Climate Change and Cities
Second Assessment Report of the Urban Climate Change Research Network

The Urban Climate Change Research Network's *Second Assessment Report on Climate Change in Cities* (ARC3.2) is the second in a series of global, science-based reports to examine climate risk, adaptation, and mitigation efforts in cities. The book explicitly seeks to explore the implications of changing climatic conditions on critical urban physical and social infrastructure sectors and intersectoral concerns. The ARC3.2 Report presents downscaled climate projections and catalogs urban disasters and risks, along with the effects on human health in cities. ARC3.2 gives concrete solutions for cities in regard to mitigation and adaptation; urban planning and urban design; equity and environmental justice; economics, finance, and the private sector; critical urban physical and social sectors such as energy, water, transportation, housing and informal settlements, and solid waste management; and governing carbon and climate in cities. Other key topics include ecosystems and biodiversity, and urban coastal zones. The primary purpose of ARC3.2 is to inform the development and implementation of effective urban climate change policies, leveraging ongoing and planned investments for populations in cities of developing, emerging, and developed countries.

This volume – like its predecessor – will be invaluable for a range of audiences involved with climate change and cities: Mayors, city officials, and policy-makers; urban planners; policy-makers charged with developing climate change mitigation and adaptation programs; and a broad spectrum of researchers and advanced students in the environmental sciences.

Cynthia Rosenzweig is a Senior Research Scientist at the NASA Goddard Institute for Space Studies, where she heads the Climate Impacts Group. She is Co-Chair of the New York City Panel on Climate Change (NPCC), a body of experts convened by the mayor to advise the city on adaptation for its critical infrastructure. She co-led the Metropolitan East Coast Regional Assessment of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change, sponsored by the U.S. Global Change Research Program. She was a Coordinating Lead Author of Working Group II for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). She is Co-Director of the Urban Climate Change Research Network (UCCRN), Co-Editor of the First and Second UCCRN Assessment Reports on Climate Change and Cities (the ARC3 series), and Co-Chair of the Urban Thematic Group for the United Nations UN Sustainable Development Solutions Network (SDSN) and the Campaign for an Urban Sustainability Development Goal (SDG). She serves as Chair of the Board of the New York City Climate Museum. She was named as one of "Nature's 10: Ten People Who Mattered in 2012" by the journal *Nature*, for her work preparing New York for climate extremes and change. A recipient of a Guggenheim Fellowship, she joins impact models with climate models to project future outcomes of both land-based and urban systems under altered climate conditions. She is a Professor at Barnard College and a Senior Research Scientist at The Earth Institute at Columbia University.

William Solecki is a Professor in the Department of Geography, Hunter College, City University of New York (CUNY). He has led or co-led numerous projects on the process of urban environmental change and transformation. As Director of the CUNY Institute for Sustainable Cities, he has worked extensively on connecting cutting-edge urban environmental science to everyday practice and action in cities. He most recently served as Co-Chair of the New York City Panel on Climate Change, as Co-Principal Investigator of the Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State (ClimAID), and as Co-Leader of the Metropolitan East Coast Assessment of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change. He is a Coordinating Lead Author of the IPCC Special Report on the Impacts of 1.5 Degree Warming and was a Lead Author of the IPCC Working Group II Fifth Assessment Report (AR5). He is also a member of International Geographical Union (IGU) Megacity Study Group and a member of the Scientific Steering Committee of the Urbanization and Global Environmental Change core project of the International Human Dimensions Programme (IHDP).

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Shagun Mehrotra is Professor of Sustainable Development at The New School University, New York, and the founding Director of the Sustainable Development Solutions Center. He is a Lead Author of the IPCC Special Report on the Impacts of 1.5 Degree Warming. He serves on UNSDSN's Urban Thematic Group charged by the UN Secretary General as an external advisory group for the post-2015 development agenda. Over the past two decades, his research and advice has widely engaged governments and private sector in North America, Africa, Asia, and Latin America on climate change, infrastructure economics and finance, and poverty reduction in cities, particularly large slums. He has led more than fifty multidisciplinary teams to assess climate risk and craft response in global cities and a dozen teams on infrastructure reforms. Previously, he served on the staff of the World Bank, leading infrastructure reform of public utilities in Africa with a focus on expanding services to the urban poor. He has facilitated global strategic partnerships for the Sustainable Development Goals SDGs and Habitat III's New Urban Agenda. He has published extensively on solutions for global urbanization, including two recent books, the first ARC3 with Cambridge University Press and another on infrastructure economics with Oxford University Press. His work has featured in *Nature* and *Scientific American*, and he is a reviewer of policy-relevant research for *Science.* He has a PhD from Columbia University in Urban Planning and Infrastructure Economics.

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Somayya Ali Ibrahim is the Associate Director of the Urban Climate Change Research Network (UCCRN). Based at the Earth Institute at Columbia University and the NASA Goddard Institute for Space Studies (NASA GISS), she develops and manages climate change projects and partnerships with large city groups, universities, development banks, and federal and UN agencies. She manages the UCCRN Secretariat in New York and its global network of projects and partnerships, including more than 800 urban scientists and practitioners and involving the establishment of the UCCRN Regional Hubs in Africa, Asia, Australia-Oceania, Europe, Latin America, and North America. She also manages the development and publication of the UCCRN Assessment Report on Climate Change and Cities (ARC3) series, an ongoing set of major global, interdisciplinary, science-based assessments on climate change and urban areas. She was one of ten individuals chosen to represent Columbia University at the UNFCCC 21st Conference of the Parties (COP21) in Paris in December 2015, and works with a leadership team striving to establish a Climate Museum in New York, one of the first of its kind in the world. She holds a B.Sc. (Hons.) in Management Sciences and an MBA from the University of Peshawar, and a Master's degree in Climate and Society from Columbia University.

Praise for the ARC3.2 Report

Anne Hidalgo, Mayor of Paris and Chair of C40

"ARC3.2 provides the critical knowledge base for city actions on climate change around the world."

Eduardo Paes, Former Mayor of Rio de Janeiro and Former Chair of C40

"The remarkable ARC3.2 will make a difference in developing effective and efficient climate change mitigation and adaptation policies in cities."

James Nxumalo, Former Mayor of Durban

"The full ARC3.2 report ... is the gold standard for science-based policymaking as we enter into the post-2015, climate change implementation era."

Joan Clos, Former Executive Secretary of UN-Habitat; Former Mayor of Barcelona

"... a great example of the benefit of interdisciplinary science-policy co-operation. ... ARC3.2 will help to ensure our future cities enable us to live more sustainably and to be more resilient."

Gino Van Begin, Secretary General of ICLEI-Local Governments for Sustainability

"The Climate Change in Cities report zooms in at the city level, providing us with a wealth of local climate data. And what these data tell us is that if we are to overcome the climate change challenge, we need more than ever the concerted efforts of all levels of government, multilateral institutions, civil society and the business sector."

Mark Watts, Executive Director for C40 Cities Climate Leadership Group

"With the international community now galvanized to put the world on a climate safe pathway, the evidence is stacking up that cities have a key role to play. The second edition of the ARC3 report from the Urban Climate Change Research Network provides a critical knowledge base for global cities as they respond to climate change challenges and seize the economic opportunities of low carbon, climate resilient development. Leading mayors, through network such as the C40, are learning from each other, exchanging ideas and thereby accelerating local action on the ground."

Senator Loren Legarda, Chair, Senate Committees on Foreign Relations, Finance, and Climate Change Global Champion for Resilience, United Nations Office for Disaster Risk Reduction (UNISDR)

"Urban areas will not stop from growing, but growth need not compromise the future. The climate crisis presents the opportunity to promote sustainable growth. Key science knowledge and practical insights are needed to allow our urban areas to meet the adaptation imperative to climate change. The ARC3.2 Report of the Urban Climate Change Research Network (UCCRN) provides vital inputs to this process."

Climate Change and Cities
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Cover Photo:

Rio de Janeiro, a city with 6.5 million residents (14.5 million in the Greater Rio de Janeiro area), is a frontrunner in climate change mitigation and adaptation. Temperatures in Rio de Janeiro are projected to rise by 3.4°C, with sea level rise of 37cm–82cm, by the 2080s. Along with developing a Climate Adaptation Plan, Rio de Janeiro is committed to reducing greenhouse gas emissions by 20% of 2005 levels by 2020. (Photo: Somayya Ali Ibrahim)

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Foreword – Anne Hidalgo, Mayor of Paris and Chair of C40

Taking action to fight climate change is increasingly a priority for cities around the world, where half the world's population now lives and where two-thirds of the inhabitants of our planet will be concentrated by 2050.

The best science has illuminated major risks facing our planet, and as mayors, we have heeded the call to tackle climate change head-on, both in terms of mitigation (reduction of greenhouse gases) and adaptation (development of resilience to climate stresses). Climate action is and must be incorporated into everyday urban planning and growth in a way that is sustainable and also financially viable. The Urban Climate Change Research Network (UCCRN) was established to meet the information needs of cities responding to climate change, and ARC3.2 provides the critical knowledge base for city actions on climate change around the world.

Because cities are both vulnerable to climate risks and are also sources of innovation for sustainable solutions, it is essential that they collaborate to find bold solutions based on cutting-edge research, such as that found in ARC3.2. The City of Paris was delighted to host the UCCRN European Hub and the launch of the *Second Assessment Report on Climate Change and Cities (ARC3.2)* at the Climate Summit for Local Leaders, hosted by the City of Paris at Paris City Hall and held during the UNFCCC Conference of the Parties 21 (COP21) in Paris at the end of 2015.

ARC3.2 focuses on key urban sectors (energy, transportation, water, and sanitation), as well as on human services in cities (health and housing). Chapters on urban ecology and coastal zones reveal important dimensions of urban climate change action. And in the chapter on equity and environmental justice, the volume highlights the need for cities to consider their most vulnerable citizens.

The City of Paris released its Climate and Energy Action Plan in 2007, updated it in 2012, and adopted a new Adaptation Roadmap in 2015 that presents comprehensive strategies for responding to the city's own climate change challenges.

The City of Paris is committed to the pathway of climate change solutions, sustainability, and transformation and looks forward to a continued partnership with UCCRN and the ARC3 series to achieve these goals.

Anne Hidalgo
Mayor of Paris
Chair of C40 Cities Climate Leadership Group

Foreword – Eduardo Paes, Former Mayor of Rio de Janeiro and Former Chair of C40

The coming years are critical to determining our future in regard to climate change. Scientists, leaders, and decision-makers are joining forces to balance growth with environmental protection and social justice.

The *Second Assessment Report on Climate Change and Cities* (ARC3.2), developed by the Urban Climate Change Research Network (UCCRN), presents cutting-edge scientific information on climate change mitigation and adaptation in cities. It offers detailed information to support policy-makers in making better, more information-informed decisions about how climate change affects public health, local infrastructures, and the economy.

The past work of the Intergovernmental Panel on Climate Change (IPCC) has been decisive in changing the mindsets of world leaders, and the UCCRN *First Assessment Report on Climate Change and Cities (ARC3.1)* provoked similar transformations at the local level. The *Second Assessment Report* now highlights how poverty and biodiversity are intimately connected to the challenges of urban climate change.

The Report stresses the importance of addressing poverty and climate change together. There is no opposition between social development and environmental protection – we must do both. Climate change in cities affects the poorest and most vulnerable members of our societies. Transforming cities into successful low-carbon communities will only be possible if these changes are made in combination with social and environmental justice.

The ARC3.2 also emphasizes the importance of environmental preservation as a means of fostering urban resilience. Rio de Janeiro – as a coastal and tropical city – experiences heavy summer rains. Their impacts will likely grow more frequent and intense with climate change. For this reason, the protection of the city's biodiversity is vital, to avoid landslides and other adverse consequences of the increased rainfall. Investing in quality green spaces is a means of strengthening resilience, while improving residents' quality of life.

Decision-makers and local leaders around the world need the support of the scientific community and the knowledge it provides; their work is complementary. That is why we have endorsed a new partnership with the Urban Climate Change Research Network to establish a Latin American Hub in Rio de Janeiro. Recently, we have been working with UCCRN on developing the Rio de Janeiro Resilience Plan. Our collaboration has resulted in studies on heat islands, the proliferation of dengue fever (and other vector-borne diseases), and other local development challenges, contributing to risk reduction for the city's residents and infrastructure.

Science works to understand the multiple dimensions of climate change hazards, imparting knowledge that is often lacking in cities. Developing cities represent the fastest-growing urban places in the world. The UCCRN Latin American Hub can identify and promote the resilience potential of cities in the region and reinforce our mitigation and adaptation policies. Lessons learned in Rio will benefit other cities in the region, just as studies elsewhere will help local policy-makers deal with their local challenges.

On the road from COP21, cities are central to supporting the ambitious commitments and to implementing the Paris agreements. Mayors from around the world have shown impressive leadership, but they need support to do more. The remarkable ARC3.2 will make a difference in developing effective and efficient climate change mitigation and adaptation policies in cities.

Eduardo Paes
Former Mayor of Rio de Janeiro
Former Chair of C40 Cities Climate Leadership Group

Foreword – James Nxumalo, Former Mayor of Durban

The future of our planet was shaped in 2015. In December, negotiating parties representing nations from around the globe met in Paris for the United Nations Framework Convention on Climate Change's 21st Conference of the Parties (COP21), and agreed on planet-saving measures to combat climate change. With a rapidly urbanizing globe, the role of cities and local governments is pivotal. Cities must be supported effectively because the challenge of climate change will be won and lost in urban areas. Cities offer twin transformative solutions, with the greatest opportunities for reducing greenhouse gas emissions through mitigation activities and localized climate risk reduction through urban adaptation. Given the uncertainty around climate change impacts at the local level, it is critical that the adaptive management decisions are informed by cutting-edge science and independent research.

