

Part I

Introduction

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Urban climate change in context

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1.1 Introduction

Cities,¹ as home to over half the world's people, are at the forefront of the challenge of climate change. Climate change exerts added stress on urban environments through increased numbers of heat waves threatening the health of the elderly, the ill, and the very young; more frequent and intense droughts and inland floods threatening water supplies; and for coastal cities, enhanced sea level rise and storm surges affecting people and infrastructure (Figure 1.1) (IPCC, 2007). At the same time, cities are responsible for a considerable portion of greenhouse gas emissions and are therefore crucial to global mitigation efforts (Stern, 2007; IEA, 2008). Though cities are clearly vulnerable to the effects of climate change, they are also uniquely positioned to take a leadership role in both mitigating and adapting to it because they are pragmatic and action-oriented; play key roles as centers of economic activity regionally, nationally, and internationally; and are often first in societal trends. There are also special features of cities related to climate change. These include the presence of the urban heat island and exacerbated air pollution, vulnerability caused by growing urban populations along coastlines, and high population density and diversity. Further attributes of cities specifically relevant to climate change relate to the presence of concentrated, highly complex, interactive sectors and systems, and multi-layered governance structures.

The Urban Climate Change Research Network (UCCRN) is a group of researchers dedicated to providing science-based information to decision-makers in cities around the world as they respond to climate change. The goal is to help cities develop effective and efficient climate change mitigation and adaptation policies and programs. By so doing, the UCCRN is developing a model of within- and across-city interactions that is multidimensional, i.e., with multiple interactions of horizontal knowledge-sharing from the developing to developed cities and vice versa. The UCCRN works simultaneously by knowledge-sharing among small to mid-sized to large to megacities as well. Free-flowing multidimensional interactions are essential for optimally enhancing science-based climate change response capacities. The temporal dimension is also critical – the need to act in the near term on climate change in cities is urgent both in terms of mitigation of greenhouse gas emissions and in terms of climate change adaptation. The UCCRN is thus developing an efficient and cost-effective method for reducing climate risk by providing state-of-the-art knowledge for policymakers in cities across the world in order to inform ongoing and planned private and public investments as well as to retrofit existing assets and management practices.

1.1.1 Contributions to climate change and cities

There are several ongoing efforts that focus on climate change and cities. On the institutional side, ICLEI – Local Governments

