexico City (organised by the National Autonomous University of Mexico-UNAM) to discuss the outcomes of the Conference in the Mexican context; (4) Conference partners, especially ICLEI, together with the UNFCCC, working towards an annual gathering of UNFCCC members, city and research partners around cities and climate; (5) Innovate4Cities initiative from the Global Covenant of Mayors, to further develop this Research and Action Agenda with cities.

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

Glossary

[1] Municipal authorities: This term includes local and municipal governments.

[62] As of 3 Aug 2018

[2] Path dependencies: The generic situation where decisions, events, or outcomes at one point in time constrain adaptation, mitigation, or other actions or options at a later point in time.

[3] Carbon lock-in: Where the inertia of technologies, institutions and behaviours individually and interactively inhibit innovation and competitiveness of low-carbon alternatives.

[4] Informal settlements: A term given to settlements or residential areas that by at least one criterion fall outside official rules and regulations. Most informal settlements have poor housing (with widespread use of temporary materials) and are developed on land that is occupied illegally with high levels of overcrowding. In most such settlements, provision for safe water, sanitation, drainage, paved roads and basic services is inadequate or lacking (IPCC 2014a)

[5] Resilience: The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation

[6] Grey infrastructure: Human-made, constructed infrastructure (European Environment Agency 2017)

[7] Green infrastructure: Green infrastructure refers to interventions to preserve the functionality of existing green landscapes (including parks, forests, wetlands, or green belts), and to transform the built environment through phytoremediation and water management techniques and by introducing productive landscapes (IPCC 2014b). This could be termed blue infrastructure if aquatic ecosystems are concerned (European Environment Agency 2017)

[8] Uncertainty: A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g., a probability density function) or by qualitative statements (e.g., reflecting the judgment of a team of experts) (Moss and Schneider 2000; Manning et al. 2004; Mastrandrea et al. 2010)

[9] Deep uncertainty: The concept of deep uncertainty has emerged to refer to situations where decision-making is needed while there is no conceptual understanding of the key drivers of change; when there is no agreement on the probability distribution of key variables affecting the changing system; when there is no agreement on the desirability of alternative outcomes. The term deep uncertainty is particularly complex and in need of further specification. (Lempert et al. 2003) have defined deep uncertainty as "the condition in which analysts do not know or the parties to a decision cannot agree upon (1) the appropriate models to describe interactions among a system's variables, (2) the probability distributions to represent uncertainty about key parameters in the models and/or (3) how to value the desirability of alternative outcomes."

[10] Living laboratories: Living laboratories are structures often operating in a territorial context, such as within a city or agglomeration, which seek to enhance collaboration between researchers and the end users or beneficiaries of research efforts, engaging community in every stage of development from concept to prototyping.

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Three Women with Umbrellas walking through Water in Berlin Streets, flooded after Days of heavy Rainfalls © Shutterstock

Annex 2

COMMITTEES

The organization of the Cities and Climate Change Science conference is led by the Scientific Steering Committee and the Organizing Committee.

Scientific Steering Committee

The Scientific Steering Committee (SSC) was composed of experts from the engineering, physical, natural and social science and humanities, as well as from the urban community. The SSC guided the organization of the conference through developing the scientific strategy, the conference program and vision to achieve the conference objectives.

Co-Chairs

Dr. Shobhakar Dhakal

With a Ph. D. in Energy and Urban Heat Island Mitigation from the University of Tokyo, Dr. Shobhakar Dhakal is an Associate Professor and the Head of the Department of Energy, Environment & Climate Change at the Asian Institute of Technology, Thailand. He also is a Coordinating Lead Author of IPCC AR6 & AR5. He has research interests in cities and climate change, the interaction of energy sector with climate mitigation, energy and sustainable development - especially energy access in developing countries, and environmental governance.

Seth Schultz

Seth Schultz is the Special Advisor on Science and Innovation to the Global Covenant of Mayors where he is leading the development of Innovate4Cities, a global, cities lead initiative to establish and implement the first global research and innovation agenda on cities and climate change. He is also a lead author on the IPCC Special Report on 1.5 Degrees (SR 1.5), sits on various boards, committees and advisory groups around the world. Previously, Mr. Schultz was the former Director of Science and Innovation for the C40 Cities Climate Leadership Group and worked with other environmental groups like the Clinton Climate Initiative, the US Green Building Council and spent 10 years in the private sector working at the federal, state and local level in the US.

Prof. Dr. Diana Ürge -Vorsatz

Diana Ürge-Vorsatz is a Professor at the Department of Environmental Sciences and Policy at the Central European University. She serves as Vice Chair of WGIII of the IPCC. She holds a Ph.D. from the University of California (Los Angeles and Berkeley). She served as the Director for the Center for Climate Change and Sustainable Energy Policy at CEU. She now serves as associate editor of the journal "Energy Efficiency", and is a member of the Editorial Board of "Annual Reviews of Environment and Resources". She has been serving on the Governing and Advisory boards of several organizations, including Innogy, the Austrian Climate and Energy Fund, the European Climate Foundation, the UK Energy Research Centre, the Hungarian Energy-Efficiency Cofinancing Program, and the Club of Budapest. She received the Hungarian Republic's Presidential Award "Medium Cross" in 2008, as well as the "Role Model" award in 2009 and was invited as a member of Academia Europaea in 2017.

Members

Prof. Xuemei Bai

Prof. Xuemei Bai has been a professor of Urban Environment and Human Ecology at the Australian National University since 2011. She has research and teaching experience at CSIRO, Yale University, and environmental research institutes in Japan. She earned a Ph. D. in civil engineering from The University of Tokyo, Japan. Her research focuses on several frontiers of urban sustainability science and policy, including drivers and impacts of urbanization, the structure, function, processes, and evolution of urban socio-ecological systems, cities and climate change, urban metabolism, urban environmental policy and governance, and urban sustainability experiments and transition. She is a Fellow of The Academy of Social Sciences in Australia.

Dr. Aliyu Barau

Dr. Aliyu Barau is a senior lecturer and the Head of Department of Urban and Regional Planning at Bayero University Kano, Nigeria. He completed a Ph. D. in Urban and Regional Planning from the Universiti Technologi, Malaysia. His areas of interest include planning decision support, climate change, urban resilience, environmental resource governance, land use planning and policy.

Dr. Helen Cleugh

Dr. Helen Cleugh completed a Ph. D. in Atmospheric Science at the University of British Columbia, Canada. She is the Director of CSIRO's Climate Science Centre, Australia. Prior to this appointment she was, inter alia, Deputy Chief of CSIRO's Marine and Atmospheric Research Division and Deputy Director of the Oceans and Atmosphere Business Unit. Her research expertise lies in quantifying the interactions between the land surface and the atmosphere, and their effects on weather, climate and hydrology, water-use and carbon uptake.

Prof. Richard Dawson

Professor Richard Dawson's research in the School of Engineering at Newcastle University focuses on the analysis and mitigation of environmental risks to infrastructure networks and urban areas. He has published over 65 journal papers, has editorial roles for the journals Climatic Change and Flood Risk Management, and been awarded the Lloyds Science of Risk and Institution of Civil Engineers Robert Alfred Carr Prize. Richard led the Infrastructure section of the 2017 UK Climate Change Risk Assessment, and was recently appointed by the United Nation's IPCC as a lead author on the Cities, Settlements and Infrastructure Chapter of their 6th Assessment Report.

Dr. David Dodman

Dr. David Dodman is an expert on climate change vulnerability and resilience in urban centres. He is the Director of the Human Settlements Group at the International Institute for Environmental Development (IIED), UK and a Senior Teaching Fellow at University College London. He holds a doctorate in Geography from the University of Oxford, UK. His main research interests are in urban studies, climate change, resilience and adaptation.

Members (cont'd)

Dr. Gian Carlo Delgadova

Dr. Gian Carlo Delgado is a tenured professor and researcher for the Interdisciplinary Research Center on Sciences and Humanities, at the National Autonomous University of Mexico, Mexico. He holds a Ph. D. in Environmental Sciences from the Autonomous University of Barcelona. He is a member of the National Research System of the Mexican Council on Science & Technology (CONACYT) and a regular member of the Mexican Academy of Sciences. His researches focus on the urban environment and climate change, urban sustainability and urban political ecology."

Lykke Leonardson

Lykke Leonardson is the Head of program for Resilient and Sustainable City Solutions, for the city of Copenhagen, where she is responsible for the development and sharing of Copenhagen's work on creating a liveable city. She has worked for the city of Copenhagen for more than 20 years, in many different fields, including neighborhood regeneration, urban planning, parks and nature conservation and waste – and storm water management.

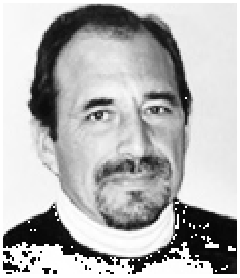
Prof. Valérie Masson -Delmotte

Dr. Valérie Masson-Delmotte is a senior scientist from Laboratoire des Sciences du Climat et de l'Environnement, Institut Pierre Simon Laplace. She is the Co-chair of IPCC Working Group I for the AR6 cycle. Her research interests are focused on quantifying and understanding past changes in climate and atmospheric water cycle, using analyses from ice cores and tree-rings as well as present-day monitoring, climate modelling; and were recognized by several prizes (EU Descartes Prize for the EPICA project, Women scientist Irène Joliot Curie Prize, to name a few). She has worked on issues such as the North Atlantic Oscillation, drought, climate response to volcanic eruptions, polar amplification, abrupt climate change and ice sheet vulnerability across different timescales. She is active in outreach for children and for the general public and has contributed to several books on climate change issues.

Dr. Debra Roberts

Dr. Debra Roberts is head of the Sustainable and Resilient City Initiatives Unit of eThekwini Municipality in Durban, South Africa. Prior to taking up this post she established and managed the Environmental Planning and Climate Protection Department of the same municipality and is the city's first Chief Resilience Officer. She was a lead author of Chapter 8 (Urban Areas) and a contributing author to Chapter 12 (Africa) of WGII of the IPCC Fifth Assessment Report and was elected as Co-Chair of WGII for the Sixth assessment cycle in 2015. She was a member of the South African UNFCCC negotiating team. She has written widely in the fields of urban open space planning, environmental management and urban climate protection. She is also an Honorary Professor at the University of KwaZulu-Natal.

Members (cont'd)



Prof. Roberto Sanchez -Rodriguez

Roberto Sánchez-Rodríguez is a Professor in the Department of Urban and Environmental Studies at El Colegio de la Frontera Norte, a research institution of Mexico's National Council of Science and Technology and a Emeritus professor in the Department of Environmental Sciences of the University of California, Riverside, USA. His research addresses the social dimension of global environmental change, vulnerability and adaptation to climate variability and climate change, disaster risk reduction, and sustainable development. He is a Vice-Chair in WGII of the IPCC Bureau, a member of Mexico's National System of Researchers. He was a lead author of chapter 15 (Adaptation Planning and Implementation) in the WGII of IPCC AR5 and Co-Chair of the core project on Urbanization and Global Environmental Change (UGEC) sponsored by ICSU, the ISSC, and UNEP.

Dr. Cynthia Rosenzweig

Dr. Cynthia Rosenzweig is a Senior Research Scientist at the NASA Goddard Institute for Space Studies and Columbia University Earth Institute, where she heads the Climate Impacts Group. She is Co-Chair of the New York City Panel on Climate Change (NPCC) and Co-Director of the Urban Climate Change Research Network (UCCRN). She earned a Ph. D. from the University of Massachusetts Amherst in Plant, Soil and Environmental Sciences. Among numerous other works, she was a Coordinating Lead Author of WGII for the Fourth Assessment Report of the IPCC. She joins impact models with climate models to project future outcomes of both land-based and urban systems under altered climate conditions.

Prof. Karen Seto

Prof. Karen Seto is Professor of Geography and Urbanization Science at the School of Forestry and Environmental Studies at Yale University. She co-founded and co-chaired the global research project Urbanization and Global Environmental Change from 2006-2016. She was a Coordinating Lead Author for Working Group III of the IPCC Fifth Assessment Report and led the chapter on urban mitigation of climate change. Her central research focuses on how urbanization will affect the planet. She uses remote sensing and a scientific lens to study the aggregate global impacts of urbanization.

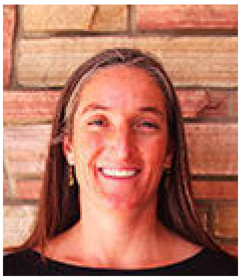
Prof. William Solecki

Solecki's served as leader or co-leader of several climate impacts studies in the greater New York and New Jersey region, including the New York City on Panel on Climate Change and the New York State ClimAID report. He currently serves as the co-PI on the Climate Change Risk in the Urban Northeast, NOAA-funded RISA project designed to promote climate risk information for decision-makers and stakeholders in the urban Northeast US. He is the participant on a NSF funded, Urban Resilience and Extreme Events (UrEX) Sustainability Research Network, a co-founder of the Urban Climate Change Research Network and co-editor of the recent ARC3. He also serves as the co-editor of the journals Current Opinion in Environmental Sustainability and the Journal of Extreme Events. His Ph.D. is in Geography from Rutgers University.

Members (cont'd)

Maryke van Staden

Maryke van Staden is the Director of the Bonn Center for Local Climate Action and Reporting (carbonn Center) and Manager of ICLEI's global Low Carbon City Program, based in Germany. She is active in many noteworthy initiatives, including: Executive Committee member of the Global 100% Renewable Energy Platform, ICLEI's lead staff representative in the Global Covenant of Mayors for Climate & Energy (GCoM), and Steering Committee member of the Cities Climate Finance Leadership Alliance (CCFLA).



Dr. Megan Melamed

Dr. Megan Melamed is the executive officer of the International Global Atmospheric Chemistry (IGAC) project at the University of Colorado's Cooperative Institute for Environmental Sciences (CIRES), USA. She earned a Ph. D. in Environmental Engineering from the University of Colorado, USA. She is interested in air pollution and climate change interactions, the impact of urbanization on air pollution and air pollution policy.

Organizing Committee

The Scientific Steering Committee (SSC) was composed of experts from the engineering, physical, natural and social science and humanities, as well as from the urban community. The SSC guided the organization of the conference through developing the scientific strategy, the conference program and vision to achieve the conference objectives.

Co-Chairs

Members

Annex

3

DETAILED CONFERENCE BUDGET

The Conference global budget is detailed below, in table 2.1. both by item and contributions of each partner organisation. The details on the budget of the Host City can be found in table 2.2.

Table 2.1: Detailed global conference budget

Item	Expensed by	Amount Spent
Scientific Steering Committee		
Pre-conference meeting room and catering	Cities Alliance	$ 500.00
Co-Chair pre-conference travel for meetings	Cities Alliance	$ 6, 200.00
SSC in-person meeting	C40 Cities	$ 20, 000.00
Commissioned background papers	UN Habitat	$ 10, 000.00
Production of conference report, International Institute for Sustainable Development	IPCC	$ 36,200.00
Total Scientific Steering Committee Spending		$ 79, 000.00
Website		
Design and maintenance	Cities Alliance	$ 9, 500.00
Total Website Spending		$ 9, 500.00
Event Management		
Events manager	C40 Cities	$ 15, 000.00
Total Event Management Spending		$ 15, 000.00
Communications and outreach		
Global Communication and Media Agency	C40 Cities	$ 80,000.00
OC Video Production	Sustainable Development Solutions Network	$ 6, 000.00
	C40 Cities	$ 6, 000.00
Total Communication and outreach Spending		$ 92, 000.00
Sponsored Travel		
Airfare, lodging and additional expenses	IPCC	$ 203, 800.00
Airfare, lodging and additional expenses	UN-Habitat	$ 30, 000.00
Airfare, lodging and additional expenses	Cities Alliance	$ 40, 183.62
Airfare, lodging and additional expenses	C40 Cities	$ 25, 154.00
Airfare	DG Clima, European Commission	$ 35, 500.00
Airfare	German government	$ 21, 716.43
Airfare	Future Earth	$ 3, 500.00
Airfare	World Climate Research Programme	$ 3, 500.00
Airfare	Louis Berger	$ 20, 000.00
Airfare	International Development Research Centre	$ 28, 600.00
Airfare, lodging and/or additional expenses	International Council for Local Environmental Initiatives	$ 9, 051.00
Total Sponsored Travel Spending		$ 306, 462.43
Total Spending		$ 500, 463.43

Table 2.2: Detailed conference budget for the host city

Item	Spent
Event management & registration	$ 109,949.68
Pre-conference cities IPCC meetings in Edmonton (venue, hospitality, accommodation, transportation)	$ 7,088.30
Venue rental, audio-visuals and technical support & equipment	$ 303,110.82
Hospitality	$ 324,397.04
Programme support, event dressing, branding and marketing, conference and exhibition support	$ 190,847.24
Travel support for developing countries	$ 105,591.67
On ground transportation and site tours	$ 56,002.65
Total Project Expenditures	$ 1,096,987.40

NOTES:

1. The City of Edmonton thanks the following government and private sector organizations that that provided funds in support of the host city budget for the conference:
   – Host Partners for the Conference including the Government of Canada and the Alberta Government;
   – Platinum level sponsorship from Epcor;
   – Gold level sponsorship from TD Bank and Insurance Bureau of Canada; and
   – Silver level sponsorship from EllisDon, Graham, Edmonton International Airport and PCL Construction.
2. Budget presented is for the CitiesIPCC Conference only. Other events were hosted by the City of Edmonton and partners in parallel with the conference; however, the budget for the parallel events ins not included in Table 2.2.
3. Budget is presented in US Currency.

Annex 4

LIST OF CONFERENCE PARTICIPANTS

The Conference welcomed 701 invited participants. Unfortunately, due to VISA application processing times and restrictions, there was a number of invited participants from the Global South who were unable to attend as they were not able to secure VISAs. The regional distribution of conference participants is summarised in table 3.1, and the full list of conference participants follows in table 3.2. We note that there were also 16 participants who did not indicate a nationality upon registration, and therefore are not represented in Table 3.1. The nationalities indicated below are those provided by conference participants at the time of registration.

Table 3.1: Number of conference participants from different regions

Africa	44
Asia	72
South America	33
North America, Central America and the Caribbean	362
South West Pacific	20
Europe	154

Table 3.2: List of conference participants

First Name	Last Name	Nationality	GS/GN	First Name	Last Name	Nationality	GS/GN
Deborah	(Matejicka) Elliott	Canada	GN	Lykke	Leonardsen	Denmark	GN
Ernest Mensah	Abraham	Ghana	GS	Lynden	Leonce	UK	GN
William	Adams	Canada	GN	Thomas	Lewis	USA	GN
Anthea	Adjei Tawiah	Ghana	GS	Hannah	Liddy	USA	GN
Rimjhim	Aggarwal	USA	GN	Eric	Lindquist	USA	GN
Sohail	Ahmad	India	GS	Thomas	Lippiatt	Canada	GN
Samuel Olumide	Akande	Nigeria	GS	Leroy	Littlebear	Canada	GN
Hashem	Akbari	Canada	GN	Wilton	Littlechild	Canada	GN
Hina	Alam	India	GS	Tom	Logan	New Zealand	GN
Jaume	Albertí	Spain	GN	Darrell	Loranger	Canada	GN
Florian	Albrecht	Germany	GN	Hina	Lotia	Pakistan	GS
Jacqueline	Alderton	Canada	GN	Peter	Love	Canada	GN
Ali	Alizadeh	Iran	GS	Natalie	Loveless	Canada	GN
Jennifer	Allan	Canada	GN	Amy	Luers	USA	GN
Justis	Allard	Canada	GN	MaryElizabeth	Luka	Canada	GN
Adrianna	Amalio	Canada	GN	Shuaib	Lwasa	Uganda	GS
Pauline Mercy	Amondi	Kenya	GS	Laura	Lynes	Canada	GN
Shaye	Anderson	Canada	GN	Jonathan	Lynn	UK	GN
Walter	Andreeff	Canada	GN	Kevin	Ma	Canada	GN
Vada	Antonakis	Canada	GN	Leslie	Mabon	UK	GN
Fernando	Aragon-Durand	Mexico	GS	Renato	Macciotta	Italy	GN
Ron	Arcand	Canada	GN	Laura	Macedo	Brazil	GS
Mark	Archibald	Canada	GN	Martha	Macedo de Lima Barata	Brazil	GS
Verónica	Arias	Spain	GN	Caitlin	Macnab	Canada	GN
Yunus	Arikan	Turkey	GN	Cheyenne	Maddox	USA	GN
Astrid	Arnslett	Norway	GN	Darshini	Mahadevia	India	GS
Kabir	Arora	India	GS	Nafisa	Mahbub	Canada	GN
Mohit	Arora	India	GS	Kelly Leilani	Main	USA	GN
Jose Miguel	Arriaza Hinojosa	Chile	GS	Maria-Ines	Maita	Canada	GN
Julie	Arrighi	USA	GN	David	Major	USA	GN
Eric	Ast	USA	GN	Sebastien	Malo	Canada	GN
Francis	Asunction	Canada	GN	Tonya	Malo	Canada	GN
Adam	Auer	Canada	GN	Felipe	Mandarino	Brazil	GS
Kenshi	Baba	Japan	GN	Shingirai	Mandizadza	Zimbabwe	GS
Simeran	Bachra	Canada	GN	Trevion	Manning	Jamaica	GS
Carl	Backstrand	Sweden	GN	Claire	Markgraf	USA	GN
Xuemei	Bai	Australia	GN	Samuel	Martin	Canada	GN

First Name	Last Name	Nationality	GS/GN	First Name	Last Name	Nationality	GS/GN
Rose	Bailey	UK	GN	María Amparo	Martínez Arroyo	Mexico	GS
Thomas	Bailey	UK	GN	Susan	Mason	USA	GN
Alexander	Baklanov	United Nations		Valéry	Masson	France	
Osman	Balaban	Turkey	GN	Valerie	Masson-Delmotte	France	GN
Catherine	Bale	UK	GN	Mmoto	Masubelele	South Africa	GS
Kelly	Bamford	Canada	GN	Érika	Mata	Spain	GN
Aliyu	Barau	Nigeria	GS	Robin	Matthews	UK	GN
Fabiana	Barbi Seleguim	Brazil	GS	Maija	Mattinen-Yuryev	Finland	GN
Karen	Barkley	Canada	GN	Ana	Mauad	Brazil	GS
Kaitlin	Barr	Canada	GN	Ian	Mauro	Canada	GN
Silvio	Barros	Brazil	GS	Shedrack	Maximilian	Tanzania	GS
Bernhard	Barth	Germany	GN	Marcus	Mayr	United Nations	
Judit	Bartholy	Hungary	GN	Alice	McClure	South Africa	GS
Chris	Bataille	Canada	GN	Darren	McCrank	Canada	GN
Heike	Bauer	Germany	GN	Shannon	McDaniel	Belgium	GN
Elisabeth	Beaubien	Canada	GN	Dan	McDougall	Canada	GN
Lan Marie Nguyen	Berg	Norway	GN	David	McGown	Canada	GN
Rob	Bernhardt	Canada	GN	Becky	McKee	Canada	GN
Paolo	Bertoldi	Italy	GN	Scott	McKeen	Canada	GN
Courtney	Bettin	Canada	GN	Catherine	McKenna	Canada	GN
Anthony Gad	Bigio	Italy	GN	Timon	McPhearson	USA	GN
Sierra	Bilton	Canada	GN	Sarah	McPike	Canada	GN
Anna	Bishop	Canada	GN	Ian	McVey	Canada	GN
Hilda	Blanco	USA	GN	Megan	Meaney	Canada	GN
Kristy	Bland	Canada	GN	Guenter	Meinert	Germany	GN
Nathalie	Bleau	Canada	GN	Megan L.	Melamed	USA	GN
Kambal	Bloxhan	Canada	GN	Fabrizio Sebastian Manuel Malpartida	Melgarejo	Peru	GS
Eva A.	Bogdan	Canada	GN	Mike	Mellross	Canada	GN
Alyssa	Bohart	Canada	GN	Kavya	Michael	India	GS
Pierre	Boileau	Canada	GN	David	Miller	Canada	GN
Nicole	Bonnett	Canada	GN	Masoumeh	Mirsafa	Iran	GS
Craig	Bonneville	Canada	GN	Carrie	Mitchell	Canada	GN
Alex	Boston	Canada	GN	Logan	Mitchell	USA	GN
Buffy	Boudjikanian	Canada	GN	Lois	Mitchell	Canada	GN
Thijs	Bouman	Netherlands	GN	Semu	Moges	Ethiopia	GS
Thomas E.	Bowman	USA	GN	Banafsheh	Mohammadi	Iran	GS
Dana	Boyer	USA	GN	Asad	Mohammed	Trinidad and Tobago	GS
Aspasia	Brasileiro Alcântara de Camargo	Brazil	GS	Azadeh	Mokhberi	Iran	GS
Geneviève	Bretagne	France	GN	Luisa	Molina	USA	GN
Allison	Bridges	USA	GN	Hayley	Moller	USA	GN
David	Bristow	Canada	GN	Jade	Monaghan	Canada	GN
Derik	Broekhoff	USA	GN	Paula	Monroy	Mexico	GS
Danielle	Bronson	Canada	GN	Franco	Montalto	USA	GN
Mark	Brostrom	Canada	GN	Sourayan	Mookerjea	Canada	GN
Halina	Brown	USA	GN	Rosa	Morales	Peru	GS
Brianna	Bruni-Bossio	Canada	GN	Timothy	Morrison	Canada	GN

First Name	Last Name	Nationality	GS/GN	First Name	Last Name	Nationality	GS/GN
Harriet	Bulkeley	UK	GN	Omar	Mosleh	Canada	GN
Yakubu	Bununu	Nigeria	GS	Gareth John	Moss	Ireland	GN
Harley	Burland	Canada	GN	Tereza	Moura	Brazil	GS
Laura	Cabral	Canada	GN	Michail	Mouzourakis	Greece	GN
Eduardo	Calvo Buendia	Peru	GS	Sophie	Muller	Canada	GN
Ines	Camilloni	Argentina	GS	Muhammad	Mumtaz	Pakistan	GS
Carolyn	Campbell	Canada	GN	Jeremy	Murphy	Canada	GN
Andres	Canavera	Colombia	GS	Issah Justice	Musah Surugu	Ghana	GS
Maruxa	Cardama	Belgium	GN	Tero	Mustonen	Finland	GN
Alexander	Carius	Germany	GN	Gifti	Nadi	USA	GN
Jeremy	Carter	UK	GN	Catherine	Nangini	Canada	GN
Tim	Cartmell	Canada	GN	Roy	Neehall	Canada	GN
Anton	Cartwright	South Africa	GS	Heather	Nelson	Canada	GN
Fabrice	Casciani	France	GN	Mani	Nepal	Nepal	GS
Sander	Chan	Netherlands	GN	Edward	Ng	UK	GN
Chris	Chang-Yen Phillips	Canada	GN	Charlene	Nielsen	Canada	GN
Pacteau	Chantal	France	GN	Dan	Nielsen	Canada	GN
Gu	Chaolin	China	GS	Alex	Nnamonu	Canada	GN
Matthew	Chapman	Canada	GN	Kate	Noble	Australia	GN
Souran	Chatterjee	India	GS	Barbara	Norman	Australia	GN
Ryan	Chavez	USA	GN	Georgina	Numbasa	Papua New Guinea	GS
Neelam	Chawla	Canada	GN	Abu Sadat Md Marjan	Nur	Bangladesh	GS
Meian	Chen	China	GS	Valentine	Ochanda	Kenya	GS
Marc	Chiappero	France	GN	Stephanie	Odayen	Canada	GN
Annapurna	Chintaluri	India	GS	Edna	Odhiambo	Kenya	GS
Dumisani	Chirambo	Malawi	GS	Liam	O'Doherty	Canada	GN
Carlos	Chiu	Peru	GS	Sean	O'Donoghue	South Africa	GS
Titash	Choudhury	India	GS	David	Oehmen	Switzerland	GN
Winston	Chow	Singapore	GN	Mark	Ojal	Kenya	GS
Eric	Chu	USA	GN	Natalia	Okutoi	Kenya	GS
Zaneta	Chui	Canada	GN	Paola	Ometto	Brazil	GS
Julia	Chung	Canada	GN	Camilo	Ordonez Barona	Colombia	GS
Sarah	Cicchini	Canada	GN	Lyndal	Osborne	Canada	GN
Amelia	Clarke	Canada	GN	Katie	O'Shea	USA	GN
Karen	Clarke-Whistler	Canada	GN	Juan	Osorio	Colombia	GS
Helen	Cleugh	Australia	GN	Holly	Palen	Canada	GN
Marieke	Cloutier	Canada	GN	Sean	Pander	Canada	GN
Adrienne	Cloutier	Canada	GN	Lumari	Pardo-Rodriguez	USA	GN
William	Cobbett	UK	GN	Jyoti	Parikh	India	GS
Linda	Cochrane	Canada	GN	Brad	Parker	NO DATA	
Marshall	Cohen	USA	GN	Charles	Parker	NO DATA	
Maurie	Cohen	USA	GN	Brenda	Parlee	Canada	GN
M'Lisa	Colbert	Canada	GN	Alberto	Pascual	Panama	GS
Sarah	Colenbrander	Australia	GN	Lorena	Pasquini	UK	GN
Marcus	Collier	Ireland	GN	Madhumita	Patel	India	GS
Sarah	Connors	France	GN	Sheela Bharat	Patel	India	GS
María	Cortés Puch	Spain	GN	Minal	Pathak	India	GS

Plenary Summaries
Parallel sessions summaries
Conference Posters
References
Annexes

First Name	Last Name	Nationality	GS/GN	First Name	Last Name	Nationality	GS/GN
Jacob	Corvidae	USA	GN	Joanne	Pawluk	Canada	GN
Peter	Cox	Ireland	GN	Benoit	Pellerin	Canada	GN
Marlies	Craig	South Africa	GS	Mark	Pelling	UK	GN
Steve	Craik	Canada	GN	Rylie	Pelton	USA	GN
Drury	Crawley	USA	GN	Eduardo	Pérez	Canada	GN
Roger	Cremades	Spain	GN	Ekaterina	Perfilyeva	Russia	GN
Elena	Crete	USA	GN	Adriaan	Perrels	Netherlands	GN
Felix	Creutzig	Germany	GN	Clare	Peters	Canada	GN
Edoardo	Croci	Italy	GN	Katie	Peterson	Canada	GN
Palmira	Cuellar-Ramirez	Mexico	GS	Shannon	Phillips	Canada	GN
Bruce	Currie-Alder	Canada	GN	Ramon	Pichs-Madruga	Cuba	GS
Thomas	Dallessio	USA	GN	Emmanuelle	Pinault	France	GN
Brent	Dancey	Canada	GN	Laszlo	Pinter	Canada	GN
Gaddafi	Danmaliki	Nigeria	GS	Hans	Poertner	Germany	GN
Aniruddha	Dasgupta	India	GS	Audrey	Poitras	Canada	GN
Debra	Davidson	Canada	GN	Cecilia	Polacow Herzog	Brazil	GS
Amy	Davison	UK	GN	Diego	Ponce de Leon Barido	Mexico	GS
Richard	Dawson	UK	GN	Rita	Pongracz	Hungary	GN
Thomas	Day	UK	GN	Lavinia	Poruschi	Australia	GN
Cecile	De Munck	France	GN	Joanne	Potter	USA	GN
Phil	DeCola	USA	GN	Prajal	Pradhan	Nepal	GS
Filiep	Decorte	Belgium	GN	Emily	Prestwood	UK	GN
Margaret	Deignan	UK	GN	Anne-Hélène	Prieur-Richard	France	GN
Sabrina	Dekker	Canada	GN	Dawn	Pritchard	Canada	GN
Gian Carlo	Delgado Ramos	Mexico	GS	Jose Antonio	Puppim de Oliveira	Brazil	GS
Stefan	Denig	Germany	GN	Sara	Radelet	USA	GN
Shobhakar	Dhakal	Nepal	GS	Melissa	Radu	Canada	GN
Jose	Di Bella	Mexico	GS	Homa	Rahmat	Iran	GS
Giovanni	Di Lullo	Canada	GN	Indrika	Rajapaksha	Sri Lanka	GS
Emily	Dietrich	Canada	GN	Bardhyl	Rama	Germany	GN
Kathleen	Diga	Canada	GN	Anu	Ramaswami	USA	GN
Andyan	Diwangkari	Indonesia	GS	Trude	Rauken	Norway	GN
Saliha	Dobardzic	Bosnia and Herzegovina	GN	Jeffrey	Raven	USA	GN
Nancy	Dodds	Canada	GN	Ilona	Rayan	USA	GN
David	Dodman	UK	GN	Gleb	Raygorodetsky	Canada	GN
Jago	Dodson	Australia	GN	Marlo	Raynolds	Canada	GN
Felix	Döhler	Germany	GN	Diana	Reckien	Germany	GN
Chelsea	Donelon	Canada	GN	Daniel	Rees	Norway	GN
Benedicte	Dousset	USA	GN	William	Rees	Canada	GN
Michael	Doust	UK	GN	Chao	Ren	China	GS
Joanne	Douwes	South Africa	GS	Gregory	Reppucci	USA	GN
Delali B.K.	Dovie	Ghana	GS	Maya	Reshef	Canada	GN
David	Draper	Canada	GN	Aromar	Revi	India	GS
Martine	Dubuc	Canada	GN	Garrett	Richards	Canada	GN
Linda	Duncan	Canada	GN	Randy	Ries	NO DATA	
Brian	Dupuis	Canada	GN	Gale	Rigobert	Saint Lucia	GS
Luiza Rodrigues	Dutra	Brazil	GS	Jan	Riise	Sweden	GN

First Name	Last Name	Nationality	GS/GN	First Name	Last Name	Nationality	GS/GN
Selene	Dykes	Canada	GN	Keith	Ripley	USA	GN
Matt	Dykstra	Canada	GN	Michael	Rivest	Canada	GN
Jon	Dziadyk	Canada	GN	Debra	Roberts	South Africa	GS
Kristie	Ebi	USA	GN	Pedro Lomando Restum de Macedo	Rocha	Brazil	GS
Amanda	Eichel	USA	GN	Maria Fernanda	Rodrigues Campos Lemos	Brazil	GS
Katrin	Eisenbeiss	Germany	GN	Sofia Valez	Rodriguez	Colombia	GS
Karim	Elgendy	UK	GN	Aura Azalea	Rodriguez Villamil	Mexico	GS
Thomas	Elmqvist	Sweden	GN	Patricia	Romero-Lankao	USA	GN
Jean Pierre	Elong Mbassi	Cameroon	GS	Mike	Roppelt	NO DATA	
George	Enei	Canada	GN	Cynthia	Rosenzweig	USA	GN
Evyatar	Erell	Israel	GN	Lauren	Ross	USA	GN
Moe S.	Esfahlani	Germany	GN	Paul	Ross	Canada	GN
Jessica	Espey	UK	GN	Sheena	Rossiter	Canada	GN
Jennifer	Ewing-Thiel	USA	GN	Amanda	Rosychuk	Canada	GN
Samuel	Ezebunandu	Nigeria	GS	Ashley	Roszko	Canada	GN
Aaron	Fairbrother	Canada	GN	Joyashree	Roy	India	GS
Andrew	Fang	USA	GN	Steve	Rumley	Canada	GN
Ira Damayanti	Fasa	Indonesia	GS	Adam	Rysanek	Canada	GN
Liam	Fee	Ireland	GN	Saeideh	Sadeghi Afjeh	Iran	GS
Christian	Felske	Germany	GN	Rasikh	Sagitov	Russia	GN
Mark	Fenwick	NO DATA		Emilia	Saiz	Spain	GN
Maria Josefina	Figueroa	Venezuela	GS	Alejandra	Salas	Spain	GN
Andres	Filella	Canada	GN	Julie	Salter-Keane	Canada	GN
Amethyst	First Rider	Canada	GN	Mogamat Igshaan	Samuels	South Africa	GS
Laura	Florez	Colombia	GS	Leon	Sanderson	NO DATA	
Sarah	Flynn	Canada	GN	Edgar Roberto	Sandoval Garcia	Mexico	GS
Henry Abanda	Fonbeyin	Cameroon	GS	Michelle	Sanfilippo	Canada	GN
Silvia Graciela	Fontan	Argentina	GS	Andréa	Santos	Brazil	GS
Bill	Fortier	Canada	GN	Caterina	Sarfatti	Italy	GN
Kansie	Fox	Canada	GN	Kwadwo Ohene	Sarfoh	Ghana	GS
Niki	Frantzeskaki	Greece	GN	Jim	Saunderson	Canada	GN
John	Freeman	Canada	GN	Bob	Savage	Canada	GN
Sandra	Gagnon	Canada	GN	Nathan	Schaffer	Canada	GN
Hana	Galal	Germany	GN	Marvin Wayne	Schmyr	Canada	GN
David Felipe González	Galindo	Colombia	GS	Alison	Schneider	Canada	GN
Kalum	Galle	Canada	GN	Sven	Scholtysik	Germany	GN
Snigdha	Garg	India	GS	Seth	Schultz	USA	GN
Matthias	Garschagen	Germany	GN	Jessica	Seddon	USA	GN
Matt	Gemmel	Canada	GN	Julia	Seixas	Portugal	GN
Ebru	Gencer	USA	GN	Guilherme	Selegium	NO DATA	
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Tirso	Gonzales	Canada	GN	Sharon	Shuya	Canada	GN
Stacia	Gordey	Canada	GN	Kevin	Sieck	Germany	GN
David	Gordon	Canada	GN	Graham	Simpkins	UK	GN
Andy	Gouldson	UK	GN	Roop	Singh	USA	GN
Stelios	Grafakos	Greece	GN	Jim	Skea	UK	GN
Carrie	Grassi	USA	GN	Karin	Smith Fargey	Canada	GN
Melodie	Green	Canada	GN	Ranon	Soans	Canada	GN
Debra	Greenspan	USA	GN	Lisa	Sobchyshyn	Canada	GN
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Kevin	Gurney	USA	GN	Stephen	Stanley	Canada	GN
Caroline	Hachem-Vermette	Canada	GN	Linda	Steg	Netherlands	GN
Dylan	Hall	Canada	GN	Fee	Stehle	Germany	GN
Rafiq	Hamdi	Belgium	GN	Perry	Stein	Canada	GN
David	Hameršak	Slovenia	GN	Michael	Steinhoff	USA	GN
Johannes	Hamhaber	Germany	GN	Daniel	Strain	Canada	GN
John	Hanson	Canada	GN	Charles	Stubblefield	USA	GN
Sinda	Haouès-Jouve	France	GN	Andrew	Sudmant	Canada	GN
Masayuki	Hara	Japan	GN	Katherine	Sugar	UK	GN
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Clare	Healy	UK	GN	Wenyuan	Sun	China	GS
Jen	Heemann	Brazil	GS	Cliff	Supernault	Canada	GN
Ben	Henderson	Canada	GN	Scott	Sutherland	Canada	GN
Yuill	Herbert	Canada	GN	Leila	Taheriazad	Iran	GS
Annel	Hernandez	USA	GN	Kelly	Tai	Canada	GN
Maria del Rosario Silva	Hernández	Colombia	GS	Alireza	Talaei	Iran	GS
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Annex

5

COMMISSIONED PAPERS

Background papers commissioned by the Scientific Steering Committee and written by leaders in the field to inform the conference discussions

Note: *These papers represent the views of the authors and do not represent the official position of CitiesIPCC.*

Commissioned Paper

1

Towards a Novel Assessment Framework for Cities and Climate Change

William Solecki[a], Cynthia Rosenzweig[b], Debra Roberts[c], Seth Schultz[d1]

The IPCC has expressed interest in learning about assessment frameworks that have particular relevance for cities and climate change. In response, the goals of this commissioned paper of the IPCC Conference on Cities and Climate Change Scientific Steering Committee are to:

1. Review past assessments, especially those related to cities and urban areas.
2. Identify needs of user communities.
3. Develop ideas for alternative novel assessment frameworks and procedures.