The climate change challenge cuts across a broad range of disciplines. The development of research partnerships that connect scientists from different disciplines to work collaboratively to inform city-level management decisions is a high priority. The Urban Climate Change Research Network (UCCRN) is an excellent example of how urban-focused climate change research can bridge the divide between researchers and policy-makers. The *First Assessment Report on Climate Change and Cities* (ARC3.1) was published in 2011 and did exactly that. It provided a multidisciplinary, global assessment of climate risks, adaptation, mitigation, and policy mechanisms that is relevant to cities and based on sound scientific principles.

The Summary for City Leaders of the *Second UCCRN Assessment Report* (ARC3.2) was launched during COP21 in Paris in 2015 and will serve as a "call to action." The full ARC3.2 report, the *Second UCCRN Assessment Report on Climate Change and Cities*, is the gold standard for science-based policy-making as we enter into the post-2015, climate change implementation era. Developing partnerships to share knowledge products will be important so that all stakeholders – especially those in low-income countries – can benefit. In this respect, the development of a knowledge network, formed around UCCRN Hubs, offers a transformative solution. We are proud that, as of the launch in 2016, the city of Durban in South Africa will function as one of these UCCRN Hubs.

Furthermore, through an agreement to collaborate with UCCRN as its key knowledge partner, the Durban Adaptation Charter will enable scaling up the knowledge-to-policy process with its signatory base of more than a thousand cities. This empowering linkage from co-generated research to implementation partnership will support city leaders from low-income countries as they operationalize climate change mitigation and adaptation policies and action plans at transformative scales.

James Nxumalo
Former Mayor of Durban, eThekwini Municipality

Foreword – Joan Clos, Former Executive Secretary of UN-Habitat and Former Mayor of Barcelona

Cities and local governments are increasingly recognized as key actors in addressing climate challenges. They are strong sources of leadership that require enabling frameworks and a combination of global, national, and local measures in order to achieve the transformational change that is needed. It is important to provide decision-makers with the latest data at different levels of granularity, as well as with global platforms for exchange of information.

Since the Urban Climate Change Research Network (UCCRN) published its innovative *First Assessment Report on Climate Change and Cities* (ARC3.1) in 2011, we have seen a significant increase of attention to this issue, as well as considerable growth of the body of knowledge. This is exemplified by the recent publications of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), which has dedicated two full chapters to the urban issue – one on mitigation and one on impacts, adaptation, and vulnerabilities. The report of the New Climate Economy has elaborated on the cost of inaction and the co-benefits of compact urban growth, connected infrastructure, and coordinated governance. This new edition, the *Second UCCRN Assessment Report on Climate Change and Cities* (ARC3.2), offers not only updated findings, but is expanded in scope and coverage. It includes an extensive database of case studies, which will allow for a continuous collection of key city data online and will enable users to compare cases and lessons learned across factors such as geography, sector, income levels, and size.

The nexus between cities and climate change is crucial for addressing the sustainable development challenges of the 21st century. More than half of the global population is already living in urban areas, and it is estimated that, by 2050, this figure will grow to more than two-thirds. Production and consumption is concentrated in urban areas, generating around 80% of gross domestic product (GDP) and more than 60% of all carbon dioxide, in addition to significant amounts of other greenhouse gas (GHG) emissions. Urban areas host most of the vulnerable populations as well as vital economic and social infrastructure. Hundreds of millions of people in urban areas across the world will be affected by rising sea levels, increased precipitation extremes, landslides, inland floods, more frequent and intense cyclones and storms, and periods of more extreme heat.

The year 2015 constituted a pivotal point for the global policy agenda on sustainable development and climate change with key conferences, such as the UN Summit for the Adoption of the Post-2015 Development Agenda, the Financing for Development Conference, the UN 21st World Conference on Disaster Risk Reduction, and the Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) in Paris. The urban issue is increasingly recognized as a key component in these global processes. Furthermore, the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) took place in Quito in October 2016. Habitat III served to reinvigorate the global commitment to sustainable urbanization and to focus on the implementation of a "New Urban Agenda."

UN-Habitat is working with partners at various levels to integrate climate mitigation and adaptation concerns into policy and infrastructure planning processes, taking into account broader sustainability considerations and economic, environmental, and social co-benefits. It is doing so, for example, in the context of the Cities and Climate Change Initiative, which targets medium-sized cities in developing and least-developed countries, as well as through the Urban-LEDS project, which promotes Low-Emission Urban Development in Emerging Economies. Climate change is also among the cross-cutting issues mainstreamed throughout UN-Habitat as per its strategic plan. Complementing its intergovernmental activities, UN-Habitat is partnering with a broad range of stakeholders to advance the implementation of a number of initiatives launched at the Secretary-General's Climate Summit in September 2014, such as the Global Covenant of Mayors, the Cities Climate Financing Leadership Alliance, the Urban Electric Mobility Initiative, and the Resilient Cities Accelerator Initiative.

I am confident that this report will contribute significantly to the body of knowledge in this area and help guide decision-makers at the various levels in their quest for sustainable urbanization. It is a great example of the benefit of interdisciplinary science policy cooperation. Cities provide tremendous opportunities to mitigate climate change and increase resilience while also improving well-being and economic output. If well planned, equipped with the necessary capacity, and managed through the appropriate governance structures, cities can be places of innovation and efficiency. ARC3.2 will help to ensure that our future cities enable us to live more sustainably and be more resilient.

Joan Clos
Former Executive Secretary of UN-Habitat
Former Mayor of Barcelona

Foreword – Christiana Figueres, Former Executive Secretary, United Nations Framework Convention on Climate Change and Vice Chair of the Global Covenant of Mayors

With the majority of the world's population living in urban areas, action by cities holds great potential to curb emissions and build resilience to climate impacts. Cities are a powerful force in meeting the global challenge of climate change. This fact was underscored at the 2015 UN Climate Change Conference in Paris (COP21), where commitments to act by cities registered on the United Nations Framework Convention on Climate Change (UNFCCC).

The Paris Agreement is a transformative vision of growth shared by the 195 countries that adopted it. It is built on a foundation of national climate change action plans. For these plans to succeed, and for us to meet the climate change challenge, cities must align policy to national goals and the long-term goal of the Paris Agreement. I welcome the *Second UCCRN Assessment Report on Climate Change and Cities (ARC3.2)* because it will help cities choose a policy suite that accelerates their local transition to low-emission and highly resilient growth. With this report as a resource, I am confident that cities can be engaged in meeting our global goals while enhancing liveability in their communities.

Christiana Figueres
Former Executive Secretary of UNFCCC
Vice Chair, Global Covenant of Mayors for Climate & Energy

Preface

This volume is the Urban Climate Change Research Network's *Second Assessment Report on Climate Change and Cities* (ARC3.2). It contains the Summary for City Leaders, an introductory section, and four parts of the report, as well as the Case Study Docking Station Annex.

This report would not be possible without the great support of Aalborg University, the African Development Bank (AfDB), The Earth Institute at Columbia University, the Helmholtz Centre for Environmental Research (UFZ-Leipzig), the Inter-American Development Bank (IDB), the International Development Research Centre (IDRC), the Japan International Cooperation Agency (JICA), the NASA Goddard Institute for Space Studies (NASA GISS), Siemens, the Urbanization and Global Environmental Change Project (UGEC), the United Nations Environment Programme (UNEP), and the United Nations Human Settlement Programme (UN-Habitat).

We especially thank Balgis Osman-Elasha and Aymen Ali at AfDB; David Wilk at IDB; Mark Redwood, formerly at IDRC; Tomonori Sudo at JICA; Keith Alverson and Stuart Crane at UNEP; and Joan Clos, Rafael Tuts, Robert Kehew, Marcus Mayr, and Andrew Rudd at UN-Habitat. They are all exemplary international public servants committed to the development of effective ways for cities to confront climate change challenges and to leading in the implementation of solutions.

We are grateful for the substantive support provided to the Case Study Docking Station by Martin Lehmann at Aalborg University and the Joint European Master in Environmental Studies – Cities and Sustainability (JEMES CiSu), and to the Economics, Finance, and the Private Sector chapter by Reimund Schwarze at UFZ-Leipzig.

We thank Stefan Denig and Michael Stevns at Siemens for generously hosting the ARC3.2 Midterm Authors Workshop at The Crystal in London in September 2014.

We appreciate the sound advice provided by the members of the UCCRN ARC3.2 Steering Group: Keith Alverson, Martha Barata, Anthony G. Bigio, Richenda Connell, Richard Dawson, Stefan Denig, Shobhakar Dhakal, David Griggs, Alice Grimm, Saleemul Huq, Martin Lehmann, Yu Lizhong, Helena Molin Valdés, Claudia E. Natenzon, Catherine Neilson, Ademola Omojola, Rajendra Pachauri, Mark Redwood, Debra Roberts, Joyashree Roy, Patricia Romero-Lankao, Roberto Sanchez-Rodriguez, Joel Scheraga, Joel Towers, Rafael Tuts, David Wilk, and Carolina Zambrano-Barragan. We also recognize the contributions of JoAnn Carmin, a UCCRN Steering Group member whom we sadly lost during the development of this report.

We thank the leaders of the UNFCCC and the IPCC who have supported the need for ARC3 – in particular Christiana Figueres, former Executive Secretary of the UNFCCC, and Debra Roberts, Co-Chair of IPCC Working Group II.

We thank the city networks and our colleagues in each of them who strive to enable cities to fulfill their leadership potential for climate change mitigation and adaptation. At ICLEI, we commend the Secretary General, Gino Van Begin, and thank our close colleague Yunus Arikan for his tireless efforts; at C40, we thank Seth Schultz, Katie Vines, and Mandy Ikert; at Cities Alliance, we thank William Cobbett, Omar Siddique, and Julie Greenwalt; and at the Medellín Collaboration on Urban Resilience, we thank Tricia Holly Davis and Laura Kavanaugh. At the Global Environment Facility (GEF), we thank Naoki Ishii and Saliha Dobardzic; at GIZ, we thank Carmen Vogt; at the Nairobi Work Programme, we thank Xianfu Lu and Laureline Krichewsky-Simon. At the U.S. Environmental Protection Agency, we thank Anthony Socci for his long-term support of the UCCRN. At EDF France, we thank Claude Nahon, Carole Ory, and Marianne Najafi; at UNISDR, we thank Jerry Velasquez, Ebru Gencer, Abhilash Panda, and Julian Templeton.

We gratefully acknowledge the discussions and feedback during sessions with Mayors, their advisors, leaders of major institutions, urban policy-makers, and scholars during our international scoping events and thank the respondents of our Information Needs Assessment Survey in 2013–2014.

We extend special gratitude to the urban leaders who represent a diverse group of cities and who have commended UCCRN and ARC3.

This Assessment Report is the product of the work of the over 350 dedicated members of the UCCRN ARC3.2 writing team, representing more than 100 cities around the world. We express our sincere thanks to each of them for their sustained and sustaining contributions, and to their institutions for supporting their participation.

We especially thank and profoundly appreciate the work of Somayya Ali Ibrahim for her tremendous efforts as the UCCRN and ARC3 series Program Manager; without her, ARC3.2 could not have been completed in such a comprehensive manner.

We thank the founding Directors and partners of the UCCRN Regional Hubs: Chantal Pacteau and Luc Abbadie for the European Hub in Paris; Martha Barata and Emilio La Rovere for the Latin American Hub in Rio de Janeiro; Sean O'Donaghue and Mathieu Rouget for the African Hub in Durban; Kate Auty, Ken Doust, and Barbara Norman for the Australian-Oceania Hub in Melbourne, Sydney, and Canberra; Franco Montalto for the North American Hub in Philadelphia; Min Liu, Xiaotu Lei, and Ruishan Chen for the East Asian Hub in Shanghai; Patricia Iglecias and Oswaldo Lucon for the Center for Multilevel Governance in São Paulo; and Martin Lehmann for the Nordic Node in Aalborg. We also thank Emma Porio and Antonia Loyzaga for their efforts to establish a UCCRN Southeast Asian Hub in Manila and Muhammad Shah Alam for working to establish a UCCRN South Asian Hub in Dhaka.

We thank the city partners of the UCCRN Hubs and the people who make those partnerships happen. In particular, we thank Anne Girault, Aurelien Lechevallier, Nicolas de Labrusse, and Yann Francoise from Paris; Rodrigo Rosa, Bruno Neele, Pedro Junqueira, Laudemar Aguiar, Luciana Nery, and Camila Pontual from Rio de Janeiro; and Debra Roberts and Sean O'Donoghue from Durban.

We give special thanks to the many students at Columbia University, Hunter College of the City University of New York, and Milano School for International Affairs at The New School for their keen interest in the field of urban climate change, which has helped to move forward the ideas of this volume.

We acknowledge the exceptional commitment of the ARC3.2 research assistants and project interns: Ioana Blaj, Antonio Bontempi, Wim Debucquoy, Julia Eiferman, Jonah Garnick, Anna Gusman, Megan Helseth, Annel Hernandez, Jonathan Hilburg, Andrea Irazoque, Christina Langone, Ipsita Kumar, Carissa Lim, Brandon McNulty, Jovana Milić, Grant Pace, Victoria Ruiz Rincón, Samuel Schlecht, Stephen Solecki, Marta De Los Ríos White, and Megi Zhamo. We also thank Chris Barrett, Nicholas Belenko, Erin Friedman, Joseph Gilbride, Benjamin Marconi, Madeline McKenna, and Paul Racco. At the Columbia University Center for Climate Systems Research and the NASA Goddard Institute for Space Studies, we thank Daniel Bader, Manishka de Mel, Vivien Green, Shari Lifson, Danielle Manley, and Erik Mencos Contreras for their assistance and technical expertise.

We recognize with great esteem the Expert Reviewers of the ARC3.2 chapters, without whom the independent provision of sound science for climate change mitigation and adaptation in cities cannot proceed.