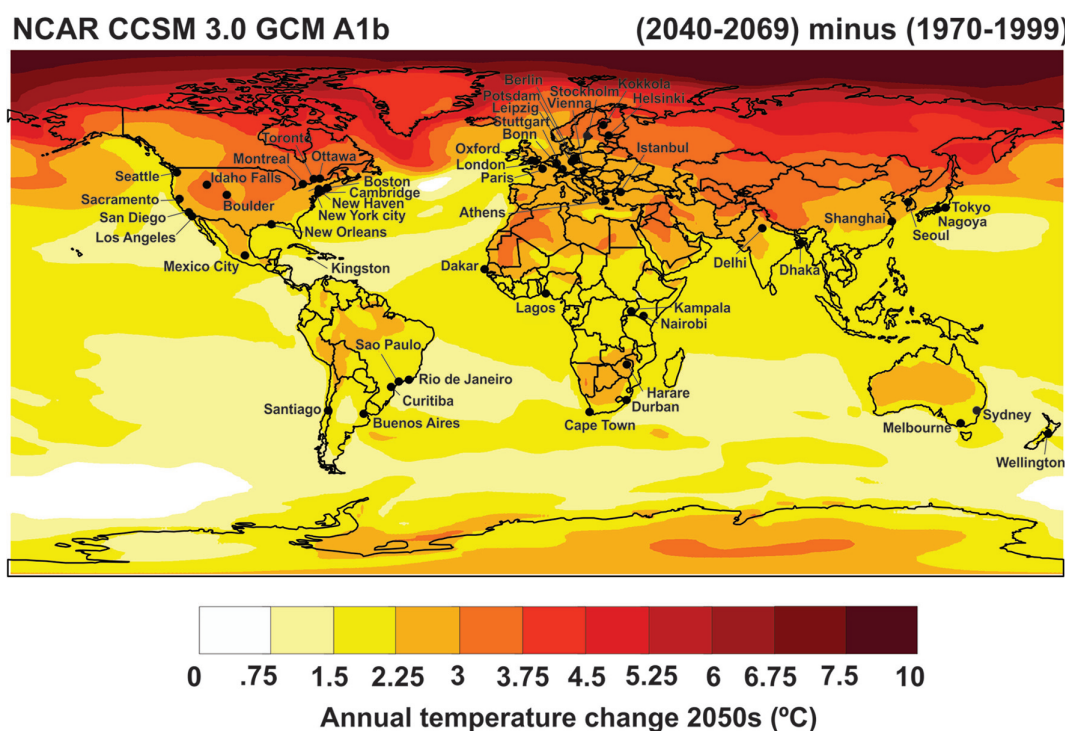


Figure 1.1: Cities represented in ARC3 and 2050s temperature projections for the NCAR CCSM 3.0 GCM with greenhouse gas emissions scenario A1b.

Source: NCAR CCSM 3.0 – Collins et al. (2006); Emissions Scenario A1b – Nakicenovic et al. (2000).

¹ We define “cities” here in the broad sense to be urban areas, including metropolitan and surrounding suburban regions.

for Sustainability has played a major role in encouraging mitigation efforts by local governments around the world. The UN-HABITAT has started a cities and climate change program, as has the World Bank and Organization for Economic Cooperation and Development (OECD). On the research side, the International Institute for Environment and Development (IIED) has focused on community aspects of climate change vulnerability in developing cities, and the World Bank has sponsored a set of research studies for the Fifth Urban Research Symposium held in Marseille in June 2009. The Global Report on Human Settlements 2011 of UN-HABITAT is focused on cities and climate change.

1.1.2 Focus on the urban poor

One of several major foci of these efforts is the developmental needs of the urban poor. In urban areas, inequities among socio-economic groups are projected to become more pronounced as climate change progresses (Mehrotra *et al.*, 2009). For example, the urban poor are less able to move from highly vulnerable locations in coastal and riverine areas at risk of enhanced flooding. This will lead to changes in the spatial distribution and density of both formal and informal urban settlements. Factors that affect social vulnerability to climate change include age, lack of material resources, access to lifelines such as transportation and communication, and lack of information and knowledge. As warmer temperatures extend into higher latitudes and hydrological regimes shift, some vector-borne diseases may extend their ranges, either re-emerging or becoming new problems. Water-borne diseases may shift ranges as well due to changes in water temperature, quantity, and quality in future climates. Such changes can cause serious consequences, especially in densely populated informal settlements in cities in developing countries.

1.1.3 Intersection of climate change and disaster risk reduction and recovery

A related focus is on the intersection of climate change and disaster risk reduction and recovery. Climate change and its effects have the potential to increase exposure to a range of urban risks, and in turn influence how disaster reduction strategies need to be conceived and executed by urban decision-makers. Current efforts by both the climate change and the disaster risk reduction communities are focused on identifying pathways and opportunities for integrating climate change adaptation strategies and disaster risk reduction activities into the daily programmatic activities of a broad range of stakeholder agencies in cities. Disaster- and hazard-related organizations as well as stakeholders who manage risk in other agencies will need to take on these challenges.

Many impacts of climate change in cities, especially in the short and medium term, will be felt in the form of enhanced variability and changing frequency or intensity of extreme events. These will often be considered “disasters.” As disaster risk reduction and climate change adaptation are beginning to

converge, there is the potential for them to be largely managed as one integrated agenda. There is not, however, complete overlap between the two fields. One difference is that disaster risk reduction covers geophysical disasters, such as earthquakes, which do not overlap with climate risk.