1. Review of past assessments

Many major climate assessments have been conducted in recent years at global, national, and regional scales. Some of these cover a wide range of topics, while others focus on a particular area such as oceans or biodiversity. Assessments that explicitly consider climate change and urban areas include those of the IPCC AR5 (including components of Working Groups II and III), the Urban Climate Change Research Network (UCCRN), and the World Bank.w

For assessments to be successful, they must be salient, credible and legitimate (Cash et al., 2002). In order for an assessment to be salient, the research being considered must be relevant to the intended audience. Therefore user knowledge needs should be explicitly solicited and answered. Use of peer-reviewed research and vetting of authors helps to create credibility, while the inclusion of scientists from a range of geographies and development status (i.e., low, moderate and high-income settings) builds legitimacy and ensures fairness when creating an assessment. By looking at how these assessments were created and at who created them, we can determine if they are credible and legitimate. By looking at the relationship between the assessment's creators and stakeholders, we can see if the assessments are also salient.

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Here we compare several important assessments that have explicitly considered cities and urban areas. Comparisons are made regardingtheir framework, organization, process, outcomes, impacts, challenges, limitations, and utility. The following questions were posed about the engagement of the assessments with stakeholders and scientific literature, the process by which they were carried out, and their governance structure:

- What is the scale of the assessment including geographical, sectoral, and systemic extents?
- What topics does the assessment cover, and how are topics selected? What topics were not included?
- What is the relationship between the authors and the stakeholders? Is there a knowledge co-generation process embedded in the assessment methodology?
- Is there a benchmarking function? And if so, is there a consistent methodology for each assessment iteration?
- How were the authors and other participants chosen?
- Does the report deal only with peer-reviewed sources or does it also include gray literature? How is gray literature defined?
- Is the assessment peer-reviewed? Is there a public review process?
- How many rounds of review does the assessment go through before public release?
- Is the assessment approved, and if so, by whom? Is there a formal process of approval?
- How is it funded?
- What is the governance structure of the assessment?
- How are issues of scientific uncertainty, likelihood, and probability incorporated?
- How are science-based conflicts dealt with?

A. IPCC The Fifth Assessment Report (AR5), Working Group II, Chapter 8 and Working Group III, Chapter 12 (2014)

Within the IPCC Fifth Assessment Report, Chapter 8 of Working Group II examines Urban Areas (Revi et al. 2014). This chapter focuses on the potential impacts of climate change on urban centers, populations, and enterprises, initiatives taken to adapt to climate change, and suggested institutional and governance changes that could improve adaptation to climate change. The authors recognize that urban areas range in size – from several thousand inhabitants to several million – and in definition, depending on boundary-setting and national urban policy. There is generally a lack of international agreement in definition of an urban center. Indicators both within and between these urban areas are analyzed throughout the chapter.

Chapter 12 of Working Group III of AR5 also has an explicit urban focus (Seto et al. 2014). The chapter assesses the connection between human settlement growth, infrastructure development and spatial planning, and conditions of GHG emissions and climate mitigation. The intense current level of urbanization and expansion of urban areas are reviewed and the key links between urbanization and GHG emissions are identified.

The IPCC Assessment Reports are funded by national contributions via the United Nations Environment Programme and the World Meteorological Organization and focus on a wide range of topics related to climate change at global and regional scales (IPCC 2013; IPCC 2014a; IPCC 2014b). Assessments are conducted in 7-year cycles. The topics of the assessment are assigned to three different working groups. The IPCC Working Group I (WG I) assesses the physical scientific aspects of the climate system and climate change. Working Group II (WG II) assesses the vulnerability of socio-economic and natural systems to climate change, negative and positive consequences of climate change, and options for adaptation. It also takes into consideration the inter-relationships among vulnerability, adaptation and sustainable development. Working Group III (WG III) assesses options for mitigating climate change through limiting or preventing greenhouse gas emissions and enhancing activities that remove them from the atmosphere. The IPCC, first established in 1988, utilizes its assessment process to create, compile, and then provide in layman's terms information on climate change to its stakeholders, which are primarily governments, the UN Framework Convention on Climate Change, and non-governmental organizations (NGOs) around the globe.

There is no standard assessment methodology for the IPCC, since the methods are updated as the assessment cycles progress in order to keep up with current research. Authors are selected based on their expertise after a call to governments and IPCC observer organizations for nominations and the submission of detailed CVs. The composition of author teams aims to reflect a range of scientific, technical, and socio-economic views and backgrounds. A comprehensive assessment requires author teams to include a diverse set of authors from different regions and from developed and developing countries to ensure that reports are not biased towards the perspective of any one country or group of countries and that questions of importance to particular regions are not overlooked. The IPCC assessments are developed through multiple rounds of drafting and review. As the culmination of an assessment's development, IPCC member governments endorse the report. The endorsement process is based on interactions between those who will use the report – the governments – and those who write it – the scientists.

The IPCC assessment materials consist of peer-reviewed literature; reports from governments, industry and research institutions; publications by international and other organizations, and conference proceedings. Information about certain experiences and practices in mitigation and adaptation activities in particular may be found in sources other than traditional scientific and technical journals. Such materials may utilize a wide range of quality-assurance mechanisms, including but not limited to formal peer review. Expert reviewers and governments are invited at different stages to comment on the scientific, technical and socio-economic assessment and the overall balance of the drafts. The review process includes wide participation, with hundreds of reviewers critiquing the accuracy and completeness of the scientific assessment contained in the drafts.

Key points related to the IPCC for urban assessments:
1. Benchmarking function
2. Rigorous review process
3. Endorsement by national governments
4. Limited focus on cities
5. Working Group structure siloes mitigation and adaptation responses

B. Urban Climate Change Research Network (UCCRN) First and Second Assessment Reports on Climate Change and Cities; ARC3.1 (2011) and ARC3.2 (2018)

The goal of the Urban Climate Research Network (UCCRN) Assessment Reports on Climate Change and Cities (ARC3) is to help cities develop effective and efficient climate change mitigation and adaptation policies and programs. By so doing, UCCRN is developing a model of within- and across-city interactions that is multidimensional, i.e., with multiple interactions of horizontal knowledge-sharing from developing to developed cities and vice versa. The UCCRN works simultaneously by knowledge-sharing among small to mid-sized to large to megacities. Free-flowing multidimensional interactions are essential for optimally enhancing science-based climate change response capacities.

Authors defined the topics covered in the first ARC3 (Rosenzweig et al. 2011) based on surveys of city officials and sustainability officers and with the help of the ARC3 Steering Group. ARC3.2 topics were updated based on surveys and on input from several scoping sessions held at large urban climate change conferences around the world where suggestions for topics were solicited.

This process resulted in ARC3 coverage of a broad range of urban climate change topics. These include risk-framing, key urban sectors, and cross-cutting issues. Chapters relate to assessment of urban vulnerability and key climate hazards, mitigation and adaptation responses in urban sectors, and the roles of land use planning and governance in responding to climate change challenges. The second iteration of ARC3, ARC3.2 (Rosenzweig et al. 2018) has double the number of chapters with updated material on certain topics and added chapters on new topics. New topics included in ARC3.2 are Urban Planning and Design; Environmental Equity and Justice; Economics, Finance and the Private Sector; Urban Ecology and Biodiversity; Urban Coastal Zones; Housing and Informal Settlements; and Urban Solid Waste.

Authors are selected from the over 750 members of the UCCRN based on expertise in the topics that arise from stakeholder interactions and surveys. ARC3 uses both peer-reviewed and gray literature; the latter is important since much cutting-edge work on climate change and cities is reported by cities themselves or by city network groups such as C40, ICLEI, and UCLG.

The assessment itself is peer reviewed. ARC3.2 underwent three rounds of rigorous peer-review with each chapter being peer-reviewed by scholars who are subject experts. The reviewers also include stakeholders from major organizations that fund urban and climate change projects, such as the World Bank, UN-Habitat, and UN Environment Programme. City practitioners and policy- makers also review the ARC3 chapters.

In addition to the ARC3.2 assessment, UCCRN has developed a Case Study Docking Station where over 115 case studies, shared throughout the book, can be easily accessed by researchers, practitioners, and policy-makers. The Case Studies display empirical evidence on city efforts on mitigation and adaptation to climate change and address challenges and opportunities for urban areas. These Case Studies address issues that cities face in regard to climate change in social, biophysical, cultural, economic, and political contexts. The Case Study Docking Station is innovative in the research, findings, and related outcomes, which are presented by practitioners and researchers from the cities themselves. With its searchable database based on key words, the ARC3 Case Study Docking Station provides opportunities for users to extract information based on a process in which there are multiple entry points for the more than 115 studies.

Stakeholder consultations proceed throughout the ARC3 writing process, allowing for flexibility as the assessment is developed. Based on these interactions, ARC3 is structured to communicate to a range of groups important for urban decision-making. These stakeholders include urban practitioners, civil society groups, scholars and city leadership groups. The ARC3.2 Summary for City Leaders was released at the Mayors Summit held at the Paris City Hall during COP21 in 2015.

6. Key UCCRN ARC3 points for effective urban assessments:
7. Free-flowing multidimensional stakeholder-scientist interactions essential for optimally enhancing science-based climate change response capacities in cities.
8. Benchmarking and updating process highly useful to ensure relevance in on-going
9. assessment process.
10. Adaptation and mitigation considered in intertwined approach.
11. Case Study Docking Station provides peer-to-peer knowledge sharing.

C. New York State ClimAID Assessment (2011, 2014)

The ClimAID assessment provides information on climate change impacts and adaptation for New York State. The assessment covers the topics of climate risks, vulnerabilities, and adaptation strategies for eight sectors: water resources, coastal zones, ecosystems, agriculture, energy, transportation, telecommunications, and public health. Observed climate trends and future climate projections were developed for seven regions across the state.

To ensure that the information provided by ClimAID was relevant to the climate-related decisions made by practitioners, stakeholder interactions were a key part of the process. Working with the New York State Research and Development Authority (NYSERDA) and the Project Advisory Committee, the sector leaders identified relevant stakeholders from the public sphere (e.g., state and local agencies), nonprofit organizations (e.g., non-governmental community and environmental groups), private-sector entities (e.g., businesses), and academic institutions for each of the sectors, and organized an on-going series of stakeholder interactions. There is a consistent methodology for each iteration of this assessment. As with the original ClimAID assessment in 2011, the 2014 edition provided updated climate risk projections for the seven regions in order to facilitate the ongoing study of the impacts of climate change and how NYS can adapt.

The ClimAID report was prepared by Columbia University, the City University of New York, and Cornell University in the course of performing work contracted for and sponsored by NYSERDA. The authors were chosen by the co-principal investigators and were vetted by New York State officials. The volume was peer-reviewed and included peer-reviewed gray literature on consideration via a case-by-case basis.

Key ClimAID points for effective urban assessments:

1. Close and frequent interactions between researchers and stakeholders
2. Development of a demand-driven assessment process where the goals, objectives, and
3. specific outcomes were derived from stakeholder interactions.
4. Integrated nodal structure of analysis as opposed to linear climate science model
5. projection output driving the process.
6. Line-of-sight linkages to other parallel assessment processes at municipal and national scales.

D. World Bank Report – Cities and Climate: Responding to an Urgent Agenda (2011)

The World Bank's 5th Urban Research Symposium on Cities and Climate Change: Responding to an Urgent Agenda, held in Marseille in June 2009, sought to highlight how climate change and urbanization are converging to create one of the greatest challenges of our time. The assessment responded to the recognition that climate change mitigation and adaptation in cities had emerged as a new theme on the global agenda, creating a strong desire among governments, the private sector, and the academic community worldwide to learn from experiences and good practice examples.

The symposium and its accompanying publication made an important contribution to the growing body of knowledge and practice in the area of cities and climate change (Hoornweg et al. 2011). During the three-day symposium, approximately 200 papers were presented to more than 700 participants representing more than 70 countries. As co-organizers, the authors found it very rewarding to have such an audience and to share the wide range of topics discussed, from indicators and measurement to institutions and governance. The publication comprises an edited selection of the papers submitted to the symposium. The entire collection of symposium papers is available as an online resource for interested readers.

Key World Bank Urban Research Symposium points for effective urban assessments:

1. Comprehensive integrated and global approach to assessment topic.
2. Interactions between research and stakeholder communities from local, national, and
3. international interest groups.
4. Extensive post-event information and data hosting online.

2. Identification of knowledge needs of user communities

The multiple user communities associated with climate change and cities assessments have a variety of knowledge needs (Table 1). Researchers need to have cutting-edge understanding of the science, identified areas of potential critical unknowns, and associated methodologies to investigate them. For example, recent assessments of sea level rise projections have accelerated the research community to investigate the long tails of the projections and the prospects for high- end, rapid ice melt scenarios. Practitioners need to have actionable, consensus-focused, evidence-based science to implement in mitigation and adaptation actions.

While there is general interest by practitioners in the full range of risks, often they are most interested in cutting-edge projections, information, and data on those conditions with the highest likelihoods and greatest certainty that will affect their cities. City decision-makers need concrete examples of what other cities are doing and how they are and are not being effective. Policy-makers need context and guidance to frame overall directives for cities to follow, not only within the domain of climate change but also with its likely interactions with the complex socio-ecological urban system.

Crucial elements of assessments are those areas in which the knowledge needs of the communities overlap and where they diverge. It is also important to recognize that these domains will shift over time as issues emerge. For example, urban ecology and urban ecosystem services issues within climate assessments were fringe topics in the early 2010s, while today they have moved toward the center of stakeholder interest.

Table 1: Interests and Knowledge Needs of Researchers, Practitioners and Policy-Makers

Researchers	Practitioners	Policy-Makers
Stakeholder-driven agendas	Evidence-based science	Policy options
State-of-the-science methods	Examples from peers	Links to national and international agencies
Focus on emergent elements	Focus on consensus elements	Focus on urban system linkages

3. Alternative novel assessment frameworks and procedures

Most fundamentally, city-climate change assessments need to recognize the unique characteristics of cities. As currently constituted, the IPCC structure is not conducive to assessing multifaceted urban systems. In particular, the separation in the IPCC between Impacts, Adaptation, and Vulnerability in Working Group II and Mitigation in Working Group III sets up a silo-ed approach that can actively hold back the development and implementation of effective urban climate change solutions. A range of alternative assessment frameworks and procedures need to be integrated to develop a novel approach for the IPCC to interact within its assessment process moving forward. Key perspectives on this novel approach are emerging.

First, the use of an urban systems approach is essential for assessing climate risks and impacts, as well as adaptation and mitigation opportunities and challenges. Urban systems operate in a variety of ways including simple linear and complex non-linear interactions and responses. Urban system sectors often involve relatively well understood, linearly structured engineering systems but are embedded in complex interdependencies with other sectors, as well as socio- ecological systems with non-linear structures. The systems approach to urban assessments provides a framework for understanding the role of the significant stresses that climate change poses on the operation of urban sectors. This approach facilitates the development of resilience and mitigation metrics, early-warning signals of potential system crises, and pending system tipping points.

The role of technology in the structure, metabolism, and management of cities is profound, and must be taken into account in the ongoing urban and climate change assessment process. The operation and potential failure of the technological systems of cities have important implications for the resilience of urban areas and for their ability to implement the mega-mitigation actions required to achieve the 1.5C temperature target (Solecki et al., 2018). Climate extremes in urban contexts reveal the potential for catastrophic collapse resulting from large-scale disturbances and cascading interdependent system failures.

Equity, environmental justice, formality, and informality must also be critical elements explicitly taken into account in on-going urban assessments. Low-income and low-status groups are the most vulnerable people in urban settings, as they tend to inhabit higher-risk areas prone to flooding and over-heating. Gender must also be critically taken into account. Informal urban systems need to be considered, and mitigation efforts need to be analyzed for their unintended consequences in regard to marginalized urban populations as well.

Finally, planning and governance are key dimensions of cities as socio-ecological systems. Urban climate change governance is a set of formal and informal rules, rule-making systems, and actor networks at all levels (from local to global), both in and outside of government that are established to steer toward mitigation and adapting to climate change (Biermann et al., 2009). Urban climate change governance occurs within the broad context of urban systems, with actors and institutions at a multitude of scales and with a broad spectrum of interests and concerns shaping the effectiveness of intervention.

Urban Climate Spectrum-Nexus Assessment Protocol

Future urban-based climate assessments need to incorporate the range of dimensions described above. These dimensions are relevant to climate change assessments generally and conditions found in city settings, specifically. These dimensions include a range of spectrum-nexus considerations that involve both the range of conditions to be assessed and how the interaction and synergies of the conditions will be evaluated. The collective assemblage of these represents the foundation for an advanced urban climate assessment protocol. The relevance of the spectrum-nexus dimensions needs to be considered when defining specific assessment goals and outcomes (Table 2). Collectively, these dimensions illustrate that a salient, credible and legitimate assessment cannot be considered as simply a single assessment, but rather should explicitly define and respond to multiple sets of users.

Table 2. Spectrum-nexus dimensions for urban climate change assessments

Assessment dimensions	Conceptual range	Typical focus of existing assessments	Preferred primary operational range
Time	Distant Past to Distant Future	Present – 30-80 future	100 years past – 100 years future
Spatial Scale	Household to Global Connections	Municipal	City District to Metropolitan Region
Type of Knowledge	Local – Expert	Expert	Local; local interpreted by experts; Expert
Weather – Climate Data	Everyday Weather to Climate Extremes	Annual Trends to Known Extremes	Seasonal to Known Extremes; Increasingly Practitioner- Policy-Maker Driven
Climate-Urbanization Nexus	Climate-Urban Systems as Separate to Fully Integrated	Climate Systems Act Upon Urban Systems – Impacts	Climate System interacting with Integrated Urban Social, Infrastructure, and Ecological Systems
Urban System	Individual Sector Analysis to Integrative Systems Analysis	Multiple, Single Sector Analysis – e.g. water, energy, etc.	Individual and Integrated Systems illustrate Flow and Cascading Connections
Informal-Formal Nexus	Completely Informal to Completely Formal	Formal Systems and Networks	Recommend Practitioner – Policy-Maker Defined

Recommendations

Arising from the review undertaken by this commissioned paper, there are two key activities that will enable progress: novel urban assessment and city science partnerships.

Moving Forward on Novel Urban Assessments

In order for city assessments to be salient, credible, and legitimate, they must be tailored to multiple sets of stakeholders and their needs. The assessment process needs to acknowledge that there are multifaceted needs and interpretations of each assessment based on the different user communities. An innovative assessment process needs to simultaneously assess the needs and

interest area of each user group, the separateness of each group, the overlaps between the groups, the interactions between groups' interests, and the boundary movements of the groups' interest.

The integration of social, ecological, and technological systems in cities provide transformative avenues leading to urban climate adaptation and mitigation. This must be the goal in the next stage of urban climate change assessment. Adaptation and mitigation must be liberated from the predominant silo-ed approaches that have resulted in individualized city approaches to adaptation and mitigation that are extremely limited. Thus, there is a strong need for inter-related approaches to adaptation and mitigation so that these synergistic approaches can minimize unanticipated conflict and avoid lock-in (Urge-Vorsatz et al., 2018).

Given these complexities, it does not necessarily follow that the IPCC itself should take on the mantle of developing and conducting on-going urban climate change assessments. It has very usefully committed to producing a *Special Report on Climate Change and Cities* in the AR7 cycle. We recommend that the IPCC create an alliance with the Urban Climate Change Research Network to provide the on-going benchmarking function of on-going assessment, and that the results of the UCCRN *Third Assessment Report on Climate Change and Cities (ARC3.3)* projected to be completed in time for the *IPCC Special Report on Cities* in order to provide a major input to the planned Special Report.

Science-Policy Linkages and the Role of City Science Partnerships

Promoting effective science-policy and scientist-policymaker-practitioner interaction is a recurring challenge in climate assessment work. Participating individuals often talk at or past one another without really talking to one another. Science-policy, scientist-policy-maker interaction easily can be described as something that needs continual dialogue and engagement. Many points of potential tension and misunderstanding exist and as a result those involved need to constantly talk not only about the content of the conversation but also its context and their own positionality. Like other contentious issues, science-policy linkage discussions simply are never fully settled or resolved but need continual attention and dialogue because the opportunity for failure is always present.

The need for ongoing partnership of cities-focused science bodies or panels to respond to these challenges in cities throughout the world is clear. Modalities of such panels will differ according to local urban contexts, but ensuring that the knowledge base for climate action is available to all cities is essential. An example in a high-income city is the New York Panel on Climate Change, which has served the City of New York as an "independent" science body that directly responds to city science queries and requirements for a decade. The discussion and debate between city officials and panel members typically is cordial but can get contentious and very difficult even as the objective interpretation of the science is maintained. The City "uses" the panel in complex ways and the boundary between the two is fluid and at times porous but is always present. Overall, the panel process has been successful and other cities (and those not as rich in resources) have started to emulate the model.

That said, there is a clear opportunity to push ahead with even a more ambitious proposal that in some ways has already started to form via UCCRN and other city networks. A network of city- science panel partnerships should be created that distributes and shares cutting-edge city relevant climate science and lessons learned on adaptation and mitigation. UCCRN embodies this spirit via a horizontal network of city practitioner-city based scientist partnerships and Regional Hubs – this process can be greatly extended.

Specific Recommendations:

1. Solicit and respond to user needs in an ongoing process throughout assessment.
2. Follow an urban systems approach, including sector interdependencies, technology, and governance.
3. Consider adaptation and mitigation in an intertwined way to encourage synergies and avoid trade-offs and lock-in.
4. Found assessment on explicit principles of equity and environmental justice, formality and informality.
5. Link to already in-place ongoing, benchmarked process provided by UCCRN ARC3 to provide input into the IPCC Special Report on Climate Change and Cities in the AR7 cycle.

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Commissioned Paper

2

Responding to climate change in cities and in their informal settlements and economies

Summary

One of the greatest challenges for climate change adaptation is how to build resilience for the billion urban dwellers who are estimated to live in what are termed “informal settlements” – sites chosen by their residents because they are less likely to be evicted as the land is unattractive to developers. Many informal settlements are on land sites at high risk from flooding and landslides.

A major challenge for climate adaptation in these informal settlements include the many ways in which these settlements break laws and contravene regulations, complicated by the fact that in many nations, local governments ignore those living in informal settlements or evict them. If urban governments do commit to building resilience they can be hampered by limited technical capacity, lack of funding and political constraints.

This paper examines the vulnerability of informal settlements and economies, and describes how lessons from upgrading informal sectors and linking informal and formal economies can help to ensure that these become more resilient and contribute (as appropriate) to lower greenhouse gas emissions in the coming decades.

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Notes

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Summary

THE CHALLENGES FROM INFORMALITY: One of the greatest challenges for climate change adaptation is how to build resilience for the billion urban dwellers who are estimated to live in what are termed informal settlements. These settlements are concentrated in urban centres in low- and middle-income nations. They have been built outside the 'formal' system of laws and regulations that are meant to ensure resilient structures, settlements and systems. Those who live in informal settlements and those who work in the informal economy form a critical part of each city's economy. But they cannot find 'formal' housing that they can afford. So, they live in settlements that are outside the formal system of regulations for recording land acquisition and for acquiring legal land tenure; also, for getting permission to develop buildings. They are outside the rules and regulations on land-use, buildings and infrastructure and service provision. Most (but not all) are on land that is illegally occupied. Most do not receive the infrastructure and services that should be provided in urban contexts such as reliable, safe water piped to homes, good provision within the household for sanitation, paved roads and paths, storm and surface drains and connection to electricity grids. Most residents of informal settlements also rely on informal services and informal employment.

ELEVATING RISKS: Many informal settlements are on land sites at high risk from flooding and landslides; these sites are chosen by their residents because they are less likely to be evicted as the land is unattractive to developers. Most housing structures in informal settlements are poor quality. The result is that most informal settlements concentrate high levels of risk from infectious and parasitic diseases, accidental fires and natural hazards and pollution. *Thus, the conditions of life in informal settlements elevate risk from most climate change impacts such as higher (and increasing) maximum temperatures and heat waves, more intense precipitation events and riverine floods, wind storms with higher wind speeds, changes in water availability and sea-level rise.*

CONSTRAINTS ON GOVERNMENT ACTION: For city governments, addressing these issues is complicated by the many ways in which informal settlements break laws and contravene regulations. It is also complicated by the fact that in many nations, local governments ignore those living in informal settlements or evict them, even when these settlements house more than half a city's residents and much of its labour force. In other instances, urban governments do commit to building resilience but are hampered by limited technical capacity, lack of funding and political constraints.

ANOTHER PATH: But there is another way for governments to view this issue that was first articulated in the 1960s – to recognize the many positive aspects of informal settlements and to work with the inhabitants and their community organizations in providing needed infrastructure and services and improving housing quality. This 'upgrading' of informal settlements has become common practice in many nations as described in Section 3 – some driven by local governments responding to democratic pressures, some driven by community organizations but supported by local governments.

THE FORMAL SYSTEM: The 'formal' system mentioned above is meant to ensure good quality buildings on safe sites with good quality infrastructure and services – the foundations for their resilience to extreme weather as well as much reduced health risks. In high-income nations, almost all urban dwellers live in housing developed within the formal system and served with what this report terms 'risk reducing infrastructure and services' – which includes piped water, sewers, storm drains, electricity, health care, emergency services .... In each country, the formal system with its legislative and administrative underpinnings developed over time in response to identified risks (and to political pressures). Responsibility for implementation was mostly located within local governments. For city governments that have taken climate change adaptation seriously, they have moved from a political commitment to act to developing new policies and technical responses. The needed move to greater resilience to climate change happens within the 'formal' world of policies, budgets, rules and regulations overseen by elected city governments.

INFORMAL SETTLEMENTS: But most cities in the Global South[1] have much of their economy and most of their population living and working outside the 'formal' world. Many cities have 30-50 percent of their population living in informal settlements – and this can go higher; Nairobi with 60%, Dar as Salaam with 70%. But in most nations and cities, there are no official statistics on informal settlements. The term informal settlement also covers a large range of settlements from those with permanent buildings and conventional site lay-outs with some infrastructure to those with buildings made of temporary materials with no infrastructure and services. In cities with a high proportion of their population in informal settlements, many lower-middle income groups live there. In many cities, there are also formal buildings that have informal occupation that contravenes health and safety standards such as houses or apartments that have been subdivided into small rental units or converted into dormitories (Satterthwaite 2017).

WHY INFORMAL SETTLEMENTS EXIST: The reason why so many people live in informal settlements is the high cost of 'formal' housing – including the cost of getting legal land title, receiving permission to develop buildings, and meeting rules and regulations on land-use, buildings and infrastructure and service provision. The key issue here is the mismatch between what a large section of the urban population can afford to pay to for housing (or land) and what is available in the formal system. Governments often blame rapid in-migration for informal settlements, but the main reason for the growth in informal settlements is the failure of urban governments to change the functioning of the formal system.

INFORMAL ECONOMY: A high proportion of the economically active population in urban areas of the Global South work in what is termed the 'informal economy'; as with informal settlements, they operate outside the 'formal' system. This includes working in unregistered enterprises, lacking security and working in premises where regulations on occupational and environmental health and safety are not met.

FORMAL-INFORMAL LINKS: Just as informal settlements form a key part in housing the (mostly low- income) population of most cities in the Global South, so too does the informal economy form a key part of the city economy and those that work in it make up a critical part of the labour market. But the interdependence of the formal and informal is seldom recognised by city authorities. There are also close connections between informal settlements and the informal economy – as most of those working in the informal economy live in informal settlements and as many informal enterprises are in informal settlements. So, the issue here is how to ensure the needs of those living in informal settlements and/or working in the informal economy are fully included in climate change adaptation measures and how can formal systems change to support this.

PRIVATE SECTOR AND SERVICES: It is obvious that enterprises that make up "the private sector" have powerful influences on how any city develops and so they also have importance for climate change adaptation (and mitigation). In

[1] The 'Global South' encompasses all low- and middle-income group nations

the absence of 'formal' provision for water, sanitation, health care, schools, solid waste collection, policing…. in informal settlements, alternative (often informal) providers operate. These range from individual water vendors and latrine emptiers to pay-to-use toilets to private utilities that have learnt to operate successfully in some informal settlements.

VULNERABILITY AND EXCLUSION: Certain individuals or groups are more vulnerable to climate change because they are more sensitive to/impacted by particular risks and/or less able to cope and to adapt. Some are more at risk because of the discrimination they face – in getting housing, jobs and services on the basis of (for instance) gender, caste, class or being a migrant. Those living in informal settlements or working in informal employment are often excluded from many services – for instance not being able to open a bank account or get a legal address (on which access to many 'formal' services and getting on the voter register may depend).

FORMAL SYSTEMS AND HEALTH RISKS: Cities range from the most to the least healthy places to live and work – seen for instance in differences in average life expectancy at birth or infant, child and maternal mortality rates. By concentrating people, enterprises, institutions, motor vehicles and their wastes, cities can be very unhealthy. But well-governed cities have effective laws and regulations in place that enormously reduce the health risks these can bring. The main means to do so have been in developing and enforcing (formal) laws, byelaws, rules and regulations on, for instance, building standards, land use, health and safety at home and at work, pollution control, motor vehicle traffic management and household appliances – and on registering land title/rights and their use and sale.

GOVERNMENT RESPONSES: Government responses to the growth of informal settlements range from upgrading them (which implies some official recognition of their inhabitants' right to be there) to ignoring them (and refusing to provide them with infrastructure and services) to bulldozing them Upgrading informal settlements encompasses measures to improve the quality of housing structures and the provision of housing and community-related infrastructure and services (such as piped water, sewers and storm drains). It may include providing residents with title deeds to their plot.

GOOD LOCAL GOVERNANCE: Upgrading informal settlements and extending trunk infrastructure to them (roads, water mains, sewers, storm drains, electricity…) has become an accepted part of what a city government does in many middle-income nations – especially in Latin America. This paper also gives examples of innovations that have particular relevance – including the work of a national government agency (the Community Organizations Development Institute) in Thailand that catalyzes and supports community-driven upgrading with upgraded settlements being incorporated into the formal systems for water, sanitation and waste collection.

COMMUNITY-LED UPGRADING: The last twenty years have brought many upgrading initiatives driven by community organizations formed by their residents. These include many initiatives by federations of slum or shack dwellers that are active in over 30 nations. These have been supported by Slum/Shack Dwellers International (SDI) and the Asian Coalition for Housing Rights (ACHR). There are also many examples of co-production of services and infrastructure by community organisations working with local governments to reduce development deficits and build resilience. This creates an entry-point for climate finance to be localised to the community level, where structures of accountability and financial management are already in place.

COMMUNITY DATA: One of the main constraints on upgrading informal settlements is the lack of data on their residents and structures, on land tenure - and often even a lack of street names and legal addresses. The community organizations and federations mentioned above have developed methodologies to document and map informal settlements and have applied these in thousands of informal settlements in over 500 cities within 'Know your City' campaigns.[2] These provide the information needed for community-led upgrading. They are also a mechanism for fostering community identity and organization, prerequisites for inclusive community action. Community-led data collection can also include enumerations of informal settlements where each structure is numbered, and each household interviewed - in effect, a census - and this can also support the formal registering of land titles.

UPGRADING, INFORMAL SETTLEMENTS AND CLIMATE CHANGE: The IPCC's Fifth Assessment recognized that upgrading informal settlements has importance to climate change adaptation. Most upgrading has not been done explicitly to build resilience to climate change but there is considerable overlap between many aspects of upgrading, disaster risk reduction and climate change adaptation. Good quality urban infrastructure and services and better housing quality are at the centre of upgrading and also of reducing risks from extreme weather. Upgrading can also support low carbon development pathways in that most upgrading takes place in dense clusters of housing with densities able to support high levels of walking, bicycling and use of public transport.

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2 http://knowyourcity.info/

MANAGING LAND USE: One essential foundation for resilient cities (and for low carbon cities) is local government capacity to manage land use and land use change within and around the city. This must address

- development issues (especially increasing the supply and reducing the cost of land for housing with infrastructure and services and ensuring adequate public space)
- land value capture (local government with the capacity to buy land before its price is elevated by city expansion to help fund infrastructure and service provision)
- disaster risk reduction and climate change adaptation (including region wide drainage and watershed management)
- climate change mitigation – understanding how support for compact cities (and settlements) and ecosystem services management can contribute to this

LOWERING HOUSING COSTS: There is a need in all growing cities for more good quality housing solutions that low-income groups want and can afford – and that meet appropriate rules and regulations for healthy living. In effect, can city governments provide formal and affordable alternatives to informal settlements. This also means reducing the high costs of most 'formal' housing and changing inappropriate regulations – as was done in Windhoek through smaller plot sizes and cheaper infrastructure. This paper also gives examples of city governments addressing this by developing and selling serviced plots.

LEAP FROGGING: Leap-frogging entails avoiding the less efficient, more expensive or more polluting development trajectories of high-income countries and moving directly to good practice options that can be applied in informal settlements – for instance low-carbon options for transport, settlement designs, home energy use, public space and waste management.

ACTING ON COMMONALITIES ACROSS AGENDAS: There is an obvious need to reconcile five different urban agendas: for economic success; for poverty reduction/basic service provision; for disaster risk reduction – and for climate change adaptation and mitigation. Although there are tensions between these and often competition for resources, there are some obvious commonalities. Poverty reduction, disaster risk reduction and climate change adaptation all share a focus on identifying and acting on local risks and their root causes, even if they have different lenses through which to view risk.

POVERTY: One obvious underpinning of informal settlements is the large number of urban dwellers with very low incomes – which also means a very limited capacity to afford housing and access services. The scale and depth of urban poverty has been under-estimated because poverty lines have not recognized the high costs that city dwellers face for rent and for basic services. The upgrading programmes described in this paper certainly contributed to reducing urban poverty – but they cannot remove poverty. One response to upgrading in an informal settlement in Guatemala City was that it was only putting a roof over their poverty.

COMPACT COMMUNITIES AND CITIES: Compact urban forms can contribute to all the above. High population densities with good quality housing, infrastructure and services, mixed land use and good connectivity can be combined with relatively low carbon emissions. Most informal settlements can also be viewed as compact cities with all the potential advantages for low carbon developments – low energy use and land use per person, most trips by walking or public transport, efficient re-use or recycling of wastes. Upgrading can support these to retain their low carbon characteristics, as well as implementing the much-needed improvements in risk reducing infrastructure and services and tenure. In-situ upgrading, particularly when locally driven can also retain and even enhance collective identity and pride in a sense of place – a critical aspect of wellbeing and a resource for resilience.

HOUSEHOLD AND COMMUNITY ADAPTATION: Many case studies of informal settlements have made evident the ways in which households seek to cope with environmental risks including flooding – for instance building on raised plinths or stilts, constructing walls around the home or compound – and for heat stress - improving ventilation. There are also case studies showing community-based risk reduction initiatives – for instance community organizations managing the installing or improving drains. But there are constraints on such actions – community organizations cannot provide the trunk infrastructure system into which their settlement should integrate (paved roads and paths, piped water mains, sewer and storm drainage system, electricity grids) or manage land use in the wider city – for instance in watersheds to reduced flood risk. As noted above, it is usually only when household and community planning and action are supported by local government that effective adaptation is possible.

INFORMATION: Municipal plans need to draw in all key actors, so they come to understand different urban pressures, share relevant data and get agreement on the needed priorities and trade-offs. City governments should not delay this because of insufficient data; for many cities, the issue is more about integrating existing information from different sectors of government and other actors including those in informal settlements and drawing on this to build a greater capacity to act.

LIVELIHOODS AND THE INFORMAL ECONOMY: Most informal enterprises face comparable constraints to residents of informal settlements. This includes being fined or arrested for contravening some regulation. Many informal enterprises also lose income because of unreliable electricity, water supplies and waste disposal. The informal economy often has large roles in service provision in informal settlements and usually includes many home-based workers (mostly women). Most of these would benefit from upgrading and better-quality services.

WATER/SANITATION/DRAINAGE: For most cities in sub-Saharan Africa and many in other regions of the global south, there are very large deficits in all these. UN estimates suggest that over 700 million urban dwellers in low- and middle-income nations lack what is termed safely managed water – and so must make do with water that is contaminated or irregular or difficult to access or expensive (or often most or all of these). For sanitation, UN estimates suggest that more than 1.6 billion urban dwellers in low- and middle-income nations lack 'safely managed' sanitation. Most of these are using toilets or latrines unconnected to sewers and many have no toilets in their home and have to rely on shared, community or public toilets. There are also comparable deficits in storm and surface drains.

ECO-SYSTEM SERVICES: Green and blue infrastructure provide a wide range of ecosystem services for urban areas that are significant for human wellbeing, climate mitigation and adaptation and can be significant for disaster risk reduction. These include provisioning services (such as food and water supplies), regulating services (such as temperature control), cultural services (such as recreational space) and supporting services (such as nutrient cycling). Low-income groups are typically more dependent on ecosystem services – for instance in obtaining food, water, fuelwood and medicinal plants. But informal settlements also develop in watersheds or other places where ecosystem services are damaged. Again, we return to the key role of local government (or governments) to work with informal settlement dwellers to resolve this.

LOCAL GOVERNANCE FOR URBAN ADAPTATION: More accountable and capacitated urban governments are central to so much of what is needed to build cities' resilience to climate change. They are also key to making a high quality of life compatible with low carbon emissions. They are also important not only for what they do but also for what they encourage and support among other actors – especially those living in informal settlements.