We especially thank Tom Bowman for his expertise and guidance in communicating climate change, for his important role in helping develop the Summary for City Leaders of the ARC3.2 volume, and for leading our Communications and Outreach Team, otherwise known as the "Troublemakers." We especially thank Ronaldo Barata for his long-term efforts in championing the UCCRN and ARC3.2.

It is a great honor that ARC3.2 is published by Cambridge University Press. We especially thank Matt Lloyd, Editorial Director for Science, Technology, and Medicine, Americas, and Mark Fox, Content Manager, Editorial/Production for Academic and Professional Books, for their expert partnership in the publication of this volume. We also thank Sathishkumar Rajendran and Allan Alphonse from Integra, for their support throughout the publication process.

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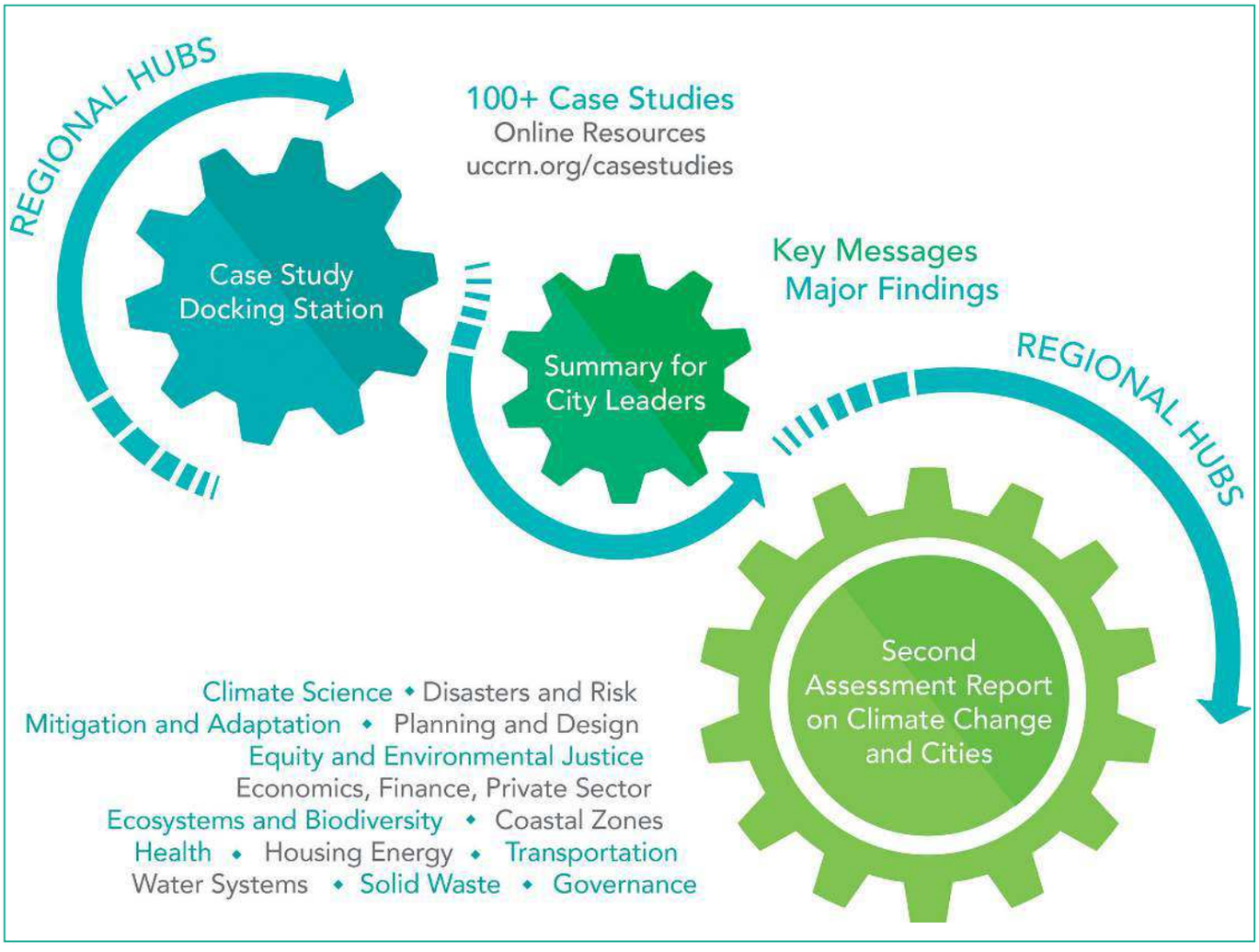
Cynthia Rosenzweig, William Solecki, Patricia Romero-Lankao, Shagun Mehrotra, Shobhakar Dhakal, and Somayya Ali Ibrahim

Co-Editors
Second UCCRN Assessment Report on Climate Change and Cities (ARC3.2)

Climate Change and Cities

Second Assessment Report of the Urban Climate Change Research Network

Summary for City Leaders



SCL Figure 1 *Components of the Second Assessment Report on Climate Change and Cities (ARC3.2) and their interactions.*

ARC3.2 Summary for City Leaders Authors

Cynthia Rosenzweig, William Solecki, Patricia Romero-Lankao, Shagun Mehrotra, Shobhakar Dhakal, Tom Bowman, and Somayya Ali Ibrahim

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ARC3.2 SUMMARY FOR CITY LEADERS

This is the Summary for City Leaders of the Urban Climate Change Research Network (UCCRN) *Second Assessment Report on Climate Change and Cities* (ARC3.2) (see SCL Figure 1). UCCRN is dedicated to providing the information that city leaders – from government, the private sector, non-governmental organizations, and the community – need in order to assess current and future risks, make choices that enhance resilience to climate change and climate extremes, and take actions to reduce greenhouse gas emissions.

ARC3.2 presents a broad synthesis of the latest scientific research on climate change and cities.[1] Mitigation and adaptation climate actions of 100 cities are documented throughout the 16 chapters, as well as online through the ARC3.2 Case Study Docking Station (www.uccrn.org/casestudies). Pathways to Urban Transformation, Major Findings, and Key Messages are highlighted here in the ARC3.2 Summary for City Leaders. These sections lay out what cities need to do to achieve their potential as leaders of climate change solutions. UCCRN Regional Hubs in Europe, Latin America, Africa, Australia-Oceania, and Asia will share ARC3.2 findings with local city leaders and researchers.

The ARC3.2 Summary for City Leaders synthesizes Major Findings and Key Messages on urban climate science, disasters and risks, urban planning and urban design, mitigation and adaptation, equity and environmental justice, economics and finance, the private sector, urban ecosystems, urban coastal zones, public health, housing and informal settlements, energy, water, transportation, solid waste, and governance. This important information is based on climate trends and future projections for 100 cities around the world.

Climate Change and Cities

The international climate science research community has concluded that human activities are changing the Earth's climate in ways that increase risk to cities. This conclusion is based on many different types of evidence, including the Earth's climate history, observations of changes in the recent historical climate record, emerging new patterns of climate extremes, and global climate models. Cities and their citizens already have begun to experience the effects of climate change. Understanding and anticipating these changes will help cities prepare for a more sustainable future. This means making cities more resilient to climate-related disasters and managing long-term climate risks in ways that protect people and encourage prosperity. It also means improving cities' abilities to reduce greenhouse gas (GHG) emissions.

While projections for future climate change are most often defined globally, it is becoming increasingly important to assess how the changing climate will specifically impact cities. The risks are not the same everywhere. For example, sea level rise will affect the massive zones of urbanization clustered along the world's tidal coastlines, and most significantly those cities in places where the land is already subsiding. In response to the wide range of risks facing cities and the role that cities play as home to more than half of the world's population, urban leaders are joining forces with multiple groups, including city networks and climate scientists. They are assessing conditions within their cities in order to take science-based actions that increase resilience and reduce GHG emissions, thus limiting the rate of climate change and the magnitude of its impacts.

In September 2015, the United Nations endorsed the new Sustainable Development Goal 11, which is to "Make cities and human settlements inclusive, safe, resilient and sustainable." This new sustainability goal cannot be met without explicitly recognizing climate change as a key component. Likewise, effective responses to climate change cannot proceed without understanding the larger context of sustainability. As ARC3.2 demonstrates, actions taken to reduce GHG emissions and increase resilience can also enhance the quality of life and social equity.

1 Cities are defined here in the broad sense to be urban areas, including metropolitan and suburban regions.

Pathways to Urban Transformation

Hyderabad, India | Cairo, Egypt | Paris, France | Phnom Penh, Cambodia | New York, USA | Rio de Janeiro, Brazil

As is now widely recognized, cities can be the main implementers of climate adaptation, and mitigation, which is now understood as encompassing low emissions development and resilience. However, the critical question that ARC3.2 addresses is under what circumstances this advantage can be realized. Cities may not be able to address the challenges and fulfill their climate change leadership potential without transformation.

ARC3.2 synthesizes a large body of studies and city experiences and finds that transformation is essential in order for cities to excel in their role as climate change leaders. As cities mitigate the causes of climate change and adapt to new climate conditions, profound changes will be required in urban energy, transportation, water use, land use, ecosystems, growth patterns, consumption, and lifestyles. New systems for urban sustainability will need to emerge that encompass more cooperative and integrated urban–rural, peri-urban, and metropolitan regional linkages.

Five pathways to urban transformation emerge throughout ARC3.2 (see SCL Figure 17). These pathways provide a foundational framework for the successful development and implementation of climate action. Cities that are making progress in transformative climate change actions are following many or all of these pathways. The pathways can guide the way for the hundreds of cities – large and small; low-, middle-, and high-income – throughout the world to play a significant role in climate change action. Cities that do not follow these pathways may have greater difficulty realizing their potential as centers for climate change solutions. The pathways are:

Pathway 1: Actions that reduce greenhouse gas (GHG) emissions while increasing resilience are a win-win. Integrating mitigation and adaptation deserves the highest priority in urban planning, urban design, and urban architecture. A portfolio of approaches is available, including engineering solutions, ecosystem-based adaptation, municipal policies, and social programs. Taking the local context of each city into account is necessary in order to choose actions that result in the greatest benefits.

Pathway 2: Disaster risk reduction and climate change adaptation are the cornerstones of resilient cities. Integrating these activities into urban development policies requires a new, systems-oriented, multi-timescale approach to risk assessments and planning that accounts for emerging conditions within specific, more vulnerable communities and sectors, as well as across entire metropolitan areas.

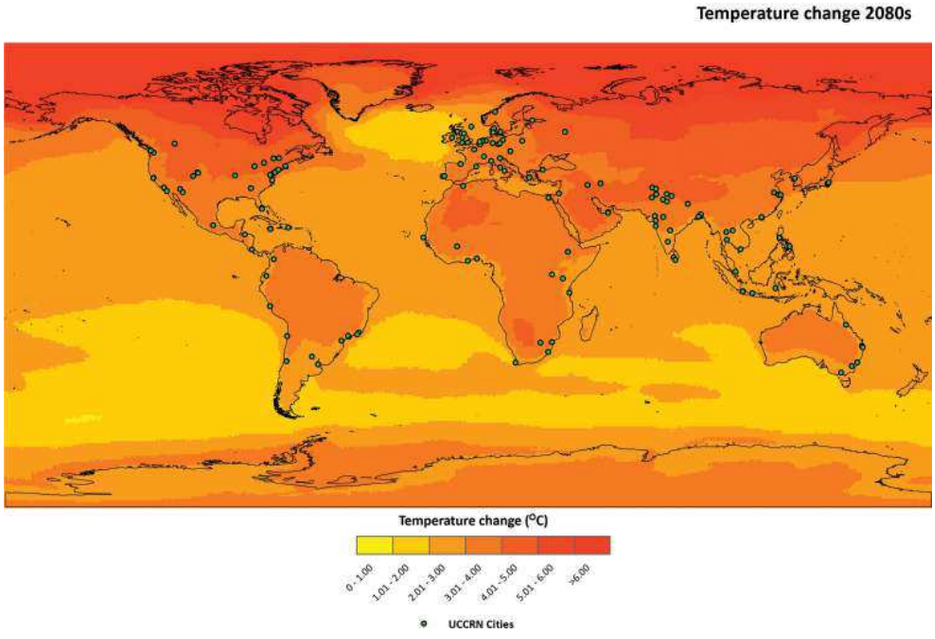
Pathway 3: Risk assessments and climate action plans co-generated with the full range of stakeholders and scientists are most effective. Processes that are inclusive, transparent, participatory, multisectoral, multijurisdictional, and interdisciplinary are the most robust because they enhance relevance, flexibility, and legitimacy.

Pathway 4: Needs of the most disadvantaged and vulnerable citizens should be addressed in climate change planning and action. The urban poor, the elderly, women, minorities, recent immigrants, and otherwise marginal populations most often face the greatest risks due to climate change. Fostering greater equity and justice within climate action increases a city's capacity to respond to climate change and improves human well-being, social capital, and related opportunities for sustainable social and economic development.

Pathway 5: Advancing city creditworthiness, developing robust city institutions, and participating in city networks enable climate action. Access to both municipal and outside financial resources is necessary in order to fund climate change solutions. Sound urban climate governance requires longer planning horizons, effective implementation mechanisms, and coordination. Connecting with national and international capacity-building networks helps to advance the strength and success of city-level climate planning and implementation.

A final word on urgency: Cities need to start immediately to develop and implement climate action. The world is entering into the greatest period of urbanization in human history, as well as a period of rapidly changing climate. Getting started now will help avoid locking in counterproductive, long-lived investments and infrastructure systems and ensure cities' potential for the transformation necessary to lead on climate change.