While climate risk is certainly connected with the increased likelihood of damaging extreme events, climate change is also conceptualized as an emerging public policy issue relating to slow transitions in many urban sectors, ranging over water supply and sanitation, public health, energy, transportation, and migration, among others, which demands response within existing management cycles and planning activities. A central challenge for cities is not only to define the links between climate change and adaptation and disaster risk reduction with respect to extreme events but also with respect to these other climate change policies, which if mismanaged could aggravate vulnerability.

In order for cities to develop effective and resource-efficient integrated strategies for climate change adaptation and disaster risk reduction, the two efforts need to be connected wherever possible with ongoing policies and actions that link the two from both directions. The climate change adaptation community of researchers and stakeholders emerged in relative isolation from long-standing disaster management policy and practices. Cross-fertilization is now being encouraged between these two groups to take advantage of already-recognized best management practices and to reduce redundancy of efforts, which cities cannot afford (IPCC, 2011). Instead, disaster risk reduction strategies and/or adaptation strategies can contribute to reduction of poverty levels and vulnerability, and promote economic development and resilience in an era of increasing climate change.

1.2 ARC3 structure and process

The ARC3 represents a new “science-into-action” model for integrating climate change into highly complex urban areas that is of great interest to both academic researchers and urban decision-makers as they seek to bridge theory and practice. The first ARC3 provides an in-depth review of research on climate science, mitigation, and adaptation addressed from an urban perspective for key city sectors, including energy and buildings, water supply and wastewater treatment, transportation, and human health as well as for land use and governance. For each of these the urban sector or system is described, specific urban climate risks are identified, adaptation strategies for both climate extremes (including disasters) and mean changes are discussed, as well as potential mitigation actions. Where information is available, the economic aspects of adaptation and mitigation are considered. Policy options are brought forward in each of the chapters, and the important role of communities in cities, both as vulnerable populations and as participants in formulating responses to climate change, is also highlighted. Knowledge and applications gaps are identified.

1.2.1 Developing and developed cities

The ARC3 recognizes that there are both similarities and differences between developed and developing city responses to climate change. For example, there is a great deal of fundamental information on climate change projections, vulnerabilities, and risk assessment methods that has a common base in both types of cities. At the same time, there are great differences in the circumstances in developing country cities. These are discussed throughout the chapters, with key points brought forward as city case studies. The city case studies, which illustrate challenges, “best practices,” and available tools to facilitate actions in developing and developed cities, are presented throughout the text. The case studies cover the status and activities related to climate change on a city-by-city basis. There are several types of case studies included throughout ARC3: those developed by the chapter authors; those invited from others that apply entirely to the chapter topic; and a third category, “cross-cutting case studies” that touch on many different urban climate change topics that a particular city or organization is addressing. The case studies have been developed by authors drawn from both the research and practitioner communities; such teams are helping to build a cadre of knowledge-providers to aid in implementation of climate change actions in cities around the world.

1.2.2 Multiple stresses and risk management

The chapters characterize urban-specific issues integrating social, economic, and physical aspects. There is explicit recognition that cities face multiple stresses – including population pressure, urban poverty, and pollution – and that climate change and these multiple stresses will likely be manifested in intertwined ways.

Another topic covered is the framing of climate change as a risk-management issue. This is evolving into a new paradigm for both mitigation and adaptation (NPCC, 2010). As described in the previous section, disaster risk reduction is an important set of activities challenging many cities, especially in the developing world, and approaches to fostering the intersection of the risk reduction community with the climate change community are put forward.

1.3 What urban decision-makers need to know about climate change

The process of creating ARC3 began with a scoping activity to solicit the key questions that urban policy makers need answered and to survey current topics in urban climate change research (UCCRN, 2008). Five questions were developed and sent to mayors, their staffs, and/or UCCRN research partners in approximately 45 C40 cities around the world and decision-makers from 15 cities (from both developing and developed countries) responded. Informal discussions about ARC3 also took place with city leaders at the C40 Large Cities Climate Summits held in New York in 2007 and in Seoul in 2009.

The survey questions focused on the climate-related challenges that cities face and information needs for adaptation and mitigation policies. The survey questions included:

What climate-related challenges does your city face?

Where are adaptation policies and actions most urgently needed?