GLOBAL AGENDAS: But so much of the international discourses around the Paris Agreement, the Sustainable Development Goals and the New Urban Agenda are focused on national governments. Urban governments may be mentioned but always in a subsidiary role. There is a very large imbalance in cities in most of the global south between the tasks and responsibilities of local governments and the resources and capacities to meet these. Both low-carbon and climate-resilient urban development are likely to be inhibited by the same constraints that have hindered more conventional forms of development: weak government and governance structures, scarce resources (including little investment capacity), constrained local powers, limited delivery capacities, vested interests, political disinterest in the urban poor and the presence of multiple competing priorities

GLOBAL FUNDS SUPPORTING LOCAL ACTION: One of the sternest tests for global climate finance is to develop the institutional channels through which to encourage and support hundreds of locally- driven upgrading initiatives in informal settlements within which resilience enhancement is embedded. This means having to work with local governments and with the grassroots organizations and federations formed by the inhabitants of informal settlements.

1: Introduction

One of the greatest challenges for climate change adaptation is how to build resilience for the billion urban dwellers who are estimated to live in what are termed informal settlements. These settlements have been built outside the 'formal' system of laws and regulations that are meant to ensure safe, resilient structures, settlements and systems. But how is it possible to build resilience for those living outside the formal systems and usually working within the informal economy?

Much of the infrastructure and services considered as part of conventional (formal) urban development is intended to reduce health risks. This paper highlights the importance for climate change resilience of what the IPCC's Fifth Assessment termed 'risk reducing' infrastructure and services (see Box 1) – and to how the lack of provision for such infrastructure and services is at the core of a lack of resilience (Revi et al 2014). For infrastructure, this lack of provision includes no paved roads and paths to each dwelling, no regular, good quality water piped to homes, inadequate or no provision for sanitation, waste water disposal, electricity, street lights and storm and surface drains. For services, this includes a lack of health care, emergency services, household waste collection and policing. As this paper will make clear, those living and/or working in informal settlements lack most or all of these – with very serious consequences for the risks they face, for their health and for building resilience to climate change impacts.

In cities in high-income nations, there is close to universal provision of these. But for most cities in low- and middle-income nations, there is only partial and fragmented infrastructure investments – for instance ignoring informal settlements. Rather than reducing risks, these investments can increase, shift or concentrate risks: road development can accelerate storm run-off while increased concretisation can increase air temperature. Investments in storm and surface drains in one location can increase flooding risks downstream. Infrastructure expansion may also be a key factor in evictions for informal settlements. A focus on risk reduction, whether focussed on proximate or root causes, challenges local governments, planners and communities to work at city scale and with integrated development of the infrastructure that should serve all urban dwellers.

Informal settlements are concentrated in urban centres in low- and middle-income nations. These are characterized by poor quality (and generally overcrowded) housing, lack of legal land tenure and lack of the 'risk-reducing' infrastructure and services listed in Box 1. Many informal settlements are located on sites at high risk from floods or landslides or from other risks (for instance on unstable waste dumps or very close to railway tracks) because the risks make them unattractive to developers. In most informal settlements, there are no legal addresses. Informal settlement residents usually have difficulties engaging with local governments or at best are trapped in clientelist relationships that perpetuate poverty and risk.

Box 1: Resilience and risk-reducing infrastructure and services

Resilience to climate change for cities comes from risk-reducing measures taken in anticipation of the hazards that such change is bringing or will bring, preparedness to cope with the impacts and beyond this to adapt (to lower future risks). The effectiveness of a resilience agenda depends on a city-wide approach and on how well it understands and responds to the needs of vulnerable groups. Resilience also implies a capacity to cope with unexpected or uncertain risks - or as in climate change, to not only increasing risks but increases and changes in increasing risk.

Much urban infrastructure provision is to reduce risks: water piped to homes and workplaces that is safe to drink and regular; connections to sewers, storm and surface drainage, electricity grids (as electric lights reduce fire risks from candles and kerosene lamps and street lights make neighbourhoods safer) and paved/all weather access roads and paths.

Most urban services also contribute to reduce risks or their impacts: health care and emergency services/ambulances/fire engines, policing, regular solid waste collection and latrine emptying. Also, the availability of insurance for homes and possessions.

There are obvious interconnections: all weather roads and paths are also important for emergency service vehicle access; street lights need electricity; functioning drains usually depend on household solid waste collection. There is also a valuable literature on the characteristics of resilient city systems that include responsiveness, redundancy, safe failure, capacity to manage and protect ecosystem services and capacity to cope with and adapt to unexpected changes (Brown 2012, Tyler and Moench 2012, Vugrin and Turnquist 2012) – but of course you need the systems in place to be able to apply these

In almost all nations in the Global South, more than half the urban workforce work in informal employment; the proportions are particularly high in South Asia (82 percent in informal employment) and sub-Saharan Africa (66 percent) (Chen 2014, Chen, Roever and Skinner 2016). These face challenging conditions of work including poor occupational health and safety, insecurity, no social protection and low incomes (Chen 2014). Many of those working in informal employment live in informal settlements – including those that work in home-based enterprises.

The interest in 'informality' was particularly notable in relation to employment from the early 1970s but this interest widened so the term "informality" is commonly used to describe a range of behaviours and practices that are not regulated or controlled by the state or formal institutions, including those related to income generation, service provision, and settlements (Chen, Roever and Skinner 2016).

Informal settlements and the informal economy fall outside the 'formal' – formal livelihoods and labour markets, formal premises, formal land/property titles and formal housing (and formal land for housing) markets for tenants and owners. They also fall outside many services – for instance for most informal settlements no government provided public services. Most fall outside infrastructure networks. Most informal settlement dwellers cannot open a bank account or get a legal address (on which access to many 'formal' services may depend). They fall outside government systems for land use planning and management. Many transactions may be 'informal' – for instance selling of housing or land for which the seller does not have a formal title. Despite the importance of informal employment to city economies and the importance of informal settlements to housing most of the low-income labour force (and their families), both are still viewed negatively by many governments.

Table 1 summarizes the different impacts from climate change on urban populations living in informal settlements and urban residents working in the informal economy. Most extreme weather disaster deaths in urban centres are in low- and lower-middle-income nations (UNISDR 2009). Risks are concentrated in informal settlements where the occupants are typically more exposed to climate events with limited or no risk-reducing infrastructure, low-quality housing, and limited capacity to cope (UNISDR 2009, IPCC 2012, Revi et al 2014). At the same time, residents of informal settlements typically have smaller ecological and carbon footprints than those of higher socio-economic status elsewhere in the city.

These issues raise questions about whether and how those living in informal settlements and those working in informal employment are more at risk from the impacts of climate change. They also require consideration of what can be done to address these risks while also attending to advancing human development and climate mitigation agendas.

Table 1: Likely impacts from climate change on urban populations living in informal settlements and working in the informal economy

Projected changes	Examples of likely impacts	Implications for residents of informal settlements and people working in the informal economy
Changes in simple extremes		
Higher (and increasing) maximum temperatures, more hot days and heat waves - over nearly all land areas	Rise in mortality and illness from heat stress in many urban locations	Many informal settlements very dense with very little open/public space and often with uninsulated corrugated iron roofs and poor ventilation that contribute to higher indoor temperatures. Largest impacts among groups particularly vulnerable – infants and young children, the elderly, expectant mothers, those with certain chronic diseases. Health risks for outdoor workers
Higher (increasing) minimum temperatures: fewer cold days, frost days and cold waves over nearly all land areas	Decreased cold-related human morbidity and mortality. Extended range and activity of some disease vectors – including mosquito and tick-borne diseases	Most informal settlements without public health measures to control or remove disease vectors and without health care systems that provide needed responses. Infants and young children particularly vulnerable
More intense precipitation events and riverine floods	Increased flood, landslide, avalanche and mud-slide damage resulting in injury and loss of life, loss of property and damage to infrastructure. Increased flood run- off often brings contamination to water supplies and outbreaks of water-borne diseases	Many informal settlements concentrated on sites most at risk of flooding with poor quality housing less able to withstand flooding and a lack of risk-reducing infrastructure. Homes, possessions and assets for generating income are not covered by insurance.
Wind storms with higher wind speeds	Structural damage to buildings, power and telephone lines, communication masts and other urban infrastructure	Corrugated iron roof sheets blowing around during high winds; they were not nailed down because they could be sold if needed and the price was less if they had nail holes (Wamsler 2007)
Changes in complex extremes		
Increased summer drying over mid-latitude continental	Decreased water resource quantity and quality; increased risk of	Informal settlement residents usually facing more water constraints and with residents
interiors and associated risk of drought	forest/bush fire; decreased crop yields and higher food prices	more vulnerable to food and water price rises
Increased tropical cyclone peak wind intensities and mean and peak precipitation intensities	Increased risk to human life and damage to property and infrastructure; risk of infectious disease epidemics; increased coastal erosion and damage to coastal ecosystems	So many informal settlements are on sites most at risk, having poor quality housing and lacking risk- reducing infrastructure
Intensified droughts and floods associated with El Nino events in many different regions	Decreased agriculture and range-land productivity in drought-prone and flood-prone regions	Impact on food availability and prices in urban areas
Increased Asian summer monsoon precipitation variability	Increased flood and drought magnitude and damages in temperate and tropical Asia	In many cities in Asia, most of those most at risk of flooding are low-income groups living in informal settlements
Changes in the mean		
Water availability	Reduced water availability in many locations – with obvious impact on agriculture and on cities where fresh water availability declines significantly	In cities facing constraints or shortages of freshwater supplies, it is likely that low-income areas will be the most affected (and least able to afford alternative sources). Difficulty in accessing water for informal livelihood activities.
Sea-level rise	Coastal erosion, land loss, more floods from storm surges; hundreds of millions of urban dwellers living in low elevation coastal zones	Many informal settlements close to the sea with poor quality housing and lacking drainage infrastructure
Higher average temperature	Disease vector range spreading, worsening air quality, higher water demand and water loss	Those living in informal settlements so often not served with the infrastructure and health care measures needed to counteract these

SOURCE: Drawn from Table 3.9 in Mitlin and Satterthwaite (2013) that drew on McCarthy et al 2001 and Parry et al 2007

It is important to consider both the direct and the indirect impacts of climate change – although there is no agreement on how these are defined. For this paper, the direct impacts of climate change include extreme weather events that cause death, illness or injury, loss of or damage to property/assets and displacement. The indirect impacts include impacts on larger systems that then impact people so it would include economic impacts that can be city wide, disruption to or close down of public transport and health care or other public services, disruptions to labour markets including access to workplaces or markets, more scarce or expensive food or water, and greater risks from infectious and parasitic diseases. If people have to move to temporary camps, there are the risks these can pose. Indirect impacts can be particularly serious for low-income groups – where sources of income are lost or prices of food increase.

The next section of this paper describes the circumstances and extent of informality in cities in low- and middle-income countries. Section 3 reviews what has been learned from upgrading informal settlements. Although few of the case studies on upgrading informal settlements mention climate change, they are describing a process that is perhaps the most important means by which low-income urban dwellers unable to afford formal housing and relying on informal livelihoods can get more resilience to climate change impacts – as well as reducing risks they face from everyday hazards and disasters. This discussion of informality also requires attention to how living and working in 'formal' settlements and employment provides a stronger foundation for adaptation and mitigation, and the means by which those in informal settlements can acquire this foundation.

Section 4 considers the ways in which informality shapes risk and vulnerability in terms of urban form, housing, industry and livelihoods, water and sanitation infrastructure and urban ecology. Section 5 discusses governance with a focus on what city and municipal governments and local civil society organizations can do to achieve more inclusive, low carbon, and climate resilient development in towns and cities around the world. Section 6 draws some conclusions.

But first, there is a need to clarify the urban focus of this paper. The urban population of any nation can be divided into 'cities' and urban areas that are not cities. There is no agreed definition for what a city is – although it is understood to be an urban centre with some importance – for instance a large population and the seat of district or provincial government. There is also no agreed definition for urban centres and each nation has its own particular definition (see United Nations 2015) but in most nations, urban centres are settlements with a population above a particular threshold – for instance 2,500 or 5,000 inhabitants.

There is very little literature on informal settlements or the informal economy of small urban centres

for instance if we define small urban centres as those settlements defined as urban by governments with populations up to 50,000 inhabitants. Most of the literature on informal settlements is in cities with populations exceeding a million. So the paper uses the term city to acknowledge how little it covers small urban centres. But small urban centres (including many with only a few thousand inhabitants) generally have local governments with the least capacities to assess climate change risks and to act; one study of a small urban centre in Malawi was sub-titled 'Where there is no local government' (Manda 2013).

2: Informal settlements, economies and services and risk

2.1 The scale of informal settlements

The term 'informal settlement' refers to urban settlements or neighbourhoods that developed outside the formal system that is meant to record land ownership and tenure and without meeting a range of regulations relating to planning and land use, built structures and health and safety. The definition used by the OECD is "areas where groups of housing units have been constructed on land that the occupants have no legal claim to or occupy illegally" or "unplanned settlements and areas where housing is not in compliance with current planning and building regulations (unauthorized housing)."[3] As discussed in more detail below, many informal settlements are not on illegally occupied land.

Consideration of urban populations and informal settlements needs to include internally displaced people and refugees. UN estimates suggest that 65.6 million people were forcibly displaced globally in 2016. This included 40.3 million that were internally displaced (remaining within their country's boundaries) with the rest being refugees and asylum seekers (UN 2017). The proportion of displaced people moving to urban areas is growing; for instance, by 2016, 60 per cent of refugees were living in urban areas rather than in camps (ibid, Archer and Dodman 2017). Refugees and internally displaced person are seen as the responsibilities of humanitarian agencies providing emergency responses but for those that live in informal settlements, they need to be included in discussions of how to improve conditions.

The term 'informal settlement' is used instead of the terms 'slum' or 'illegal settlement' because it is less pejorative; terming a settlement a slum can legitimate **bulldozing it (see**

[3] https://stats.oecd.org/glossary/detail.asp?ID=1351

Gilbert, 2007). But importantly informal settlements and slums are not the same. Definition of informal settlements are based on contraventions of specific laws, rules and regulations. Definitions of slums are usually based around measures of housing quality, service provision and overcrowding. There are informal settlements that would not be considered as slums. These include settlements on land acquired from the owner (and thus not illegally occupied) but that were illegally sub-divided. These can have plots in a regular grid plan (and may even meet municipal regulations), houses built with permanent materials and good provision for water and sanitation.

There are also neighbourhoods that are termed slums that are not informal settlements because they were not built illegally. These include houses or apartments that met formal standards when they were built that have been subdivided into small rental units or deteriorated due to poor maintenance. In many cities, these include poor quality and poorly maintained public housing (Rojas 2018).

In most low- and middle-income nations, there are no official data on the population living in informal settlements or slums. Information on housing conditions and service provision are usually drawn from censuses and national sample surveys (including the Demographic and Health Surveys). Most censuses do not identify 'informal settlements' or 'slums' as a category, and national sample surveys have sample sizes too small to be able to report on the scale of informal settlements or on conditions there. While there are many case studies of informal settlements (e.g. Moser 2009, Perlman 2010) and some city-wide studies (e.g. Karanja 2010, Livengood and Kunte 2012), these represent a small sample from among hundreds of thousands of urban centres and informal settlements. However, case studies of cities in low- and middle-income nations show many with more than a third of their population in informal settlements with some showing a much higher proportion – for instance for Nairobi, 60% (Weru 2004, Lines and Makau 2017) and for Dar es Salaam 70% (Kiunsi 2013).

The United Nations does not have data on the population living in informal settlements. It does have data on the population living in what it defines as 'slums' and it classifies households as 'slum households' if they lack one or more of four criteria: lack of durable housing, inadequate living space (3 or more persons per room) improved water and improved sanitation (UN-Habitat, 2016). Originally, households were to be classified as slum households if they lacked secure land tenure, so this would have contributed to global estimates on the number of informal settlement dwellers. But this was dropped from the definition because there were no data on this for most nations.

UN Habitat's global and regional estimates of the number of urban households that are 'slum' households, are likely to include most residents of informal settlements. These estimates suggest that there were 880 million 'slum dwellers' in 2016, including some 56 per cent of the urban population in sub-Saharan Africa and more than 30 percent of the urban population of South Asia (UN-Habitat 2016, p. 203). But the accuracy and validity of this data on slum households is contested, especially the inappropriateness in the indicators used for assessing water and sanitation provision in urban areas. If the indicators were appropriate to dense urban contexts, UN estimates of the number of slum dwellers would increase (Mitlin and Satterthwaite 2013; Satterthwaite 2016).

In considering this and considering the population living in informal settlements that are not within the slum population estimates, it is likely that at least a billion urban dwellers currently live in informal settlements.

Informal settlements grew (and in many nations still grow) because their residents could not find accommodation that they could afford to buy, build or rent in formal settlements. It is also because urban governments refused to address their needs – or lacked the capacity to do so. This is also linked to the inappropriateness of many 'formal' rules and regulations and the cumbersome, time consuming and often expensive procedures needed to be 'formal' (Watson 2009, Porter 2011). It is also because international aid agencies have not seen upgrading informal settlements as a priority.

Informal settlements are usually defined or characterized by the many ways they contravene some 'imagined ideal' of planned cities (see Porter 2011, Watson 2011). An informal settlement will commonly differ from a formal settlement because of unclear (often illegal) land occupation, because the settlement and its buildings did not receive official permission, and/or because the site layouts and structures contravene regulations (for instance, plot sizes are smaller than the minimum specified by planning regulations). In many cities, informal settlements are so common and house such a high proportion of the population and the workforce that they cannot be seen as a "state of exception" from the formal city (Roy 2005). If laws and regulations are deeming illegal the homes and livelihoods of much of the city population, then it is their legitimacy that should questioned.

2.2. Informal land markets, services and employment

The process of buying or selling land and buying, selling or building housing in compliance with legal requirements is often unnecessarily complicated and costly (Payne et al., 2014; Burns, 2015, Berrisford et al 2018). Getting formal land tenure (and the legal document to verify this) is usually complicated by difficulties and expenses of getting formal land title documentation (and there may be no land information system to support this). Land for informal settlements may be obtained from traditional chiefs with widely accepted rights to allocate land – but outside any formal government system to record land titles. Or land may be obtained from informal brokers. Urban land markets may be further complicated by speculation by real estate agents, overlap with traditional tenure systems and/or political interests, which contribute to opaque land ownership and decision-making structures (Durand-Lasserve, Durand-Lasserve and Selod 2015; Andreasen et al., 2011; Leck and Roberts, 2015).

In most cities, there is considerable diversity among the informal settlements in regard to the illegality (or not) of the land occupation and use, the quality of the site, the accessibility to labour markets, the risk of eviction, housing size and quality, provision for infrastructure and services and extent of tenants within the settlement's population (Hardoy and Satterthwaite 1989, Roy, 2005; Payne et al., 2014, Krishna et al 2014). As Roy 2005 notes, there is spectrum of "differentiation within informality" and differentiation in power, exclusion and legitimacy (p. 149). At one end of the spectrum, many informal settlements include multi storey buildings (Hasan 2010, Lanzt and Engqvist 2008). There are also buildings that are not 'informal' but that provide 'informal' accommodation – for instance where legal buildings have been converted into cheap boarding houses with dormitories where beds can be rented that contravene regulations on density and water and sanitation provision.

Much of the urban population (especially those living in informal settlements) rely on informal providers of goods and services because of the lack of provision from formal providers/utilities. This informal provision can cover water (purchased from tankers, vendors or kiosks), pay-to-use public or community toilets (because of no toilets in the home), electricity (from illegal connections to grid) and a range of services (household waste collection, day care, schools, health care….). But there are usually serious deficiencies in the quality of provision and high cost.

UN statistics show the scale of the urban population that lacks good provision for water and sanitation in their homes. Most of this population is likely to be in informal settlements. The 2017 report of the WHO and UNICEF Joint Monitoring Programme suggests that over 700 million urban dwellers in low- and middle-income nations lack what is termed safely managed water (WHO and UNICEF 2017). So they have to make do with water that is contaminated or irregular or difficult to access or expensive (or often most or all of these). Many nations had a lower percentage of their urban population with water accessible on premises in 2015 compared to 1990 (Satterthwaite 2016). UN estimates suggest that more than 1.6 billion urban dwellers in low- and middle-income nations lack 'safely managed' sanitation. Most of these are using toilets or latrines unconnected to sewers; many cities in Asia and sub-Saharan Africa have no sewers or sewer systems that only serve a very small percent of their population. There are no comparable statistics for drainage – but given the very large deficits in trunk infrastructure for water and sanitation, it is likely that there are comparable deficits in storm and surface drains.

The introduction noted how in almost all nations in the Global South, more than half the non- agricultural workforce work in informal employment. Women generally have a higher proportion in informal employment than men (Chen 2014). In most cities in the Global South, much of the informal economy is located in informal settlements (including many home based enterprises) although there are many in informal employment in the formal economy – and enterprises in informal settlements that are 'formal' in the sense that they are producing for or servicing external markets.

The informal economy includes the production and employment in unincorporated small or unregistered (informal) enterprises and informal employment - employment without legal and social protection that includes construction workers, domestic workers, home-based producers, street vendors, transport workers and waste pickers, plus many low-end service occupations (Chen 2014).

The informal economy also represents an important part of the national economy – and many informal firms and workers are producing for or serving formal firms (Chen 2014). But many governments do not recognize informal workers as economic actors or the contribution of the informal economy to city and national economies. Many enforce punitive government regulations such as arresting or fining street trader or confiscating their goods or evicting workers – as home- based workers are evicted. Urban renewal and infrastructure projects often include the eviction of street traders (ibid).

Where informal settlements house a significant proportion of a city's population, they also house a significant proportion of its labour force (including many working in the formal economy). And many informal settlements have large and diverse informal economic activities. It is common for informal settlements to develop close to ports, markets, industrial areas and airports/bus/rail terminals, as many of their inhabitants provide the labour these depend on (see, for instance, Farouk and Owusu 2012). Many informal settlements develop large and varied economies of their own – serving their population or fabricating goods or providing services to external markets

(World Bank 2016, Lantz and Engqvist 2008). Inadequate provision for essential services, including the lack of electricity, water piped into their premises, sanitation/drainage and solid waste collection also constrain enterprises in informal settlements (World Bank 2016).

As Ela Bhatt, founder of the Self-Employed Women's Association (SEWA) put it: 'The challenge is to convince the policy makers to promote and encourage hybrid economies in which micro- businesses can co-exist alongside small, medium, and large businesses: in which the street vendors can co-exist alongside the kiosks, retail shops, and large malls ... Just as the policy makers encourage bio diversity, they should encourage economic diversity. Also, they should try to promote a level playing field in which all sizes of businesses and all categories of workers can compete on equal and fair terms' (quoted in Chen 2014).

Box 2: The full spectrum of risk

Understanding the full spectrum of risk facing urban populations means understanding all the risks that can impoverish, injure, sicken or kill any individual. Due largely to the lack of 'risk-reducing infrastructure and services' (see Box 1 for details), everyday risks pose a constant "everyday" threat to residents based on their living and working environments – from, for example, indoor air pollution, fire risk, and poor-quality water and provision for toilets. In informal settlements in particular, what can be termed every day risks often contribute more to premature death and serious illness or injury than disasters just by dint of their frequency, pervasiveness and likelihood. Certain population groups are more vulnerable to different risks - for instance the greater susceptibility of infants to food-borne or water-borne diseases. Different categories of risk are distinguished by the scale of their potential impact and the frequency of their occurrence. Disasters may be seasonal, such as flooding, or once-in-a-hundred years.

Understanding the full spectrum of risk as faced by residents of informal settlements can help assess which 'risk-reducing' infrastructure and services need to be prioritised – such as affordable and accessible clean piped water, sewer connections, or health centres and emergency services. Data on risks (and many health determinants) can be gathered through censuses and hospital or police records, but to be useful, they need to be 'disaggregatable' - available at the neighbourhood or street level, to show concentrations of risk. This is where local populations can supplement information bases, through their own surveys or maps (see section 3 for examples), or through focus group discussions and interviews.

Source: Satterthwaite and Bartlett, 2017, Manda and Wanda 2017, Bull-Kamanga, Diagne, Lavell et al 2003)

It is obvious that enterprises that make up "the private sector" have a powerful influence on how any city develops and so they also have importance for climate change adaptation (and mitigation). But the term the private sector encompasses all the enterprises in the informal economy as well as the formal economy and so it ranges from street vendors to the largest companies. In regard to climate change adaptation, those companies working within a city's formal and informal land markets influence the price, availability and location of land for housing and the form that city expansion takes.

In the absence of 'formal' provision for water, sanitation, health care, schools, solid waste collection, policing.... in informal settlements, so alternative (often informal) providers develop. These encompass individual water vendors and latrine emptiers and private utilities that have learnt to operate successfully in some informal settlements – for instance providing electricity or water through kiosks. In many informal settlements, inhabitants have to rely on private pay-to-use toilets because they lack toilets in their homes or plots. Many informal service providers have links to the

formal - for instance as water tankers and vendors draw water from government mains and as some household waste collection and latrine emptying services rely on government managed collection or disposal points.

2.3. How the 'formal' helps to reduce risk

Cities range from the most to the least healthy places to live and to work – seen for instance in differences in average life expectancy at birth or infant, child and maternal mortality rates (Mitlin and Satterthwaite 2013, Eze et al 2017). By concentrating people, enterprises, institutions, motor vehicles and their wastes, cities can be very unhealthy. But well-governed cities have measures in place that enormously reduce the health risks these can bring. The main means to do so has been in developing and enforcing (formal) laws, byelaws, rules and regulations on, for instance, building standards, land use, health and safety at home and at work, pollution control, motor vehicle traffic management and household appliances – and on registering land title/rights and their use and sale.

Social, political and health focused studies of the history of cities in what are today high-income nations show how such laws and regulations were developed – including the political complications of doing so (and where and how these were or were not overcome) (Wohl 1983). But over time, these established a wide-ranging set of rules and regulations (and regulatory bodies to ensure compliance) – most directly or indirectly about reducing risk or its health consequences. In addition, they were developed (and where needed changed) within particular local contexts in response to locally identified needs.

The households, enterprises and institutions who function within these laws, rules and regulations can be seen as the 'formal' – living in 'formal' housing with a 'formal' address on land for which there is formal title (and where tenants have formal contracts with the land or house owners) and working in 'formal' enterprises or institutions. Also, where there is 'formal' infrastructure and services. No city will have all its population, workers, enterprises and institutions working entirely within all these aspects of the 'formal' but in cities in high-income nations, nearly all will be.

For those in the formal city, all or nearly all live and work in buildings that meet formal standards for health and safety. They have legal addresses – that are often required to get on the voter register, open a bank account, get 'formal' connections to water, sanitation and drainage infrastructure and access entitlements and welfare payments such as support to those unable to work and pensions. Almost all have reliable legal household waste collection and electricity services, receive water of drinkable quality piped to kitchens, toilets and bathrooms, are connected to sewers, have provision for storm drains that are maintained. Households have access to paved roads and footpaths, street lighting, as well as policing, emergency services, schools and healthcare. Residents will have insurance for their home and possessions (facilitated by having access to bank accounts and legal documents) and buildings and building plots are registered and occupied or rented out by their legal owner.

Taken together, these laws, rules and regulations have brought very large gains in health outcomes and provision of key health determinants in cities in high-income and many middle-income nations. They have also reduced susceptibility to harm from extreme weather events and other shocks and stresses. However, it is worth noting that it took decades of political organization and pressure to get many of these and there is still need for progress and greater effectiveness in some. But what deserves our attention is the contribution of all of this to resilience (including building adaptive capacity to climate change) and to providing the instruments for mitigation.

City and municipal governments usually have responsibilities for ensuring compliance with a large and diverse range of standards for housing and other buildings, infrastructure and enterprises (much of it for environmental or occupational health and safety). Where such standards are appropriate and affordable - and enforced - this has underpinned improving conditions, including the resilience of buildings and infrastructure to extreme weather.

But in many low and middle-income nations, standards and regulations for housing and land use are based on imported models – including many that date back to colonial rule. What they require in, for instance, very large minimum lot sizes help make them unaffordable for most of the population. Infrastructure standards can also have the same effect – so rather than reducing risks, they exclude large sections of the urban population from the protections that standards are meant to provide.

The laws, rules and regulations that formally guide urban development should complement and support those applied to buildings and infrastructure – and help local authorities and utilities to manage urban expansion, including extending infrastructure and service provision to un-served and under-served parts of the city. They form an important part of urban planning, management and governance to help public agencies to achieve their desired urban forms and functions (MacDonald et al., 2014). This could include climate-related aspirations such as promoting compact urban development, ensuring sufficient good quality accessible green space, and protecting watersheds. However, in many cases, either the content of laws, rules and regulations or their application contribute to the growth of informal settlements.

The proportion of individuals and households that live in informal settlements is in effect a measure of the failure of formal systems. Inappropriate building and infrastructure standards and land use regulations act to push up the cost of the cheapest formal house beyond what most households can afford. Informal markets pick up those unable to find or afford (or occasionally want) accommodation in formal housing markets. So informal settlements exist largely because their inhabitants could not afford to buy, build or rent formal legal housing, and because governments have not responded effectively to this market failure. People choose to live in informal settlements either because it best meets their needs (especially for access to jobs and services) and limited capacities to pay - or because this is the only place where they can obtain or afford accommodation. The inhabitants of informal settlements will not consider moving to formal settlements unless they compare favourably with their current accommodation on issues such as price and location, as well as quality and tenure. Living in an informal settlement underlies most of the risks that residents face to their lives, health, home, livelihoods and assets – to which climate change is adding or exacerbating or will do so.

3: Responses to informal settlements

3.1. The potential offered by upgrading

Upgrading is a term given to government measures to improve the quality of housing structures and the provision of housing and community-related infrastructure and services (such as piped water, sewers and storm drains) to settlements that are considered to be (or officially designated as) 'slums' or informal settlements. It accepts the validity of government agencies working in informal settlements – homes and settlements that contravene laws, regulations and standards. This includes connecting them to public infrastructure and service systems. As discussed later, upgrading came to include community-driven upgrading too and upgrading undertaken by local government- community organization partnerships.

Upgrading has particular importance to climate change adaptation where the upgrading includes addressing the risks that climate change is bringing or exacerbating. Upgrading informal settlements has not been done explicitly to build resilience to climate change but there is a very large overlap between many aspects of upgrading and climate change resilience – for instance better quality housing, functioning piped water, sewer and storm drainage systems, paved roads (that allow emergency services to function in informal settlements) and paved footpaths, reliable public transport and electricity supplies, and solid waste collection.

The IPCC has long recognized the importance of upgrading informal settlements for climate change adaptation. The IPCC's Third and Fourth Assessments from Working Group II recognized the higher risks facing those living in informal settlements because of poor quality housing and inadequate services and because many are located on hazardous sites (Scott et al 2001, Wilbanks et al, 2007). The Third Assessment stated the need to "Regularize property rights for informal settlement and other measures to allow low-income groups to buy, rent, or build good quality housing on safe sites" (Scott et al 2001, page 406). The Fourth Assessment noted how "Informal settlements within urban areas of developing-country cities are especially vulnerable, as they tend to be built on hazardous sites and to be susceptible to floods, landslides and other climate-related disasters" (Wilbanks et al 2007, page 372); also "how the poor tend to live in informal settlements, with irregular land tenure and self-built substandard houses, lacking adequate water, drainage and other public services.... "(ibid, page 373). These issues were also mentioned in the 4th Assessment (WGII) chapter on health – and this also highlighted risks facing those in poor housing in high density urban areas (Confalonieri et al 2007).

The chapter on urban areas in the Fifth Assessment (Working Group II) notes: "Reducing basic service deficit could reduce hazard exposure, especially of the poor and vulnerable, alongside upgrading of informal settlements, improved housing conditions and enabling the agency of low- income communities" (Revi et al 2014, page 562). This chapter also mentions examples of good experiences with community-driven 'slum' or informal settlement upgrading in reducing risk and vulnerability to extreme weather events. It notes how "it has become more common for local governments to work with community-based organizations in upgrading their homes and settlements in disaster risk reduction and with community-based adaptation building on these experiences and capacities" (page 581). Other references to upgrading point to how informal settlements that become incorporated into the formal city often mean "an increased expectation on the state to reduce vulnerability, including long-term and strategic adaptation investments through access to schools, health care, infrastructure, and safety nets" (page 581). It therefore highlights that informality both shapes the consequences of climate change impacts, and that upgrading has the potential to contribute significantly to urban resilience.

Government responses to informal settlements range from bulldozing them to ignoring them to 'upgrading' them. Often all three responses are evident in a city as the government response for each informal settlement differs depending on particular characteristics of each settlement. Within bulldozing, responses range from forced eviction to evictions that are negotiated. Within those that are negotiated, some provide for resettlement of the evictees and these include instances where the evictees were engaged in organizing and managing their move and choosing the resettlement location (Patel et al 2002, Lines and Makau 2017). Upgrading, either by the government or by communities themselves, represents a radical change in approach.

Upgrading informal settlements may also lead to the first map of the settlement and provide each household with a legal 'formal' address. This then allows or facilitates residents' access to entitlements such as enrolling their children in public schools, getting on the voter registers, receiving social protection or subsidized food and fuel. Having a legal address means being able to receive post and may be required for getting connection to (formal) piped water and electricity, a bank account, insurance for homes and possessions or a phone line (although mobile phones, if affordable, overcome this constraint).

All the above represent a shift in informal homes and settlements towards the formal (with its laws, rules and regulations) that can contribute to increased resilience. But as discussed below, this being an incremental process, the final outcome may not meet all official regulations (or which might catalyse changes in official regulations to lower the cost of 'formal' housing (see Mitlin and Muller 2004).

For the inhabitants of informal settlements, their preference is usually upgrading rather than resettlement since this improves conditions but with no need to move and find alternative accommodation (although there may be temporary relocation during reblocking or infrastructure installation). This has particular importance for residents of informal settlements that are well located in relation to labour markets because this keeps down time and transport costs. But these are also generally the settlements whose central location makes their land valuable and with government and real estate interests keen to evict the residents and redevelop the site. For informal settlements that have many renters, the benefits of upgrading may be captured by their landlords as they increase rents or deny the tenants access to (for instance) toilets.

3.2. Types of upgrading

Upgrading informal settlements was recommended in the 1960s (see Mangin 1967 and Turner 1968) and it received strong endorsement by the governments meeting at the First UN Conference on Human Settlements in 1976, by which time upgrading was receiving support from the World Bank and from UNICEF. By the mid-1970s, many city governments were implementing upgrading schemes although some also continued to bulldoze informal settlements (typically those in the most valuable locations) and continued with (mostly ineffective) public housing programmes (Hardoy and Satterthwaite 1981). As discussed later, there are also public schemes that are described as be upgrading where the inhabitants get displaced while their settlement is bulldozed and new apartment blocks built, but where there is no guarantee that those displaced will be able to return (Patel 2013).

Viewing the documented experiences with upgrading up to the present, there are very large differences in what the upgrading provided, what it cost per house served, who implemented it, who paid for it and the extent to which it engaged the population (and served their needs). Upgrading ranges from some rudimentary provision of infrastructure – for instance public water points where water can be collected or purchased and a storm drain – to a full range of 'risk reducing' infrastructure and services, often community facilities and sometimes income generation or support for house improvement or extension) and land tenure granted to the occupiers (see for instance Stein with Castillo 2005, Almansi 2009).

Comprehensive upgrading can be expensive – costing several thousand dollars per house – Almansi 2009, Rojas 2018). The legal costs of sorting out tenure for the occupiers can be particularly high as the legal landowners' demand compensation and there are the costs of preparing a cadastre to define and register ownership of plots and their boundaries. Land titling programmes are also not only expensive and complicated, they are also beyond the capacity of many urban governments (Burns 2015). The costs of upgrading are usually paid for by the public agency implementing the initiative although as discussed below, it may include a household or community contribution, or a mixture of government provided loan and grant – or funding drawn entirely from households.

3.3. Lessons from upgrading initiatives

Upgrading schemes vary from conventional 'projects' organized and managed by government agencies (national, state or municipal) that usually contract out much of the work, to building companies, to initiatives in which the inhabitants and their own grassroots organizations have much larger roles. Experience in community-led upgrading and co-production (communities working with local governments) in particular offers potential for climate change resilience-building because of its recognition of local hazards, its reflection of community priorities, and its ability to contribute to enhanced adaptive capacity.

3.4. Government-led upgrading

Where government upgrading works well, it has proved to be very effective as it greatly improves housing conditions, infrastructure (including links to city-wide systems for paved roads, water, waste water and storm drainage that contribute to resilience) and access to services. It removes or greatly reduces the risk of eviction. It builds on the investments that those living in informal settlements had made before the upgrading – and, crucially, does not require residents to move to another settlement (with all the costs this brings as well as disruptions of social networks and almost always with less favourable locations). As such, upgrading contributes much to reducing risks for a range of risks that climate change is bringing, may bring or will bring and to capacities to cope and adapt. In future, upgrading schemes could consider (often minor) adjustments could increase safety margins for a range of climate change impacts. They could usefully integrate disaster risk reduction into these considerations: if a city starts working in DRR it will necessarily have to address informality issues, urban planning, services and infrastructure, housing, participation and governance. It is worth repeating that good development, disaster risk reduction and climate change adaptation all focus on identifying and acting on local risks and vulnerabilities and there are many beneficial overlaps between them (Satterthwaite, Bartlett, Roberts et al 2016).

But care is needed in upgrading schemes not to impose costs that cannot be afforded – for instance as households now having to pay more than they can afford for water, sanitation and electricity. There is also the need to ensure good maintenance and repair for community infrastructure and services (upgrading providing a one-off improvement with public agencies needing to take over maintenance – which they often fail to do).

There are also many government initiatives that upgrade informal settlements that were not formally labelled as upgrading. In many Latin American cities, provision of piped water, sewers and storm drains and electricity have been expanding to reach almost all residents, including those in informal settlements. Some cities have improved bus services that also bring benefits to informal settlement dwellers. These are components of upgrading that are not labelled upgrading – including some that bring city-wide benefits – see for instance the experience in Rosario, Argentina (Almansi 2009) and Porto Alegre in Brazil (Abers 1998).

There seems to be an acceptance by local governments in much of Latin America that upgrading or provision of services to informal settlements is the conventional policy response;

so different to the conventional policy responses in the 1960s and 1970s of bulldozing or ignoring them (Portes 1979, Hardoy and Satterthwaite 1989) One factor behind this was the political changes brought in many nations with the return to democracy and the changes that strengthened the capacities and accountabilities of city governments that included elected mayors and city governments (Fernandes 2007). These were in turn often supported by land titling programmes in informal settlements (Lula da Silva et al 2003) and participatory budgeting – that gives each district of a city the right to influence priorities in public works and makes the city budget more transparent (Cabannes 2015).