Climate Observations and Projections for 100 ARC3.2 Cities



SCL Figure 2 *Projected temperature change in the 2080s. Temperature change projection is mean of 35 global climate models (GCMs) and two representative concentration pathways (RCP4.5 and RCP8.5). Colors represent the mean change in mean annual temperature (2070–2099 average relative to 1971–2000 average). Dots represent ARC3.2 cities. ARC3.2 Cities include Case Study Docking Station cities, UCCRN Regional Hub cities, UCCRN project cities, and cities of ARC3.2 Chapter Authors.*

- 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 0.12–0.45°C per decade over the 1961–2010 time period.[1]
- Mean annual temperatures in 153 ARC3.2 cities around the world are projected to increase by 0.7–1.6°C by the 2020s, 1.4–3.1°C by the 2050s, and 1.7–5.0°C by the 2080s (see SCL Figure 2).[2]
- Mean annual precipitation in 153 ARC3.2 cities around the world is projected to change by –7 to +10% by the 2020s, –9 to +14% by the 2050s, and –11 to +20% by the 2080s.
- Sea level in 71 ARC3.2 coastal cities is projected to rise 4–18 centimeters by the 2020s, 14–56 centimeters by the 2050s, and 22–118 centimeters by the 2080s.[3]

1 At the 99% significance level. Data are from the NASA GISS GISTEMP dataset.

2 Temperature and precipitation projections are based on 35 global climate models and two representative concentration pathways (RCP4.5 and RCP8.5). Timeslices are 30-year periods centered around the given decade (e.g., the 2050s is the period from 2040 to 2069). Projections are relative to the 1971–2000 base period. For each of the 153 cities, the low estimate (10th percentile) and high estimate (90th percentile) was calculated. The range of values presented is the average across all 153 cities.

3 Sea level rise projections are based on a four-component approach that includes both global and local factors. The model-based components are from 24 global climate models and 2 representative concentration pathways (RCP4.5 and RCP8.5). Timeslices are 10-year periods centered around the given decade (e.g., the 2080s is the period from 2080 to 2089). Projections are relative to the 2000–2004 base period. For each of the 71 cities, the low estimate (10th percentile) and high estimate (90th percentile) was calculated. The range of values presented is the average across all 71 cities.

4 Like all future projections, UCCRN climate projections have uncertainty embedded within them. Sources of uncertainty include data and modeling constraints, the random nature of some parts of the climate system, and limited understanding of some physical processes. In the ARC3.2 Report, the levels of uncertainty are characterized using state-of-the-art climate models, multiple scenarios of future greenhouse gas concentrations, and recent peer-reviewed literature. The projections are not true probabilities, and scenario planning methods should be used to manage the risks inherent in future climate.

What Cities Can Expect

Smog over Jakarta, Indonesia, November 2011. Photo: Somayya Ali Ibrahim

People and communities everywhere are reporting weather events and patterns that seem unfamiliar. Such changes will continue to unfold over the coming decades and – depending on which choices people make – possibly for centuries. But the various changes will not occur at the same rates in all cities of the world, nor will they all occur gradually or at consistent rates of change.

Climate scientists have concluded that although some of these changes will take place over many decades, even centuries, there is also a risk of crossing thresholds in the climate system that cause some rapid, irreversible changes to occur. One example would be melting of the Greenland and West Antarctic ice sheet, which would lead to very high and potentially rapid rates of sea level rise.

Major Findings

- Urbanization tends to be associated with elevated surface and air temperature, a condition referred to as the *urban heat island* (UHI). Urban centers and cities are often several degrees warmer than surrounding areas due to the presence of heat-absorbing materials, reduced evaporative cooling caused by lack of vegetation, and production of waste heat.

- Some climate extremes will be exacerbated under changing climate conditions. Extreme events in many cities include heat waves, droughts, heavy downpours, and coastal flooding; these are projected to increase in frequency and intensity.

- The warming climate, combined with the UHI effect, will exacerbate air pollution in cities.

- Cities around the world have always been affected by major, naturally occurring variations in climate conditions, including the El Niño Southern Oscillation, the North Atlantic Oscillation, and the Pacific Decadal Oscillation. These oscillations occur over years or decades. How climate change will influence these recurring patterns in the future is not fully understood.

Key Messages

Human-caused climate change presents significant risks to cities beyond the familiar risks caused by natural variations in climate and seasonal weather patterns. Both types of risk require sustained attention from city governments in order to improve urban resilience. One of the foundations for effective adaptation planning is to co-develop plans with stakeholders and scientists who can provide urban-scale information about climate risks, both current risks and projections of future changes in extreme events.

Weather and climate forecasts of daily, weekly, and seasonal patterns and extreme events are already widely used on international, national, and regional scales. These forecasts demonstrate the value of climate science information that is communicated clearly and in a timely way. Climate change projections perform the same functions on longer timescales. These efforts now need to be carried out on the city scale.

Within cities, various neighborhoods experience different microclimates. Therefore, urban monitoring networks are needed to address the unique challenges facing various microclimates and the range of impacts of extreme climate effects at neighborhood scales. The observations collected through such urban monitoring networks can be used as a key component of a citywide climate indicators and monitoring system that enables decision-makers to understand the variety of climate risks across the city landscape.

Managing Disasters in a Changing Climate

SCL Figure 3 *Damaged homes in New York as a result of Hurricane Sandy, November 2012. Photo: Somayya Ali Ibrahim*

Globally, the impacts of climate-related disasters are increasing. These may be exacerbated in cities due to interactions of climate change with urban infrastructure systems, growing urban populations, and economic activities (see SCL Figure 3). Because the majority of the world's population is currently living in cities – and this share is projected to increase in the coming decades – cities need to focus more on climate-related disasters such as heat waves, floods, and droughts.

In a changing climate, a new decision-making framework is needed to fully manage emerging and increasing risks. This involves a paradigm shift away from impact assessments that focus on single climate hazards based on past events. The new paradigm requires integrated, system-based risk assessments that incorporate current and future hazards throughout entire metropolitan regions.

Major Findings

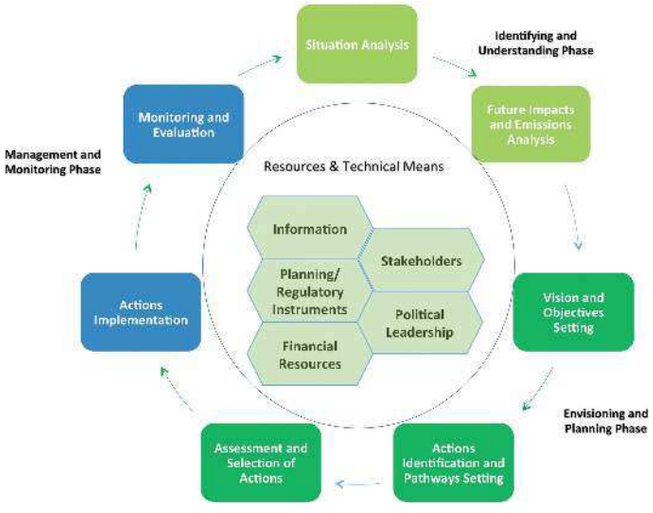
- The number and severity of weather and climate-related disasters is projected to increase in the next decades; because most of the world's population lives in urban areas, cities require specific attention to risk reduction and resilience building.
- The vulnerability of cities to climate-related disasters is shaped by the cultural, demographic, and economic characteristics of residents, local governments' institutional capacity, the built environment, the provision of ecosystem services, and human-induced stresses. The latter include resource exploitation and environmental degradation such as removal of natural storm buffers, pollution, overuse of water, and the UHI effect.
- Integrating climate change adaptation with disaster risk reduction involves overcoming a number of barriers: among others, adding climate resilience to a city's development vision; understanding of the hazards, vulnerabilities, and attendant risks; closing gaps in coordination between various administrative and sectoral levels of management; and development of implementation and compliance strategies and financial capacity.
- Strategies for improving resilience and managing risks in cities include the integration of disaster risk reduction with climate change adaptation, urban and land-use planning and innovative urban design, financial instruments and public–private partnerships, management and enhancement of ecosystem services, building strong institutions and developing community capabilities, and resilient post-disaster recovery and rebuilding.

Key Messages

Disaster risk reduction and climate change adaptation are the cornerstones of making cities resilient to a changing climate. Integrating these activities with a city's development vision requires a new, systems-oriented approach to risk assessments and planning. Moreover, since past events cannot inform decision-makers about emerging and increasing climate risks, systems-based risk assessments must incorporate knowledge about current conditions and future projections across entire metropolitan regions.

A paradigm shift of this magnitude will require decision-makers and stakeholders to increase the capacity of communities and institutions to coordinate, strategize, and implement risk-reduction plans and disaster responses. This is why promoting multilevel, multisectoral, and multistakeholder integration is so important.

Integrating Mitigation and Adaptation as Win-Win Actions



SCL Figure 4 *Main resources and technical means that can be used by cities in their planning cycle for integrating mitigation and adaptation.*

Urban planners and decision-makers need to integrate efforts to alleviate the causes of climate change (mitigation) and adjust to changing climatic conditions (adaptation). Actions that promote both goals provide win-win solutions. In some cases, however, decision-makers have to negotiate tradeoffs and minimize conflicts between competing objectives.

A better understanding of mitigation and adaptation synergies can reveal greater opportunities for urban areas. For example, strategies that reduce the UHI effect, improve air quality, increase resource efficiency in the built environment and energy systems, and enhance carbon storage related to land use and urban forestry are likely to contribute to GHG emissions reduction while improving a city's resilience. The selection of specific adaptation and mitigation measures should be made in the context of other sustainable development goals by taking current resources and the technical means of the city, plus needs of citizens, into account.

Major Findings

- Mitigation and adaptation policies have different goals and opportunities for implementation. However, many drivers of mitigation and adaptation are common, and solutions can be interrelated. Evidence shows that broad-scale, holistic analysis and proactive planning can strengthen synergies, improve cost-effectiveness, avoid conflicts, and help manage tradeoffs.
- Accurate diagnosis of climate risks and the vulnerabilities of urban populations and territory is essential. Likewise, cities need transparent and meaningful GHG emissions inventories and emission reduction pathways in order to prepare mitigation actions.
- Contextual conditions determine a city's challenges, as well as its capacity to integrate and implement adaptation and mitigation strategies. These include the environmental and physical setting, the capacities and organization of institutions and governance, economic and financial conditions, and sociocultural characteristics.

Integrated planning requires holistic, systems-based analysis that takes into account the quantitative and qualitative costs and benefits of integration compared to stand-alone adaptation and mitigation policies (see SCL Figure 4). Analysis should be explicitly framed within local priorities and provide the foundation for evidence-based decision support tools.

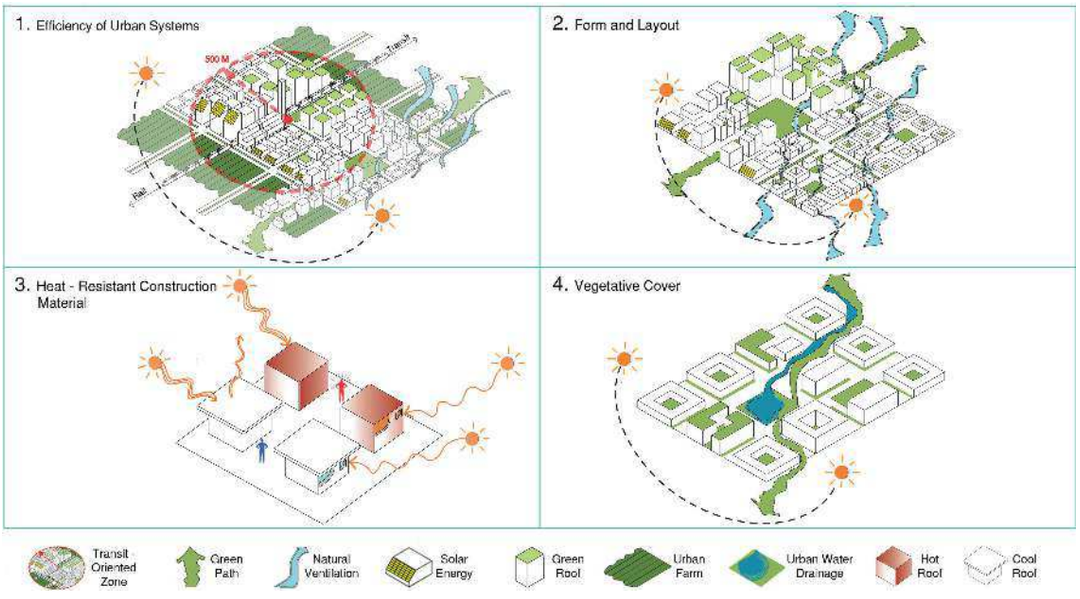
Key Messages

Integrating mitigation and adaptation can help avoid locking a city into counterproductive infrastructure and policies. Therefore, city governments should develop and implement climate action plans early in their administrative terms. These plans should be based on scientific evidence and should integrate mitigation and adaptation across multiple sectors and levels of governance. Plans should clarify short-, medium-, and long-term goals; implementation opportunities; budgets; and concrete measures for assessing progress.

Integrated city climate action plans should include a variety of mitigation actions (those involving energy, transport, waste management, water policies, and more) with adaptation actions (those involving infrastructure, natural resources, health, and consumption policies, among others) in synergistic ways. Because of the comprehensive scope, it is important to clarify the roles and responsibilities of key actors in planning and implementation. Interactions among the actors must be coordinated during each phase of the process.

Once priorities and goals have been identified, municipal governments should connect with federal legislation, national programs, and, in the case of low-income cities, international donors in order to match actions and foster helpful alliances and financial support.

Embedding Climate Change in Urban Planning and Urban Design



SCL Figure 5 *Main strategies used by urban planners and designers to facilitate integrated mitigation and adaptation in cities: (a) reducing waste heat and greenhouse gas emissions through energy efficiency, transit access, and walkability; (b) modifying the form and layout of buildings and urban districts; (c) use of heat-resistant construction materials and reflective surface coatings; and (d) increasing vegetative cover. Source: Jeffrey Raven, New York Institute of Technology, 2016*

Urban planning and urban design have a critical role to play in the global response to climate change. Actions that simultaneously reduce GHG emissions and build resilience to climate risks should be prioritized at all urban scales: metropolitan region, city, district/neighborhood, block, and building. This needs to be done in ways that are responsive to and appropriate for local conditions.