In what fields do you see potential for strong mitigation efforts in your city?

What policy mechanisms is your city potentially or actually implementing?

What other special issues would you like the ARC3 to address?

The main themes that emerged as a result of the city-stakeholder responses and that have been incorporated into the content of the ARC3 are vulnerability, science–policy links, urbanization and land-use issues, and equity and environmental justice. These themes were then incorporated into the sector chapter templates. The volume thus responds to expressed stakeholder needs as well as it draws from and provides broader perspectives on urban mitigation and adaptation to climate change.

1.3.1 Vulnerability

Regarding vulnerability, the stakeholder concerns deal with the impacts on their inhabitants of the predicted increase in hotter days, likelihood of more intense rain events at potentially more frequent intervals, flooding that will likely result from these rain events, and sea level rise and storm surge. One inland city’s authorities pointed out that they also need to be concerned with sea level rise since they are a likely destination of people seeking refuge from higher seas and the accompanying damages from coastal flooding.

1.3.2 Science–policy linkages

The second theme that emerged from the stakeholder survey is the challenge of linking science and policy. City decision-makers are unsure how much mitigation and adaptation they should undertake, when, and at what cost. Methods for risk assessment are needed since there is a large amount of uncertainty in climate change science. Related questions brought forward by stakeholders include: Who should be assessing the risks a city faces, how can risks be assessed effectively and efficiently, and how often should risks be reassessed?

1.3.3 Urbanization

The third theme is the challenge of dealing with ongoing urbanization in conjunction with the climate-related challenges that cities face. A major concern is the potential for increasing flooding to disrupt urban development along coasts and rivers. For developing cities, a key issue is how to plan for new infrastructure, taking climate change adaptation and mitigation into account. For developed cities, the challenge is often related to retrofitting existing infrastructure to make it more energy efficient and climate change resilient, but siting and protecting new

developments along coasts and rivers are challenges in developed cities as well. Another question raised by city stakeholders relates to the urban heat island effect: What will be the impacts on their city's population and the surrounding areas of the combined effects of the urban heat island and climate change?

1.3.4 Equity and environmental justice

The fourth theme to emerge from the urban stakeholder responses relates to equity and environmental justice. Many of the same populations are vulnerable to the effects of climate change regardless of whether they find themselves in a developed or developing city. These populations tend to be the elderly, the very young, and the poor in cities everywhere.

1.3.5 Climate risks, adaptation and mitigation, and governance

Some specific climate change topics that respondents wanted ARC3 to address include urban climate risks, adaptation and mitigation and their interactions, and strategies for effective policy development.

City leaders wanted to understand key climate processes that pertain specifically to urban areas, such as how urban areas are simulated in climate models and the critical interactive processes related to the urban heat island effect, climate change, and their effects on urban populations.

Urban policymakers are particularly interested in knowing how to decide when and how much to adapt to climate change. They want to ensure that adaptation is flexible enough to deal with the uncertainties in climate projections. Further, they asked for help in identifying the point at which adaptation needs to go beyond simply making incremental improvements and in undertaking explicit revision of existing standards and practices.

In regard to mitigation, city decision-makers require information on determining the role of renewable energy in urban areas and its relation to emerging technologies at various scales. They also see the need to link climate change to the broader energy agenda – including access to energy, poverty and equity issues, fuel choice, and energy network infrastructure – rather than considering it in isolation.

Urban policymakers are well aware that adaptation and mitigation responses are interactive, and that their interactions can be positive or negative. The goal is to enhance the synergies between mitigation and adaptation, while minimizing the constraints. Key policy areas for explicitly addressing these challenges are: retrofitting existing urban residential development and infrastructure to reduce greenhouse gas emissions as well as heat stress of residents; and devising strategies for seaports and airports, since they are both vulnerable to climate change and central to reductions of greenhouse gas emissions.

At the governance level, a key issue that the ARC3 addresses is the need to delineate the role of the city authority in regard to climate change compared to regional, national, and international bodies. This is germane to another need expressed by city stakeholders, which is determining climate change risks and levels of acceptability.