The South African government has made strong commitments to upgrading and to community-led practices for upgrading. This has included many positive commitments by city governments (and ministers within national governments). But it has proved difficult to put this into practice on the ground within the formal processes of local government with its sectoral rivalries, bureaucratic inertia and range of (often inappropriate) rules and regulations (Fieuw and Hendler 2017).

There are also case studies that show upgrading schemes that have not served the local population – and indeed some that end up evicting the residents (Patel 2013, Mitra et al 2017). Some government led 'upgrading' projects displace the residents when the whole point of upgrading is not to do so - see the assessment of the government of India's Basic Services for the Urban Poor (BSUP) programme (Patel 2013). Many of the 'upgrading 'projects "…are simply public housing construction re-labelled – and often with very inadequate provision for upgrading "basic services" (Patel 2013, page 177). In many such schemes, the former residents do not get accommodation in the 'upgraded' settlement. But even where there is some success in improving conditions, it may have grave limitations. This is illustrated by the comment of a community leader in South Africa:

> **If it is just physical upgrading you are doing then the project can be finished in a few days. You don't need to do much work, you can just send a contractor to do it. But the people won't be changed. Their capacities won't be changed. Their relationships won't be changed, they will still be a poor, vulnerable, marginalized and unorganized group of people who happen to live together in the same slightly improved informal settlement.**
>
> (SDI 2016)

Upgrading can be seen as a challenge to conventional government 'housing for low income groups' programmes, most of which are ineffective as they are located far from labour markets and impose costs that low-income households have difficulty affording (Buckley et al 2016). Many also suffer from poor maintenance. The South African government has long had a major programme of support for new housing for low income groups but little support for upgrading. This is beginning to change **and** the national development plan calls on government to "stop building houses in poorly located land and shift more resources to upgrading informal settlements provided that they are in areas close to jobs" (South African SDI Alliance 2013). Balancing the locational needs of low-income groups, and exposure to climate change-related hazards, will be one of the most critical decisions to be made when considering whether upgrading is appropriate in any particular location.

3.5. Community-led upgrading

There are many initiatives in urban areas of Asia and Africa that contribute to upgrading that are not labelled as such. For instance, the hundreds of community-designed and managed toilets and washing facilities in informal settlements in Mumbai (Burra et al 2003) would not be labelled as upgrading. In many informal settlements, there are improvements in basic services that come from pressure from residents or their community organizations on local governments although these are usually partial and not always of good quality.

However, the last twenty years have brought many upgrading initiatives driven by community organizations formed by their residents. These include many initiatives by federations of slum or shack dwellers that are active in over 30 nations. These have been supported by Slum/Shack Dwellers International (SDI) and the Asian Coalition for Housing Rights (ACHR). These have also developed methodologies to document and map informal settlements and this can also provide the information needed for community-led upgrading and registering of land titles.

One of the main constraints on upgrading informal settlements is the lack of data on their residents and structures, on land tenure - and often a lack of street names and legal addresses. Developing an upgrading programme in high density informal settlements that residents approve of is time consuming and expensive if done by professionals. It often has to deal with conflict (for instance between tenants and landlords) and with residents' hostility to interviewers (for instance as they fear the survey is a prelude to their eviction) (Weru 2004).

But there are many examples of community-organization-led upgrading schemes that have done this successfully. This was noted in the IPCC's 5th Assessment: "In a growing number of cities, residents' organizations supported by grassroots leaders and local NGOs are mapping and enumerating their informal settlements with eventual support and recognition from city governments (Patel and Baptist, 2012). This provides the data and maps needed to plan the installation or upgrading of infrastructure and services. Some of these enumerations also collect data on risks and vulnerabilities to extreme weather and other hazards" (page 582) (see Livengood and Kunte, 2012, Karanja 2010). There is the potential to tailor mapping processes towards collecting data on climate-related hazards, such as to identify areas that flood or areas with limited access to tap water. All the data is presented back to the residents to engage them in designing the intervention.

In Epworth (Zimbabwe), the Local Board used the enumeration conducted by the Zimbabwe Homeless People's Federation to develop an in situ upgrading plan for an area with high levels of informal housing (Chitekwe-Biti et al 2011). The South African SDI Alliance has secured two government tenders to profile and enumerate over one hundred informal settlements to inform city-wide urban planning (SDI 2016). The Kenyan Homeless People's Federation has undertaken upgrading schemes in several informal settlements – and they are developing an upgrading scheme for the 101,000 households that live in Mukuru (Nairobi) with support from local government (Lines and Makau 2017). The Kenyan federation also showed how it was possible to get agreement between landlords and tenants in upgrading Huruma, an informal settlement in Nairobi with 2,800 household (Weru 2004).

In Pune (India), in situ upgrading in Mother Teresa Nagar managed by Mahila Milan (Women Together, a federation of women slum and pavement dweller savings groups) showed how upgrading was possible despite very high densities and space that had to be cleared to allow infrastructure in. Rehousing was minimized and those that had to move were rehoused in four storey buildings within the settlement (Patel 2013). In Thailand, within the CODI programme described below, where densities were high, community-directed upgrading was often in the form of two or three storey terraces as these can accommodate 200 or more households per hectare (Boonyabancha 2005). For Dharavi in Mumbai with several hundred thousand inhabitants and thousands of enterprises in two square kilometres – upgrading is being organized in small clusters in which agreement is reached among all the residents in each cluster as to how upgrading will be implemented. All these community-driven upgrading schemes have relevance for climate change adaptation, in part because of what they achieve on the ground that contributes to resilience, in part because they have the institutional capacity to do so.

In Thailand, the Baan Mankong (secure tenure) programme implemented by the Community Organizations Development Institute (CODI) is a mix of government-supported upgrading led by community organisations. CODI is a national government agency that provides infrastructure subsidies and housing loans direct to community organizations formed by low-income inhabitants in informal settlements. The community organizations plan and carry out improvements to their housing or develop new housing including negotiating to purchase or lease the site or part of the site from the owner. If this is not possible, they find another site close by. Then they can work with local governments or utilities to provide or improve infrastructure and services. CODI has particular significance in three aspects: the scale; the extent of community-involvement; and the extent to which it seeks to institutionalize community-driven solutions within local governments. It is also significant in that it is funded by domestic resources – a combination of national government, local government and community-contributions. By 2017, more than 100,000 households have benefitted from this programme (Boonyabancha 2005, 2009, Shand 2017).

In all of the above examples, the upgrading has met deficits identified by local residents in terms of infrastructure and housing. This helps to address some of the climate-related and other hazards the settlements face – however, as discussed below, without access to adequate information and downscaled climate projections in an accessible form, there is a risk that future climate impacts are not taken into account when planning upgrading initiatives.

3.6. Relocation and new build

Most inhabitants of informal settlements would move to formal settlements if these better met their needs and capacities to pay. This is especially so if they currently live on sites that are particularly at risk to extreme weather, to eviction or to other shocks and stresses. The CODI programme described above focused on supporting community organizations to buy land they already occupied – but where this was not possible to support them finding and acquiring lands close by. There are some examples of urban governments successfully providing 'formal' alternatives in Ilo, Peru through providing cheap 'formal' plot (López Follegatti, 1999), in Solo, Indonesia through providing financial support to households living in sites that got flooded regularly to find and build on safer sites (Taylor 2015), in Windhoek by making the cost of formal plots cheaper (reducing minimum plot sizes and infrastructure standards) (Mitlin and Muller 2004). There are also many examples of less success – including many nations and cities where governments have very large scale 'low-cost' housing that either never got allocated to low income groups or whose poor quality and distant location made them unsuitable (Fiew and Mitlin 2018, Buckley et al 2016, Rojas 2018). But despite these examples, many governments still favour large an expensive public housing programmes, in part supported by pressures from the private sector construction companies, in part because they are easier to administer, in part because they are politically more visible (see Patel 2013). Rojas (2018) notes that the funding for these policies would have been a lot more effective if made available to city governments to expand infrastructure and services.

Most urban governments find it difficult to get access to land that can be developed for housing. This encourages them to develop sites for low-income housing on the periphery of the city where land costs are lower and land acquisition easier – but this also means locations distant from labour markets and services (which is why people do not want to move there). Residents of an informal settlement on a dangerous site may not want to move (see Neto and Heller 2016) – but what limit is set on how much to invest to protect an area and justify an upgrading programme rather than relocation? But at least in two cases, relocation from dangerous sites was successful because those who were moved were organized and engaged in finding solutions that worked best for them (Patel et al 2002, Lines and Makau 2017).

3.7. NGO-led upgrading

Some of the most successful upgrading programmes have been driven by local NGOs working with residents and their organizations who then built partnerships with local governments. The Orangi Pilot Project Research and Training Institute has implemented one of the largest and most successful informal settlement upgrading programmes bringing together household and community investment and government investment – thus integrating community systems to city-wide systems. This began by supporting households in each lane in Orangi (an informal settlement in Karachi with over one million inhabitants) to plan, implement and finance the 'internal components' of high quality sanitation systems - sanitary toilets in the houses, underground sewers in the lanes and neighbourhood collector sewers. Then it showed how it was possible for local governments to plan, finance and implement the larger 'external' trunk sewers into which the neighbourhood sewers feed and 'end-of-pipe' treatment plants. In each lane, the inhabitants had to raise the funding to cover the costs of the street and neighbourhood components (the small pipes) and in over 300 locations in Pakistan, communities have financed, managed and built their own internal sanitation systems. Local governments were then able to install the external systems (the big pipes) as they no longer have to fund and manage the 'small pipes' and as the NGO helped them develop lower-cost methods for planning and building trunk sewers and supported the conversion of open drains to closed drains (Hasan 2006). Similar approaches will need to be developed that engage with protective infrastructure to reduce the effects of climate change-related hazards.

The Asian Coalition for Community Action (ACCA) developed a novel way to catalyse community- driven upgrading (Archer 2012, Papeleras et al 2012) through supporting over 1,800 small community upgrading projects and more than 100 larger housing initiatives – working in 215 cities in 19 different nations. ACCA provided community organizations with up to US$3,000 with the flexibility to choose what to do. The most popular interventions were improvements in water, sanitation, drainage, solid waste management electricity and street lights and community centres. In each city, the community organizations undertaking ACCA supported initiatives go together to present their work to city government. In most of the cities, some kind of joint working group has been established at the city level to provide a platform for community networks, city governments, civic groups, NGOs and academics to plan and to manage the upgrading; and to identify responses to land issues. In many of the cities involved in the ACCA programme, new local funds have been developed, jointly managed with local government (Boonyabancha and Mitlin 2012). As of 2014, of the 136 city funds existing across 19 Asian countries in the ACHR network totalling USD 21.6 million, communities had contributed USD 15.26 million while governments had contributed USD 2.1 million, with the rest coming from project funding and other sources (ACHR, 2017).

There is a growing recognition of the need to match the growth in the competence and capacity of community organizations in upgrading with the flexible funding they need to expand the scale and scope of what they do – and to support partnerships with local government. As described above, CODI provided this. The initiatives of the Kenyan Homeless People's Federation Muungano wa Wanavijiji have support from the Akiba Mashinani Trust which also raises and manages bridging finance. The Trust has provided 7,000 households with loans for shelter upgrading as well as supporting many community-led upgrading (Weru et al 2017). The National Slum Dwellers Federation in Uganda and the government of Jinja City have set up a jointly managed Community Upgrading Fund (Shand 2017). SDI manages the Urban Poor Fund International that draws support from international donors and this in turn supports many community-driven upgrading programmes (Shand 2017). These funds provide potential entry points for funding for climate-related interventions, as prioritised and implemented by local communities – including resources from climate funds.

3.8. The potential of upgrading for addressing urban risk

Upgrading has significance for climate change adaptation since good quality 'risk reducing' urban infrastructure and services and better housing quality are at the centre of reducing risks from extreme weather – and as noted earlier this is acknowledged by the IPCC. Upgrading can also support low carbon development pathways in that most upgrading takes place in dense clusters of housing with upgrading able to support high levels of walking, bicycling and use of public transport. However, this needs to come with support to local community organisations, NGOs and local governments to access and interpret climate data, so that their interventions can be sufficiently forward-looking. Gaps in downscaled data also need to be addressed, as this rarely is available at the city-scale.

There is the issue of how well upgrading serves groups that are more vulnerable to many risks (see Box 3). For instance, how well does upgrading reduce risks to which infants or children are particularly susceptible? Does it address discrimination (for instance on the basis of age, sex/gender or social group). If upgrading includes providing land tenure, this may exclude tenants (although as noted above this can be avoided). It may discriminate against women in the allocation of tenure

Thus, there is a need to consider who is excluded from or disadvantaged in accessing housing, land and land tenure and financial services. Also, who is excluded from being active politically and having leadership roles. There are important gender dimensions to these. Discriminatory inheritance and divorce practices can exclude women from owning or realising the value of land and property; gender norms can stigmatise single or divorced women from renting or living alone and make it harder for women to access credit (Chant and McIlwaine, 2016; Rakodi, 2014; Moser, 2017; Chitekwe-Biti and Mitlin, 2016). Unpaid domestic care burdens and lower incomes limit access to good-quality shelter and infrastructure (ibid.). In many cities, women are disproportionately represented among renters due to these overlapping, gender-inequitable barriers to home-ownership (Rakodi 2014).

However, enhancing women's property ownership through land certification programmes (especially joint tenure of marital property) has been shown to expand women's agency and provide them with greater levels of economic independence. There are also the many examples of upgrading that had a strong engagement with community organizations (especially savings groups where most members and managers are women) that ensure that all residents benefit – including women, children, the elderly, and those with disabilities (Colenbrander and Archer, 2016).

Since any individual or group is only vulnerable when exposed to risk, they are no longer vulnerable if successful upgrading removes the risk. When vulnerability assessments are locally owned but feed into wider planning processes the act of collecting and analysing data can itself build local capacity and enable a more equal conversation between those at risk and urban planners or developers

Box 3: Vulnerability in informal settlements

Assessments of vulnerability have particular importance for highlighting individuals or groups among informal settlement residents who are more sensitive to/impacted by risks and/or less able to cope and to adapt. They can also assess who is more at risk because of discrimination on the basis of (for instance) gender, caste, class or being a migrant – which may mean vulnerability in regard to many risks.

So vulnerable individuals or groups are:

- Those who are more susceptible or sensitive to any of the life or health threatening risks evident in poor housing, living and working conditions including lack of capacity to cope or beyond this to adapt
- Those whose age, sex or health status make them more susceptible to particular hazards and/or have limited capacities to avoid hazards, cope with them or adapt including through transformative pathways.
- Those individuals or groups that face discrimination that decreases their capacities to cope and to adapt and transform and may increase risk levels
- Those with less (household and collective) capacity to cope and to adapt (i.e. reduce exposure to hazard)

There is also the issue of whose time and effort is expended in making up for the absence of formal service provision – the time and effort needed to access and bring water and fuel (often from distant sources) to manage disposal of household toilet, liquid and solid wastes and/or access to community or public toilets, to nurse sick or injured family members…… this does not get covered adequately within the discussions of vulnerability. Responsibilities for these usually fall to women.

At present, the international funds that are meant to support climate change adaptation do not see informal settlement upgrading as a priority. They also lack the structures to engage with local governments and local civil society organization to make this happen. The potential is there for a very large expansion in upgrading, with local government and community support and with the international, national and city funds through which to channel funding in place. National governments, donor agencies, and international climate finance institutions will require clearer evidence about the role that upgrading plays in increasing climate resilience, if they are to support this more extensively.

4: Addressing development, mitigation and adaptation in informal settlements

4.1. Lack of evidence

Whilst the previous section highlighted the importance of upgrading to development and disaster risk reduction, there remains a lack of evidence on the complex interactions between these – and between climate mitigation and adaptation. We need to learn more on the effectiveness of potential synergies between these agendas and of trade-offs. Thus, there is an urgent need for research on

the preconditions and contingencies for a successful transition to low-carbon, climate and disaster- resilient, health enhancing urban development. This research needs to assess what can be learnt from participatory and negotiated processes to determine what 'success' might look like in diverse contexts and for diverse interests (Colenbrander et al., 2016; Ziervogel et al., 2017). Questions of equity and justice need to be at the heart of this research agenda, or low-income and other marginalised groups who have contributed the least to climate change will also bear most of the costs from direct and indirect impacts. However, it should be noted that development/ poverty reduction, disaster risk reduction and climate change adaptation share a focus on identifying and acting on local risks and their root causes, even if they have different lenses through which to view risk.

4.2. Balancing development, adaptation and mitigation

For one informal settlement upgrading programme in Guatemala City, the residents felt that it was 'cementing poverty, putting a roof over its head' when what they needed most was adequately paid jobs (Diaz et al 2001). While provision of all the 'risk reducing' infrastructure and services to informal settlements brings much improved health, better possibilities of home-based work and more time (for instance cutting time lost to accessing water), it does not address their lack of income. The scale and depth of urban poverty has been under-estimated because poverty lines have not recognized the high costs that low-income city dwellers face for rent and for (often informal) service provision (Mitlin and Satterthwaite 2013). The upgrading programmes described in this paper certainly contributed to reducing urban poverty – but by themselves, they cannot remove it.

Across Africa and Asia, urban residents with lower per capita incomes use less energy and produce much lower greenhouse gas emissions than their higher-income counterparts (Marcotullio et al., 2013). However, the infrastructure deficits they face also theoretically creates opportunities to 'leapfrog' to low or zero emission systems and structures. Leap frogging entails avoiding the less efficient, more expensive or more polluting development trajectories of high-income countries and moving directly to good practice options (Unruh and Carrillo-Hermosilla, 2006) - for instance low- carbon options for transport, settlement designs, home energy use, public space and waste management. Successful leapfrogging will require decision-makers to re-imagine service and infrastructure provision in informal settlements in an affordable, low-carbon way.

Climate commitments and innovations could create new incentives and opportunities for pro-poor urban planning and policy, particularly with respect to improving livelihoods, access to services and environmental health. Low-carbon considerations reinforce the importance of ensuring that walking and cycling are safe and attractive modes of transport (Cervero, 2013), and of supporting urban forestry and agriculture that can sequester carbon while enhancing livelihoods and resilience (Lwasa et al., 2014, Roberts et al 2012). The modular design of many renewable energy technologies could allow incremental deployment as incomes and energy demand grow (Colenbrander et al., 2015), while environmentally friendly building materials can improve the quality and reduce the cost of low-income housing (Dobson et al., 2015). Emission reduction policies can deliver improvements in air quality – so much needed in the hundreds of cities with air pollution concentrations far above WHO guidelines.[4] Domestic energy programmes that support shifts from dirty to clean fuels reduce indoor and outdoor air pollution and generally lower carbon emissions – with most of the health benefits being captured by low-income groups (Slovic et al., 2016). Good practice in solid waste collection and management supports resource recovery, re-use and recycling and there are many examples of municipal authorities doing this, working with and supporting the work of waste pickers. However, there are also many examples of solid waste collection being contracted out with large disadvantages in regard to waste recovery (and less waste to dispose of) and cost.[5]

However, in many cases, there are also tensions between the development, mitigation and adaptation agendas in informal settlements. For mitigation, many climate-compatible options require greater planning and technical capabilities than conventional approaches or involve paying a premium. For example, mass transit, energy-efficient buildings and renewable technologies have higher capital costs than fossil fuel generation or road networks, even where they prove more economically attractive in the longer-term (Gouldson et al., 2015). Their delivery depends on strategic public sector-led investment, which has been notably absent in informal settlements.

Established development priorities and planning practices in functions like land-use management, construction, or infrastructure provision may not be aligned with the goals or practice of adaptation. Combined with the lack of accountable and transparent governance systems, local populations find themselves without government support to address their development and adaptation needs. There may be trade-offs

[4] http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/

[5] http://www.wiego.org/informal-economy/occupational-groups/waste-pickers

among different temporal and geographic scales, or among economic, cultural and ecosystem functions (Chelleri et al., 2015). For the many informal settlements located on sites at risk from floods and landslides, there are examples of successful relocation (see Velasquez 1998 and Valsagna, Tejedor and Botteron 2017) but also examples of residents not wanting to leave (see Neto and Heller 2014).

4.3. Urban form

Urban form and structure have significant implications for the carbon intensity of urban activities (Seto et al., 2014). With rapid urban population and economic growth in much of Asia, decisions made around spatial patterns of infrastructure investments and land-use arrangements today will strongly influence whether urban areas will be able to reach net zero emissions in the second half of the century (Creutzig et al., 2015). From a mitigation perspective, global evidence suggests that decision-makers should promote compact urban form, with high average population densities, mixed land use and good connectivity through high quality bus and rail. This can reduce greenhouse gas emissions by reducing demand for intra-city transport (especially for private car use), emissions from the construction of networked infrastructure and land use management and change around the urban periphery (Seto et al., 2014).

However, many cities in the global South already have very high population densities: Dhaka has 44,500 people per square kilometre, followed by Mumbai (31,700), Medellin (19,700), Manila (14,800), Casablanca (14,200) and Lagos (13,300) (UN Habitat, 2017). For these and other cities, planning or managing land use and infrastructure provision in their (often low density) peripheries is key, both to compact urban forms and to increasing the supply and reducing the cost of housing plots (see for instance Patel et al 2018).

Most informal settlements are a combination of very high density and one or two storey buildings with lack of access roads. Their high densities mean economies of agglomeration for the costs of upgrading. So upgrading can also retain the advantages of compact urban form. But without needed infrastructure and services (especially good quality toilets, piped water in each home and solid waste collection) high population densities bring high health burdens (premature death, illness and injury) (Ezeh et al., 2017).

In addition, fierce competition for limited urban land resources and weak governance can result in exclusionary and inequitable forms of urban development (Zhu, 2012). Efforts to replace or redevelop informal settlements in pursuit of 'smart' or 'green' cities has often led to the eviction of low-income households, and their displacement to peripheral urban areas with longer commutes and poorer service provision (Revi and Rosenzweig, 2013). This contributes to urban sprawl and increases exposure to economic, social and environmental risks. It is also difficult (and expensive) to provide infrastructure to low-density peri-urban development or to retrofit it to reduce greenhouse gas emissions.

Spatial planning and strategic infrastructure investment to promote high but liveable density could improve the lives of low-income urban residents. Higher population densities reduce unit distribution costs and permit economies of scale and agglomeration, enabling cities to drive down the average per capita costs of infrastructure and service provision (Turok and McGranahan, 2013). Avoiding sprawl can preserve biodiversity and ecosystem services around the urban periphery, which can enhance resilience to climate-related shocks and stresses (Campbell-Lendrum and Corvalán, 2007; McPhearson et al., 2012). Compact urban forms can enhance access to jobs, services and amenities (Ahlfeldt and Pietrostefani, 2017), and reduce the probability that low-income residents will need to live in hazardous areas within and around the city in order to enjoy the benefits of proximity (Dodman et al., 2017). However, the potential benefits of higher urban population density will only be realised through inclusive approaches to development, where aspirations for compact urban form are accompanied by in-situ upgrading of informal settlements. Secure tenure and investment in basic infrastructure (piped water, sewers, drains and mass transit) are particularly important to anchor urban form and to minimise the costs of density and risks of displacement.

4.4. Buildings, shelter and infrastructure

For individuals and households, living in a well-built, affordable house in a safe, legal location is one of the most critical determinants of their resilience. But for many residents of informal settlements, both the location of the dwelling and the quality of the shelter it provides are vastly inadequate in providing protection from current climate variability and future climate change. The factors shaping urban land use, and the outcomes this generates in terms of the location of low-income and informal housing are addressed elsewhere in this paper; this sub-section focuses primarily on the quality of buildings in informal settlements and approaches that can be taken to develop better shelter for their inhabitants.

The characteristics common to most informal settlements were noted already – mostly low-rise, poor quality housing, high densities, lack of urban infrastructure and services….and often on dangerous sites. We also noted earlier how the IPCC 4th and 5th Assessments identified informal settlements as being particularly at risk to the impacts of climate change. Good quality housing has an important role in linking disaster risk reduction and post-disaster recovery with climate resilience (Moench et al, 2017). Housing should also protect household assets. It is frequently the place where household members earn a livelihood (particularly for women as home-based workers), and a site where particular vulnerable persons may live – the elderly, those with disabilities or very young.

One indicator of the relative roles of 'formal' and 'informal' housing is the proportion of city households living in formal housing – and how this is changing (Rojas 2018). What proportion of households can afford to buy, build or rent formal housing? As discussed already, government attempts to address this by financing large scale public housing programmes have long been known to be ineffective. But governments can have key roles in lowering the cost of 'formal' housing – through cutting the costs of getting land for housing, increasing serviced land (see Patel et al 2018 for how to support this through bus rapid transit), adjusting or removing inappropriate regulations (e.g. smaller minimum plot sizes), and supporting housing finance. Here, government acts as the enabler, as it supports the market to deliver quality 'formal' housing that lower-income groups can afford to rent or purchase.

Many case studies of informal settlements have made evident the ways in which households seek to cope with environmental risks including extreme weather (Stephens et al 1995, Wamsler, 2007; Adelekan, 2010; Jabeen et al 2010, 2010; Livengood and Kunte, 2012; Kiunsi, 2013). This includes modifying hazards or reducing exposure—for example, through ventilation and roof coverings to reduce high temperatures; barriers to prevent floodwater entering homes; keeping food stores on top of high furniture; having electrical systems as high as possible and moving temporarily to safer locations (Stephens et al 1995, Wamsler 2007, Douglas et al., 2008, Jabeen et al 2010, Revi et al 2014). Wamsler 2007 in particular highlights the many ways that households and communities can reduce risk through building improvements and site and other environmental improvements within the neighbourhood, and organizational, institutional and social measures including insurance – and how these measures also contribute to post-disaster recovery.

There are examples of efforts to implement climate resilient housing in an affordable manner, specifically with low-income populations in mind, though it is important to ensure that these designs are developed in such a way to ensure local input and cultural acceptability. In Gorakhpur, India, designs for flood resilient housing with raised plinths, second-storey bedrooms and screen brick- work techniques for improved ventilation, are estimated to be feasible for 18% less than the cost of standard construction, by using some low-cost materials such as bamboo (Moench et al, 2017). In Vietnam, designs for typhoon-resistant housing included thicker walls, positioning of concrete pillars, anchoring of roofing materials and establishment of safe rooms. These designs were estimated to increase construction costs by 33% compared to those who have no elements of typhoon-resistance in their housing. However, this cost would be recouped by avoiding the need for extensive post-disaster reconstruction (ibid). Retrofitting improvements to build resilience is possible – though in most cases, householders will want to ensure some measure of security of tenure before investing in their housing, and therefore this underlying issue must be addressed in order to enable the development of climate-resilient housing.

There are also opportunities for housing designs and technologies to produce mitigation co-benefits, for example with designs that maximise natural ventilation and reduce the need for cooling systems, or growing vines over roofs for cooling (Jabeen et al 2010, Haque, Dodman and Hossain, 2014). Affordable housing materials can also have environmental co-benefits, such as the interlocking soil-stabilised bricks developed by the National Slum Dwellers Federation of Uganda, which do not require firing and hence help reduce deforestation and are cheaper per metre than regular fired bricks (Dobson, Nyamweru and Dodman, 2015). However, these cheaper materials are sometimes available only in specific locations and therefore insufficient to meet the scale of need.

But there are many constraints on action for low-income households. They cannot provide the trunk infrastructure systems into which their settlement must integrate (paved roads and paths, piped water mains, sewer and storm drainage system, street lighting…). or manage land use in watersheds to reduce flood risk.

There are also the constraints on disaster response. Do warnings get issued in cities in anticipation of storms, high rainfall or heat waves? Do they reach the inhabitants of informal settlements? And if they do, can these inhabitants act on these warnings – for instance, is transport to safe sites provided? The inhabitants of informal settlements are often reluctant to leave their homes because of risks of looting or fears of not being allowed back – or from fears for personal safety in the areas to which they are meant to move (Jabeen et al., 2010; Hardoy et al., 2011).

In most cities and neighborhoods, where infrastructure coverage is incomplete and household incomes limited, community- based adaptation can contribute to adaptation and prepare for future risk – and support household adaptation. A range of studies document the depth of knowledge and capacities held by local populations around reducing exposure and vulnerability (Stephens et al 1996, Wamsler 2007, Anguelovski and Carmin, 2011; Dodman and Mitlin, 2011; Livengood and Kunte, 2012). For a high proportion of the households that live in informal urban settlements, household and community-based adaptation is their only means of responding to risk. But it too needs the trunk infrastructure and the land-use management for the wider city into which to integrate.

IFRC (2010) identifies three broad requirements for successful urban community-based disaster risk reduction that can be extended to assess coping and adaptive capacity: the motivation and partnership of stakeholders; community ownership, with flexibility in project design; and sufficient time, funding, and management capacity. The effectiveness of community-based action also depends on how representative and inclusive the community leaders and organizations are (Appadurai, 2001; Wamsler, 2007; Banks, 2008; Houtzager and Acharya, 2011; Mitlin, 2012). This includes their capacity to generate pressure for larger changes within government that also depends on the quality of the relations between community organizations and different levels and sectors of government (Boonyabancha and Mitlin, 2012, Arputham 2016).

But considering again city-wide problems, upgrading informal settlements needs to be complemented by growth in the housing stock including housing that is affordable to households currently living in informal settlements. Well located informal settlements are densifying (see Hasan 2010). Accommodation there may be becoming increasingly expensive, especially if the settlement is upgraded. Low-income households may be forced to move by rising rents. Large scale upgrading can help limit this. But as importantly, most city governments need to greatly increase the supply and reduce the cost of serviced land plots that low income groups can afford and that are well located in relation to income earning opportunities. So a larger supply of well-located serviced land for housing widens choices for low-income households. Communities that are engaged in upgrading may choose to develop community-ownership of their land that can limit informal settlement 'gentrification' (Boonyabancha 2005).

4.5. Knowledge and capacity

Municipal plans need to draw in all key actors, so they come to understand different urban pressures and get agreement on the needed trade-offs (Hardoy et al 2017). Participatory decision making is essential where uncertainty and complexity characterize scientific understanding of policy problems (Funtowicz and Ravetz, 1993; Liberatore and Funtowicz, 2003). It will need to take into account

uncertainty about future climates and extremes (Revi et al 2014) and the complexity and dynamics of evolving socio-ecological systems (Ibid, Kennedy et al., 2011). A lack of understanding of how the different services and infrastructure connect to reduce risks can mean priorities/demands focus on the most visible everyday problems or the most frequent disasters, not necessarily those that generate the greatest risks. For instance, the main causes of infant and child deaths in informal settlements – typically diarrhoeal diseases, acute respiratory infections and often malaria – often get left out of discussions of risk (Mitlin and Satterthwaite 2013). But drawing from recent dialogues with city governments in Latin America, Hardoy et al 2017 stress the importance of cities not delaying action or embarking on developing complicated scientific information systems; the issue in many cities is more about integrating existing information (that is also in similar formats – e.g. geo- referenced what is possible), common language, easily accessible to all/ and up dated easily, and co-built with all local actors/owned locally.

To avoid maladaptation in housing design and ensure most effective use of resources, climate science and models should be accessible to those agents making decisions about housing investments – including home-owners. Expert input by architects or engineers may be necessary, but their designs need to be developed in a responsive and consultative manner to ensure that local needs are incorporated, in order to maximise take-up. The architects and engineers themselves should also be aware of climate projections to incorporate these in their designs. Community architects are particularly skilled in working on participatory, affordable designs in response to community needs, making use of local materials where appropriate. Community architects can play a role in bridging the physical and social aspects of housing and neighbourhood design (Archer, Luansang and Boonmahathanakorn, 2012) – and there is an opportunity here to insert consideration of local climate risks into this process. For this they may require training to raise their own understanding of local climate risks and projections and how to communicate this effectively, and ensure these considerations get discussed with residents in inclusive ways and are then integrated into housing designs and site layouts.

The government can play a role in facilitating the take-up of such technologies and designs through targeted financial mechanisms such as micro-credit or subsidies, expert support in housing design, and improvements to other integrated urban systems such as water supply, drainage and power supply which will affect the resilience of housing (Moench et al, 2017). Whilst building regulations may also be used to this effect, in many instances regulations help make housing unaffordable –so putting in place by-laws to take into account the particular needs of low-income populations, and building regulations supporting incremental constructions, would be more responsive to local needs and capacities.

Local organisations can also facilitate take up – for example, as part of the ACCCRN initiative[6], the Women's Union in Da Nang, Vietnam, made available low-interest finance for members to reinforce their homes against storms through a pilot program for 400 households. The Women's Union staff also received training on climate change and disaster risk reduction, whilst local builders were trained in building and design of resilient low-income housing (Reed, 2013). Another project in Da Nang saw seed funding from GIZ in partnership with the city government and the Association of Vietnamese Cities (ACVN) for a community-level climate fund in Hoa Hiep Bac Ward. This fund was managed by the community for upgrading and strengthening housing, adaptation of income-generating activities, planting trees and purchasing shared back-up generators.

4.6. Industry / livelihoods

We noted earlier how in almost all nations in the Global South, more than half the non-agricultural workforce work in informal employment; the proportion exceeds 80% in some countries (Chen 2014). Also, how 'informal' employment covers many categories including those employed in informal enterprises and those in informal employment within formal (public or private) enterprises. How the informal economy also represents an important part of the national economy. And the particular importance of the informal economy for women, including home-based workers.

As with land use, buildings and infrastructure, an adaptation and mitigation lens can be brought to livelihoods and to the new employment possibilities generated by good management of eco-system services and of waste (Roberts, Boon, Diederichs et al 2011). Below, we give an example of how waste collection and management can contribute much to livelihoods while also keeping down greenhouse gas emissions.

Most cities in the Global South have large and important informal 'waste' economies that grow where formal systems do not operate – for instance in the collection and disposal of households' solid, liquid and toilet wastes. It is also common for large concentrations of waste pickers to work on formal and informal solid waste dumps and for there to be high levels of resource recovery. Informal settlements often develop next to waste dumps and contain many enterprises cleaning and sorting waste and organizing its sale.

How the 'waste' economy is managed has importance for development, for climate change mitigation and often for disaster risk reduction and climate change adaptation. Regarding development, informal settlements usually lack a regular household waste collection service which means households use nearby informal dumps (or just open spaces or drains) or they seek to bury or burn it. Local authorities generally lack the means to act (the trucks and equipment they have with a capacity far below what is needed) or to provide accessible and well-managed disposal sites. Or as an alternative, they contract out collection services.

The 'waste economy' in cities in low- and middle-income nations is important to the green economy, providing livelihoods and contributing to waste reduction and GHG emission reduction (Ayers and Huq, 2009). But local governments generally ignore the large informal system for waste collection, waste-picking, sorting and re-use/recycling. They do not see the contribution of informal waste collectors and pickers to serving households, cleaning streets and reclaiming waste, saving city governments large amounts of would-be expenditures as well as reducing carbon emissions (Scheinberg et al, 2010).

The ways city governments choose to work with (or ignore) those in this waste economy have obvious implications for employment and for resource use. Rather than ignoring it (or considering it as illegal), city governments can incorporate the informal waste economy into a more effective city- wide waste collection and management systems. Organizations of waste pickers in India, Argentina, Brazil and Colombia, have fought legal cases to secure the right to bid for solid waste management contracts, with some success (Chen, Roever and Skinner 2016).

Chen, Roever and Skinner (2016) suggest three needed lines of action for informal workers: "reduce the negatives" - for instance stopping the harassment and evictions by local authorities; "increase the positives" – that includes establishing informal workers' legal identity as workers and pushing for regulatory reforms that recognize their work and contribution to the economy; and access to infrastructure and basic services for informal workers at their workplaces, whether in public space or in their homes. They also point to many positive examples of change driven by grassroots organizations formed by those working in the informal economy. These include examples of legal cases and campaigns to persuade municipal officials and urban planners to take home-based producers and street-based vendors into account when they develop local economic, housing, land use and zoning plans.

[6] The Asian Cities Climate Change Network https://www.acccrn.net/

4.7. Drainage, sanitation, waste and water

The IPCC's 5th Assessment (WGII) highlighted the very large deficits in provision for water, sanitation, wastewater management and drainage among urban centres in low-income and many middle- income nations. Most of the deficits are in informal settlements, although provision for these is so inadequate in many cities that it impacts on middle income groups and 'formal' housing. "Reducing basic service deficits and building resilient infrastructure systems (water supply, sanitation, storm and waste water drains, electricity, transport and telecommunications, health care, education, and emergency response) can significantly reduce hazard exposure and vulnerability to climate change, especially for those who are most at risk or vulnerable" (Revi et al, 2014, page 539).

Upgrading informal settlements should be the means by which deficits in provision for these are cut and in many cities in Latin America, conventional systems have been extended to many informal settlements. But a large proportion of the urban population lack good provision for water and sanitation (WHO and UNICEF 2017), especially in sub-Saharan Africa and Asia and it is likely that much of this population are living in informal settlements. We noted earlier that households and community organizations can contribute to resilience within their settlements, but they cannot make the investments needed in district and city-wide storm and surface drains and watershed management to reduce the volume and velocity of flood waters. Wastewater and sanitation systems will be increasingly overburdened during extreme precipitation events if attention is not paid to maintenance, the limited capacity of drainage systems in old cities, or lack of provision for drainage in most unplanned settlements and in many urban centres (see Douglas et al 2008).

Managing water, waste water management and storm drainage usually needs a city-region perspective – for instance for protecting watersheds (important for water supply and often for disaster risk reduction) and coping with storm and surface run off. This often means a need for agreement between city government and different local government jurisdictions around the city – for instance on watershed management to reduce the volume and slow the speed of flood waters for the city.

4.8. Public space

The informal processes by which cities develop and expand outside the control of a functioning public land use management framework usually means very little land is allocated to public space. Or there are no controls over encroachments onto public space. At the city scale, spaces on streets, sidewalks and traffic intersections are the place of work for many fixed-site and mobile traders, who provide goods and services to consumers at all times of day. Other commonly used public places are parks and municipal markets. But access to use of these spaces by traders and vendors is often contested and they may be prevented from being there – or fined or arrested or their goods confiscated (Chen, Roever and Skinner 2016).

Public space limitations are even greater in most informal settlements that have very little public space and trees - especially in the better located settlements that have high land values. What public spaces exist are usually not well managed – and often sites with uncollected domestic wastes.

There are no 'cooler' public spaces to help moderate extreme temperatures and where residents can go to get some relief from the very high temperatures within their dwelling (see Scott et al., 2017).