Major Findings

Urban planners and designers have a portfolio of climate change strategies that guide decisions on urban form and function (see SCL Figure 5).

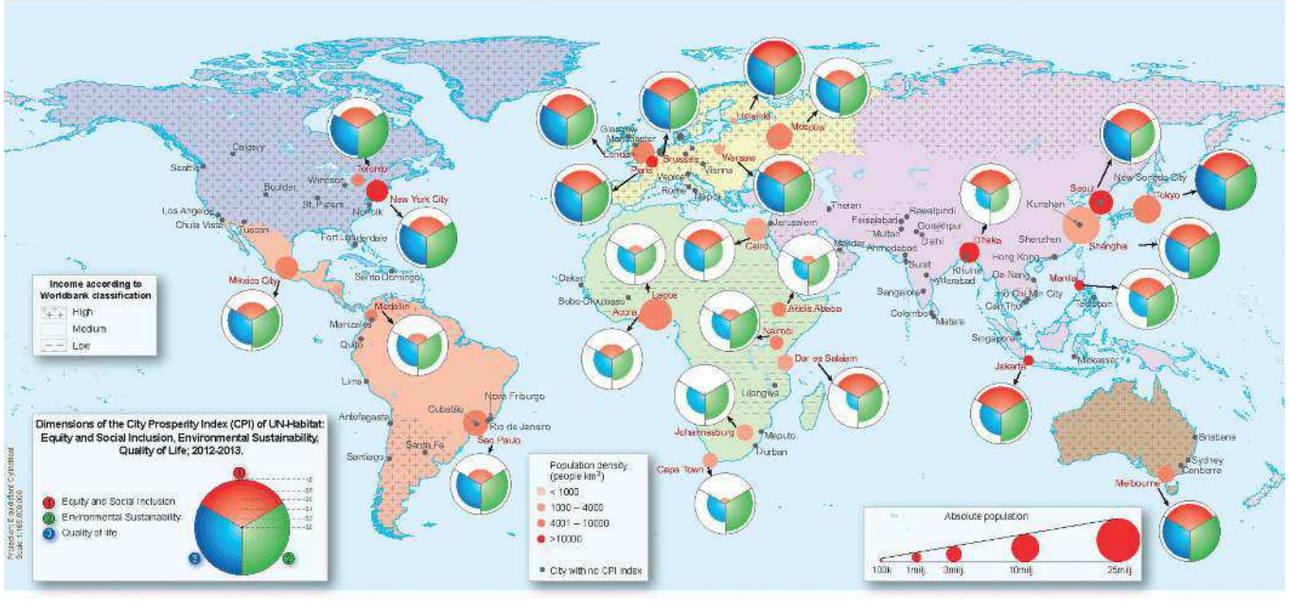
- Urban waste heat and GHG emissions from infrastructure – including buildings, transportation, and industry – can be reduced through improvements in the efficiency of urban systems.
- Modifying the form and layout of buildings and urban districts can provide cooling and ventilation that reduce energy use and allow citizens to cope with higher temperatures and more intense runoff.
- Selecting construction materials and reflective coatings can improve building performance by managing heat exchange at the surface.
- Increasing the vegetative cover in a city can simultaneously lower outdoor temperatures – building cooling demand, runoff, and pollution – while sequestering carbon.

Key Messages

Climate change mitigation and adaptation strategies should form a core element in urban planning and urban design, taking into account local conditions. Decisions on urban form have long-term (>50 years) consequences and affect the city's capacity to reduce GHG emissions and respond to climate hazards. Investing in mitigation strategies that yield concurrent adaptive benefits should be prioritized.

Urban planning and urban design should incorporate long-range strategies for climate change that reach across physical scales, jurisdictions, and electoral time frames. These activities need to deliver a higher quality of life for urban citizens as the key performance outcome.

Equity, Environmental Justice, and Urban Climate Change



SCL Figure 6 *Case study cities included in this assessment, along with a number of dimensions of the City Prosperity Index (CPI) (where available) and including equity and social inclusion. The CPI is a multidimensional index developed by UN-Habitat (2013b) and comprising six dimensions with subdimensions (and indicators) that are measured for each city. Source: Adapted from Metz, 2000*

Cities are characterized by the large diversity of socioeconomic groups living in close proximity. Diversity is often accompanied by stratification based on class, caste, gender, profession, race, ethnicity, age, and ability. This gives rise to social categories that in turn affect the ability of individuals and various groups to endure climate stresses and minimize climate risks.

Differences between strata often lead to discrimination based on group membership. Poorer people and ethnic and racial minorities tend to live in more hazard-prone, vulnerable, and crowded parts of cities. These circumstances increase their susceptibility to the impacts of climate change and reduce their capacity to adapt and withstand extreme events.

Major Findings

- Differential vulnerability of urban residents to climate change is driven by four factors: (1) differing levels of physical exposure determined by the location of residential/occupational areas; (2) urban development processes that lead to risks, such as failure to provide access to critical infrastructure and services; (3) social characteristics that influence resources for adaptation; and (4) institutional and governance weaknesses such as ineffective planning and absence of community engagement (see SCL Figure 6).

- For New York, London, Dar es Salaam, and Durban, risk levels increase dramatically for all key risks in the long-term, especially for the 4°C warming. But, at least for now, in the near-term, and mostly for the long-term with a 2°C temperature rise, a high level of adaptation can keep risks down. However, under a 4°C temperature rise, adaptation measures are likely to be ineffective not only in Dar es Salaam but also in cities with currently high levels of adaptation, such as New York and London.

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

- Frequently occurring climate events – such as droughts in many drought-prone areas – can, over time, undermine everyone's resource base and adaptive capacity, including better-off urban residents. As climate events become more frequent and

intense, this can increase the scale and depth of urban poverty overall.

- Mobilizing resources to increase equity and environmental justice under changing climatic conditions requires (1) participation by impacted communities and the involvement of civil society, (2) nontraditional sources of finance, including partnerships with the private sector, and (3) adherence to the principle of transparency in spending, monitoring, and evaluation.

Key Messages

Urban climate policies should include equity and environmental justice as primary long-term goals. They foster human well-being, social capital, and sustainable social and economic development, all of which increase a city's capacity to respond to climate change. Access to land situated in nonvulnerable locations, security of tenure, and access to basic services and risk-reducing infrastructure are particularly important.

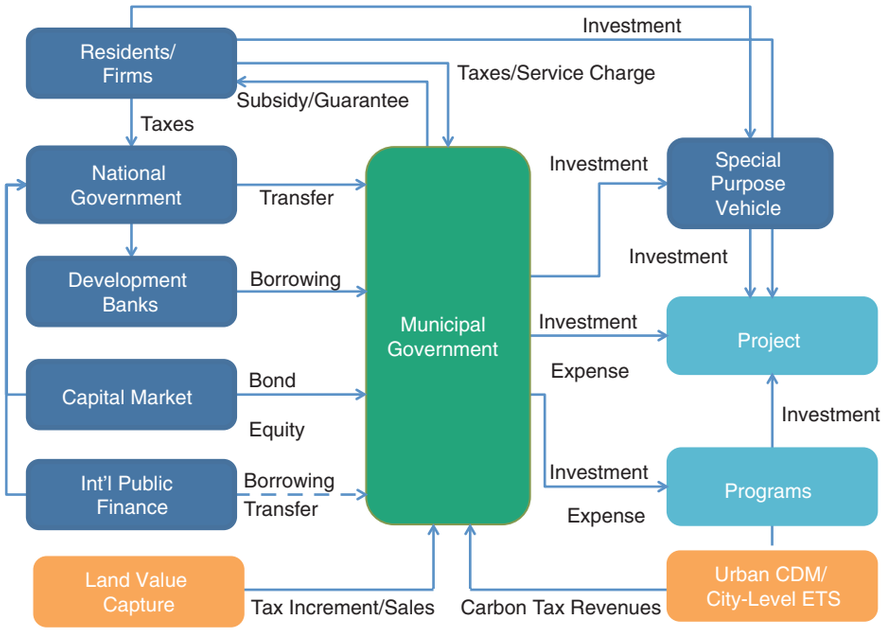
Cities need to promote and share a science-informed policy-making process that integrates multiple stakeholder interests and avoids inflexible, top-down solutions. This can be accomplished by participatory processes that incorporate community members' views about resilience objectives and feasibility.

Over time, climate change policies and programs need to be evaluated and adjusted in order to ensure that sustainability, resilience, and equity goals are achieved. Budgetary transparency, equitable resource allocation schemes, monitoring, and periodic evaluation are essential to ensure that funds reach target groups and result in equitable resilience outcomes.

Financing Climate Change Solutions in Cities

Since cities are the locus of large and rapid socioeconomic development around the world, economic factors will continue to shape urban responses to climate change. To exploit response opportunities, promote synergies between actions, and reduce conflicts, socioeconomic development must be integrated with climate change planning and policies.

Public-sector finance can facilitate action, and public resources can be used to generate investment by the private sector (see SCL Figure 7). But private-sector contributions to mitigation and adaptation should extend beyond financial investment. The private sector should also provide process and product innovation, capacity-building, and institutional leadership.



SCL Figure 7 *Opportunities of climate finance for municipalities.*

Major Findings

- Implementing climate change mitigation and adaptation actions in cities can help solve other city-level development challenges, such as major infrastructure deficits. Assessments show that meeting increasing demand will require a more than doubling of annual capital investment in physical infrastructure to more than US$20 trillion by 2025, mostly in emerging economies. Estimates of global economic costs from urban flooding due to climate change are approximately US$1 trillion a year.

- Cities cannot fund climate change responses on their own. Multiple funding sources are needed to deliver the large infrastructure financing that is essential to low-carbon development and climate risk management in cities. Estimates of the annual cost of climate change adaptation range between US$80 and US$100 billion, of which about 80% will be borne in urbanized areas.

- Public–private partnerships are necessary for effective action. Partnerships should be tailored to the local conditions in order to create institutional and market catalysts for participation.

- Regulatory frameworks should be integrated across city, regional, and national levels to provide incentives for the private sector to participate in making cities less carbon-intensive and more climate-resilient. The framework needs to incorporate mandates for local public action along with incentives for private participation and investment in reducing business contributions to emissions.

- Enhancing credit worthiness and building the financial capacity of cities is essential to tapping the full spectrum of resources and raising funds for climate action.

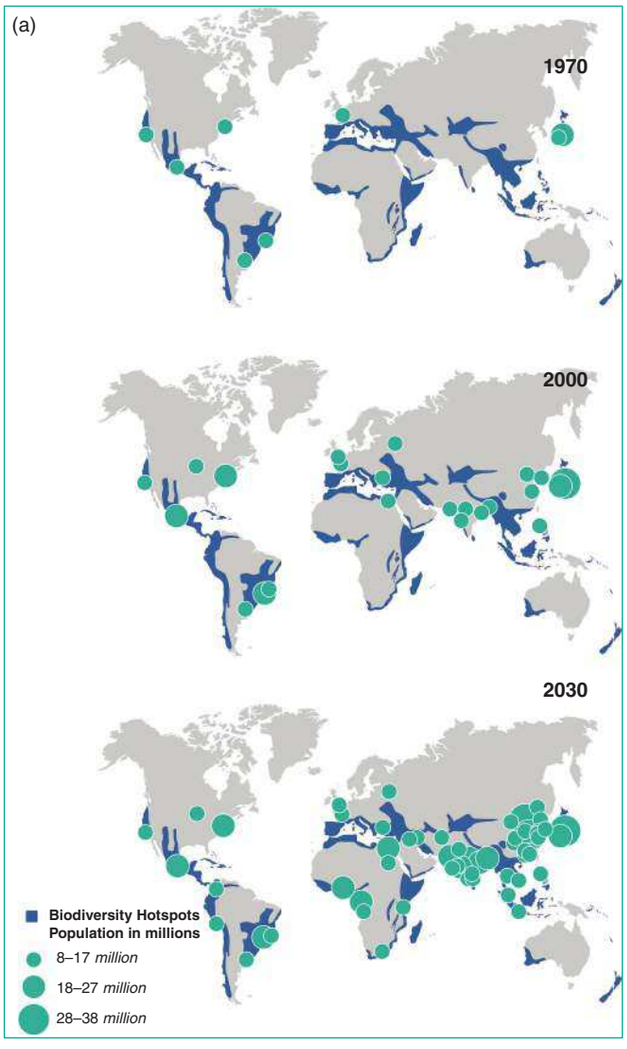
Key Messages

Financial policies must enable local governments to initiate actions that will minimize the costs of climate impacts. For example, the cost of inaction will be very high for cities located along coastlines and inland waterways due to rising sea levels and increasing risks of flooding.

Climate-related policies should also provide cities with local economic development benefits as cities shift to new infrastructure systems associated with low-carbon development.

Networks of cities play a crucial role in accelerating the diffusion of good ideas and best practices to other cities, both domestically and internationally. Therefore, cities that initiate actions that lead to domestic and international implementation of nationwide climate change programs should be rewarded.

Urban Ecology in a Changing Climate



SCL Figure 8a *Urban areas (green) with large populations in 1970, 2000, and 2030 (projected), as examples of urban expansion in global biodiversity hotspots (blue).*

SCL Figure 8b *Settlements on hillsides (bairros-cota); invaded areas belong to the Serra do Mar State Park. Such a settlement creates several hazards to its inhabitants, including landslides, floods, road accidents, and freshwater contamination.*

Almost all the impacts of climate change have direct or indirect consequences for urban ecosystems, biodiversity, and the critical ecosystem services they provide for human health and well-being in cities. These impacts are already occurring in urban ecosystems and their constituent living organisms.

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.

Conserving, restoring, and expanding urban ecosystems under mounting climatic and nonclimatic urban development pressures will require improved urban and regional planning, policy, governance, and multisectoral cooperation.