But it is common for informal settlements to have indoor and outdoor community spaces that residents helped create. Many of the slum/shack dweller federations have built community or resource centres which is where the federation savings groups meet and keep their records. These are also used for training and hired out for weddings and parties. Many meeting rooms have been built on top of community toilets (see Burra, Patel and Kerr 2003) – so they avoid the difficulties and costs in getting land (d'Cruz with Patel and Mazvi 2014). Formal schools located within informal settlements often have some outdoor space such as playgrounds that can be used by residents - and schools may provide indoor spaces for community meetings outside teaching hours.

Community-driven reblocking in informal settlements can enlarge open spaces, as in the secure tenure programme of the Community Organizations Development Institute that was described in section 3.4 (see Boonyabancha 2005, Shand 2017). Community planning in Cape Town made use of lost space between communities to create more useful space. By realigning their internal spaces and pathways, communities were able to create open space within their settlements for women children and young people to have safe spaces to socialize (d'Cruz with Patel and Mazvi 2014).

The lack of open space in any settlement usually means intense use of paths and streets. For instance, in Kisenyi, one of the largest informal settlements in Kampala, groups gather around porches, courtyard verandas and other open spaces to cook dinner, chat, wash clothes and play (ibid).

Given the intense competition for land in cities (in both formal and informal markets), it is difficult to see how to better meet needs for public and open space both within informal settlements and within the larger city. At city level, there are examples of elected city governments that have substantially increased parks and other public spaces. In Rosario (Argentina), this was achieved through the city government working with private landowners to restore the riverbank area and create many new neighbourhood parks, pedestrian zones, public beaches and themed educational parks for children (Almansi 2009). Attention to climate change issues have been added onto this (Hardoy and Ruete 2013). The city of Manizales in Colombia greatly increased public space by a relocation programme for the inhabitants of informal settlements on sites at high risk of landslides – but then using this land for eco-parks managed by community organizations (Velasquez 1998). The city of Santa Fe in Argentina is combining a relocation programme for those who settled in flood risk areas with the creation of a nature reserve (combining education, environmental protection and flood risk reduction) and the creation of a city park on a former landfill with green and blue infrastructure initiatives (Valsagna, Tejedor and Botteron 2017). The city of Durban has recognized the importance of land use management in and around the city that protects the globally significant biodiversity and the eco-system services on which the city depends while also supporting new 'ecopreneur' employment opportunities as foundations for ecosystem-based community and city climate change adaptation (Roberts and O'Donoghue 2012, Roberts, Boon, Diederichs et al 2013).

4.9. Urban ecology

Green and blue infrastructure provide a wide range of ecosystem services for urban areas that are significant for human wellbeing, climate mitigation and adaptation and can be significant for disaster risk reduction. These are commonly categorised as provisioning services (such as food and water supplies), regulating services (such as temperature control), cultural services (such as recreational space) and supporting services (such as nutrient cycling). The functioning of cities, including informal

settlements, is dependent on ecosystem services produced far beyond municipal boundaries. Urban residents depend on the hinterland for both consumption and waste absorption (Gómez-Baggethun et al., 2013), and the movement of people, goods and capital between rural and urban areas is important for both individual livelihoods and city-scale processes of development (Tacoli, 2006). While the quality of the regional environment has significant implications for the wellbeing of all urban dwellers, this section focuses particularly on ecological conditions and impacts within informal settlements.

Green and blue infrastructure within informal settlements is often degraded. This is partially because many informal settlements are located in areas that are ecologically fragile and/or valuable, where formal development is prohibited (Benítez et al., 2012). Many cities have informal settlements that developed in watersheds or around reservoirs and along river or canal banks and into which their wastes get disposed of.

Even small increases in pollution or changes in land use can negatively affect biodiversity and ecological processes in these areas (Roberts et al 2012) – and rapid urban expansion into these ecosystems constitutes a major disruption. Local ecosystem services are also likely to be degraded in informal settlements because of the absence of effective planning or infrastructure to safeguard natural environments. The absence of sewers or waste collection services, for example, means that residents of informal settlements often depend on rivers or lakes for disposing of their toilet wastes and/or household wastes (Vollmer and Grêt-Regamey, 2013; Corburn and Hildebrand, 2015). It is important to note that, even if inhabitants of informal settlements are more likely to live in degraded environments, they typically have small ecological footprints - much smaller than middle or upper income groups. It is also important not to confuse environmental health risks with environmental degradation.

Low-income and other marginalised urban residents are typically more dependent on ecosystem services than higher-income groups. Even in large cities, low-income groups are more likely to obtain food, water, fuelwood, medicines or other resources from urban wetlands, lakes and forests (Ward and Shackleton, 2016; Mundoli et al., 2017). They are also more likely to use gardens for productive rather than ornamental purposes (Cilliers et al., 2013). This dependence means that the wellbeing, livelihoods and resilience of low-income groups are more sensitive to decreases in the extent, quality or accessibility of green and blue infrastructure, including loss and damage attributable to climate change. For example, where lakes have been privatised, polluted or converted into recreational parks, the supply of provisioning ecosystem services can be affected. This particularly affects urban residents without reliable or sufficient incomes, who cannot afford to pay for these goods and services, and those without secure land tenure, who lack the option of establishing a private garden to produce them (Hettiarachchi et al. 2014; Derkzen et al., 2017).

As noted above, informal settlements are often located in hazardous parts of the city, such as floodplains, low-lying coastal areas or steep slopes. These environmental risks intersect with social drivers of vulnerability such as low-income and gender discrimination, so that the most marginalised urban residents are most at risk (Porio, 2014). However, there is evidence that green and blue infrastructure can mitigate environmental risks in informal settlements. For example, it can contribute to floodwater retention and temperature regulation through evapotranspiration and shading (da Silva et al., 2012). The extent and configuration of urban environmental spaces determine how effectively they can mitigate environmental risks. For example, evidence from Addis Ababa suggests informal settlements have higher proportions and better composition of green space, so these areas have the lowest land surface temperatures in the city (Cavan et al., 2014). By contrast, temperatures in informal settlements in Nairobi are several degrees higher than in many formal residential areas, which can be attributed to the lack of vegetation, high density and the high albedo of metal housing (Scott et al., 2017).

Recognising and reconciling tensions between different development and environmental agendas is a major challenge. By definition, the informal nature of urban growth makes it difficult to safeguard ecologically significant sites, especially if these are well-located in relation to labour markets. Yet the loss of ecosystem function and services can compound poverty and increase vulnerability to climate- related risks. There are many documented examples of these conflicts and, too often, residents of informal settlements are excluded from the relevant decision-making forums (Harper et al., 2011; Mehta and Karpouzoglou, 2015). However, there is a growing body of evidence on participatory approaches to urban environmental governance that can mediate these conflicts: for example, see van Horen 2001, Menegat 2002, Douglas 2016, Mguni et al. 2015, Seeliger and Turok 2014 and Sundaresan et al. 2016.

These studies underscore the importance of community-based strategies that seek to simultaneously improve opportunity, security and living standards, and that obtain support from municipal authorities and other formal actors. If environmental strategies do not address the priorities of residents of informal settlements, there is little prospect of establishing green and blue infrastructure in these areas at a scale sufficient to reduce climate-related risks or significantly contribute to other development goals.

5: Governance for urban adaptation

5.1. The role of effective urban governance

The IPCC's Fifth Assessment emphasized how urban governments are uniquely situated to understand local contexts, raise local awareness, respond to citizens' and civil society pressures (including face to face meetings), and work to build an inclusive policy space (Revi et al 2014, citing Grindle and Thomas, 1991; Brunner, 1996; Cash and Moser, 2000; Brunner et al., 2005; Healey, 2006). As the key components of climate change adaptation have become apparent, so too has the recognition that much of what has to be done falls within local government responsibilities.

Revi et al 2014 recognized two key governance issues for adaptation: the competence, capacity and accountability of urban (municipal, city, metropolitan) governments, and the measures taken at higher level (e.g. state and national governments) to support urban governments through cooperative multilevel governance. So, there is an interest in urban government capacity that at one extreme includes cities with relatively well-resourced local government institutions that can ensure provision of infrastructure and services and adherence to relevant codes and standards. But at the other extreme there are poorly resourced local governments unable to provide these or to put in place the framework ensuring provision by private, NGO or community enterprises. There is also an interest in how acting on climate change is influenced by the quality of local government and governance that ranges from cities with democratic and accountable local government structures to undemocratic, unaccountable and often clientelist local government. The examples given in the section on learning from upgrading initiatives highlighted the importance of this.

An IPCC assessment of adaptation capacity among urban governments showed that most had very little capacity or some capacity but as yet no willingness to act (Revi et al 2014). While there are many city governments taking steps to address adaptation and mitigation, they represent a very small proportion of the world's urban population and are dominated by larger and wealthier cities, mostly from high-income nations. Meanwhile, the urban centres with least adaptive capacity are generally in low- and middle-income nations and these are also the urban centres with the largest deficits in infrastructure and service provision. These urban centres also house almost all the urban population living in informal settlements.

Climate change adaptation in urban areas (and its development underpinnings) are not possible if urban governments refuse to engage with their population living in informal settlements and working in the informal economy. This also needs a shift in how urban governments view and understand informality - to recognizing informal settlements and the informal economy as critical parts of the urban fabric and urban economy. Examples were given earlier of where this has happened. But many national and urban governments do not recognize this shift – and claim that the growth of informal settlements and of deficits in provision for infrastructure and services are caused by rapid urbanization or, for a particular city, rapid population growth.

But informal settlements can also be viewed as a failure of governance – as (mostly local) governments fail to meet their responsibilities for infrastructure and service provision and land-use management. There are also fast-growing cities where their governments did meet these responsibilities and have much smaller proportions of their populations in informal settlements. Adverse impacts in urban areas from natural disasters can also be seen as "a failure of urban management" (UN 2009) because of deficits in the infrastructure and services that should have anticipated and reduced disaster risk.

Both low-carbon and climate-resilient urban development are likely to be inhibited by the same constraints that have hindered more conventional forms of development: weak government and governance structures, scarce resources (including little investment capacity), constrained local powers, limited delivery capacities, vested interests, political disinterest in the urban poor and the presence of multiple competing priorities (Berrisford, Cirolia and Palmer 2018, UCLG 2014, Chelleri et al 2016).

5.2. Inclusive urban governance

As described already, most urban centres in Africa and Asia and many in Latin America have a substantial proportion of their residents living in informal settlements and engaged in informal livelihood activities. What local changes can address their needs while contributing to resilience and what roles for local government and local civil society? What aspects of this involve both the formal and the informal private sector, especially in relation to access to land and service provision?

So one important governance issue for informal settlements is the nature of their residents' relationship with (mostly local) government bodies and politicians and with utilities. How is their settlement viewed by local civil servants and politicians, and how is upgrading in them constrained (or prohibited) by their contravention of laws, rules or regulations?

How residents of informal settlements choose to organize, act, and interface with (mostly local) government has importance for what can be done (Herrle, Ley and Fokdal, 2015). So too has their learning of how to be more effective – both in the organizations they form and in how these interact with local government (Arputham 2008). Residents of informal settlements may favour a direct engagement – for instance as they lobby for particular changes such as upgrading or avoiding eviction or develop relations with particular civil servants or politicians. They may engage through a well-connected individual within a clientelist relationship. Or they may engage through representative democracy - influencing government through voting for elected representatives (although as noted earlier, informal settlement residents may lack the documentation needed to get on the voter register).

For low-income groups living in informal settlements, the following political factors can facilitate or constrain their access to safe shelter and risk reducing infrastructure and services:

Politics of getting 'formal' infrastructure and services in informal settlements — which has to overcome hostility to 'illegal' settlements and often needs changes in law. Or they face particular difficulties extending formal provision – for instance, for water supplies, operating a billing system in settlements with no maps, street names and official addresses.

How politics influences the setting and applying of terms and conditions for informal settlements' access to formal infrastructure, including the costs of connections to infrastructure (e.g. piped water supplies, sewer connections, electricity grids) and the cost of services once connected

Politics of avoiding eviction: Informal settlements by definition have aspects of illegality (for land occupation, land use or structures) that governments can use as the justification for evicting their inhabitants. Residents of informal settlements facing eviction threats may undertake settlement- wide surveys to demonstrate to city governments their importance to the city economy and avoid displacement (Arputham 2008, Karanja 2010, Farouk and Owusu 2012).In Surabaya, the residents of informal settlements along a main river were being blamed for exacerbating flooding (claiming that they were disposing of their wastes into the river). When they were threatened with eviction, one response was to show how they should be seen as the guardians of the river, preventing waste disposal into it (Some et al 2009). Also important in many contexts, urban poor organizations use the law and courts to question the legality of evictions; however, the courts can act to legitimize evictions and to serve middle and upper income group interests (Bhan 2009). One important strategy of the slum dweller federations is for all households to collect documentation that shows and can legitimate their occupation (Arputham 2008, 2012).

Politics of relations with city, district and ward-level governments. Those living in informal settlements lack the protection of the law and are often impacted by exclusionary policies and practices of government at different levels. This may disadvantage particular groups such as recent migrants or particular ethnic groups or, (for many cities) refugees or internally displaced persons. The many slum/shack dweller federations and their support NGOs whose work was described in Section 3 have long recognized that the most powerful resource of any poor community is being organized - bringing its own ideas, resources and strategies to the table (Patel 2014). Federations actively seek good relations with politicians and civil servants at different levels. They can use this to present their plans (supported by detailed maps and surveys) and negotiate for support and co- production (see for instance Lines and Makau 2017). The foundation of these federations are community managed savings groups with most savers and savings group managers being women, so their needs and priorities are fully included.

Politics of space for informal livelihoods: This includes city authorities' provision for fixed spaces on streets, in public spaces or within markets and on what terms. Also, government attitudes to vendors and other informal labourers, and the politics of regulating or controlling informality (Roever and Skinner 2016, Chen et al. 2016). Can local authorities promote and encourage hybrid economies in which micro- businesses can co-exist alongside small, medium, and large businesses and in which street vendors can co-exist alongside the kiosks, retail shops, and large malls (see Bhatt quoted in Chen 2014).

Politics of getting land tenure for residents in informal settlements and legal addresses (which may be complicated by opposition by politically-powerful absentee landlords – see Weru 2004, Lines and Makau 2017). However, many upgrading schemes have included provision of tenure or support for the residents to buy or lease the land they occupy (ibid, Boonyabancha 2005).

Politics of land access - getting legal land sites that low-income groups can afford that are realistic alternatives to informal settlements. There are the difficulties of getting land for housing in formal or informal markets due to competing formal/informal actors, such as local politicians, brokers and private developers, and rights and roles of traditional authorities.

Section 3 on upgrading described where community organizations have taken the lead – and in how they used this to engage with local governments and often to get local government-community organization partnerships. In many cases, the settlement improvements implemented by community organizations contribute to their climate resilience – such as functioning drainage systems, paved roads and upgraded houses. Sometimes the act of upgrading by local citizens can incentivise local authorities to step in and complete or supplement the improvements. Where local governments are willing to contribute financially to the initiatives of community organisations, and participate in decision-making about the allocation of funds, this signifies a shift in relationships. Previously marginalised residents of low-income settlements are regarded as legitimate citizens of the city with a voice in local decision-making and the power to take action. This creates more accountability in decision-making, with mechanisms for meaningful citizen participation to ensure decisions are taking local needs into account.

But for these community-led processes to also address underlying issues of social and political exclusion, there is a need to consider rights and justice in approaches to urban governance. Building resilience will require a long-term approach which equips all urban residents, including those in informal settlements, with the capacity to prepare for and adapt to climate change, not just physically but also socially, politically and economically.

Many aspects of adaptation are implemented not only through what urban governments do and control but also what they encourage, allow and support among other stakeholders. Public engagement, openness, and transparency can help ensure democratic debate to balance public interests and longer-term goals against the short-term benefits of unconstrained development. The IPCC's Fifth Assessment (Working Group II) noted the experience in some cities of engaging a wide number and range of stakeholders in early stages in a risk assessment and how it creates political support and momentum for follow-up research and adaptation planning (Revi et al 2014; see also Rosenzweig and Solecki, 2010; Anguelovski and Carmin, 2011; Hunt and Watkiss, 2011). In informal settlements with little or no formal infrastructure and services, stakeholder engagement is a means for participatory community risk assessment, where local adaptive capacity is built in part through local knowledge (Livengood and Kunte, 2012; Kiunsi 2013). Box 4 gives an example of a participatory planning process that catalysed local government interest in climate resilience in three Latin American cities.

Box 4: Catalyzing local government interest in climate resilience

A study of decision-making in regard to climate resilience in three cities, Dosquebradas (Colombia), Santa Ana (El Salvador) and Santo Tomé (Argentina), used a participatory planning process, to analyse different problems and propose a portfolio of actions that could contribute to climate resilience and improve decision-making processes. During workshops, local actors jointly evaluated problems and options and trade-offs between the options proposed. This participatory process helped to produce a clearer idea of the WHAT (kind of options and actions necessary), WHAT FOR (context and justification), WHERE (place), WHEN (timing), WHO WITH (who are part of this process, who must get involved, who are "winners and losers"), WITH WHAT RESOURCES, and HOW (technical and financial support, different knowledge bases and experiences). These are all aspects that need to be addressed during the construction of a portfolio of action options.

Participants highlighted the need to work across different topics: establish a common vulnerability and risk base line, develop comprehensive plans of land management (e.g. to curb developments in fragile ecosystems, define protection zones, assess urban expansion trends with its positive and negative impacts, etc), define green and grey infrastructure needs that reduce risks (stream recovery and sustainable management of watersheds; water and sewage network expansion), and strengthen a communication strategy (within government areas and between government and civil society – community organizations. From this came project proposals for city portfolios that included reforestation with native vegetation and recovery of creeks and streams within urban and peri urban areas. They also included the development of community-government organizational mechanisms to monitor environmental conditions, plans and follow up on green and grey infrastructure works, measures to develop disaster risk and resilience action plans, and the strengthening both of internal measures (working within the city) and external capacities (connecting with the "outside - other cities, regions, donors, etc).

Source: Hardoy et al, 2017

Representative democracy has worked in urban centres in high-income and some upper middle- income nations in that almost all their population (including most households with low-incomes) live in secure, permanent (formal) housing with (formal) infrastructure and services. They do not have a significant proportion of their population in informal settlements. Residents do not have to actively lobby for piped water, connection to sewers and storm drains or participate in their planning, construction and management. There are political or bureaucratic channels for complaints for anyone who feels they have been poorly served or cheated by any public service and safety nets if they are unable to work or they lose their source of income. Local governments may have limitations and may fail to adequately serve a proportion of the population (typically the poorest) but they do not have large and growing proportions of their populations in informal settlements

Representative democracy has not worked for residents of most informal settlements. This helps explain why new forms of (mostly local) governance have emerged in informal settlements. As described in Section 3, this includes grassroots organizations and federations that organized to address their own needs (mostly in informal settlements) and to offer partnerships to local government. It includes participatory budgeting although here citizen and civil society engagement focused on getting their priorities accepted and holding local government to account (Cabannes 2015). The IPCC's Fifth Assessment noted how participatory processes figured prominently in cities that have been leaders in urban adaptation (Revi et al 2014, citing Rosenzweig and Solecki, 2010; Brown et al., 2012; Carmin et al., 2012;). Many forms of direct citizen participation in government have included upgrading as this improved provision of infrastructure and services – including through processes of co-production, whereby local communities and local government have joined forces in the provision of services and shelter.

This 'co-production' (Mitlin, 2008, Ostrom, 1996] of services and infrastructure by community organisations and local governments can reduce development deficits and build resilience. It also creates an entry-point for climate finance to be localised to the community level, where structures of accountability and financial management are already in place (see for instance Weru et al 2017). If community organisations can be further resourced with national or international climate adaptation finance, it 'carves out the political space for them to use adaptation as a means to pursue justice across multiple dimensions of urban development' by further addressing underlying causes of risk and vulnerability (Colenbrander, Dodman and Mitlin, forthcoming). Furthermore, this can create incentives for state and national governments to support and resource local governments – the governance of climate change adaptation requires action from multiple spheres and types of actors: public, private and civil society.

Section 3 included clear evidence of the potential of organisations formed by residents of informal settlements to negotiate with local governments for more inclusive urban development, through processes that give more voice to population groups that are traditionally marginalised. Community- based adaptation to climate change, and community-driven development more generally, can be viewed as responses to failures in top-down climate change adaptation or development approaches (Boyd et al. 2009). Community-driven approaches open up opportunities for partnership and co- production (Papeleras, Bagotlo and Boonyabancha, 2012; Mitlin, 2008), which can begin to address some of the underlying structural inequalities and lack of resources that drive vulnerability. Where citizens are empowered and engaged, they can foster a culture of inclusion, responsiveness and collaboration between different urban actors, whether state or non-state – that builds resilience to the shocks and stresses generated by climate variability and change.

There are examples of good practice that illustrate mechanisms for meaningful participation, accountability and transparency. There are also examples of political and financial decentralisation that have enabled different actors within cities, both state and non-state, to address development and adaptation deficits (Bahadur and Thornton 2015). Section 3 also outlined the many examples of organised low-income communities in the SDI and ACHR networks building their own capital base through savings groups and revolving loan systems. This creates city-wide funds shared across several community groups, to address housing and infrastructure needs, as well as livelihoods, education and welfare (Archer, 2012). The citywide funds managed by the community organisations can include contributions from other sources, including local government (Lines and Makau 2017) There are also instances of disaster insurance funds being created, filling a gap where many informal dwellers cannot access insurance services. But in many nations, there are political and institutional constraints on these kinds of processes.

Governance challenges may arise if there are “mismatched priorities between different government spheres” related to climate change efforts. So the ‘relational dynamics’ between different levels of government and between government and non-government actors are central to urban climate governance (Leck and Simon 2012: 1221).

There is increasing acceptance that the governance of urban climate change ‘implies a recognition of the multiple actors who intervene’ (Castan Broto, 2017:1) through multiple forms of governance – a shift away from the top-down, state-led approach. There is also growing agreement of the need for ‘pro-poor forms of adaptation that support the urban poor’s assets’ (Castan Broto, 2017:3) The involvement of a variety of stakeholders is needed for effective and inclusive decision-making on planning and resource allocations which takes into account the needs of diverse urban actors including those in informal settlements and those working within the informal economy. And while local community organisations may increasingly be playing a role in this, this should not absolve local and national governments of their responsibilities towards all citizens.

Section 3 described how community-led surveys, maps and enumerations of informal settlements in many countries had generated the data needed for planning and managing upgrading – and how these had also led to better relations with local authorities as they served as a valuable negotiating tool, as this information is vital for planning effective and targeted infrastructure and housing improvements. These also contain data on residents’ past experience in coping with extreme weather and residents’ perceptions of the most serious risks that they face – and so a good foundation for climate change risk assessments.

City governments need information systems about climate change that inform their decisions. In many cities, this is mostly about bringing together and integrating already available information (geo referenced where possible), ensuring this is builds on the knowledge of local actors, is available to and accessible to all within a process that constantly updates it (Hardoy et al 2017).

A study of decision making in regard to climate resilience in Dosquebradas (Colombia), Santa Ana (El Salvador) and Santo Tomé (Argentina) found that there was usually sufficient information to guide actions. The problem was that needed information was held by different government offices, universities, research centres and private sector bodies and not shared. In many instances, key actors did not know of others’ information base. The information was often in different formats and not geo-referenced. So the problem was not so much the lack of relevant information as the impossibility to access it and use it to initiate a dialogue between actors and support better- informed decisions.

On the other hand, certain types of information may be unavailable or inaccessible to particular population groups. Where it is available, it may be difficult to interpret – such as climate models and predictions. This may lead to climate adaptation plans and activities that benefit certain areas or population groups – often those with most negotiating power, such as industrial lobbies – whilst increasing impacts are faced by more marginalised groups. There is therefore a need to develop a culture of learning and openness around such data to facilitate inclusive adaptation planning. This also needs a recognition that climate change adaptation cannot consist solely of technological solutions imposed by experts from above, but requires fostering an informed, inclusive and empowered society engaged in decision-making processes.

6. Conclusions

SCALE OF PROBLEM: Around one in four of the world's urban population lives in informal settlements in low and middle-income nations. It is in these settlements that most of the urban deficit in infrastructure and services (including water, sanitation and drainage) and the worst quality housing are concentrated. This also means their inhabitants face high risks from most climate change impacts, yet their contribution to climate change is likely to be minimal. Most of their livelihoods and housing is 'informal' as are most of the services they use in the absence of government provision. Most are also in urban centres where local government lacks the funding and capacity to address this.

CITIES IN WEALTHY NATIONS: In high-income and some upper-middle income nations, almost all cities have functioning governments. They have what the IPCC terms 'risk-reducing' infrastructure and services in place covering almost all their populations, such as reliable, safe water piped to homes, good provision within the household for sanitation, paved roads and paths, storm and surface drains and connection to electricity grids. Almost all housing conforms to official standards which protects inhabitants from extreme weather. Almost all building owners have insurance while almost all households have insurance covering possessions.

Here, addressing climate change adaptation is seen as a responsibility of government, mostly city government with support from national government. Building resilience to climate change is seen as what any good and accountable city government should do. The foundations are there for building a city's resilience to climate change – the infrastructure and services, the local governance systems, the needed laws, rules and regulations. City-wide infrastructure systems are in place so their resilience can be enhanced – while recognizing their interconnectedness and as Box 1 notes, the need for responsiveness, redundancy and 'safe failure.'

For city governments that have taken climate change adaptation seriously, they have moved from a political commitment to act to developing new policies and technical responses. Thus, the needed move to greater resilience to climate change happens within the 'formal' world of policies, budgets, rules and regulations overseen by elected city governments.

CITIES IN THE GLOBAL SOUTH: But what can be done in a city where city government has little technical and no investment capacity and much of the population live in informal settlements that lack almost all the 'risk reducing infrastructure and services mentioned above. Many cities and countries are failing to deliver even basic infrastructure and services to urban residents, so how are they going to find ways to ensure that these are compatible with low-carbon and climate-resilient urban development? These will be inhibited by the same constraints that have hindered more conventional forms of development: weak government and governance structures, scarce resources (including little investment capacity), constrained local powers, limited delivery capacities, vested interests, political disinterest in the urban poor and the presence of multiple competing priorities The difficulties in getting needed action can be seen in the contrast between city governments with the capacity and willingness to manage land use and land use changes in the public interest (including needs for adaptation and mitigation) and where there is none with urban sprawl, large speculative profits within legal and informal land markets and the exclusion of low-income groups.

It is difficult to imagine how the much-needed changes in development and in climate change policies will happen without more committed, competent and resourced urban governments that work well with those in informal settlements. Building climate resilience in these settings requires local governments' flexibility and a willingness to go outside conventional 'formal' responses copied from high-income nations. This includes a willingness to innovate and a commitment to co-produce solutions with informal settlement residents.

ANOTHER PATH: But there is another way for governments to view this issue; to recognize the many positive aspects of informal settlements and to work with the inhabitants and their community organizations in providing needed infrastructure and services and improving housing quality. This paper has given examples of how in particular informal settlements, upgrading has expanded and improved provision of infrastructure and services, supported housing improvements and sometimes supported legal tenure being provided to the occupiers. This 'upgrading' of informal settlements has become common practice in many nations. Some are driven by local governments responding to democratic pressures - for instance, in many Latin American cities, upgrading informal settlements and extending trunk infrastructure to them (roads, water mains, sewers, storm drains, electricity...) has become an accepted part of what a city government does.

The work of the Community Organizations Development Institute in Thailand was also described earlier – and how it catalyzes and supports community-driven upgrading with upgraded settlements being incorporated into the formal systems for water, sanitation and waste collection. Previous sections also described now the last twenty years have also brought many upgrading initiatives in informal settlements driven by community organizations formed by their residents. These include many initiatives by national federations of slum or shack dwellers that are active in over 30 nations.

There are also many examples of co-production of services and infrastructure by community organisations working with local governments to reduce development deficits and build resilience. Although few of these case studies mention climate change, they are describing processes that are perhaps the most important means by which low-income urban dwellers unable to afford formal housing can get more resilience to climate change impacts – as well as reducing risks they face from everyday hazards and disasters.

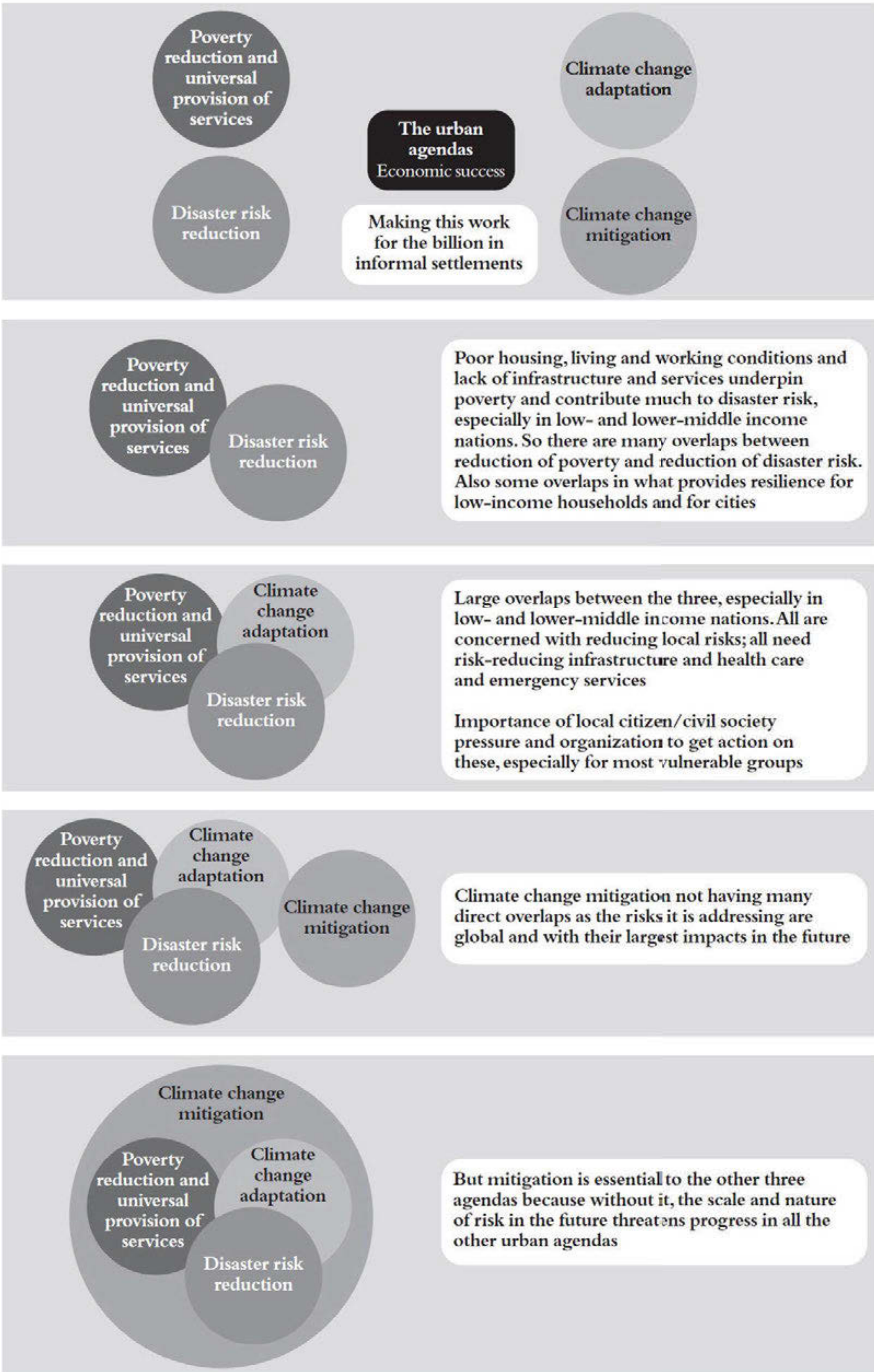
NATIONAL GOVERNMENT: The crucial role of urban governments and urban civil society in adaptation (and development) is being ignored. There are important issues that are beyond the scope of this paper that need highlighting. One is the very low priority given by most international development assistance agencies to urban issues – including informal settlement upgrading and city- wide water and sanitation systems. Another is the lack of connection between global United Nations agreements and agendas (such as the New Urban Agenda, the Sustainable Development Goals and the Paris Agreement) and what is needed to build resilience in urban areas that engages low income groups. Urban governments can be drawn into these UN agendas but always in a subsidiary role. The global agendas focus so heavily on national government commitments – and so little on the two most important actors for climate change adaptation in urban areas - urban government and urban civil society.

KNOWLEDGE GAPS: In terms of knowledge gaps, we need to build the evidence base on the interactions between urban development, disaster risk reduction, climate mitigation and climate adaptation, and identify potential synergies and trade-offs between these agendas. There is also an urgent need for research on the preconditions and contingencies for a successful transition to low-carbon, climate-resilient urban development – and this needs to include cities with limited government capacities and large infrastructure backlogs. Questions of equity and justice need to be at the heart of this research agenda, including who is excluded from accessing housing, land and land tenure and financial services. Or who faces discrimination in this, on the basis of (for instance) gender, age or ethnic group?

TRANSFORMATION: The issues raised by the 5th IPCC Assessment on the needed shift from resilience to transformation also need emphasis. Here, transformation is understood as where urban centres have integrated their development, disaster risk reduction, and adaptation policies and investments within an understanding of the need to contribute to mitigation and sustainable ecological footprints (Revi et al 2014 – see Table 8.2, page 546; see also Satterthwaite, Bartlett, Roberts et al 2016). Figure 1 illustrates this.

NEW FUNDING CHANNELS: How can the number of positive examples of local government led and community-led adaptation be multiplied? One of the sternest tests for global climate finance is to develop the institutional channels through which to encourage and support hundreds of locally- driven upgrading initiatives within which resilience enhancement is embedded. This means that global funds for adaptation will have to work out how to work with local governments and with the grassroots organizations and federations formed by the inhabitants of informal settlements.

Figure 1: The four agendas and their overlaps



SOURCE: Satterthwaite, Bartlett, Roberts et al 2016

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Commissioned Paper

3

Financing low-carbon, climate-resilient cities

Summary

In many parts of the world, urban development is becoming more inefficient, unsustainable, and carbonintensive. Urban spatial expansion is outstripping urban population growth and the share of urban trips by private vehicles is increasing in all developing regions. Meanwhile, millions of urban residents lack access to risk-reducing infrastructure and services, such as sewers, piped water, drains, waste collection or healthcare.

A transition to low-carbon, climate-resilient cities will require both a substantial increase in the total quantity of urban infrastructure investment, and a shift in financing. There is a need for innovation, learning and scaling of financing instruments, financial architecture and governance structures.

This paper outlines how cities and countries can enhance fundamental financial capabilities and systemically mainstream climate commitments into financial decision-making.

COALITION FOR URBAN TRANSITIONS

A New Climate Economy Special Initiative

COALITION FOR URBAN TRANSITIONS

A New Climate Economy Special Initiative

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1. Executive Summary

In many parts of the world, urban development is becoming more inefficient, unsustainable, and carbon-intensive. Urban spatial expansion is outstripping urban population growth and the share of urban trips by private vehicles is increasing in all developing regions. Meanwhile, millions of urban residents lack access to risk-reducing infrastructure and services, such as sewers, piped water, drains, waste collection or healthcare.

A transition to low-carbon, climate-resilient cities will require both a substantial increase in the total quantity of urban infrastructure investment and a shift in the way that existing streams of finance are allocated. There is therefore a need for innovation, learning and scaling of financing instruments, financial architecture and governance structures. This paper outlines how cities and countries can enhance fundamental financial capabilities and systemically mainstream climate commitments into financial decision-making.

1.1. Demand for finance

To achieve the Paris Agreement, mature cities will need to refurbish existing systems and infrastructures, and fast-growing cities will need to shift towards lower-carbon development pathways. There is therefore a need for investment in new power generation technologies to decarbonise the electricity grid; energy efficiency in buildings, lighting and appliances; transport infrastructure than enables modal shift to public and non-motorised transport options; next generation mobility, particularly electric vehicles; and solid waste management. Urban form will have a major influence on the type and feasibility of different low-carbon measures, particularly through patterns of density, land-use mix, connectivity, and accessibility.

The scale of adaptation investment needed will depend on the scale of mitigation investment mobilised. In other words, the finance required to adapt cities to a 1.5°C increase in global temperatures are a fraction of those required to adapt to a rise of 4°C. Adaptation investment needs are a function of physical exposure to climate risk and adaptive capacity. This suggests three broad categories of adaptation investment: (1) reducing exposure to everyday hazards through the provision of basic infrastructure and services, such as sewers, piped water and healthcare; (2) managing new risks by integrating climate considerations into the design, implementation or retrofit of urban infrastructure; and (3) building new infrastructure and services specifically to respond to new climate hazards, such as sea level rise.

Low-carbon and climate-resilient urban investments are institutionally more complex than conventional urban investments and may entail higher upfront costs. Consequently, the financing and funding arrangements will generally be more sophisticated than existing systems.

1.2. Supply of finance

Domestic public finance has traditionally been a significant source of infrastructure investment, and is currently equivalent to about three per cent of global GDP. However, public budgets are often insufficient for larger and more complex infrastructure projects, particularly in the context of limited own-source revenues, austerity or competing priorities. This is particularly true at the local level: many municipalities in sub- Saharan Africa and elsewhere have an annual planned budget of less than US$20 per person, most of which is committed to operating costs such as salaries. Governments may also be constrained from near-term infrastructure investment by the need to pay attention to fiscal sustainability, which is necessary to ensure long-term access to private finance.

International public finance is also an important source of infrastructure investment, but it is not sufficient to fill the financing gap. There is therefore a need to use this finance strategically to develop an enabling environment for low-carbon, climate- resilient investment in urban areas. This could be through supporting the design of climate- sensitive policy frameworks and institutional arrangements; building local capacities to plan and deliver climate-compatible infrastructure; supporting early entrants in key markets, such as renewable energy technologies or energy-efficient appliances; and crowding in private investment through reducing project risk. Development and climate finance can also be used to promote inclusive decision-making processes and equitable project outcomes, thereby addressing some of the drivers of climate vulnerability.

Private investors could be drawn to sustainable urban infrastructure projects where a sufficient return on investment is forecast based on project income flows or low-risk government debt repayments. Bankability and creditworthiness are therefore prerequisites to attracting private finance. Commercial banks, investment companies, pension funds, insurance companies and sovereign wealth funds manage over US$110 trillion of assets, much of which could be steered into sustainable urban infrastructure. It is important to recognise that these different investor types will have different risk-return expectations and investment horizons, and to identify and structure projects appropriately for these different sources of finance.

1.3. Connecting demand for, and supply of, finance

Governments have a range of financing and funding mechanisms available to secure investment. Equity involves contributing resources in return for a share in the ownership of a project. This typically means that the completed project must be operated as a company of some sort so that the equity can be placed. Debt involves contributing resources in return for repayment, typically on an agreed schedule with interest. Public financing entities may also use grants or risk mitigation instruments to reduce the costs or perceived risks to private investors. In addition, governments have access to a funding base of taxes, charges, fees and other revenues, and can additionally use asset-based instruments to secure private finance. Some of these instruments will be used routinely as part of a government's revenue- raising and steering efforts; others may be deployed to mobilise the investment for a specific project or sector.

There is scope to use or adapt many of these financing instruments to advance climate aspirations. For example, land and property taxes may be designed to incentivise more compact urban growth, while guarantees may be used to reduce the risks associated with emerging low-carbon technologies. Four instruments have particular promise to support investment in sustainable urban infrastructure at scale: pricing, regulation and standards, debt financing, land value capture and public-private partnerships.

A major barrier to financing low-carbon, climate-resilient infrastructure is the lack of robust implementing entities, particularly entities with a strong understanding of sustainability and resilience. Implementing entities need to be capable of structuring projects to suit the diverse risk appetites, time horizons and expectations of returns of prospective investors. Such projects must have sufficient bankability, or such entities must have sufficient creditworthiness, to attract affordable capital. For maximum cost-effectiveness, implementing entities should be able to utilise a wide range of financing and funding models, and administer project design and procurement processes that can leverage private finance. Implementing agencies should also have clear responsibility for, and support to, integrate climate criteria into project design, implementation and evaluation.

1.4. Enhancing urban finance readiness

As a precondition for either low-carbon or climate-resilient urban development, governments need to raise sufficient resources or improve the efficacy of expenditure sufficiently to fill the financing gap. Their capacity to do so can be understood as their urban finance readiness.

The binding constraint in high-income countries is not the supply of finance, but the coherence and effectiveness of demand-side institutions. Given high per capita incomes, infrastructure such as renewable energy systems, water networks and building developments can generate revenue streams that provide private investors with attractive returns on investment. Governments can also raise revenue through taxation, fees, charges, tariffs and asset management. However, demand-side institutions vary in their capacity to package and structure investment projects to secure the necessary resources. Central governments in high-income countries will typically have sophisticated capabilities that allow them to deploy a range of financing and funding instruments. The effectiveness of subnational institutions is more varied.

In contrast, both the demand and supply sides of the urban finance market are often constrained in low- and middle-income countries. Low per capita incomes mean lower tax revenues and less ability to pay user fees and charges at a level that provides a sufficient profit margin for investors. It follows that poorer countries and cities are less likely to have access to the same range of financing mechanisms that are available to wealthy nations and cities. However, urban finance readiness is not just a function of per capita incomes, but also of the quality of relevant demand- and supply-side institutions. Institutional weaknesses may manifest as imperfect information; politicised decision making; corruption; lack of clarity or certainty around regulatory and legislative frameworks; poorly functioning land and property markets; poor collection and management of own-source revenue; or weak project management and technical capabilities.

Crucially, this analysis suggests that cities and countries do not need substantial increases in per capita incomes to improve their urban finance readiness. Governments have opportunities to raise and steer infrastructure investment through:

1. **Strengthening fiscal and financial systems** by expanding the fiscal space through tax and expenditure measures, and tackling gaps in the availability and costs of long-term finance.
2. **Providing a stable, enabling policy environment** by developing detailed urban spatial plans and infrastructure strategies, and by clarifying regulations and legislation to reduce investment risks and transaction costs.
3. **Improving project development and implementation** systems by clarifying agency mandates and funding sources, and by supporting project preparation activities.

1.5. Mainstreaming climate considerations into urban finance systems

Climate-compatible urban development will require fundamental reforms to urban finance systems to make good practice ubiquitous, and to improve on good practice. The reform priorities can be grouped according to the three opportunities identified above.

There are large opportunities to mainstream climate considerations into fiscal and financial systems through pricing, accounting and procurement mechanisms. Pricing climate-related externalities appropriately offers huge potential to steer investment towards more sustainable forms of investment. Governments should prioritise eliminating pervasive fossil fuel subsidies and adopting carbon pricing. Accounting for physical, liability and transition risks can also steer help to shift investment away from projects with large carbon footprints or high exposure to climate impacts. Such accounting systems may be introduced by financial intermediaries, regulators or central banks. Looking beyond infrastructure investment, green public procurement policies are an effective means to establish markets for more sustainable goods and services. Central and local governments can introduce environmental standards into technical specifications, procurement selection and award criteria, and contract performance clauses.

The financial and fiscal architecture can also be used to reduce systemic vulnerability (including to climate risk) by creating space for low-income and other marginalised urban residents to influence the allocation of public resources and governance of private investment. Proven models exist, such as participatory budgeting or city development funds.

Policy frameworks, spatial plans and infrastructure strategies should clearly direct investment towards low-carbon, climate-resilient modes of development. This requires coordinated multi-level governance (across national, regional and city governments) and horizontal policy integration. For maximum effectiveness and legitimacy, such plans and strategies must also address other local priorities, such as housing affordability and air quality. Policy instruments can also tackle non-financial obstacles to low-carbon and climate-resilient investment, such as split incentives, inadequate access to finance and industry fragmentation. Such policies will need to be tailored to the local institutional, legal, economic and cultural context, and to target a range of prospective investors including households, small and medium enterprises, commercial banks and local authorities.

Lead agencies can adopt project appraisal and valuation systems that systematically capture environmental externalities over an asset's lifecycle, and apply rigorous and consistent environmental safeguards to planned investments. Optimising a project design across multiple criteria typically requires a professional and multidisciplinary team with legal, technical, scientific and financial expertise. An appropriate choice of shadow carbon price and discount rate can further ensure that the long-term, social costs of climate change are meaningfully accounted for when designing and delivering new infrastructure projects.

1.6. Research priorities

1. Strengthening the economic and financial case for climate-compatible urban development from the perspective of a range of different actors (including diverse investors).
2. Understanding the spatial allocation of productive assets, households and jobs relative to climate risk.
3. Identifying the components of urban finance readiness, and activities or reforms that can enhance readiness.
4. Assessing the different ways that climate goals can be mainstreamed into urban finance systems on both the supply and demand side.
5. Assessing the different ways that urban financial systems could enhance inclusion and equity, and thereby reduce vulnerability to climate change.
6. Determining best practice in engaging private actors in sustainable urban
7. infrastructure projects of different kinds, and articulating the conditions or contingencies for success.
8. Evaluating the best actors and mechanisms to best support learning, replication and scaling on both the supply and demand side.
9. Accounting for flows of climate finance and improving the use of international public
10. finance to achieve paradigm shifting potential.

Introduction

Today, more than half of the global population live in urban areas, which contribute over 80 per cent of global GDP (UN, 2015). The concentration of people and economic activity means that urban areas are responsible for a substantial share of resource use and waste production, with 67 to 76 per cent of global energy consumption and 71-76 per cent of carbon dioxide emissions from final energy use being attributed to urban activities (Seto et al., 2014). The world's urban population is projected to increase by one billion in the next 15 years (UN DESA, 2015). The increase in urban populations, economies and carbon emissions will be the greatest in emerging and developing countries (ibid.). Recognising the growing proportion of global emissions associated with urban activities, 113 Nationally Determined Contributions (NDCs) under the

Paris Agreement include urban-related content on adaptation and mitigation. This is most pronounced in the rapidly urbanising regions of Africa and Asia (UN-Habitat, 2017).

Unfortunately, in many parts of the world, urban development is becoming more inefficient, unsustainable, and carbon-intensive. Urban spatial expansion is far outstripping urban population growth (Angel et al., 2011), and the share of urban trips by private vehicles is projected to increase in all developing regions by 2050 (OECD/ITF, 2017). Meanwhile, millions of urban residents lack access to risk-reducing infrastructure and services, such as sewers, piped water, drains, waste collection or healthcare. It is therefore urgent that urban development be designed and implemented in a way that mitigates and adapts to climate risks. A transition to climate-compatible cities will require both a substantial increase in the total quantity of urban finance and a shift in the way that existing streams of finance are allocated. There is therefore a need for innovation, learning and scaling of financing instruments, financial architecture and governance structures.

The methodologies used to calculate financial requirements for climate-positive urban infrastructure are, to date, very limited in their scope. While imperfect, existing estimates reveal that:

1. There is a huge gap between demand for, and supply of, urban infrastructure investments.
2. The financing gap is largest in emerging and developing countries.
3. Additional resources will be required to finance climate-compatible investments, which often have higher upfront costs or higher risks than conventional projects.

The next chapter considers demand for finance for sustainable urban infrastructure. This encompasses the agencies undertaking projects, the type of projects and the funding required to repay finance. Chapter 3 looks at the supply of finance for investment projects, mapping possible investors and their likely risk appetites, return expectations, liquidity needs and time horizons. Chapter 4 considers the financing and funding mechanisms that can be deployed on the demand side to raise and steer finance from the supply side, and at integrating climate considerations into the project preparation process. Chapter 5 presents the concept of urban finance readiness: the capacity of supply- and demand-side institutions to address the infrastructure financing gap. It assesses key opportunities to strengthen fiscal and financial systems, policy environments and frameworks, and project development and implementation processes. The chapter then explores how climate considerations can be mainstreamed into urban finance systems. Chapter 6 concludes with research priorities going forward.

2. Demand for finance for sustainable urban infrastructure

Global investment in core infrastructure is currently around US$3.4 trillion per annum. However, to meet human and economic development needs over coming decades, a total of US$5 to US$6 trillion is required each year (Bhattacharya et al., 2016). The annual deficit in infrastructure investment is therefore above US$1 trillion a year. 70 per cent of the projected investment needs for sustainable infrastructure will be required in emerging and developing countries, with a particularly fast rate of increase in Africa where urban population growth rates are highest (Bhattacharya et al., 2016).

To avoid dangerous levels of climate change and to adapt to existing risks, planned investment must be steered towards lower-carbon, climate-resilient options. For example, the global residential floor area is projected to increase from 164 billion square metres in 2012 to 354 billion square metres in 2050 (Dulac, 2014); it is essential that this new construction is energy efficient and located in areas with minimal exposure to environmental hazards. One estimate suggests that the total incremental financing needs associated with climate-compatible development are equivalent to around five per cent of total investment requirements (Bhattacharya et al., 2016). The higher financing needs reflect the higher capital costs, technological substitution and technical risks associated with many sustainable infrastructure options.

Estimates of the scale of urban investment needs vary according to the different assumptions surrounding the sectors considered, choices around infrastructure and technology, rates of technological learning, the value of avoided investment costs, and the ambition of measures to reduce the environmental impact of infrastructure. Irrespective of the precise values involved, it is clear that there is an urgent need to scale up levels of infrastructure investment in cities around the world, particularly in those in the global South, and to steer investment towards more sustainable options.

While climate-positive approaches might have higher incremental investment needs, there is a growing body of evidence to suggest that they might generate a net financial return. Early analysis suggests that, although new green districts in urban areas cost 8 to 10 per cent more than `brown' districts, lower operating costs of this infrastructure allow for payback periods of only three to five years (Bouton et al., 2015). Another study finds that investing in sustainable urban infrastructure would have a net present value of US$17 trillion of economic benefits globally by 2050, primarily from energy savings, within relatively manageable investment repayment schedules (Sudmant et al., 2016). In other cases, the economic returns of climate actions may be even broader.

For instance, avoided mortality through reductions in air pollution has estimated health benefits worth US$50-380 per tonne of carbon dioxide (West et al., 2013). In impoverished neighbourhoods in temperate regions, the value of other health benefits from investments in insulation may be worth ten times as much as energy savings. These gains accrue to households, businesses and public health systems, and may therefore be difficult for prospective investors to recover (Gouldson et al., 2018).

There is already substantial demand for finance to adapt urban infrastructure to environmental risks, which will increase with the severity and intensity of climate change. Many cities are located in areas that are very exposed to the effects of climate change, such as extreme weather conditions, sea-level rise, and storm surges. As of 2007, an estimated 13 per cent of the world's urban population lived in low elevation coastal zones (less than 10m above sea level), and the share was higher in Least Developed Countries (21 per cent), where there are greater infrastructure deficits than in OECD countries (11 per cent) (McGranahan et al., 2007).

The World Bank estimates that US$11-20 billion is needed annually to 2050 to ensure urban infrastructure is adapted to climate risks (Hughs et al., 2010), while UN Environment calculated that the requirements were US$120 billion to 2030 (CCFLA, 2015). These estimates arguably understate the need for investment in basic infrastructure, such as drains, sewers and piped water supplies, which are important preconditions for urban resilience. When accounting for this 'adaptation deficit' (which is mostly a development deficit), the financing gap is much greater (Parry et al., 2009). Quite apart from the moral imperative to meet and climate-proof human development goals, there is a long-term economic case for such adaptation investment as articulated in `The Stern Review' (Stern, 2006). But this can be difficult to translate into near-term investments that satisfy the risk-return criteria of financiers.

2.1 Investments in low-carbon urban development

The Paris Agreement aspires to limit the global temperature rise this century to no more than 1.5°C above pre-industrial levels. This will require greenhouse gas emissions to reach net zero in the second half of the century, with net negative emissions thereafter (Rogelj et al., 2016).

Urban form has a major influence on the type and viability of low-carbon investments and strongly influences levels of greenhouse gas emissions, particularly through patterns of density, land-use mix, connectivity, and accessibility (Seto et al., 2014). Integrated land-use, housing and transport planning can steer investment towards more compact and connected modes of urban development, which are more carbon-efficient than urban sprawl (Rode et al., 2017). Higher levels of population density can also improve the cost-effectiveness of more energy-efficient options such as mass transit, cycling, walking and district heating and cooling. Urban form (and the policies that drive it) therefore has a major influence on the carbon intensity of urban activities.

Mature cities will need to refurbish existing systems and infrastructures, and fast-growing cities will need to shift towards lower-carbon development pathways (Davis et al., 2010; Müller et al., 2013). Within the constraints of urban form, investments in four interconnected sectors arguably have the greatest abatement potential. These are:

1. Decarbonising the electricity grid
2. Energy efficiency in buildings
3. Modal shift and next generation mobility, and
4. Waste management.

Interventions in these sectors each require a defined set of investment types, which, in turn, require a set of institutional arrangements to implement. These institutional arrangements are not in place on a systemic basis, otherwise the required investments would be occurring. But prototypes and/or small-scale versions of all the elements needed for systemic arrangements are operating successfully – somewhere – in almost all these sectors. This section will define the key investments required in each of these sectors and some of the obstacles to unlocking the necessary finance.

2.1.1. Decarbonising the electricity grid

Major investments will be required in new power generation from renewable sources, whether through centralised or decentralised technologies. In some contexts, this will involve new capacity in response to unmet or new demand – particularly in fast-growing cities of the global South. In other contexts, this will involve replacing or refurbishing existing capacity to reduce the emissions associated with power generation. Action by national and regional governments is important, as the current institutional arrangements in many countries place cities in a relatively weak position to influence these investments (Cowell et al., 2017). However, this is not to say that some effective influence cannot be exerted.

There are a few fundamental financing challenges associated with investments in renewable energy. While a growing array of renewable energy technologies are economically competitive in an increasing number of geographic contexts, some continue to be more expensive than fossil fuel alternatives. Even where the levelised cost of energy (LCOE) is competitive with current market prices, renewable energy technologies tend to have higher capital costs than conventional power generation options. This is particularly relevant for developing and emerging economies, where capital and financing costs tend to be higher than in rich countries (Hirth and Steckel, 2016). Lack of access to sufficient finance and the short time horizons of some potential investors can therefore constrain finance flows, particularly where there are significant opportunity costs to any public expenditure (Colenbrander et al., 2016).

In addition to this direct financial barrier, low-carbon energy technologies are often perceived as more risky than conventional generation options due to – among other things – the relative capital intensity of the investment, complicated or unfavourable permit processes and financial and public institutions designed for different investment needs (Schmidt, 2014; Granoff et al., 2016). In Indonesia, for example, geothermal power could be economically attractive, but investment has been constrained by unfavourable tender processes, artificially low electricity prices, and the technical risk associated with establishing a new plant (Smith, 2012).

By comparison, coal power generation has been indirectly subsidised through a national policy, setting the price of domestic coal below international rates (Chattopadhyay and Jha, 2014). Local firms and investors may also be deterred by lack of awareness or familiarity with new technologies, or with the financing mechanisms required to support their deployment (Kennedy and Basu, 2013). Again, poor information about different options is more likely in lower-income contexts, although (as seen in the US), selective use of available information can be equally problematic.

Distributed generation has many of the same financing/funding issues as large power plants. There are also additional challenges related to consumer awareness and cost recovery. For example, high rates of property turnover mean that individuals who buy rooftop solar panels may not enjoy much of the return on their investment (unless their investment manifests in higher house prices).

2.1.2. Energy efficiency in the buildings sector

Major investments will be required to improve the efficiency of the building envelope and of heating and cooling systems. Recent technological developments and improved knowledge allow the construction of very low- and zero-energy buildings, often at comparable costs to conventional buildings. Where there are higher upfront costs, these may have payback periods as short as five years (IEA, 2013a). In principle, new building stock could all be constructed to high energy efficiency standards through regulation and the extension of existing financing/funding systems. The challenges are not financial, but relate to awareness and enforcement – particularly in contexts such as China and India where the majority of new building construction is anticipated.

In contrast, the issue of retrofitting existing buildings is fraught with difficulty. Substantial energy savings (50-90 per cent of total energy consumption) have been achieved in individual buildings throughout the world through deep retrofits. However, even where measures are cost-effective, there are strong barriers to uptake, including imperfect information, split incentives, lack of awareness, transaction costs, inadequate access to financing, and industry fragmentation (Lucon et al., 2014). There is therefore a need for innovative finance mechanisms and business models, particularly if energy utilities, businesses, and financial institutions are to successfully aggregate multiple small projects and overcome first-cost hurdles (Veeraboina and Yesuratnam, 2013). There are a number of systematic performance- based financing models emerging from energy service companies (ESCOs) in China (Kostka and Shin, 2013), the UK (Hannon et al., 2013), and the USA (Stuart et al., 2014), although their success is varied. One of the particularly sensitive issues relating to retrofit will be sharing the funding burden, as low-income households are more likely to rent (meaning that the incentives of tenants and owners do not align) or live in lower-quality housing (which requires more substantive and therefore costly retrofits).

2.1.3. Low-carbon transport

The nature of low-carbon transport infrastructure investments will vary depending on population size, rates of population growth, levels of income, technical and financial capabilities, and established infrastructure stock. Mitigation pathways vary among regions, with the largest opportunities to shape transport systems and infrastructure around low- carbon options arguably in rapidly urbanising countries of the global South (Sims et al., 2014). Transport projects that are likely to need financing and funding are outlined in Table 1.

Many of these activities and projects can be implemented at relatively low cost; others can be financed by steering planned investments towards lower-carbon options (for instance, mandating that consumers purchase more efficient cars). However, some transport projects have high investment needs.

Redirecting funding from unsustainable transport (highways, overpasses) could increase the public finance available for funding sustainable transport (Sakamoto et al., 2010). This can be constrained by wider political considerations and economic frameworks, such as job creation associated with the vehicle manufacturing industry. It is therefore necessary that investment in public and non-motorised transport is accompanied by proactive demand management to discourage the use of private vehicles; for example, by increasing parking costs and reallocating car lanes for buses and bicycles.

Even where these barriers can be overcome, large transport infrastructure projects will likely still exceed the capacity of public budgets. This means that decision makers must seek to create a `package' of financial sources, often blending public finance with private finance to reduce the total cost of capital or perceived investment risk. Leveraging private finance is critical: in 2011, foreign direct investment in the transport sector exceeded overseas development assistance and climate finance combined (ITC, 2013). Land-based taxes and fees are increasingly recognised as a promising mechanism to unlock private investment, notably in Indian cities (Newman et al., 2013). Land value capture instruments enable the state to secure a proportion of the higher values associated with investments in public transport infrastructure.

Technological and institutional innovations are creating new opportunities to decarbonise the transport sector. Product innovation (such as transport electrification and autonomous cars) creates opportunities to reduce the carbon intensity of fuel or the total number of cars on the road. The carbon implications of new forms of shared mobility (such as e-hailing and car/bike sharing schemes) are unpredictable (Canales et al., 2017). The ease and low cost of e-hailing systems such as Uber, OlaCabs and Didi Chuxing, for instance, might either shift public transport users into cars or create a feasible alternative to private vehicle ownership.

2.1.4. Low-carbon waste management

Waste collection, processing, recycling and disposal are priorities for municipalities, particularly those in the global South. In the absence of effective waste management systems (including municipal solid waste, wastewater and sewage), the higher density of people living in urban areas leads to significant health costs that are mostly borne by children and the poor. The economic costs of healthcare, lost productivity,

Table 1: Opportunities to decarbonise urban transport networks through an avoid-shift-improve approach.

	Strategy	Activities / projects
AVOID long and unnecessary trips.	Dense and mixed-use development	Renovation of historic districts and downtown areas; master plans, integration of land use and transport planning.
	Use of information technologies to reduce trips	Teleworking, virtual meetings through improved connectivity and internet access; digital journey planning and ticketing.
SHIFT the movement of goods and people to more carbon- efficient modes	Improved facilities for biking and walking	Recovery of invaded sidewalks and public spaces; rehabilitation of waterfront sidewalks with adequate design, urbanism and furniture; bikeways and bike lanes, safe bike parking
	Improved public transport systems	Bus networks (including Bus Rapid Transit), cable cars, ferries, passenger trains, metro, trams.
	Disincentives to individual motor vehicle use	Administrative restrictions (using plate numbers), congestion pricing, taxes on fuels and registration, urban tolls.
IMPROVE the efficiency of vehicles, fuels and energy carriers, as well as the operational management of transport services.	Clean and low-carbon fuels	Electrification of transport; elimination of lead content, reduction of sulphur content, use of biofuels; support for Compressed Natural Gas (CNG) and Gas to Liquid (GTL).
	Clean and low-carbon vehicles Safe cars and roads	Fuel economy standard, hybrids (internal combustion engine-electric), road inspection programmes.
	Command and control improved management	Technical inspection programs, including air pollutant controls; traffic control networks, centralised dispatch and control of transit services.

Source: Modified from Hidalgo and Huizenga (2013) flood damage, tourism and clean-up costs are estimated to be five to ten times greater than the financial costs of proper waste management (Wilson and Velis, 2015). Yet it is common for municipalities in the global South to spend up to 50 per cent of their municipal budget on solid waste management (Aleluia and Ferrão, 2017), often while serving less than half their population.

There is a range of ways that cities can manage solid waste, including landfill, recycling, composting and waste-to-energy technologies. These may be used together in different combinations. Emissions from landfills can be reduced through landfill gas flaring and utilisation. Waste-to-energy can be particularly carbon-effective, as energy generated from waste can displace fossil fuel alternatives. Waste-to-energy options include incineration, gasification, pyrolysis, anaerobic digestion and refuse-derived fuel. There are also opportunities to reduce waste upstream through measures to reduce waste in the manufacturing and packaging phases. There is evidence that some of these waste management strategies can generate a commercial return, subject to the policy environment and market for specific energy products (Papargyropoulou et al., 2015).

Financing and funding waste management is now fairly routine, even if best practice is no longer universal. Improving access to capital finance will be essential in low- and lower-middle income countries. Recycling, composting and waste-to-energy systems offer some prospect for returns on investment, and therefore opportunities to leverage private finance. The Clean Development Mechanism played an important role in building the technical capabilities and financial case for investment in low-carbon waste technologies (Agamuthu et al., 2009). However, the geographical spread of CDM projects and other loans for solid waste management has been very uneven: between 2003 and 2012, the top ten recipients were all middle-income countries, which accounted for over two thirds of the total value of grants and loans (Lerpiniere et al., 2014). There is therefore an urgent need for donors to reorient towards low-income countries, which commensurately involves a renewed focus on building local capacities, rather than just project preparation.

2.2. Investments in climate-resilient urban development

The more the global temperature increases, the more severe the impacts of climate change. Therefore, the scale of adaptation investment needed will depend on the scale of mitigation investment mobilised. In other words, the finance required to adapt cities to a 1.5°C increase in global temperatures are a fraction of those required to adapt to a rise of 4°C. This section will explore the relationship between development and adaptation investments, some of the barriers to mobilising these investments, and some of the institutional arrangements and financing mechanisms that might be deployed to fill the financing gap.

Adaptation investment needs are a function of physical exposure to climate risk and adaptive capacity. Adaptive capacity is in turn significantly dependent on the level of `development' of a community, resulting in a continuum of needed interventions (see Figure 1). This suggests three broad categories of adaptation, which each need different approaches to financing:

1. **Addressing drivers of vulnerability.** At the development end of this spectrum, there is a need for investment in basic urban infrastructure and services: sewers, piped water, drains, all-weather roads, waste collection, healthcare and emergency services. Although clearly an important part of conventional `development', these are essential investments to reduce urban residents' exposure and sensitivity to a range of climate-related risks, such as flooding (World Bank, 2015). These investments need to factor in likely increases in climate impacts. This is a priority for cities and communities with low levels of development and, accordingly, low adaptive capacity.

2. **Building response capacity and managing climate risk.** All urban infrastructure should be resilient to the impacts of climate change, which may involve additional finance to enhance its robustness, create redundancy or introduce fail-safe systems (Dodman et al., 2017). Urban planning should also be informed by climate change projections to minimise land development in hazardous areas, such as low- lying coastal zones or floodplains:
   a. New infrastructure must be designed and built to be climate compatible. This is a priority for cities with rapid population/economic growth and with significant infrastructure deficits.
   b. Existing infrastructure must be modified or retrofitted to be resilient to climate impacts, or replaced with climate-compatible infrastructure. This is a priority for cities with an established infrastructure stock.

3. **Confronting climate change.** At the adaptation end of this spectrum, there is a need for investment in new infrastructure and services specifically to respond to new climate hazards, such as sea level rise, water scarcity and more frequent and intense storms. Relevant measures could include grey, green or blue infrastructure, such as sea walls, emergency warning systems, canals, levee dykes or green spaces that serve as floodplains. A priority for cities and communities with high physical exposure to climate risks.

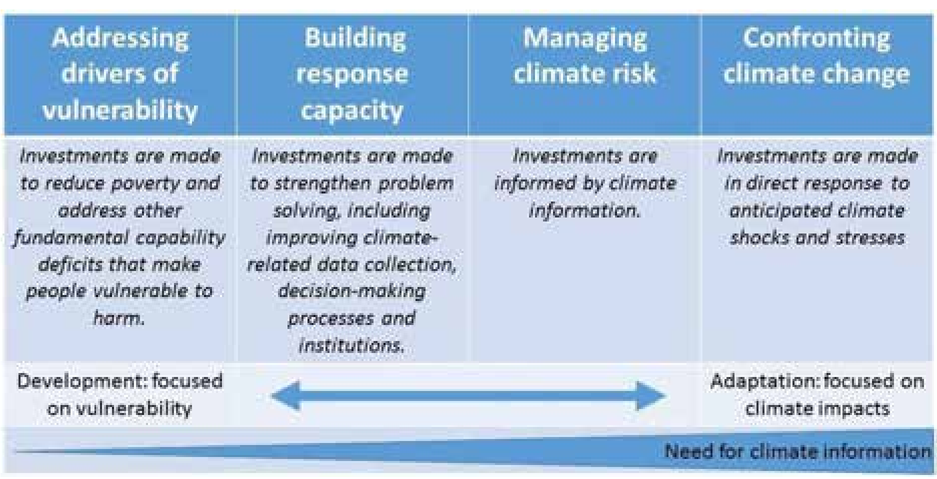
There is a need for the institutions allocating climate finance to recognise the development- adaptation continuum. Low-income urban residents and cities face everyday risks associated with inadequate basic infrastructure and poverty, and these risks will be exacerbated rather than necessarily caused by climate change (Pelling et al., 2018). A preoccupation with `additionality' – the principle that adaptation finance should only be allocated in response to risks that can be explicitly linked to climate change – makes it more difficult to integrate development and adaptation investments effectively (Fankhauser and Burton, 2011). Rather than focusing narrowly on climate adaptation or other hazards, this underscores the need for holistic policymaking and demand-led planning to achieve resilient urban development – enabled by appropriately flexible and responsive urban finance systems.

In each category of investment above, there is a need for investment in `soft' infrastructure (such as human capital and institutions) as well as the `hard' infrastructure that comprises the built environment. Soft infrastructure might include the provision of education and healthcare, establishing participatory decision-making processes, or designing and enforcing regulatory frameworks that contribute to public health and safety (such as traffic management or pollution control). Investments in soft infrastructure may be more cost-effective than hard infrastructure, and can also enhance the effectiveness of other types of adaptation investment (Fankhauser and Burton, 2011).

The focus on vulnerability and soft infrastructure highlights an important challenge with respect to financing adaptation. The bulk of adaptation investment is required in low-income cities of the global South, and in low-income neighbourhoods within cities. These actors typically have limited capacity to raise or attract capital, as is evident from current infrastructure deficits. City governments in low-income countries, particularly smaller cities, are likely to have a small revenue base combined with weak revenue collection and management systems. This limits their access to sources of finance, such as capital markets (Floater et al., 2017a), that could enable investment in development or adaptation. Within cities, low-income communities lack access to finance. These urban residents are also often systematically excluded from public services, due to processes that favour the formal sector over the informal, and higher-income groups over lower-income groups. For example, urban residents living in informal settlements may not have a legal address, which in turn means that they cannot open a bank account, obtain insurance, connect to utilities, send children to school, receive healthcare, or register on the electoral roll (Satterthwaite et al., 2018).

Adaptation investment in low-income cities and neighbourhoods will therefore require fundamental reforms to political and financial structures to successfully engage with powerful, and often entrenched, political economic interests (Chu et al., 2017). Municipal governments need to establish decision-making processes that are accountable and responsive to urban residents who are vulnerable to climate change, such as low-income groups, women, children, the elderly, persons with disabilities, and others. Although there are few documented examples of sustained engagement, there are many promising experiments focused on encouraging public participation and building civic capacities for urban climate adaptation (Sarzynski, 2015). Where local governments are accountable to their citizens, resourcing and empowering these administrations can reduce vulnerability by enhancing incentives to produce services and infrastructure that meet

Figure 1. The development-adaptation investment continuum.



Source: Modified from McGray et al. (2007).

the SDGs and reduce exposure to climate risk (Colenbrander et al., 2017). Fiscal risk must be contained at the same time.

A second challenge concerns achieving satisfactory risk-return ratios for both development and adaptation investments in urban settings. In the long term, there are substantial economic returns associated with climate-resilient development, and substantial costs can be avoided through investments in adaptation. But these are often non-monetised, indirect returns with high degrees of uncertainty, so they need to be financed with public resources.

However, there are opportunities to steer private investment towards climate-resilient forms of investment (and deter private investment in maladaptation) through information, regulatory or fiscal instruments. Particularly large opportunities exist with respect to (World Bank, 2011):

1. Privately-held infrastructure that provides public services, such as transport, electric power networks, water systems, and solid waste. Governments can use regulation and procurement policies to require private constructors and operators to ensure the resilience of these systems.
2. Private properties that have a direct incentive to enhance their adaptive capacity, such as downtown buildings that could be renovated with green roofs to minimise the urban heat island effect.
3. Insurance and other risk management instruments that provide protection in the event of high-severity, low-frequency events, and can incentivise more climate-compatible behaviour.

In summary, climate-positive urban investments are institutionally more complex than historical and current urban investments. They may also entail higher upfront costs, if they are not all together more expensive by conventional economic and financial metrics. Consequently, the financing and funding arrangements will generally be more sophisticated than existing systems.

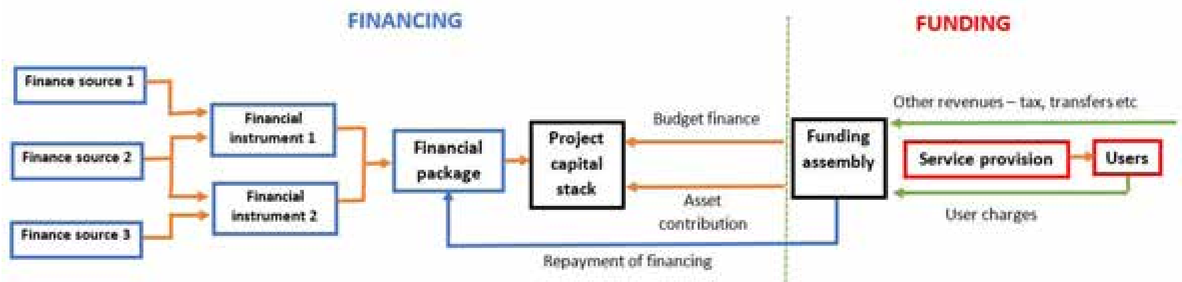
3. Supply of finance for sustainable urban infrastructure

Although the **financing** needed to get a project built and running can come from a wide variety of sources, the **funding** for climate-related and other infrastructure must ultimately come from users and other stakeholders (Figure 2). Sometimes national and municipal governments will be able to draw on their own funds to finance large infrastructure projects, but even cities with relatively large own-sources revenues and access to intergovernmental transfers will generally require additional financing. Cities must examine all options carefully when structuring a project to ensure its financial sustainability over the long term. In this chapter, we explore possible sources of financing and funding.

3.1. Domestic public finance

Government infrastructure investment is equivalent to about three per cent of global GDP (Standards and Poor's Rating Service, 2014). Governments have traditionally financed a significant proportion of infrastructure investment, but sourcing sufficient urban infrastructure finance is a challenge. Higher-income countries have reduced infrastructure spending due to various austerity measures and reprioritisation of other public services (WWF and Z/Yen Group, 2015). Emerging and low-income countries have been increasing their public expenditure on infrastructure and a large part is directed to urban areas (Bhattacharya et al., 2016). However, many governments are constrained in their spending on infrastructure due to competing priorities and the need to manage existing debt. Larger and more complex projects may also be beyond the capacity of public budgets (with a few notable exceptions, such as China). Additionally, countries that do not pay sufficient attention to fiscal sustainability in the medium term also tend to suffer balance of payments crises and loss of access to private sector financing or credit that can constrain future investment. Balancing near- and long-term financing needs is therefore important.

Figure 2. Financing and funding urban infrastructure.



Source: Authors.

The responsibility for funding and financing urban infrastructure has increasingly shifted away from national governments towards municipalities and cities. Poor own-source revenues can turn these spending assignments into unfunded mandates. Many local authorities, particularly those in sub-Saharan Africa, have an annual planned budget of less than US$20 per person (Cabannes, 2015), most of which is committed to operating costs, such as salaries. Local revenue collection is often inefficient, and local governments frequently have little or no control over rates or bases at the margin. Opportunities for land-based financing may be constrained by poor market information, incomplete or inaccurate land and property registries, and undue influence on the decision-making process by vested interests (Berrisford et al., 2018). Additionally, few low- and lower middle-income countries have the enabling multi-level governance arrangements in place that could equip local authorities to act effectively on climate change (Gouldson et al., 2015; Kithiia, 2011). Only 42 per cent of countries worldwide are recorded as devolving fiscal or legislative powers to subnational governments (IADB, 2015), and of these, the depth of revenue-raising powers is highly variable.

3.1. International public finance

Multilateral, regional and bilateral development organisations are able to provide significant financing and funding (including in the form of grants). Development banks alone have provided up to US$160 billion for urban infrastructure (Bhattacharya et al., 2016). Many, although not all, development banks and agencies have committed to ensure that their investments are compatible with the Paris Agreement. In addition, international public climate finance is projected to play an increasingly prominent role in leveraging and enabling private investment in sustainable infrastructure. Some of this will be distributed through established development banks and agencies, but ultimately, the Green Climate Fund (GCF) is intended to be the main channel for mobilising US$100 billion of climate finance by 2020, of which half is committed to mitigation and half to adaptation. To date, difficulties translating donor pledges to well-capitalised funds with a viable project pipeline have resulted in relatively limited impact from multilateral climate funds.

While national governments may choose to work with these agencies to finance urban infrastructure, few agencies are permitted or willing to work directly with city governments. For example, many climate funds can only allocate resources to central governments or require a sovereign guarantee to allocate resources to sub-national governments (Paulais and Pigey, 2010; van Kerkhoff et al., 2011). This can constrain city governments' capacity to respond to locally identified priorities where there is poor coordination or political differences with national agencies. Where development agencies are able to allocate resources to sub- national governments, local authorities rarely have structural relationships with such bodies and often speak a different technical language. Such information can be supplied by specialised consultants, but cities have limited budgets to commission such expertise. Many donors prefer large-scale projects, which are perceived to have lower transaction costs than small-scale ones (van Kerkhoff et al., 2011). Local governments (particularly in smaller areas) may lack the capacity to implement large-scale projects, absorb large sums of money or leverage co-financing. The lending criteria of many development banks and climate funds indicate a preference for investments in `hard' infrastructure, such as solar farms and sea

3.2. Financing Low-Carbon, Climate-Resilient Cities

walls, which are typically the responsibility of national government agencies, rather than `soft' infrastructure, such as capacity building and raising awareness, which tend to be delivered (and required) by local organisations (Fankhauser and Burton, 2011). The long lead times and approval processes may further frustrate local efforts to secure international public finance. Therefore, control of climate-related projects and opportunities for capacity development may remain concentrated at the national level.

The GCF and the Adaptation Fund have introduced a number of relatively new institutional features with the aim of channelling a larger share of climate finance to the local level, including direct access modalities and fit-for-purpose organisational accreditation and project approval processes. These are intended to reduce the transaction costs for local governments and civil society. To date, however, these have been little utilised. As of March 2017, only 36.2 per cent of resources committed by the Adaptation Fund and only 6.2 per cent of those committed by the GCF were to National Implementing Entities; the remainder has been or will be disbursed through International Implementing Entities, such as United Nations agencies, multilateral development banks, international financial institutions and regional institutions (Colenbrander et al., 2017). This means that some of the same social, political and economic processes that create and sustain inequalities within a country will be the same processes that determine how adaptation finance is used. Well-meaning interventions therefore risk consolidating inequality and exclusion by concentrating assets in the hands of a few. The climate finance architecture therefore risks entrenching differential access to public resources, and continuing the political exclusion that contributes to climate vulnerability (Barrett, 2013).