Major Findings

- Urban biodiversity and ecosystems are already being affected by climate change.
- Urban ecosystems are rich in biodiversity and provide critical natural capital for climate adaptation and mitigation.
- Climate change and urbanization are likely to increase the vulnerability of biodiversity hotspots, urban species, and critical ecosystem services (see SCL Figure 8a and 8b).
- 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.
- Investing in the quality and quantity of urban ecosystems and green infrastructure has multiple co-benefits, including improving quality of life, human health, and social well-being.

Key Messages

Cities should follow a long-term systems approach to ecosystem-based climate adaptation. Such an approach explicitly recognizes the role of critical urban and peri-urban ecosystem services and manages them to provide a sustained supply over time horizons of 20, 50, and 100 years. Ecosystem-based planning strengthens the linkages between urban, peri-urban, and rural ecosystems through planning and management at both urban and regional scales.

The economic benefits of urban biodiversity and ecosystem services should be quantified so that they can be integrated into climate-related urban planning and decision-making. These benefits should incorporate both monetary and non-monetary values of biodiversity and ecosystem services, such as improvements to public health and social equity.

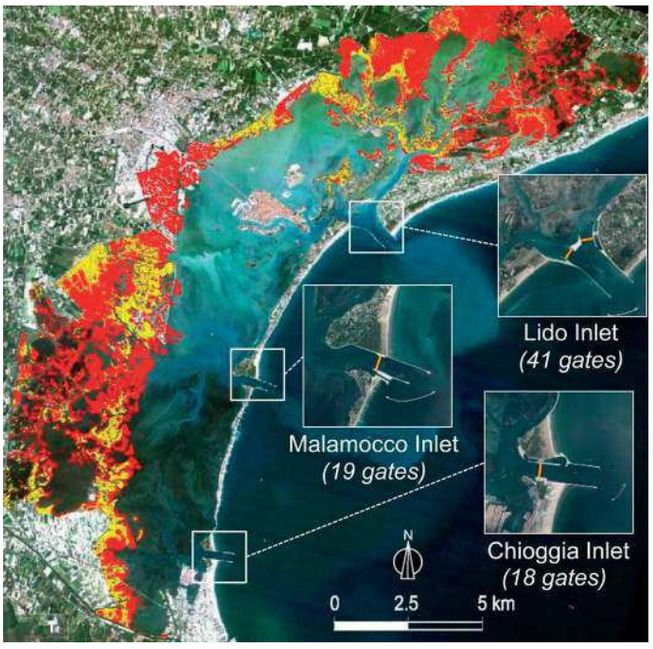
Cities on the Coast: Sea Level Rise, Storms, and Flooding

Coastal cities have lived with extreme climate events since the onset of urbanization, but climatic change and rapid urban development are amplifying the challenge of managing risks. Some coastal cities are already experiencing losses during extreme events related to sea level rise. Meanwhile, urban expansion and changes and intensification in land use put growing pressure on sensitive coastal environments through pollution and habitat loss.

The concentration of people, infrastructure, economic activity, and ecology within the coastal zone merits specific consideration with regard to hazards exacerbated by a changing climate. Major coastal cities often locate valuable assets along the waterfront or within the 100-year flood zone, including port facilities, transport and utilities infrastructure, schools, hospitals, and other long-lived structures. These assets are potentially at risk for both short-term flooding and permanent inundation.

Major Findings

- Coastal cities are already exposed to storm surges, erosion, and saltwater intrusion (see SCL Figure 9). Climate change and sea level rise will likely exacerbate these hazards.
- Around 1.4 billion people could live in the coastal zone, worldwide, by 2060. The population within the 100-year floodplain at risk to a 10–21 cm sea level rise could increase from around 286 million to 411 million people between 2030 and 2060. Three quarters of the exposed populations live in south and southeast Asia.
- Expansion of coastal cities is expected to continue over the 21st century. Although costs of coastal protection could reach US$12–71 billion by 2100, these expenses would be substantially less than taking no action.
- 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.
- Increasing shoreline protection can be accomplished by either building defensive structures or by adopting more natural solutions, such as preserving and restoring wetlands or building dunes. Modifying structures and lifestyles to "live with water" and maintain higher resiliency is a key adaptive measure.



SCL Figure 9 *The MoSE project for the defense of the city of Venice from high tides. Yellow indicates marsh areas surviving at the beginning of the 21st century; red, marshes that have disappeared over the course of the 20th century. Source: Modified from Consorzio Venezia Nuova – Servizio Informativo*

Key Messages

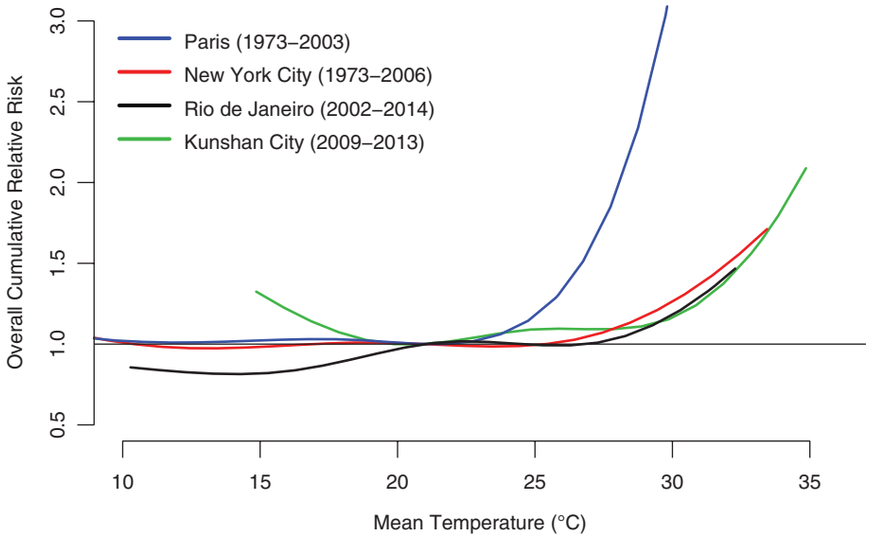
Coastal cities must be keenly aware of the rates of local and global sea level rise and future sea level rise projections, as well as emerging science that might indicate more rapid rates (or potentially slower rates) of sea level rise.

An adaptive approach to coastal management will maintain flexibility to accommodate changing conditions over time. This involves implementing adaptation measures with co-benefits for the built environment, ecosystems, and human systems. An adaptive strategy requires monitoring changing conditions and refining measures as more up-to-date information becomes available.

Simple, less costly measures can be implemented in the short term while assessing future projects. Land-use planning for sustainable infrastructure development in low-lying coastal areas should be an important priority. Furthermore, cities need to consider transformative adaptation, such as large-scale relocation of people and infrastructure with accompanying restoration of coastal ecosystems.

Delivering integrated and adaptive responses will require robust coordination and cooperation on coastal management issues. This must be fostered among all levels of local, regional, and national governing agencies and include engagement with other stakeholders.

Managing Threats to Human Health



SCL Figure 10 *Overall cumulative heat-mortality relationships in Paris, New York, Rio de Janeiro, and Kunshan City (China).*

Climate change and extreme events are increasing risks of disease and injury in many cities. Urban health systems have an important role to play in preparing for these exacerbated risks. Climate risk information and early warning systems for adverse health outcomes are needed to enable interventions. An increasing number of cities are engaging with health adaptation planning, but the health departments of all cities need to be prepared.

Major Findings

- Storms, floods, heat extremes, and landslides are among the most important weather-related health hazards in cities (see SCL Figure 10). 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.

- The public's health in cities is highly sensitive to the ways in which climate extremes disrupt buildings, transportation, waste management, water supply and drainage systems, electricity, and fuel supplies. Making urban infrastructure more resilient will lead to better health outcomes, both during and following climate events.

- Health impacts in cities can be reduced by adopting "low-regret" adaptation strategies in the health system and throughout other sectors such as water resources, wastewater and sanitation, environmental protection, and urban planning.

- Actions aimed primarily at reducing GHG emissions in cities can also bring immediate local health benefits and reduced costs to the health system through a range of pathways, including reduced air pollution, improved access to green space, and opportunities for active transportation on foot or bicycle.

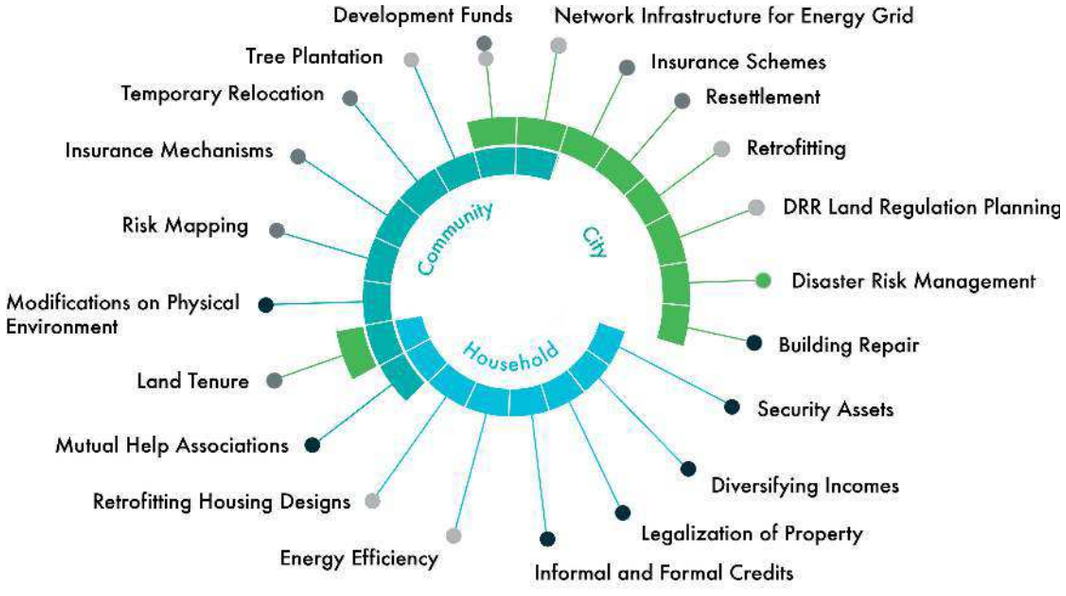
Key Messages

In the near term, improving basic public health and health care services; developing and implementing early warning systems; and training citizen groups in disaster preparedness, recovery, and resilience are effective adaptation measures.

The public health sector, municipal governments, and the climate change community should work together to integrate health as a key goal in the policies, plans, and programs of all city sectors.

Connections between climate change and health should be made clear to public health practitioners, city planners, policy-makers, and the general public.

Housing and Informal Settlements



SCL Figure 11 *Overlapping coping, adaptation, and mitigation strategies at household, community, and citywide scales.*

Addressing vulnerability and exposure in the urban housing sector can contribute to the well-being of residents. This is especially true in informal settlements, where extreme climate events present the greatest risks. Understanding the impacts of mitigation and adaptation strategies on the housing sector will help decision-makers make choices that improve quality of life and close development and equity gaps in cities (see SCL Figure 11).

Major Findings

- The effects of hazards, people's exposure, and their vulnerability collectively determine the types and levels of risk. Risks are associated with specific social and physical factors within each city. Mapping risks and developing early warning systems, preparedness plans, and pre-disaster recovery strategies – especially for informal settlements – can support decision-makers and stakeholders in reducing exposure and vulnerability.
- Developed countries account for the majority of the world's energy demand related to buildings. Incentives and other measures are enabling large-scale investments in mass retrofitting programs in higher income cities.
- Housing construction in low- and middle-income countries is focused on meeting demand for more than 500 million more people by 2050. Efficient, cost-effective, and adaptive building technologies can avoid locking in carbon-intensive and non-resilient options.
- Access to safe and secure land is a key measure for reducing risk in cities. Groups that are already disadvantaged in regard to housing and land tenure are especially vulnerable to climate.
- Among informal settlements, successful adaptation depends on addressing needs for climate-related expertise, resources, and risk-reducing infrastructure.

Key Messages

City managers should work with the informal sector to improve safety in relation to climate extremes. Informal economic activities are often highly vulnerable to climate impacts, yet they are crucial to economies in low- and middle-income cities. Therefore, direct and indirect costs to the urban poor should be included in loss and damage assessments in order to accurately reflect the full range of impacts on the most vulnerable urban residents and the city as a whole.

Evidence of affordable insurance schemes in developing countries' low-income communities that fulfill adaptation goals is limited. Several implementation-related hurdles need to be addressed if insurance schemes are to be successful. These are excessive reliance on government and donor subsidies, lack of local distribution channels, poor financial literacy of communities, and overall limited demand.

Retrofits to housing that improve resilience create co-benefits such as more dignified housing, improvements to health, and better public spaces. Meanwhile, mitigating GHG emissions in the housing sector can create local jobs in production, operations, and maintenance, especially in low-income countries and informal settlements.

Energy Transformation in Cities

Demands on urban energy supply are projected to grow exponentially due to the growth trends in urbanization and the size of cities, industrialization, technological advancement, and wealth. Increasing energy requirements are associated with rising demands for vital services including electricity, water supply, transportation, buildings, communication, food, health, and parks and recreation.

With climate change, the urban energy sector is facing three major challenges. The first is to meet the rising demand for energy in rapidly urbanizing countries without locking into high-carbon-intensive fuels such as coal. The second is to build resilient urban energy systems that can withstand and recover from the impacts of increasingly extreme climate events. The third is to provide cities in low-income countries with modern energy systems while replacing traditional fuel sources such as biomass.

Major Findings

- Urbanization has clear links to energy consumption in low-income countries. Urban areas in high-income countries generally use less energy per capita than do nonurban areas due to the 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.
- Key challenges facing the urban energy supply sector include reducing environmental impacts such as air pollution, the UHI effect, and GHG emissions; providing equal access to energy; and ensuring energy security and resilience in a changing climate.
- While numerous examples of energy-related mitigation policies exist across the globe, less attention has been given to adaptation policies. Research suggests that radical changes in the energy supply sector, customer behavior, and the built environment are needed to meet the key challenges.
- Scenario research that analyzes energy options requires more integrated assessment of the synergies and tradeoffs in meeting multiple goals: reducing GHG, increasing equity in energy access, and improving energy security.

Key Messages

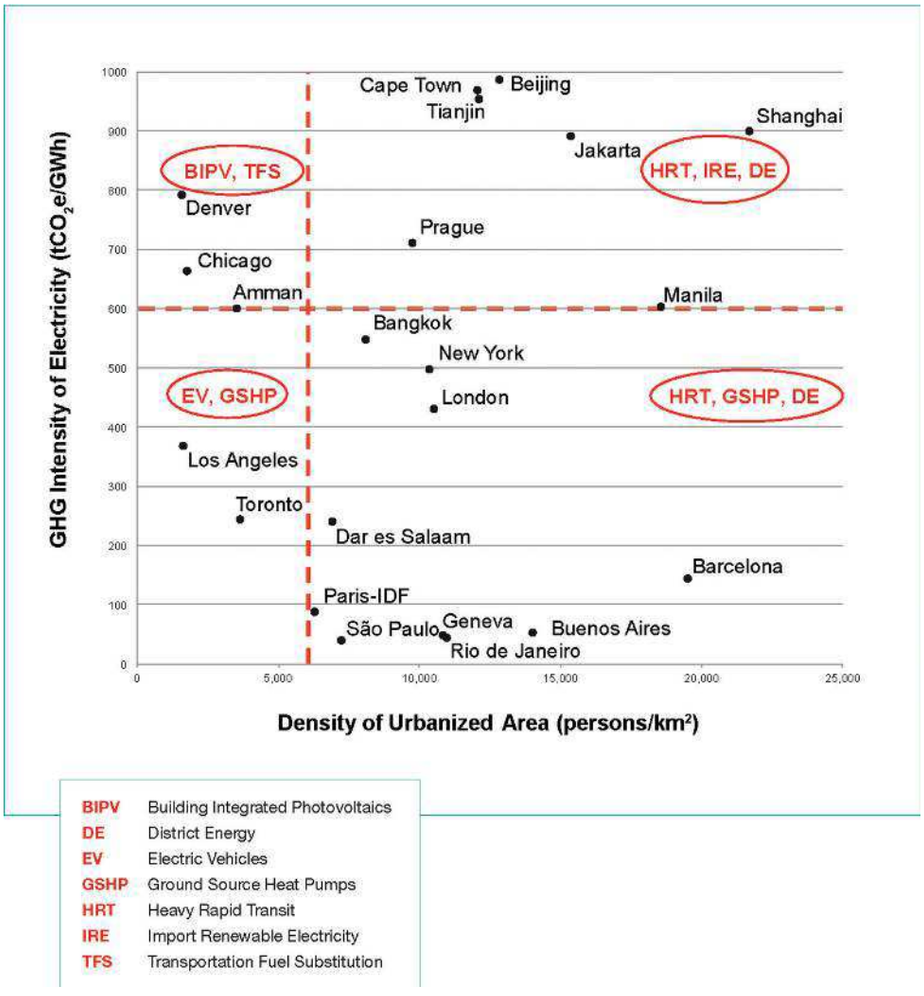
In the coming decades, rapid population growth, urbanization, and climate change will impose intensifying stresses on existing and not-yet-built energy infrastructure. The rising demand for energy services – mobility, water and space heating, refrigeration, air conditioning, communications, lighting, and construction – in an era of enhanced climate variation poses significant challenges for all cities.

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.

Yet future low-carbon transitions may also differ from previous energy transitions because future transitions may be motivated more by changes in governance and environmental concerns than by the socioeconomic and behavioral demands of the past. Unfortunately, the governance of urban energy supply varies dramatically across nations and sometimes within nations, making universal recommendations for institutions and policies difficult, if not impossible. Given that energy-sector institutions and activities have varying boundaries and jurisdictions, there is a need for stakeholder engagement across the matrix of institutions to cope with future challenges in both the short and long term.

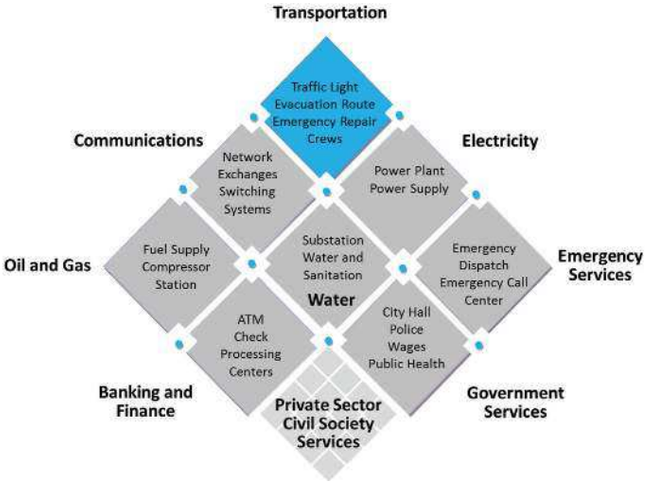
To achieve global GHG emission reductions through the modification of energy use at the urban scale, it is critical to develop an urban registry that has a typology of cities and indicators for both energy use and GHG emissions (see SCL Figure 12). This will help cities benchmark and compare their accomplishments and better understand the mitigation potential of cities worldwide.

Energy Transformation in Cities (continued)



SCL Figure 12 *Low-carbon infrastructure strategies tailored to different cities based on both urban population density and average GHG intensity of the existing electricity supply. Both factors need to be taken into account in developing sustainable urban energy solutions. Source: Adapted from Kennedy et al., 2014*

Transport as Climate Challenge and Solution



SCL Figure 13 *Urban transport's interconnectivity with other urban systems. Source: Adapted from Melillo et al., 2014*

Urban transport systems are major emitters of GHG and are essential to developing resilience to climate impacts. At the same time, cities need to move forward quickly to adopt a new paradigm that ensures access to clean, safe, and affordable mobility for all.

In middle-income countries, rising incomes are spurring demand for low-cost vehicles and, together with rapid and sprawling urbanization and segregated land use, are posing unprecedented challenges to sustainable development while contributing to climate change.

Expanded climate-related financing mechanisms such as the Green Climate Fund are being developed at national and international levels. Local policy-makers should prepare the institutional capacity and policy frameworks needed to access financing for low-carbon and resilient transport.

Major Findings

- Cities account for more than 70% of GHG emissions, with a significant proportion due to urban transport choices. The transport sector directly accounted for nearly 30% of total end-use, energy-related CO2 emissions. Of these, direct emissions from urban transport account for 40%.

- Urban transport emissions are growing at 2–3% annually. The majority of emissions from urban transport are from higher income countries. In contrast, 90% of the growth in emissions is from transport systems in lower income countries.

- Climate-related shocks to urban transportation have economy-wide impacts extending beyond disruptions to the movement of people and goods. The interdependencies between transportation and other economic, social, and environmental sectors can lead to citywide impacts (see SCL Figure 13).

- Integrating climate risk reduction into transport planning and management is necessary in spatial planning and land-use regulations. Accounting for these vulnerabilities in transport decisions can ensure that residential and economic activities are concentrated in low-risk zones.

- Low-carbon transport systems yield co-benefits that can reduce implementation costs, yet policy-makers often need more than a good economic case to capture potential savings.

- Integrated low-carbon transport strategies – Avoid-Shift-Improve – involve avoiding travel through improved mixed land-use planning and other measures; shifting passengers to more efficient modes through provision of high-quality, high-capacity mass transit systems; and improving vehicle design and propulsion technologies to reduce fuel use.

- Designing and implementing risk-reduction solutions and mitigation strategies requires supportive policy and public–private investments. Key ingredients include employing market-based mechanisms; promoting information and communication technologies; building synergies across land-use and transport planning; and refining regulations to encourage mass transit and non-motorized modes.

Key Messages

Co-benefits such as improved public health, better air quality, reduced congestion, mass transit development, and sustainable infrastructure can make low-carbon transport more affordable and sustainable and can yield significant urban development advantages. For many transport policy-makers, co-benefits are primary entry points for reducing GHG emissions. At the same time, policy-makers should find innovative ways to price the externalities – the unattributed costs – of carbon-based fuels.

The interdependencies between transport and other urban sectors mean that disruptions to transport can have citywide impacts. To minimize disruptions due to these interdependencies, policy-makers should take a systems approach to risk management that explicitly addresses the interconnectedness among climate, transport, and other relevant urban sectors.

Low-carbon transport should also be socially inclusive because social equity can improve a city's resilience to climate change impacts. Automobile-focused urban transport systems fail to provide mobility for significant segments of urban populations. Women, the elderly, the poor, non-drivers, and disadvantaged people need urban transport systems that go beyond enabling mobility to fostering social mobility as well.

Sustaining Water Security

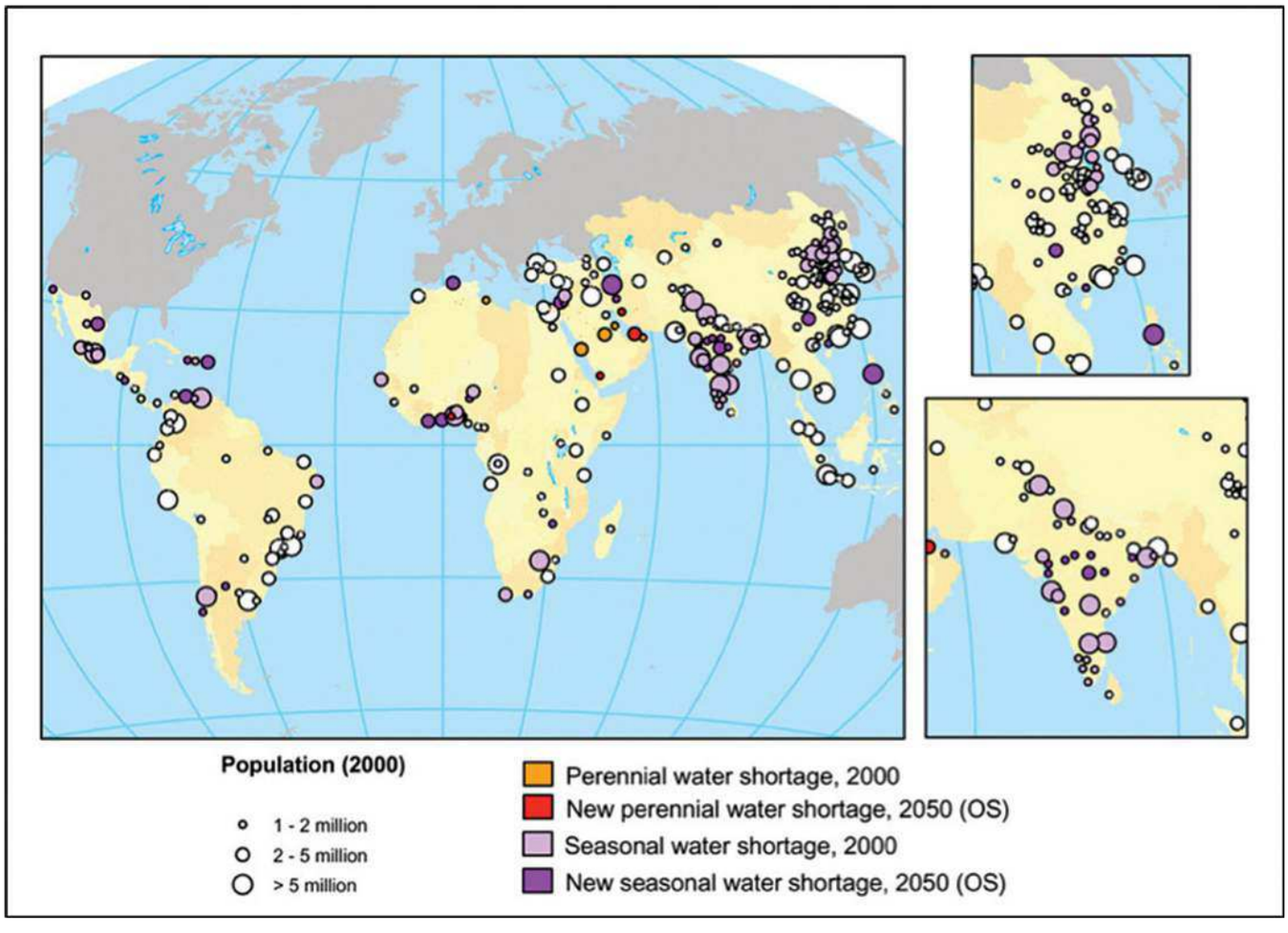
Water is both a resource and a hazard in climate change. As a resource, good-quality water is basic to the well-being of the ever-increasing number of people living in cities. Water is also critical for many economic activities, including peri-urban agriculture, food and beverage production, and industry. However, excess precipitation or drought can lead to hazards ranging from increased concentrations of pollutants – with negative health consequences, a lack of adequate water flow for sewerage, and flood-related damage to physical assets.

Projected deficits in the future of urban water supplies will likely have a major impact on both water availability and costs. Decisions taken now will have an important influence on future water supply for industry, domestic use, and agriculture.

Major Findings

- The impacts of climate change put additional pressure on existing urban water systems and can lead to negative impacts for human health and well-being, economies, and the environment (see SCL Figure 14). Such 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.

- A lack of urban water security, particularly in lower income countries, is an ongoing challenge. Many cities struggle to deliver even basic services to their residents, especially those living in informal settlements. As cities grow, demand and competition



SCL Figure 14 *Distribution of large cities (>1 million population in 2000) and their water shortage status in 2000 and 2050. Gray areas are outside the study area. Source: McDonald et al., 2011*

for limited water resources will increase, and climate changes are very likely to make these pressures worse in many urban areas.