3.3. Private finance

Commercial banks and investment companies manage nearly US$70 trillion of assets, while pension funds, insurance companies and sovereign wealth funds (which tend to have lower risk appetites and longer-term investment horizons) represent nearly US$44 trillion more (McKinsey, 2016). These investors could be drawn to public infrastructure investments where a sufficient return on investment is forecast based on project income flows, or low-risk government debt repayments based on sensible fiscal sustainability criteria. Bankability and creditworthiness are therefore prerequisites to attracting private finance into sustainable urban infrastructure (Floater et al., 2017b). However, these finance sources have not been successfully steered towards climate-positive urban investments. For example, pension funds remain mostly untapped with only about one to three per cent directed at sustainable infrastructure (Liebreich and McCrone, 2013).

Unpacking the constituent elements within these pools of public, private and institutional capital is important, given the differing factors such as risk-return expectations and investment horizons of various investor groups. For example, private equity and infrastructure funds seek the greatest return and will make equity investments in projects with strong growth potential. These funds are often willing to invest in relatively unproven markets and technologies over the medium term (5-15 years). In contrast, pension funds and life insurance companies search for investments that provide predictable income streams to meet long-term obligations such as pensions or insurance claims, but need relatively high liquidity to meet claims. Public capital sources and private investor profiles will therefore suit different types and life-cycle stages of public infrastructure projects, and the largest capital pool in terms of assets under management may not necessarily be the most promising source of finance (Floater et al., 2017b). Public finance and development assistance can play an important role in improving the risk-adjusted returns associated with different infrastructure projects and in catalysing private and institutional sector participation.

Table 2. Potential sources of private finance for sustainable urban infrastructure, and barriers faced by each investor type.

	Key barriers					
Finance Source	Lack of upfront public capital	Institutional inertia	Institutional capacity	Risk	Low returns	Imperfect information
Commercial banks and investment companies		e.g. National lending caps on banks for infrastructure financing (e.g. in India)	e.g. Lack of experience with project finance and municipal bond issues	e.g. Political risks and regulatory changes that impact income flows leading to non-performing loans	e.g. High capital requirements constrain long term investments (e.g. Basel III)	e.g. Lack of commercial knowledge in emerging markets for loan syndication
Developers and infrastructure operators		e.g., Better profit-making opportunities in servicing existing assets than new asset development		e.g. Local currency variability in project income against foreign currency denominated debt	e.g. High local market interest rates make projects unattractive	e.g. Lack of familiarity with operating partners in emerging markets
Private equity and infrastructure funds		e.g. Investors lack trusted relationships with partners and counterparties in 3C infrastructure		e.g. Risk that government guarantees could be reversed	e.g. Private equity hurdle rates unsuited to infrastructure investments	e.g. Lack of information on value potential of new technologies
Pension funds and insurance		e.g. Appetite for very large investments may miss smaller urban-scale opportunities			e.g. Liquidity requirements limit long-term investments (e.g. Solvency II)	e.g. Lack of knowledge in infrastructure
Sovereign wealth funds		e.g., Fund prohibitions from investing in infrastructure		e.g. Uncertainty with asset performance in new technology	e.g. Numerous small projects mismatched with large capex strategy	e.g. No clear partner strategy in unfamiliar emerging markets

Source: Modified from Floater et al. (2017a).

4. Financing Low-Carbon, Climate-Resilient Cities Connecting supply and demand to deliver sustainable urban development

4.1. Financing and funding instruments

This section explores financing and funding mechanisms available to national and local governments. Some of these will be used routinely as part of a government's revenue-raising and steering efforts; others may be deployed to mobilise the investment for a specific project or sector.

There are a few broad categories of financing instruments. Governments have a **funding base** of taxes, charges, fees and other revenues, and can additionally use **asset-based instruments** to secure private finance. **Equity** involves contributing resources in return for a share in the ownership of a project. This typically means that the completed project must be operated as a company of some sort so that the equity can be placed. **Debt** involves contributing resources in return for repayment, typically on an agreed schedule with interest. Public financing entities may use **grants** or **risk mitigation instruments** to reduce the costs or perceived risks to private investors. Specific instruments within each of these categories are listed in Table 3.

Table 3. Possible financing and funding mechanisms available to leverage finance from different sources.

SOURCES OF FINANCE: / INSTRUMENT:	Internal	External	
	Domestic public finance	International public finance	Private finance
- Relevant institutions	- National governments - National development banks - Municipal development funds - Subnational governments	- Multilateral development banks - Bilateral development agencies	- Commercial banks and investment companies - Developers and infrastructure operators - Private equity and infrastructure funds - Pension funds - Sovereign wealth funds - Philanthropic foundations
- Funding base	- Intergovernmental fiscal transfers		- Property taxes - Betterment levies or value capture taxes - Tax increment financing
- Asset-based instruments	- Sale of land - Lease of public land assets - Sale of development rights		- Fees, tariffs and charges - In-kind contributions
- Debt	- Specific purpose concessional loans	- Loans - Concessional loans - Subordinated debt and mezzanine loans - Sukuk and Sharia compliant finance	- Bank loans (including syndicated bank loans) - Subordinated debt and mezzanine loans - Project bonds - General obligation bonds - Sukuk and Sharia compliant finance - Securitisation and asset- backed securities - Crowdfunding
- Equity	- Public-private partnerships - Project equity - Yieldcos		- Public-private partnerships - Project equity - Listed infrastructure corporates and funds - Preferred shares - Yieldcos - Trusts - Co-investment platforms
- Grants	- Specific purpose grants	- Grants	- Philanthropic grants
- Risk mitigation instruments	- Credit guarantee - Credit insurance	- Credit guarantee - Credit insurance	- Business insurance - Credit insurance

Source: Authors

There is scope to use or adapt many of these financing instruments for specifically green or climate purposes. In debt-based financing, for example, the total value of `green bonds' reached US$156.7 billion in 2017 (Climate Bonds Initiative, 2018). Such green bonds may be tied to specific, environmentally positive projects such as public transport, renewable energy or solid waste management. Alternatively, governments may issue general obligation green bonds (as the cities of Johannesburg, Mexico City and Ottawa have done) to raise finance for environmental projects without clear revenue streams, including adaptation initiatives. Similarly, fees, taxes and charges may be designed to steer investment towards climate- compatible forms of urban development. Carbon pricing is arguably the most economically efficient way to accelerate a low-carbon transition (Stiglitz et al., 2017). Otherwise, the design of land/property taxes or additional interventions such as congestion pricing can be used to incentivise more carbon-efficient modes of urban growth. Development financing institutions already widely use risk mitigation instruments and grants to crowd in private investment for low-carbon infrastructure projects, but this could be accelerated and scaled (Bhattacharya et al., 2016). Out of the diversity of mechanisms set out in Table 3, some have particular promise to support investment in sustainable urban infrastructure at scale (Floater et al., 2017a).

Pricing, regulation and standards can drive investments into sustainable urban infrastructure. Economic efficiency points to the advantages of a common global carbon price, with emissions reductions taking place wherever the marginal costs are lowest (Stern, 2006). By 2017, 42 national and 25 subnational jurisdictions were pricing carbon (Stiglitz et al., 2017). In the absence of a carbon price or where additional externalities must be considered (such as air pollution or technological learning), additional pricing schemes can further spur investment. For example, incentives for electric cars and rooftop photovoltaic panels have played a major role in growing those markets in China and Europe.

Regulatory measures are particularly powerful for creating a shift from infrastructure investment that locks in high-carbon pathways to new green technologies in the urban economy. Policies regarding the entry, treatment and protection of different investors are important to create an enabling environment, but financial regulation can go further to encourage or mandate investment in green projects. Governments can also regulate developers and operators (such as utilities) to preferentially invest in climate-compatible options. Renewable energy portfolio standards, for instance, can mandate that utilities provide a certain fraction of renewable energy, which increases investors' certainty about the size and value of future markets. Minimum energy performance standards or voluntary labelling codes for appliances, buildings, lighting and vehicles can encourage businesses and households to choose more efficient options.

Governments can:

- Create efficient and effective regulatory frameworks and standards that steer investment into sustainable infrastructure projects and investments. This is particularly important in sectors characterised by small investment sizes and where consumer choices are key investment drivers, such as energy efficiency, distributed energy, non-motorised and electric mobility, shared mobility, and green buildings.

- Work with commercial banks, banking regulators, and capital market authorities on green finance voluntary practices and mandatory measures, including new market and finance product development, environmental impact reporting, and green secondary market rules.

- Establish pricing systems (whether negative pricing, such as emission trading schemes, or positive pricing, such as feed-in tariffs) to steer investment into sustainable infrastructure investments. Again, this is particularly important in sectors where firm and household choices are key investment drivers, or where sustainable infrastructure options have higher costs than conventional options without government intervention.

Debt financing is an important tool for raising upfront capital to finance sustainable urban infrastructure. Debt capital can be raised in the form of a bank loan, syndicated loans (with multiple lenders) or bonds. In most countries, bank lending tends to predominate early in a city's financial development with bond transactions emerging later (although bank lending will likely persist to cater to different elements of the market). This trend is explained by the generally lower transaction costs and complexity associated with bank lending compared to bonds. Loans can be further differentiated between short-term `project finance' used to pay the cost of project construction, and longer-term `permanent finance' used to support assets during their operational life. Permanent finance typically has lower interest rates as the risks are more predictable than for project finance. Labelling and standards can also ensure that debt finance is used for green investments, which are typically cost-effective for the issuer (Ernst and Young, 2016).

Debt financing may be secured at the national or city level. As a prerequisite to debt financing, governments need budgetary, accounting and financial management capabilities and sufficient sources of funding for making repayments. This is a major constraint for urban infrastructure in low-income countries, where users may be unwilling or unable to pay high enough charges to allow full cost recovery plus a return on investment (Bielenberg et al., 2016). Asset-backed securities can also help to reduce risk for private and institutional investors, but could shift liabilities to central government. Even when a city has achieved an investment- grade credit rating, sound financial management is essential to minimise the risk of future default and to provide headroom for future investments while debt repayments of older projects are still ongoing. In the absence of fiscal decentralisation or as a complement to municipal debt financing, creditworthy national governments can collaborate with cities to identify investment priorities and structure bankable projects or national bond issues to support them.

Governments can facilitate debt financing by:

- Reforming national regulations to allow local borrowing and clarify the conditions for bank lending or bond issuance. This could include liberalising regulations dictating whether cities (and/or utilities) can borrow and how much, borrowing procedures, whether they can borrow in a group, what currencies they can borrow in, the type of collateral that they may pledge to secure borrowing, and action in cases of default.

- Building the capacity of subnational governments to improve budgetary planning, accounting and financial management in local governments. This can reduce the costs of borrowing either through bank lending or bond issuance. They could also help to build local governments' experience with borrowing through joint projects or credit guarantees.

- Developing project pipelines, either via national borrowing or with support for project preparation. This could include the use of pooling instruments to aggregate similar small projects, for example through a national fund for energy efficiency, decentralised renewable and other same-type infrastructure investments across secondary and tertiary cities.

- Participating in programmes focused on enhancing (municipal) creditworthiness, e.g. those run by Climate KIC and the World Bank. They could also promote standards and labelling to encourage preferential issuance of green bonds at both national and subnational level.

Land value capture (LVC) includes a range of instruments by which the public sector can capture a proportion of rising land prices to fund large urban infrastructure projects. Investments in water, sanitation and transport infrastructure can lead to increased land and property values nearby. This uplift in value can be used as a source of revenue. At the same time, land-based financing can be used to drive more compact urban development.

The effectiveness of LVC can be increased where governments integrate spatial planning policies and infrastructure investment strategies. This can underpin nodes and corridors of managed urban growth, enhancing land values within close proximity. A transparent land and property market and an effective tax system can further enhance the efficacy of land value capture approaches. National governments can provide strong regulatory frameworks and guarantees that enable municipalities to capture land value uplifts, though cities will need significant technical capacities for successful implementation. Where land is owned by national agencies (as in China or Ethiopia), they can directly influence or capture the gain related to land sales or ground leases.

Governments can facilitate wider deployment of LVC instruments through:

- Developing national LVC regulatory frameworks that outline whether cities can sell and trade development rights, land leasing systems and the rules governing rights exchanges. They could additionally create best practice guidance for local co- investment based on local-level LVC.

- Coordinating spatial plans and infrastructure strategies across different scales, and align them with LVC mechanisms.

- Investing in more efficient property markets, for example by systematising valuation practices, registration and titling, and introducing transparent transaction registries. This also creates opportunities to improve public land and built asset registries and condition assessments to determine where there is investment potential and uncaptured value in government holdings.

- Multi-level collaboration to identify projects suited to LVC (recognising there are several specific LVC instruments available with different finance raising/repayment characteristics) and identify bridge financing sources (for example, concessional finance from development finance institutions) if needed so that projects can be initiated in advance of LVC revenue flows.

Public-private partnerships (PPPs) are contracts which allocate risks between public and private entities, and often play a role where governments face technical, institutional and financial constraints (UNCTAD, 2013). There are many forms of PPP, but their potential is typically limited to projects that involve commercial returns on revenue-generating assets. Energy and road infrastructure projects have attracted the vast majority of global PPP finance, subject to market regulations and thanks to clear income streams from these assets (ibid.).

PPPs are complex structures. Asymmetric information between levels of government, and between the public and private partners, can lead to rent-seeking behaviour. Without tight monitoring and public expenditure management, PPPs can effectively create hidden liabilities for government agencies. Therefore, PPPs are a particularly important instrument in middle and high income countries with mature financial systems, as the effectiveness of this mechanism depends heavily on appropriate project identification, structuring, contractual arrangements and government capacity.

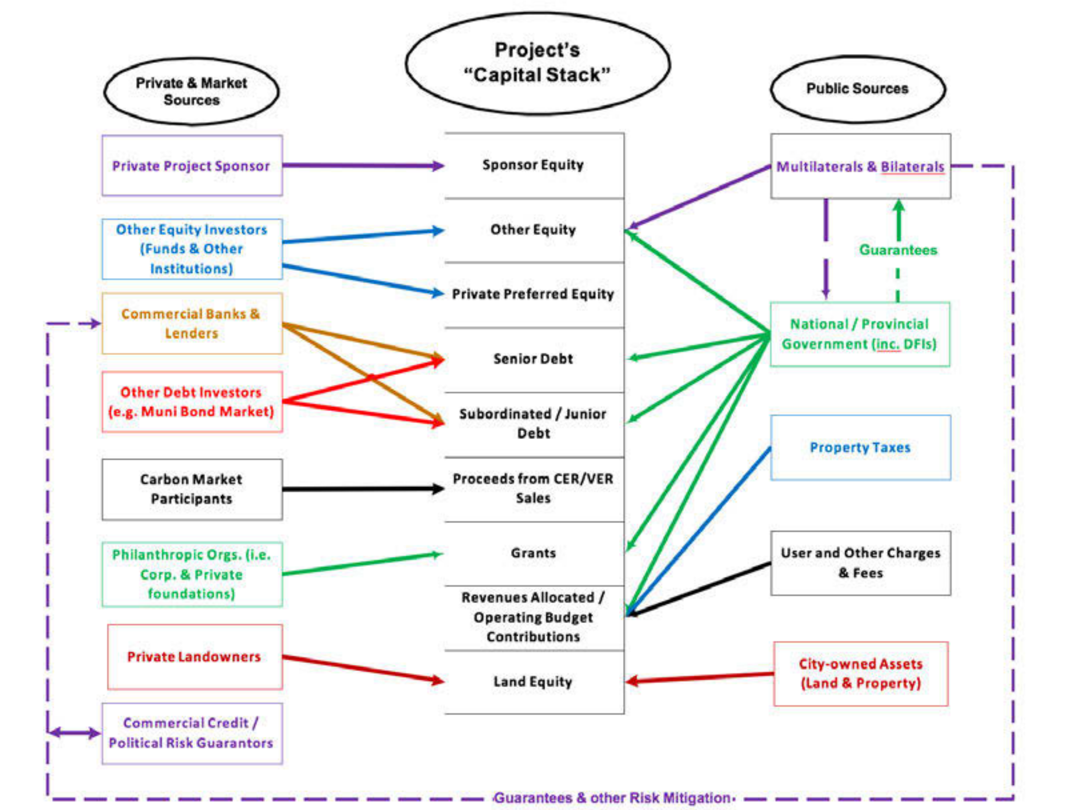
Governments can enable greater use of PPPs through:

- Evaluating the asset types and prospective investments that are suited to PPPs and contribute to sustainable urban form and infrastructure development. This can be used to prepare a long list of feasible pilot or exemplar projects.
- Establishing regulation and legislation outlining the ability of cities/utilities to enter into PPP transactions, and detailing the corporate framework for entities which may be established to do so, the way in which tariffs are set, and the mandate of regulatory oversight processes and agencies.
- Establishing national PPP units that can support project preparation and tendering, drawing on international technical assistance as required to ensure the feasibility, accountability, transparency and competitiveness of the process.

4.2. Developing financially-viable climate-positive projects

Central and city governments often have to deploy a range of instruments to accumulate different sources of finance to develop, construct and operate a project. This can be depicted as the `capital stack' (Figure 3).

Figure 3. Illustrative capital stack showing how different sources of finance can be combined by deploying a range of instruments. Sources of private finance are on the left and public finance on the right. Each of these prospective investors will have different risk/return profiles. A range of financing instruments is therefore deployed, each with different terms and conditions to suit a particular investor type.



Source: Authors

In the near term, there is scope for a rapid growth in climate-positive infrastructure investment by strengthening the project development and structuring systems in public and private institutions, and by building their familiarity with urban and climate opportunities. Focusing attention on these issues could enable national and local governments to develop pipelines of viable, bankable climate-focused investments to realise some mitigation potential and build some adaptive capacity immediately. Prioritised programmes and projects should be designed to meet both sectoral and climate objectives.

On the demand side, there is a lack of organisational structures that can address the unique challenges of climate investments set out in Chapter 2. There is a need to develop robust implementing entities capable of structuring projects to suit the diverse risk appetites, time horizons and expectations of returns of prospective investors. Such projects must have sufficient bankability, or such entities must have sufficient creditworthiness, to attract affordable capital. This might require the establishment of special purpose vehicles with segregated funding and accounting that are able to undertake long-term contracts, particularly to mobilise finance for cities in low- and lower middle-income countries. For maximum cost-effectiveness, these implementing entities must also be able to utilise and combine a wide range of financing and funding models. This will require the development of the skills base of local governments, and of their counterpart national and regional agencies. In many cases, it also implies the need for a review of intergovernmental fiscal relations, revenue raising powers and cost-sharing arrangements.

On the one hand, such entities benefit from clarity and specificity regarding governance arrangements. National, regional, metropolitan and local level plans need to be mutually consistent and fully legitimate from the perspective of all stakeholders, and with sufficient base information to enable the efficient development of concept designs. The responsibilities of different sectoral agencies and levels of government also need to be clear and agreed so that there is neither overlap nor gap in implementation of an agreed urban climate investment plan. On the other hand, implementing entities benefit from flexible planning and implementation mandates rather than detailed, technical prescriptions of projects. A performance-based approach to financing (and indeed, other aspects of designing and implementing urban infrastructure projects) offers space for efficiencies and innovations.

These implementing entities need to be able to administer project design and procurement processes that can leverage private sector resources, and encourage good quality bids offering value for money. A deeper understanding of how available finance sources can suit different projects and markets can create better targeting between investment needs and capital resource. For example, private equity and infrastructure funds seek the greatest return and will make equity investments in projects with strong growth potential. These funds are often willing to invest in relatively new or unproven markets and technologies. In contrast, pension funds and insurance companies search for investments that provide predictable income streams to meet long-term obligations, such as pensions or insurance claims.

It is also important to recognise that structuring projects to appeal to private investors is a rigorous process, and resulting structures can be more complicated than purely public financing. While the private sector can bring important technical and managerial capabilities as well as finance, there is a need for effective public oversight to balance social and private returns.

Important characteristics of the project development processes include:

- Concept development should be done in the context of a comprehensive assessment of how a prospective project will contribute to human and economic development goals.

- Pre-feasibility assessments should identify and evaluate a range of financing/funding options against a range of criteria, including climate implications.

- Bid processes should be efficient and effective, ensuring competition but allowing for physical and financial innovation in order to meet both sector and climate objectives. Calls to tender should recognise that the owners of private capital or their fund managers will seek the highest returns commensurate with risk and other investment objectives, and structure investment opportunities so as to be attractive in a competitive market.

- Bid assessments should be transparent and based on pre-defined criteria. These criteria should incentivise projects that minimise life-cycle costs (rather than just initial investment costs) and that encourage private and community participation. This can both leverage funding from non-government sources and increase public acceptance of climate-related projects.

- Projects must offer options for appropriate consideration of changes in ownership and financing structures after construction has been completed. Equity and debt investors often require some level of liquidity, and therefore need ways to withdraw or recover their money (for example, through property sales).

5. Financial institutional structures

5.1. Conceptualising urban finance readiness

Governments need to raise sufficient resources or improve the efficacy of expenditure sufficiently to fill the urban infrastructure financing gap. Their capacity to do so can be understood as their urban finance readiness, a concept initially introduced in *Financing the Urban Transition: Policymakers' Summary* (Floater et al., 2017b).

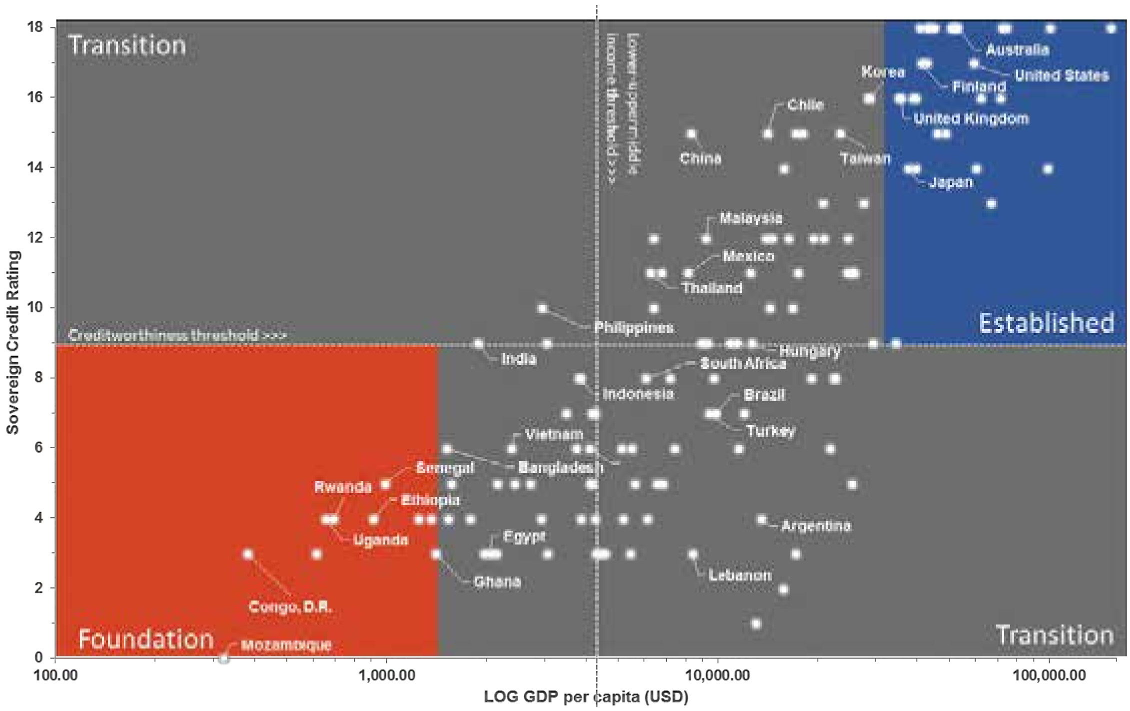
High-income countries are likely to have sophisticated financial capabilities, which allow them to deploy a range of financing instruments. Central and sometimes subnational governments are likely to have well-developed land and property registries to enable land-based financing; investment-grade credit ratings to enable access to affordable debt finance; and effective contracting and procurement processes to enable the structuring of public-private partnerships. Appropriately designed mechanisms can both expand public budgets and secure or steer private investment. Additionally, given high levels of income per capita, infrastructure such as renewable energy production and distribution, water networks and building developments can generate consumer revenue streams that incentivise private investors to purchase equity as a long-term investment. The binding constraint in high-income countries is therefore not the supply of finance, but the coherence and effectiveness of demand-side institutions.

In contrast, many low- and middle-income countries face severe constraints to accessing finance. Low per capita incomes can limit the levels at which government can mobilise urban investment (although China is an obvious exception). Lower incomes mean lower tax revenues and less ability to pay user fees and charges at a level that provides a sufficient profit margin for investors (even for potentially revenue generating assets such as electricity and water supplies) (Bielenberg et al., 2016). This means that governments have less scope to use public finance and public services to leverage private investment.

However, levels of urban finance readiness are not just a function of per capita incomes. Institutional weaknesses on both the demand and supply side may mean that governments are less capable of raising and steering finance towards sustainable infrastructure options. Institutional weaknesses may manifest as imperfect information; politicised decision making; corruption; lack of clarity or certainty around regulatory and legislative frameworks; poorly functioning land and property markets; poor collection and management of own-source revenue; or weak project management and technical capabilities. These conditions contribute to perceived and actual risks that may deter commercial and institutional investors. To illustrate, a one to two per cent reduction in financing costs could be achieved through greater policy predictability, and could be worth up to US$100 billion per year (Bhattacharya et al., 2015). Thus, in low- and middle-income countries, both the demand and supply sides of the urban finance market are often constrained. It follows that poorer countries and cities are less likely to have access to the same range of financing mechanisms that are available to wealthy nations and cities.

Credit ratings can be a useful proxy for a government's financial readiness. Credit ratings of countries (and the cities within them) capture some important aspects of urban finance readiness, such as the availability, diversity and reliability of revenue sources, debt levels and management of public finances. The concept of urban finance readiness is illustrated in Figure 3 (Floater et al., 2017b), which shows that sovereign credit ratings correspond to average levels of income. However, outliers such as the Philippines or Thailand have achieved a sovereign credit rating that is much higher than might be predicted based on their per capita GDP. This is due to better institutional performance across at least some of the factors that influence credit ratings.

Figure 4. The relationship between average per capita GDP and sovereign credit ratings (as graded by Standard and Poor's) in selected countries. Many countries have clearly developed good financial management capabilities relative to their levels of economic development, and therefore have greater capacity to raise and steer finance for climate-compatible urban infrastructure. The foundation, transition and established stages are defined by three thresholds: the cut-off between investment grade and `junk' credit ratings (BBB-); and the lower and upper bounds of the World Bank middle-income band (US$1,025 to US$12,475 per capita).



Source: Floater et al. (2017b).

The legal and regulatory environment, particularly at the national scale, is arguably an especially important determinant of levels of urban finance readiness. National policies comprise the `rules of the game' that guide both supply and demand aspects of urban finance. For example, national governments may impose lending caps that limit commercial investment in certain asset classes or liquidity mandates to ensure that banks can meet short- term customer obligations. These regulations may change the attractiveness of different types of investments.[1] Policy and regulatory certainty is also important, as this affects perceptions of risk. Investors in large-scale, longer-term capital projects demand certainty about the legal basis of regulatory regimes, their ability to be amended, a country's track record of adjusting or replacing legislation and whether this is planned and transparent, and the impact of a change of political party in government (BNEF et al., 2016).

Although national policies are of primary importance, the quality of subnational institutions is also important and may vary within countries. Capitals and financial centres often perform better than smaller cities, leading to asymmetric quality of infrastructure and access to public services.

Urban finance readiness is therefore determined by the quality of the institutions that determine the amount and sources of finance and funding that might be available to governments. Those with greater capabilities not only have more public finance to invest, but also greater scope to crowd in finance by creating an enabling environment for private investment and structuring specific projects in a way that is commercially attractive. Further, the above analysis suggests that cities and countries do not need substantial increases in per capita incomes to improve their urban finance readiness. Key opportunities include (Bhattacharya et al., 2016):

1. **Strengthening fiscal and financial systems.** In particular:
   a. *Expanding the fiscal space through tax and expenditure measures.* Both central and subnational governments have scope to improve their revenue

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[1] Although introduced for legitimate reasons, lending caps and liquidity mandates may create a mismatch between investor needs and investment opportunities. The impact on the supply of finance is significant for infrastructure projects, which are typically long term and relatively illiquid. The mismatch is most pronounced in countries with shallow capital markets and chronic balance of payments constraints.

structures, rationalise spending and tackle tax avoidance and evasion. This offers greater scope to use government balance sheets to directly finance investment, as well as improving access to debt financing while lowering its cost.

   b. *Tackling gaps in the availability and costs of long-term finance.* Infrastructure investments offer steady long-term returns and opportunities for risk diversification across sector and countries. This should be attractive to institutional investors, if governments can support the development of bank lending and markets for bonds, equity, and asset-backed securities.

2. **Providing a stable policy environment and strengthening investment frameworks.** In particular:
   a. *Clarifying and reforming regulation.* Creating an enabling policy environment for infrastructure investors can reduce myriad risks and transaction costs, allowing both public and private sector organisations to develop a pipeline of viable investment projects. On the supply side, for instance, governments can reform investment limits, capital adequacy, reserve requirements, the valuation of assets and liabilities, and limits on foreign investment to encourage investors to make longer-term and cross-border investments.
   b. *Developing national and city-scale urban infrastructure strategies and plans.* Infrastructure strategies should be used to develop a clear pipeline of projects on the demand side, with lead agencies clearly identified. These projects should include coherent financing and funding strategies, and have transparent tendering processes. Infrastructure strategies should be closely integrated with spatial plans and align with NDCs.

3. **Improving project development and implementation systems.** In particular:
   a. *Clarifying agency mandates and funding sources.* Agencies need appropriate mandates and resources to design, finance, implement and operate urban infrastructure. National governments need to clearly articulate who is responsible for specific types of projects and activities, and provide those agencies with sufficient resources and capacities. The ability to plan and undertake long-term contracts is particularly important for cost-effective financing. Where investments are multi-sectoral, lead agencies should be clearly identified and appropriate mechanisms for consultation and collaboration must be established.
   b. *Supporting project preparation activities.* Many public bodies struggle to structure projects in a way that satisfies the criteria of prospective financiers, whether central line ministries or private investors. National governments and international agencies can provide dedicated support for project preparation to overcome this barrier, particularly for new or complex financial instruments. There are many PPP units around the world, for example, that specifically support the design and procurement of PPPs.

In summary, more functional and cohesive urban finance systems will be necessary if government agencies are to mobilise the additional resources necessary to fill the infrastructure financing gap. Directing finance towards climate-positive investments will prove a related but additional challenge, as outlined in the next section.

5.2. Mainstreaming climate considerations into urban finance systems

The urban climate literature widely recognises the need for transformational change towards climate-positive forms of development. This will require fundamental reforms to urban finance systems to make good practice ubiquitous, and to improve on good practice. The reform priorities can be grouped according to the three opportunities identified in Section 5.1.

5.2.1. Fiscal and finance systems

Governments can mainstream climate goals into fiscal and financial systems. Effective enabling legislation, targeting criteria, and monitoring, reporting and validation systems can help to embed climate considerations into private and public financial decision making. Few countries have established coherent policies in this area, although China offers an example (The People's Bank of China et al., 2016).

As a first step, governments should seek to eliminate pervasive fossil fuel subsidies and adopt carbon pricing. Pricing climate-related externalities appropriately offers huge potential for additional public and private revenues that could be used more appropriately, including to fill the financing gap for sustainable infrastructure. The IMF estimates that fossil fuel subsidies cost US$5.3 trillion in 2015, or 6.5 per cent of global GDP (Coady et al., 2015). There is progress on this front; more than 30 countries have reduced or phased out fossil fuel subsidies since 2013. However, there is a need for further reform to address implicit subsidies (for example, for extraction of fossil fuels). Where national governments have failed to act, many cities and regions have adopted carbon pricing at subnational scales.

Financial systems further need to address the three ways in which climate change creates financial risk: **physical risk** whereby climate impacts such as sea level rise and more severe storms damage property and disrupt trade; **liability risks** whereby parties who have suffered loss and damage seek compensation from those that they hold responsible; and **transition risks** whereby structural adjustment to a low-carbon economy results in repricing of assets and commodities (Farid et al., 2016). Accounting for such risk should shift investment away from sectors and projects where risks are highest and into sustainable infrastructure options. To be effective, accounting for climate risks needs to be done by all relevant actors, including financial intermediaries such as banks, securities markets and institutional investors, as well as by those actors and institutions regulating financial markets, including credit ratings agencies, regulatory and supervisory bodies and central banks (Bhattacharya, 2016).

Looking beyond urban infrastructure projects, public procurement (the purchase of goods and services by government) accounts for a substantial share of Gross Domestic Product. Greening public procurement can demonstrate demand for more sustainable goods and services, creating an incentive for prospective suppliers to build key capabilities and innovate in this space. Governments can introduce environmental standards into technical specifications, procurement selection and award criteria, and contract performance clauses. Establishing green procurement processes requires ongoing consultation with stakeholders and suppliers to assess available green solutions; it may also require manuals, training and guidance to professionalise public sector procurement strategies (OECD, 2015).

The urban finance architecture can also reduce systemic vulnerability to risk (including climate risk) if it creates space for low-income and other marginalised groups to influence the allocation of public resources and governance of private investment. Proven models exist. For example, in Southeast Asian cities, city development funds have facilitated collaborative decision making by grassroots organisations of the urban poor, local authorities and private landowners (Boonyabancha and Kerr, 2018). In Latin American cities, participatory budgeting has proven capable of improving citizen-state linkages so that public resources are allocated in ways that address the priorities of low-income groups (Cabannes and Lipietz, 2018). These structures provide a conduit for information between local government and residents, which is an important way of building adaptive capacity (Williams et al., 2015). In both cases, relatively small-scale financial systems have ensured that an increased share of public funds are allocated in ways that reduce the vulnerability of urban residents, as well as creating a platform for low-income groups to collaborate and negotiate with public agencies on issues such as tenure security, infrastructure provision and regulatory reform (Archer et al., 2014). These efforts in turn shape wider patterns of investment and development at the city scale.

5.2.2. Policy and planning systems

Policy frameworks, urban plans and infrastructure strategies should clearly direct investment towards climate-compatible forms of development. Tax policies and urban plans, for example, might promote sprawling patterns of urban growth through single land-use zoning or tax incentives for single-family dwellings and private cars (Godfrey and Zhao, 2016). This mode of development is less carbon efficient than urban forms with higher density, mixed land use and better connectivity or accessibility (Seto et al., 2014). There is therefore a need for coordinated multi-level governance (across national, regional and city governments) and horizontal policy integration to effectively support the planning, implementing and financing climate-positive investments within sustainable urban forms. Urban plans and infrastructure strategies should articulate a coherent vision that is fully sustainable, whereby planned investments minimise greenhouse gas emissions and take into account projected climate conditions. For maximum effectiveness and legitimacy, such plans and strategies must also respond to other local priorities, such as access to affordable housing and air quality.

Careful design of policy instruments may also help to address non-pricing barriers that constrain investment. Effective project packaging and structuring (see Chapter 4.2) can help to improve incentive structures to attract private finance. However, this will not resolve problems such as imperfect information, split incentives, inadequate access to finance, capacity deficits and industry fragmentation (IEA, 2013b). Political economy barriers may prove even more significant, such as opposition from local industries (Cragg et al., 2013; Jenkins, 2014). Such factors may manifest as financial hurdles, but they cannot necessarily be overcome through pricing mechanisms. To mainstream climate considerations across all urban investment, there is a need to design policy instruments that specifically tackle these non-financial obstacles. Such policies will need to be tailored to the local institutional, legal, economic and cultural context, and to target a range of prospective investors including households, small and medium enterprises, commercial banks and local authorities (Colenbrander et al., 2017).

In low- and middle-income countries, international public finance could better support the development of an enabling environment for financing climate action in cities, for example through the design of climate-sensitive policy frameworks and participatory institutional structures. It could be used to build local capacities to deliver climate-compatible urban infrastructure, for example by training urban planners, architects and construction workers in the design of carbon-neutral buildings. It could also be used to support early entrants to climate-positive markets (for example, in renewable energy technologies or energy-efficient appliances) and reduce barriers to subsequent investors, developers and financial intermediaries. Lastly, public finance could be systematically used to crowd in private investment by reducing project risk through (for example) the use of subordinated debt or guarantees (Sierra, 2011).

5.2.3. Project development, structuring and implementation

Cities do not typically function as investment vehicles; climate-relevant urban projects may be the provenance of multiple levels of government, multiple sectoral agencies and multiple local jurisdictions. Coherent green infrastructure projects require coordination across these demand-side entities to identify and manage environmental externalities. The lead agency or investment vehicle can adopt project appraisal and valuation systems that systematically capture environmental externalities, and apply rigorous and consistent environmental safeguards to planned investments (Qureshi, 2016). Optimising a project design across multiple criteria typically requires a professional and multidisciplinary team with legal, technical, scientific and financial expertise.

When selecting or designing infrastructure projects, it is important that agencies assess value for money over an asset's life cycle. This can be difficult with new technologies and systems, as lack of data on financial and risk performance complicates evaluation. Additionally, rapid rates of technological change can make historical performance data outdated (Bielenberg et al., 2016). Where data are available, two factors that can affect this lifecycle analysis are the choice of shadow carbon price and discount rate. The shadow carbon price should theoretically approximate the social cost of greenhouse gas emissions, although some analyses suggest that this would require investment in all technically feasible mitigation potentials (Ackerman and Stanton, 2012). The choice of discount rate should reflect public perceptions of distributive justice over generations, as the benefits of low-carbon, climate-resilient infrastructure will largely be felt in the long term (Dasgupta, 2008). One option is to use a declining discount rate for larger projects with longer lifespans, as adopted in the United Kingdom (Guo et al., 2006).

Multilateral development banks could play a catalytic role by pioneering new sustainable infrastructure investments. However, they will likely need to make changes to strengthen their individual and collective roles and garner deeper support from shareholders and private actors. Possible measures include: (i) increases in paid-in capital; (ii) increases in callable capital; (iii) greater flexibility in using balance sheets, including securitising existing loans, exchange of assets and standardising/scaling the green bond market; (iv) more effective use of guarantee instruments, including creating or supporting new investment vehicles; and (v) more effective targeting of blended finance instruments, especially for low-income countries (Bhattacharya et al., 2015).

6. Research priorities

1. **Strengthening the economic and financial case for climate-compatible urban development from the perspective of a range of different actors (including diverse investors).**
   A detailed economic and financial case for low-carbon, climate-resilient cities can change the political economies of decision making and galvanise a range of critical actors, including Ministries of Finance, development banks, commercial banks and investment companies. The limitations and gaps in this evidence base are clearly documented (Gouldson et al., 2018). In particular, there is a paucity of research on smaller cities in low- and lower-middle income countries; indeed, there is a paucity of financial data to enable better decision making. There is therefore a need to strengthen the economic and financial case for climate action. Where possible, research should identify synergies between climate action and local priorities (such as air quality, congestion or job creation) in order to build political and public buy-in.