- Water security challenges extend to peri-urban areas as well, where pressure on resources is acute and where there are often overlapping governance and administrative regimes.

- Governance systems have largely failed to adequately address the challenges that climate change poses to urban water security. Failure is often driven by a lack of coherent and responsive policy, limited technical capacity to plan for adaptation, limited resources to invest in projects, lack of coordination, and low levels of political will and public interest.

Key Messages

Adaptation strategies for urban water resources will be unique to each city since they depend heavily on local conditions.

Understanding the local context is essential to adapting water systems in ways that address both current and future climate risks.

Acting now can minimize negative impacts in the long term. Master planning should anticipate projected changes over a time frame of more than 50 years. Yet, in the context of an uncertain future, finance and investment should focus on low-regret options that promote both water security and economic development, and policies should be flexible and responsive to changes and new information that come to light over time.

Many different public and private stakeholders influence the management of water, wastewater, stormwater, and sanitation. For example, land-use decisions have long-lasting consequences for drainage, infrastructure planning, and energy costs related to water supply and treatment. Therefore, adapting to the changing climate requires effective governance as well as coordination and collaboration among a variety of stakeholders and communities.

Cities should capture co-benefits in water management whenever possible. Cities might benefit from low-carbon energy production and improved health with wastewater treatment. Investment strategies should include the application of life cycle analysis to water supply, treatment, and drainage; use of anaerobic reactors to improve the balance between energy conservation and wastewater treatment; elimination of high-energy options such as interbasin transfers of water wherever alternative sources are available; and recovering biogas produced by wastewater.

Managing and Utilizing Solid Waste

Municipal solid waste management is inextricably linked to increasing urbanization, development, and climate change. The municipal authority's ability to improve solid waste management also provides large opportunities to mitigate climate change and generate co-benefits such as improved public health and local environmental conservation.

Driven by urban population growth, rising rates of waste generation will severely strain existing municipal solid waste infrastructure in low- and middle-income countries. In most of these countries, the challenge is focused on effective waste collection and improving waste treatment systems to reduce GHG emissions. In contrast, high-income countries can improve waste recovery through reuse and recycling, and promote upstream interventions to prevent waste at the source (see SCL Figure 15).

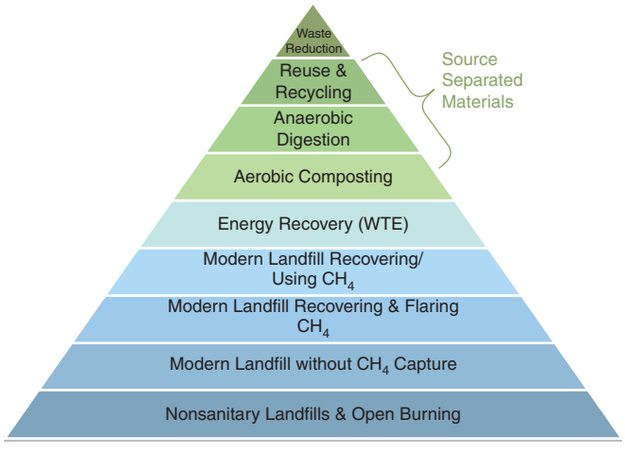
Because stakeholder involvement, economic interventions, and institutional capacity are all important for enhancing solid waste management, integrated approaches involving multiple technical, environmental, social, and economic efforts will be necessary.

Major Findings

- Globally, solid waste generation was about 1.3 billion tons in 2010. Due to population growth and rising standards of living worldwide, waste generation is likely to increase significantly by 2100. A large majority of this increase will come from cities in low- and middle-income countries, where per capita waste generation is expected to grow.

- Up to 3–5% of global GHG emissions come from improper waste management. The majority of these emissions is methane – a gas with high greenhouse potential – that is produced in landfills. Landfills, therefore, present significant opportunities to reduce GHG emissions in high- and middle-income countries.

- Even though waste generation increases with affluence and urbanization, GHG emissions from municipal waste systems are lower in more affluent cities. In European and North American cities, GHG emissions from the waste sector account for 2–4% of total urban emissions. These shares are smaller than in African and South American cities, where emissions from the waste sector are 4–9% of the total urban emissions. This is because more affluent cities tend to have the necessary infrastructure to reduce methane emissions from municipal solid waste.



SCL Figure 15 *The hierarchy of sustainable solid waste management. Source: Kaufman and Themelis, 2010*

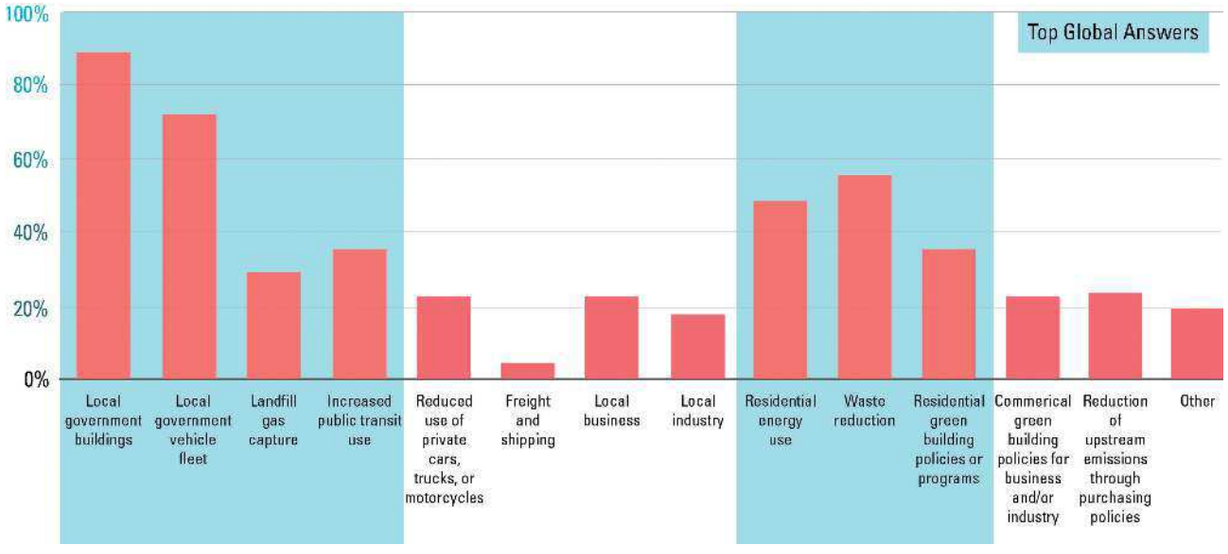
- In low- and middle-income countries, solid waste management represents 3–15% of city budgets, with 80–90% of the funds spent on waste collection. Even so, collection coverage ranges only from 25% to 75%. The primary means of waste disposal is open dumping, which severely compromises public health.

- Landfill gas-to-energy is an economical technique for reducing GHG emissions from the solid sector. This approach provides high potential to reduce emissions at a cost of less than US$10 per tCO_2eq. However, gas-to-energy technology can be employed only at properly maintained landfills and managed dumpsites, and social aspects of deployment need to be considered.

Key Messages

Reducing GHG emissions in the waste sector can improve public health; improve quality of life; and reduce local pollution in the air, water, and land while providing livelihood opportunities to the urban poor. Cities should exploit the low-hanging fruit for achieving emissions reduction goals by using existing technologies to reduce methane emissions from landfills. In low- and middle-income countries, the best opportunities involve increasing the rates of waste collection, building and maintaining sanitary landfills, recovering materials and energy by increasing recycling rates, and adopting waste-to-energy technologies. Resource managers in all cities should consider options such as reduce, re-use, recycle, and energy recovery in the waste management hierarchy.

Urban Governance for a Changing Climate



SCL Figure 16 *Mitigation interventions and uptake by cities, resulting in measurable emission reductions. Source: Aylett, 2014*

GHG emissions and climate risks in cities are not only local government concerns. They challenge a range of actors across jurisdictions to create coalitions for climate governance. Urban climate change governance occurs within a broader socioeconomic and political context, with actors and institutions at a multitude of scales shaping the effectiveness of urban-scale interventions. These interventions may be particularly powerful if they are integrated with co-benefits related to other development priorities, creating urban systems (both built and institutional) that are able to withstand, adapt to, and recover from climate-related hazards.

Collaborative, equitable, and informed decision-making is needed to enable transformative responses to climate change, as well as fundamental changes in energy and land-use regimes, growth ethos, production and consumption, lifestyles, and worldviews. Leadership, legal frameworks, public participation mechanisms, information sharing, and financial resources all work to shape the form and effectiveness of urban climate change governance.

Major Findings

- While jurisdiction over many dimensions of climate change adaptation and mitigation resides at the national level, along with the relevant technical and financial capacities, comprehensive national climate change policy is still lacking in most countries. Despite this deficiency, municipal, state, and provincial governmental and non-governmental actors are taking action to address climate change (see SCL Figure 16).
- Urban climate change governance consists not only of decisions made by government actors, but also by non-governmental and civil society actors in the city. Participatory processes that engage these interests around a common aim hold the greatest potential to create legitimate, effective response strategies.
- Governance challenges often contribute to gaps between the climate commitments that cities make and the effectiveness of their actions.
- Governance capacity to respond to climate change varies widely within and between low- and high-income cities, creating a profile of different needs and opportunities on a city-by-city basis.
- The challenge of coordinating across the governmental and non-governmental sectors, jurisdictions, and actors that is necessary for transformative urban climate change policies is often not met. Smaller scale, incremental actions controlled by local jurisdictions, single institutions, or private and community actors tend to dominate city-level actions.
- Scientific information is necessary for creating a strong foundation for effective urban climate change governance, but governance is needed to apply it. Scientific information needs to be co-generated if it is to be applied effectively and meet the needs and address the concerns of the range of urban stakeholders.

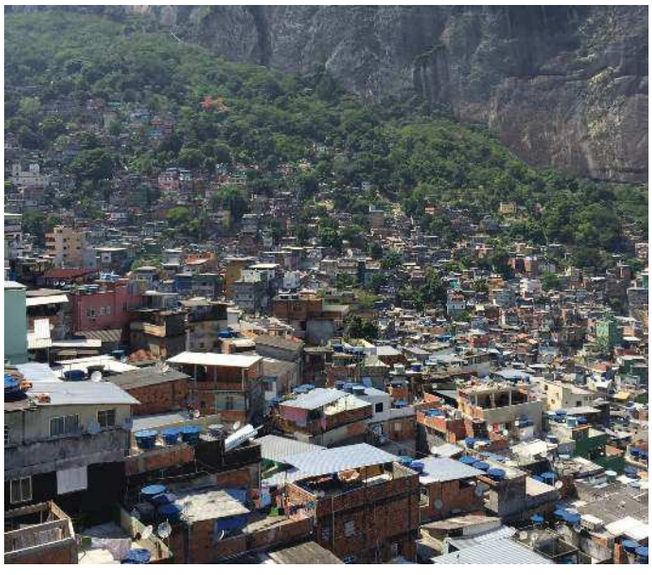
Urban Governance for a Changing Climate (continued)

Key Messages

While climate change mitigation and adaptation have become a pressing issue for cities, governance challenges have led to policy responses that are mostly incremental and fragmented. Many cities are integrating mitigation and adaptation, but fewer are embarking on the more transformative strategies required to trigger a fundamental change toward sustainable and climate-resilient urban development pathways.

The drivers, dynamics, and consequences of climate change cut across jurisdictional boundaries and require collaborative governance across governmental and non-governmental sectors, actors, administrative boundaries, and jurisdictions. Although there is no single governance solution to climate change, longer planning timescales; coordination and participation among multiple actors; and flexible, adaptive governance arrangements may lead to more effective urban climate governance.

Urban climate change governance should incorporate principles of justice in order that inequities in cities are not reproduced. Therefore, justice in urban climate change governance requires that vulnerable groups be represented in adaptation and mitigation planning processes, that priority framing and setting



The Rocinha Favela in Rio de Janeiro, October 2015. Photo: Somayya Ali Ibrahim

recognize the particular needs of vulnerable groups, and that actions taken to respond to climate change enhance the rights and assets of vulnerable groups.

UCCRN Regional Hubs

Building on a series of scoping sessions with stakeholders and members, UCCRN is transitioning from a report-focused organization to one that leads an ongoing, sustained global city-focused climate change knowledge assessment and solutions program, through the founding of the UCCRN Regional Hubs. The Regional Hubs operate at continental scale (e.g., Europe, Latin America, Africa, South and East Asia, Australia-Oceania) and will be linked to other relevant regional and global resource nodes.

The UCCRN Regional Hubs serve to promote enhanced opportunities for new urban climate change adaptation and mitigation knowledge and information transfer, both within and across cities, by engaging in a real-time monitoring and review process with cities through ongoing dialogue between scholars, experts, urban decision-makers, and stakeholders.

Since its launch, the Regional Hubs Program has made great strides. The first UCCRN Regional Hub was launched in Paris in July 2015, as the European Hub, shortly followed by the launch of the UCCRN Latin American Hub in Rio de Janeiro in October 2015, and the announcement of the UCCRN Australia-Oceania Hub, co-located in Canberra, Melbourne, and Sydney, at the COP21 conference in December 2015. The UCCRN African Hub was launched in Durban, South Africa in May 2016, followed by the UCCRN East Asian Hub in Shanghai in August 2016, and the UCCRN North American Hub in Philadelphia in November 2016.

In addition to the formal Hubs, a Nordic Node has also been established at Aalborg University to help coordinate Northern European urban climate change efforts. São Paulo State is the home of the UCCRN Center for Multilevel Governance, which has the overall objective of discussing implementation of climate policies at the subnational level and their jurisdictional circumstances. The UCCRN is exploring other potential Asian Hubs in Dhaka and Manila.

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SCL Figure 17 *The UCCRN ARC3.2 Pathways to Urban Transformation*