2. **Understanding the spatial allocation of productive assets, households and jobs relative to climate risk.**
   Different urban neighbourhoods and different cities vary in their exposure to diverse climate impacts, including extreme temperatures, flooding, sea level rise and storms. Understanding the value of productive assets, homes and jobs that are at risk can help make the case for climate action to decision makers. Micro-level spatial analysis is important to engage specific companies and agencies, while the aggregated conclusions can help to make the macroeconomic case for investment in mitigation or adaptation.

   Access to local climate projections is also important for prospective investors so that they can minimise exposure to future risk. Climate funds also require this information as a precondition for disbursing adaptation finance. There is therefore a need for detailed, locally specific projections of future climate risk at the neighbourhood level or lower. This information should be prepared and published in ways that are accessible and meaningful to different users, ranging from large public tenders (e.g. for transport infrastructure) to private developers (e.g. for new commercial buildings) to grassroots organisations (e.g. for slum upgrading).

3. **Identifying the components of urban finance readiness, and activities or reforms that can enhance the readiness of different departments and agencies.**
One of the primary barriers to climate action in many cities is lack of finance. There is therefore a need to address fundamental weaknesses in urban finance systems. Many public agencies are experimenting with fiscal and planning processes, regulatory and legislative frameworks and institutional arrangements to strengthen urban finance systems and mainstream climate considerations into planning and investment. Many of these initiatives have not been documented in detail, let alone rigorously evaluated beyond narrow financial metrics. A comprehensive collection of comparative and longitudinal studies focused on demand-side institutions (rather than project finance) could inform the development of integrated, extensive investment programmes that systematically mobilise and direct finance. One example is the recent analysis of sub-national project preparation facilities in Asia and Latin America, published by the Cities Climate Finance Leadership Alliance (Oberholzer et al., 2018).

4. **Assessing the different ways that climate goals can be mainstreamed into urban finance systems on both the supply and demand side.**
Increasing levels of urban finance is no guarantee that cities will transition to lower-carbon or more climate-resilient paths. Policy and regulatory reforms will be required to break organisational lock-in and steer investment towards climate-compatible options. Researchers can generate the evidence base necessary for national and local governments to design urban climate frameworks that take advantage of synergetic effects and improve policy coherence; avoid blind spots, inefficient duplication and redundancy; overcome poor sequencing; enhance social learning; and escape institutional inertia and enable innovation (Rode et al., 2017). Nor will not be sufficient to merely improve financial returns through – for example – carbon pricing. Policies must mandate sustainability criteria into all investments, or be designed to tackle non-financial obstacles to climate-positive investment, such as capacity deficits or split incentives. The reforms and activities required to embed climate considerations into financial decision making will vary among countries, so there is a need for local political and policy analysis.

5. **Assessing the different ways that urban financial systems could enhance inclusion and equity, and thereby reduce vulnerability to climate change.**
Vulnerability to climate change is not just a function of increased exposure to environmental risks, but also of existing social, economic and political processes (Khan and Roberts, 2013). Adaptation must therefore involve engagement with the drivers of vulnerability: exclusion, marginalisation and inequality. The financial architecture can serve to perpetuate exclusion; for example where banks require a formal address to open an account; or facilitate inclusion, for example where a proportion of public budgets is allocated through participatory processes. There is a need for further research on financial inclusion (going beyond just access to savings and credit, although these are important) and the implications for urban resilience.

6. **Determining best practice in engaging private actors in sustainable urban infrastructure projects of different kinds, and articulating the conditions or contingencies for success.**
There is a growing number of low-carbon and/or climate-resilient projects around the world, including in cities in the global South. This creates opportunities to understand what financing sources and instruments are appropriate for different project types to more efficiently match demand for, and supply of, urban finance. There is a particular need to understand how to stimulate private sector participation in these projects, and the conditions and contingencies for accountable, effective collaborations. As outlined above, neither domestic nor international public finance is sufficient to fill the investment gap. There is therefore a need to raise and steer private finance, but also to balance social and private returns. Future research could evaluate project approaches and outcomes in individual sectors (e.g. renewable power generation, public transport), by particular institutions (e.g. utilities or commercial banks), or with specific financial instruments (e.g. land value capture or public-private partnerships).

7. **Evaluating the best actors and mechanisms to best support learning, replication and scaling on both the supply and demand side.**
A huge range of low-carbon and climate-resilient urban projects have been financed successfully, but have not achieved scale. There is therefore a need for horizontal replication (the reproduction of proven approaches through multiple, small initiatives) and/or vertical mainstreaming (integrating proven approaches into dominant institutional policy and practice) (Pelling, 2011). Future research could usefully evaluate how learning can be disseminated among and within both supply- and demand-side institutions: for example, the relative importance of individual change agents; formal training, shadow networks; or reforming decision-making processes. Where organisations are primarily dedicated to such knowledge sharing (for example, city networks), there is greater scope to document and evaluate different strategies to enable other organisations to emulate best practice.

8. **Accounting for flows of climate finance and improving the use of international public finance to achieve paradigm shifting potential.**
Accounting for climate finance flows is difficult and often contested. There is a need for clear methodologies to estimate the scale of: (a) domestic public climate expenditure; (b) private investments in mitigation, especially relating to energy efficiency, transport and land use; and (c) adaptation finance, particularly private and domestic public investments (Buchner et al., 2017).

Because international climate finance is ultimately limited, it must be used to catalyse transformative change. The GCF articulates its role as supporting "a paradigm shift to low- emission and climate-resilient development". There is a need for detailed empirical research to understand how climate and development finance can systemically change the way that other investment is allocated. This might involve measures to increase local ownership, improve economic competitiveness, facilitate knowledge and learning, create an enabling investment environment, or develop critical capabilities to allow deployment and scaling of climate-compatible options.

Air pollution by smoke coming out of factory © Shutterstock

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Commissioned Paper

4

Urban Climate Change Science, Impacts and Vulnerabilities: State-of-the-Art Findings and Key Research Gaps

Summary

A climate change signal is now embedded in the everyday weather of cities and their long-term climate trends. A central question is what are the interactions between climate change, urban climate, and urban areas, e.g. local precipitation patterns, heat waves and more complex interactions with urban heat islands?

Urban systems are highly interconnected, and increasing climate extremes can lead to cascading failures. Climate change interacts with ongoing and often pervasive environmental stresses and threats found in urban environments, most significantly between ongoing air quality challenges in urban and climate change contexts.

Vulnerability reflects exposure and adaptive capacity when facing extreme events and climate disasters and risks, as well as more systemic risk contexts where climate vulnerabilities intersect with ongoing social and economic inequities. Topics related to key climate change vulnerabilities are disasters and risk, equity and environmental justice, and the health of urban populations.

The research-practitioner community has entered into a period of rapid data availability and needs growth as well as data and information translation and application needs.

Authors:

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The IPCC has expressed interest in learning about the intersections between climate change science, impacts and vulnerabilities with a specific focus on state-of-the-art conditions and key research gaps. In response, the goals of this commissioned paper of the IPCC Conference on Cities and Climate Change Scientific Steering Committee are to:

- How is the climate of cities changing? What are city-specific changes?
- What are the interactions between climate change and urban areas, such as regarding local precipitation patterns and urban heat islands?
- What are the most important impacts of climate change that cities should consider? What are the most significant chronic shifts and extreme weather events?
- How is urban air quality affected by changes in climate?
- If socio-economic, infrastructural and geographical characteristics are also considered, what are the key vulnerabilities?
- What are the key knowledge gaps?

The responses to these questions presented in this commissioned paper are based on the Urban Climate Change Research Network (UCCRN) *Second Assessment Report on Climate Change and Cities* (ARC3.2), published by Cambridge University Press in 2018 (see Rosenzweig et al. 2018). The ARC3.2 effort is the most comprehensive climate change and cities assessment ever compiled and as a result serves as valuable source material. The Commissioned Paper presented here is a synthesis of the report's findings and also summarizes data and information technology needs for research and practice provided by the more than 100 ARC3.2 co-authors (see www.uccrn.com for more information on author teams).

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This Commissioned Paper is divided into six sections. The chapters in the ARC3.2 from which the relevant information and data derived are noted. Overall, the paper aims to stimulate research that will generate new knowledge to contribute to the IPCC Special Report on Cities, scheduled for the seventh assessment cycle due to commence in 2024.

i. How is the climate of cities changing? What are city-specific changes?

A climate change signal is now embedded in the everyday weather of cities and their long-term climate trends. A central question is what are the interactions between climate change, urban climate, and urban areas, such as regarding local precipitation patterns, heat waves and more complex interactions with urban heat islands?

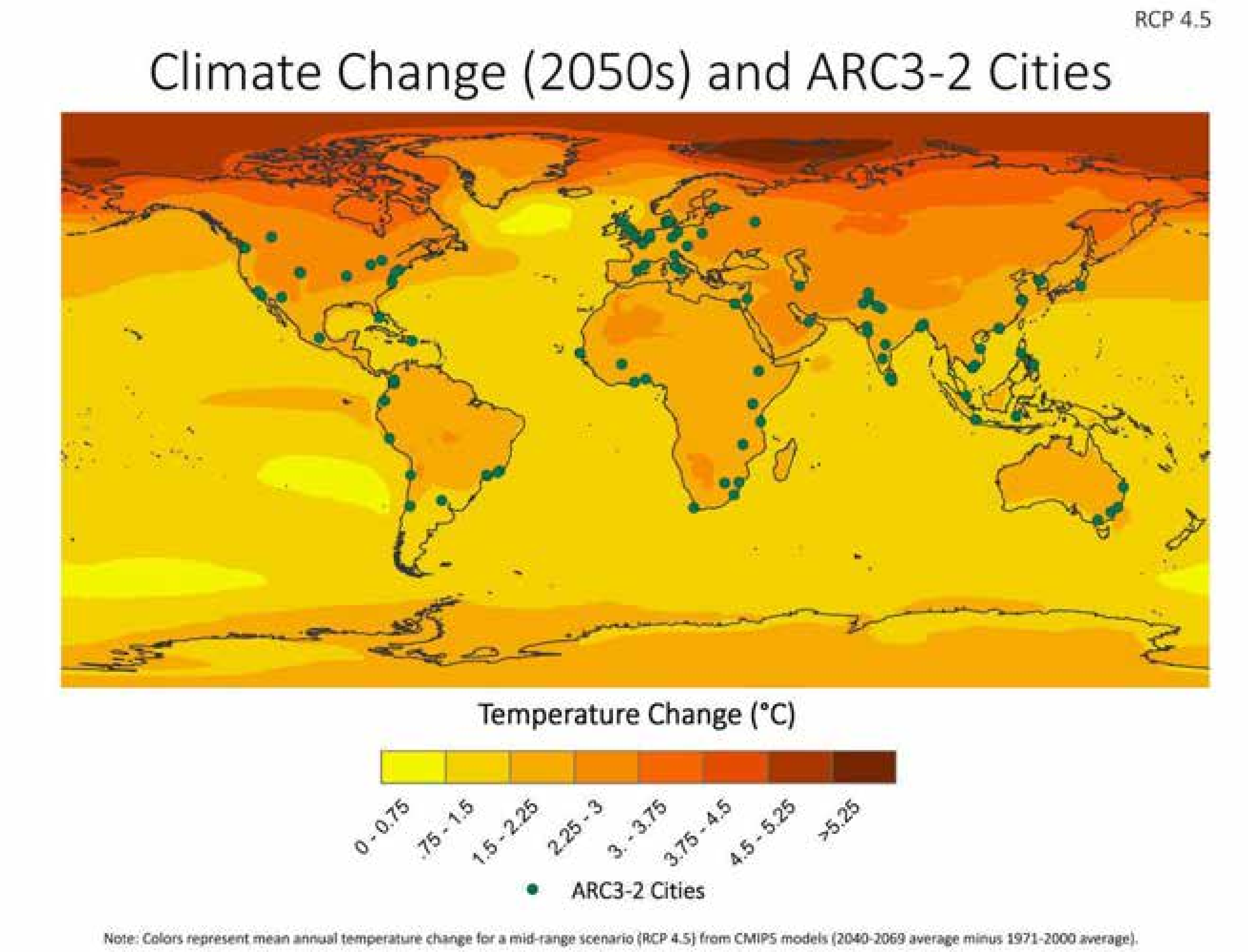
Urban Climate Science (Chapter 2)

- Temperatures are already rising in cities around the world due to both climate change and the urban heat island effect. Mean annual temperatures in 39 ARC3.2 cities have increased at a rate of 0.12 to 0.45°C per decade over the 1961 to 2010 time period.
- Mean annual temperatures in the 100 ARC3.2 cities around the world are projected to increase by 0.7 to 1.5°C by the 2020s, 1.3 to 3.0°C by the 2050s, and 1.7 to 4.9°C by the 2080s (Figure 1).
- Mean annual precipitation in the 100 ARC3.2 cities around the world is projected to change by -7 to +10% by the 2020s, -9 to +15% by the 2050s, and -11 to +21% by the 2080s.
- Sea level in the 52 ARC3.2 coastal cities is projected to rise 4 to 19 cm by the 2020s; 15 to 60 cm by the 2050s, and 22 to 124 cm by the 2080s.

ii. What are the most important impacts to consider for cities?

Several key impacts can be identified for each of the relevant urban sectors. Assessment literature has typically focused on engineered systems that provide critical resources for cities including water, transportation and energy, but urban health is of critical importance. Recent expansion of literature has also focused on a range sectors increasingly recognized as critical for effective urban climate action as such urban ecosystem services and housing. A final crucial point is that urban systems are highly interconnected, and that increasing climate extremes can lead to cascading failures. An example of this is more intense coastal storms leading to power outages, which in turn compromise water supplies, telecommunications, and health services.

Figure 1. Global temperature changes in the 2050s for RCP4.5 and UCCRN cities (ARC3.2 SCL).



Human Health (Chapter 10):

- Storms, floods, heat extremes, and landslides are among the most important weather-related health hazards in cities.
- Climate change will increase the risks of morbidity and mortality in urban areas due to greater frequency of weather extremes.
- Children, the elderly, the sick, and the poor in urban areas are particularly vulnerable to extreme climate events.
- Some chronic health conditions (e.g., respiratory and heat-related illnesses) prevalent in urban areas will be exacerbated by climate change.
- Actions aimed primarily at reducing greenhouse gas emissions in cities can also bring immediate local health benefits and reduced costs to health systems by reducing air pollution, improving access to green space, and increasing opportunities for walking and biking.

Water Systems (Chapter 14):

- The impacts of climate change put additional pressure on existing urban water systems and can lead to negative impacts for human health and wellbeing, economies, and the environment.
- Impacts include increased frequency of extreme weather events leading to large volumes of storm water runoff, rising sea levels, and changes in surface water and groundwater.
- As cities grow, demand and competition for limited water resources will increase, and climate changes are very likely to make these pressures worse in many urban areas.

Transportation (Chapter 13):

- Climate-related shocks to urban transportation have economy-wide impacts, beyond disruptions to the movement of people and goods.

- Interdependencies between transportation and other economic, social, and environmental sectors can lead to citywide impacts (Figure 2).
- Accounting for climate risks in transport decisions can ensure that residential and economic activities are concentrated in low-risk zones.

Energy (Chapter 12):

- Urbanization has clear links to energy consumption in low-income countries. Urban areas in high-income countries generally use less energy per capita than non-urban areas due to economies of scale associated with higher density.
- Current trends in global urbanization and energy consumption show increasing use of fossil fuels, including coal, particularly in rapidly urbanizing parts of the world.
- In the coming decades, rapid population growth, urbanization, and climate change will impose intensifying stresses on existing and not-yet-built energy infrastructure. The rising demand for energy services—e.g., mobility, water and space heating, refrigeration, air conditioning, communications, lighting, and construction—in an era of enhanced climate
- variation poses significant challenges for all cities. Warming is projected to intensify demand for energy-intensive air conditioning, further increasing greenhouse gas emissions if energy sources do not include renewables.
- Depending on the type, intensity, duration, and predictability of climate impacts on natural, social, and built and technological systems, threats to the urban energy supply sector will vary from city to city. Local jurisdictions need to evaluate vulnerability and improve resilience to multiple climate impacts and extreme weather events.
- While numerous examples of energy-related mitigation exist across the globe, less attention has been given to adaptation. Research suggests that radical changes in the energy supply sector, customer behavior, and the built environment are needed to develop resilient urban energy systems.

Coastal Zones (Chapter 9):

- Coastal cities are already exposed to storm surges, erosion, and saltwater intrusion (Figure 3). Climate change and sea level rise will likely exacerbate these hazards.
- Assessments show that the value of assets at risk in large port cities is estimated to exceed \$3.0 trillion USD (5% of Gross World Product in 2050).
- Expansion of coastal cities is expected to continue over the 21st century, with over half the global population living in cities in the coastal zone by mid-21st century. Annual coastal flood losses could reach \$71 billion by 2100.
- Climate-induced changes will affect marine ecosystems, aquifers used for urban water supplies, the built environment, transportation, and economic activities, particularly following extreme storm events. Critical infrastructure and precariously built housing in flood zones are vulnerable.

Figure 2. Interdependencies of urban transportation systems (Chapter 13).

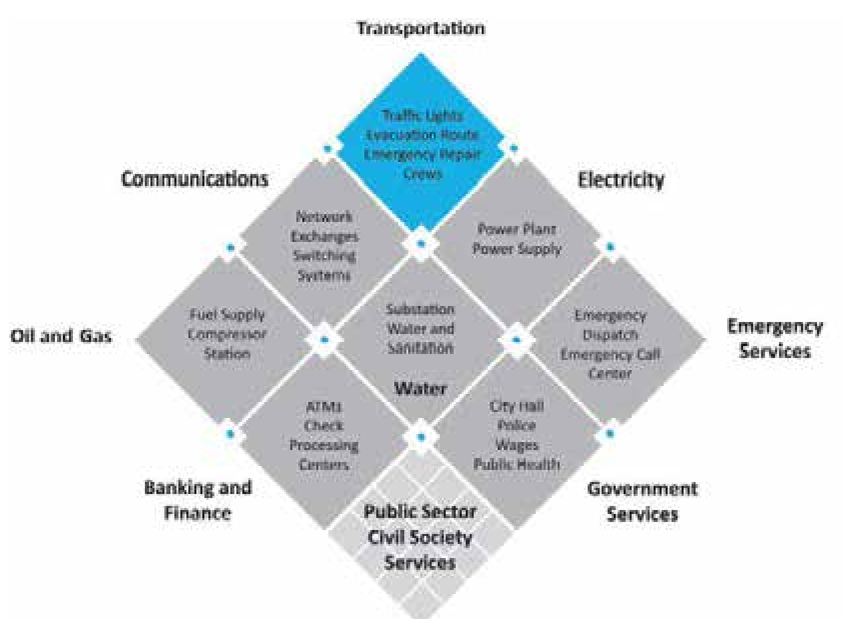
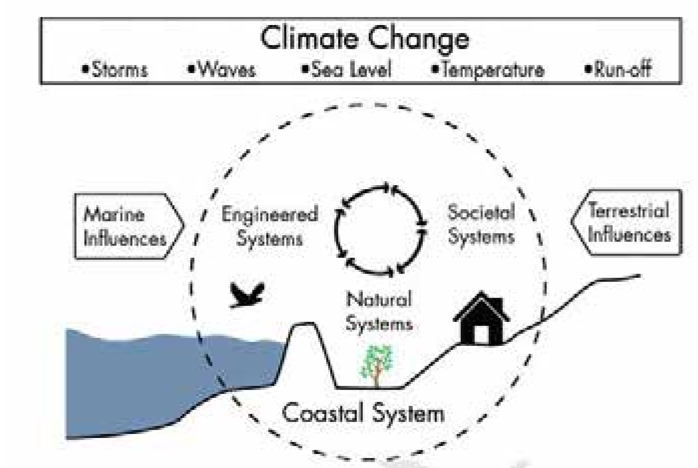


Figure 3. Coastal system and climate change (Chapter 9).



Ecosystems and Biodiversity (Chapter 8):

- Climate change and urbanization are likely to increase the vulnerability of biodiversity hotspots, urban species, and critical ecosystem services (Figure 4).
- Urban species and ecosystems are already being affected by climate change.
- Urban ecosystems and biodiversity have an important and expanding role in helping cities adapt to the changing climate. Harnessing urban biodiversity and ecosystems as adaptation and mitigation solutions will help achieve more resilient, sustainable, and livable outcomes.
- Integrated urban planning that incorporates a multidisciplinary perspective to target actions that support increased use of green infrastructure and forest restoration can help advance sustainable urban development while reinforcing climate mitigation and enhancing the quality and quantity of urban ecosystem services.
- Investing in urban ecosystems and green infrastructure can provide cost-effective, nature- based solutions for adapting to climate change while also creating opportunities to increase social equity, green economies, and sustainable urban development. This has multiple co- benefits, including improving quality of life, human health, and social wellbeing.

Housing and Informal Settlements (Chapter 11):

- Developed countries account for the majority of the world's energy demand related to buildings.
- Housing construction in low- and middle-income countries is focused on meeting demand for over 500 million more people by 2050. Cost-effective, and adaptive building technologies can avoid locking in carbon-intensive and non-resilient options.
- Groups that are already disadvantaged in regard to housing and land tenure are especially vulnerable to climate.

iii. **How is urban air quality affected by changes in climate?**

Climate change interacts with ongoing and often pervasive environmental stresses and threats found in urban (Figure 5). The most significant interactions occur between ongoing air quality challenges in urban and climate change (Chapter 2).

- Urban air quality varies regionally. Using satellite observations, Lamsal et al. (2013) for example showed that regional differences in industrial development, per capita emissions, and geography were related to the population–pollution relationship. The study showed that, for the same population, a developed city might experience six times the pollution concentration of a developing city.

Figure 4: As urban areas expand, biodiversity hotspots become more vulnerable to negative impacts (Chapter 8).

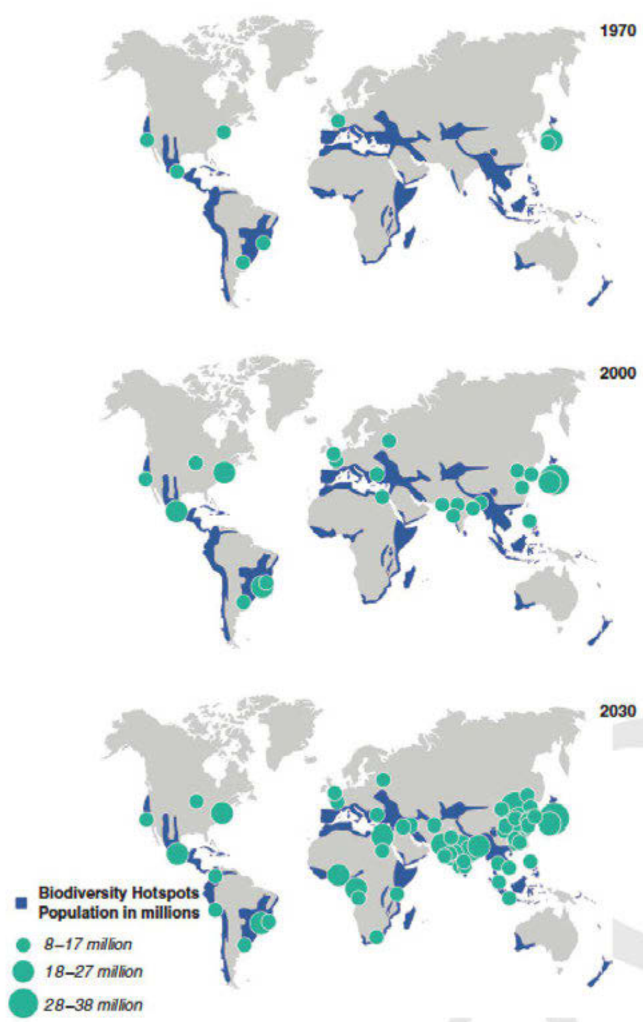
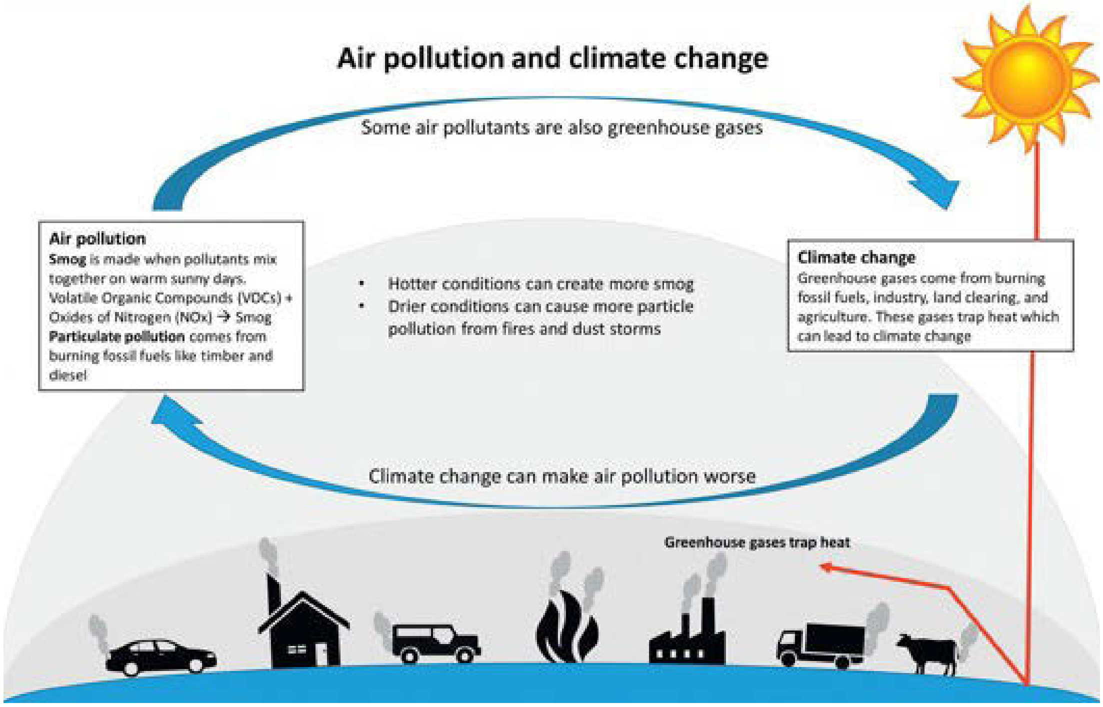


Figure 5. The relationship between air pollution and climate change (Chapter 2).



- A recent study (Karagulian et al., 2015) found that for global particulate matter emissions, traffic is the largest source, followed by domestic fuel burning for cooking and heating. Warming temperatures are linked to higher levels of ground-level ozone in many cities, and ozone concentrations are projected to increase, particularly in the United States and Europe.
- Green infrastructure (e.g., in urban street canyons) can be very effective deposition sites, reducing nitrogen dioxide (NO2) by 40% and particulate matter by 60% (Pugh et al., 2012). Along with other proven benefits to the urban center, particularly in the context of climate adaptation, vegetation can also be an efficient urban pollutant filter that helps to raise air quality at the street level in dense urban areas. A study of Toronto found that increasing the surface area for green roofs by 10–20% would greatly improve air quality in the city through pollutant removal (Currie and Bass, 2008).
- One study found that in Gothenberg, Germany, winter temperature inversions are associated (increasingly more frequent with climate change) with higher levels of traffic-related pollutants, including carbon monoxide, nitrous oxide, and nitrogen dioxide (Janhäll et al., 2006). Urban air quality in Hong Kong has also been linked to El Niño phases, which increasingly have a climate signal (Kim et al., 2013).

iv. **What are the key vulnerabilities considering socio-economic, infrastructural and geographical characteristics of cities?**

Vulnerability reflects exposure and adaptive capacity in the face of extreme events and climate disasters and risks as well as more systemic risk contexts where climate vulnerabilities intersect with ongoing social and economic inequities. Topics related to key climate change vulnerabilities are disasters and risk, equity and environmental justice, and the health of urban populations.

- *Climate Disasters and Risk:* The vulnerability of cities to climate-related disasters is shaped by cultural, demographic and economic characteristics of residents, local governments' institutional capacity, the built environment, the provision of ecosystem services, and human-induced stresses such as resource exploitation and environmental degradation such as removal of natural storm buffers, pollution, over-use of water, and the urban heat island effect (Chapter 3).
- *Equity and Environmental Justice:* Differential vulnerability of urban residents to climate change is driven by four factors: (1) differing levels of physical exposure; (2) urban development processes that have created a range of built-in risks, such access to critical infrastructure and urban services; (3) social characteristics that influence the allocation of resources for adaptation; and (4) access to power, institutions, and governance (Chapter 6) (Figure 6).

- *Urban Health*: Storms, floods, heat extremes, and landslides are among the most important weather- related health hazards in cities (Figure 7). Climate change will increase the risks of morbidity and mortality in urban areas due to greater frequency of weather extremes. Children, the elderly, the sick, and the poor in urban areas are particularly vulnerable to extreme climate events. Some chronic health conditions (e.g., respiratory and heat-related illnesses) and infectious diseases will be exacerbated by climate change. These conditions and diseases are often prevalent in urban areas (Chapter 10).

Figure 6. Conceptualization of equity in climate policy (Chapter 6).

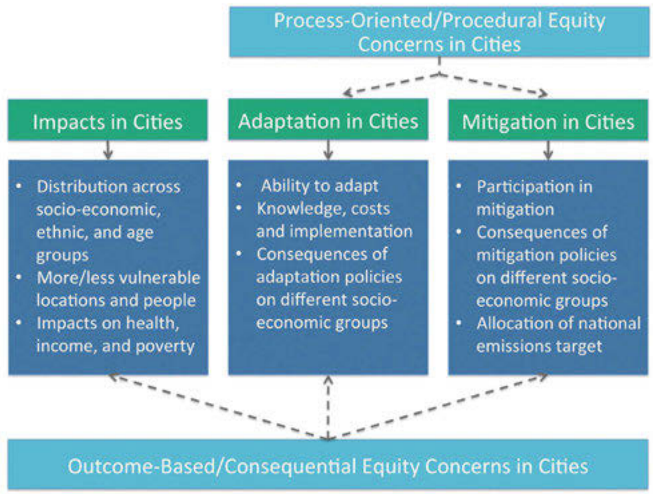
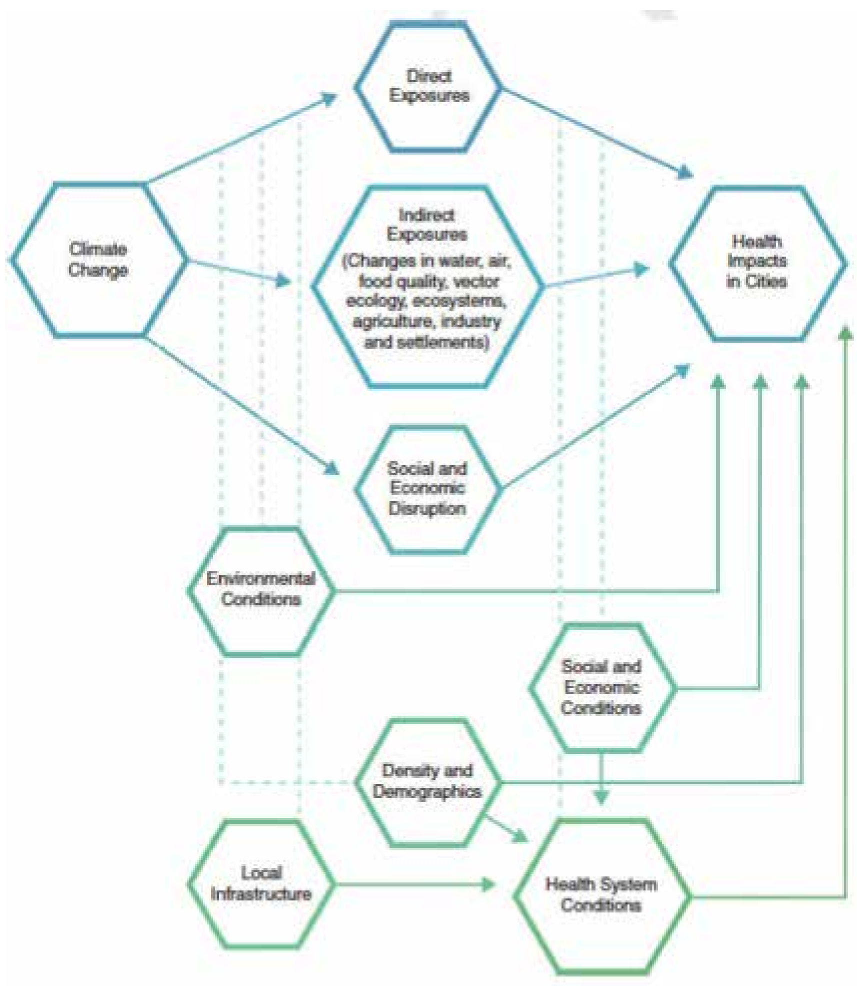


Figure 7 Climate change and its impact on health in cities ***(Chapter 10 Urban Health).***



v. **Key knowledge gaps**

The UCCRN ARC3.2 presents five entry points for transformative changes in cities to achieve their potential in responding to climate change. The sixteen chapters that make up the report provide descriptions of the key knowledge gaps and research needs required for cities to be able to successfully follow these pathways. These entry points, as pathways, are elaborated below.

Pathway 1: Disaster risk reduction and climate change adaptation are the cornerstones of resilient cities

- Investment decisions and implementation of successful transitions in coastal city management have both technical and social dimensions, and analysis capable of delivering these multiple dimensions is needed to develop adaptation pathways under uncertain futures. (*Chapter 9 Urban Areas in Coastal Zones*)
- Research methods are needed that take a long-term integrated approach to coastal management and inclusive governance. These methods are essential to adapt to climate change impacts and manage cities in the coastal zone in the third millennium (Nicholls et al., 2015). (*Chapter 9 Urban Areas in Coastal Zones)*

Pathway 2: Actions that reduce greenhouse gas emissions while increasing resilience are a win-win

- There is a need to better understand how urban systems work in an integrated manner in regard to climate change and sustainability (Satterthwaite, 2007, Jones et al., 2014). Therefore, holistic studies and interdisciplinary research frameworks such as urban metabolism studies that explore material flows and mass balances of water, energy, food, and waste provide the knowledge necessary to design and plan climate adaptation and mitigation in cities. (*Chapter 1 Pathways to Urban Transformation)*
- Integrating mitigation and adaptation requires an extra effort to understand the research and/or policy object (i.e., what exactly is being addressed). The terminology employed frequently varies between individuals because there is very little synthesized knowledge to date, and methods and theoretical frameworks vary widely. *(Chapter 4 Mitigation and Adaptation)*
- It is essential to develop urban GHG emission inventories and experiment with alternative urbanization patterns and management that facilitate low-carbon urban development. Opportunities are greater in medium-sized cities in rapidly developing countries for implementing low-carbon infrastructure because they are not already locked into long-lived, high-emissions infrastructure., Such cities are likely to accommodate the majority of expected urban population growth. (*Chapter 5 Urban Planning and Urban Design*)

Pathway 3: Risk assessments and climate action plans co-generated with the full range of stakeholders and scientists are most effective

- It is important to determine which factors determining the success of particular interventions were broadly applicable and thus can be transferred to other regions and which are unique to a location (such as strong commitment of an individual policy-maker to health adaptation). Stakeholder engagement is crucial to building and evaluating successful adaptation projects. *(Chapter 10 Urban Health)*

Pathway 4: Needs of the most disadvantaged and vulnerable citizens should be addressed in climate change planning and action

- Linking GIS mapping of impacts or potential risk indicators with estimations of social vulnerability is a promising way forward to assess relations between climate-related impacts and socioeconomic effects (Cutter and Fince, 2008). *(Chapter 6 Equity, Environmental Justice, and Urban Climate Change)*
- Because the processes that exacerbate inequity, vulnerability, and risk may not match the processes that promote equity and resilience, there is substantial need to investigate factors that can foster positive change, such as involving women's organizations in climate change planning processes. *(Chapter 6 Equity, Environmental Justice, and Urban Climate Change)*
- Increases in urbanization and incomes imply new pressures, including increased demands for food, increased waste, and, if unchecked, increased contamination. Understanding the implications of these issues for urban health systems that are also facing climate change deserves more research. *(Chapter 9 Urban Health)*
- If climate change data as well as disaster risk and impact information are to inform sustainable development, work is needed to understand much more fully self-organization modus operandi and the complex manner in which the informal sector operates. *(Chapter 11Housing and Informal Settlements)*

Pathway 5: Advancing city creditworthiness, developing robust city institutions, and participating in city networks enable climate action.

- Research on how cities can develop creditworthiness and maintain access to both municipal and outside financial resources is necessary in order to fund climate change solutions. *(Chapter 7 Economics, Finance, and Private Sector)*
- Promotion of sound urban climate governance requires research on how to achieve longer planning horizons, effective implementation mechanisms, and multi-sector, multi- community coordination. *(Chapter 16 Governance)*

- Research is urgently required on how to scale up best practices demonstrated by city climate change networks and on how to connect a critical mass of cities with national and international capacity-building groups. *(Chapter 1 Pathways to Urban Transformation)*
- Analyze how to achieve effective multi-level governance and effective mechanisms so that contribute to the accomplishment of nationally determined commitments (NDCs) and the Paris Agreement, as well as the Sustainable Development Goals, New Urban Agenda, and the Sendai Framework. (*Chapter 1 Pathways to Urban Transformation)*

vi. **Data Platform and Information Technology Needs**

The research-practitioner community has entered into a period of rapid data availability and needs growth as well as data and information translation and application needs.

- Information needs to be provided in a format that meets the practical demands of the targeted stakeholders, with emphasis placed on a process of monitoring and updating if it is to reflect the dynamics of a changing climate and shifting parameters of municipal vulnerability. *(Chapter 3 Disasters and Risk in Cities)*
- More improved city-based data, especially in demographics, are needed. National level demographics hide the scale and depth of inequality within urban populations. Moreover, national data is taken every 10 years; this is not frequent enough. *(Equity, Environmental Justice, and Urban Climate Change)*
- Urban climate change governance requires access to new, context-specific, and complex sources of information, such as future climate projections, GHG inventoris, and climate vulnerability assessments. *(Chapter 16 Governance)*
- Capacity to conduct comparison case studies across climate and climate-related data information is critical in order to provide investigators, practitioners, and decision-makers with state-of-the-art knowledge. Structural elements of a case study docking station have been defined and should be further enhanced in the future. *(Annex 1 Case Study Docking Station)*

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