1.4 Urban climate change issues covered in ARC3

The ARC3 is divided into four parts: Introduction; Defining the risk framework; Urban sectors; and Cross-cutting issues. The chapters within these sections relate to assessment of urban vulnerability and key climate hazards, mitigation and adaptation responses in urban sectors, and the roles of land use planning and governance in responding to climate change challenges.

1.4.1 Vulnerability and risk assessment

Estimation of spatially and temporally disaggregated risks is a critical prerequisite for the assessment of effective and efficient adaptation and mitigation climate change strategies and policies in complex urban areas (Chapter 2). Risk may be considered as the intersection of three vectors – hazards, vulnerabilities, and adaptive capacity. These vectors consist of a combination of physical science, geographical, and socio-economic elements that can be used by municipal governments to create and carry out climate change action plans. Some of these elements include climate indicators, global climate change scenarios, downscaled regional scenarios, changes anticipated in extreme events (including qualitative assessment of high-impact, low-probability phenomena), qualitative assessment of high-impact and low-probability events, associated vulnerabilities, and the ability and willingness to respond. The focus is on articulating differential impacts on poor and non-poor urban residents as well as sectorally disaggregating implications for infrastructure and social well-being, including health.

1.4.2 Urban climate hazards

Cities already experience special climate conditions in regard to the urban heat island and poor air quality (Chapter 3). In addition to these, climate change is projected to bring more frequent, intense, and longer heat waves in cities, and most cities are expected to experience an increase in the percentage of their precipitation in the form of intense rainfall events. In many cities, droughts are expected to become more frequent, severe, and of longer duration. Additionally, rising sea levels are extremely likely in coastal cities, and are projected to lead to more frequent and damaging flooding related to coastal storm events in the future.

In regard to critical urban infrastructure, degradation of building and infrastructure materials is projected to occur,

especially affecting the energy and transportation sectors. The gap between water supply and demand will likely increase as drought-affected areas expand, particularly for cities located in the lower latitudes, and as floods intensify. While precipitation is expected to increase in some areas, particularly in the mid and high latitudes, water availability is projected to eventually decrease in many regions, including cities whose water is supplied primarily by meltwater from mountain snow and glaciers.

Overall, climate change and increased climate variability will alter the environmental baselines of urban locales, shifting temperature regimes and precipitation patterns (Mehrotra *et al.*, 2009). Changes in mean climate conditions and frequency of extreme events will have direct impacts on water availability, flooding and drought periodicity, and water demand. These dynamic changes will affect system processes within multiple sectors in cities interactively, increasing the uncertainty under which urban managers and decision-makers operate.

1.4.3 Energy and buildings

Climate change will affect urban energy through the complex regulatory, technical, resource, market, and policy factors that influence the design and operation of local energy systems. A key attribute for effective climate change response is the ease with which changes can be made to address climate change mitigation and adaptation (Chapter 4). The International Energy Agency (IEA) estimates that 67 percent of global

primary energy demand – or 7,903 Mtoe* – is associated with urban areas (IEA, 2008). While literature on the impacts of climate change on this sector is still limited, urban energy systems can be dramatically affected by climate change at all parts of the process including supply, demand, operations, and assets (Figure 1.2).

In developed countries, climate change concerns are leading cities to explore ways to reduce greenhouse gas emissions associated with fossil fuel combustion and to increase the resiliency of urban energy systems. In developing countries, cities often lack access to adequate, reliable energy services, a significant issue. In these cities, scaling up access to modern energy services to reduce poverty, promote economic development, and improve social institutions often takes precedence over climate-related concerns.

However, if adoption of mitigation measures brings greater reliance on renewable sources of energy (including biomass-based cooking and heating fuels), some cities may become even more vulnerable to climate change, since production of biomass-based fuel is itself subject to changing climate regimes.

1.4.4 Urban water supply and wastewater treatment

Long-term planning for the impacts of climate change on the formal and informal water supply and wastewater treatment sectors in cities is required, with plans monitored, reassessed, and

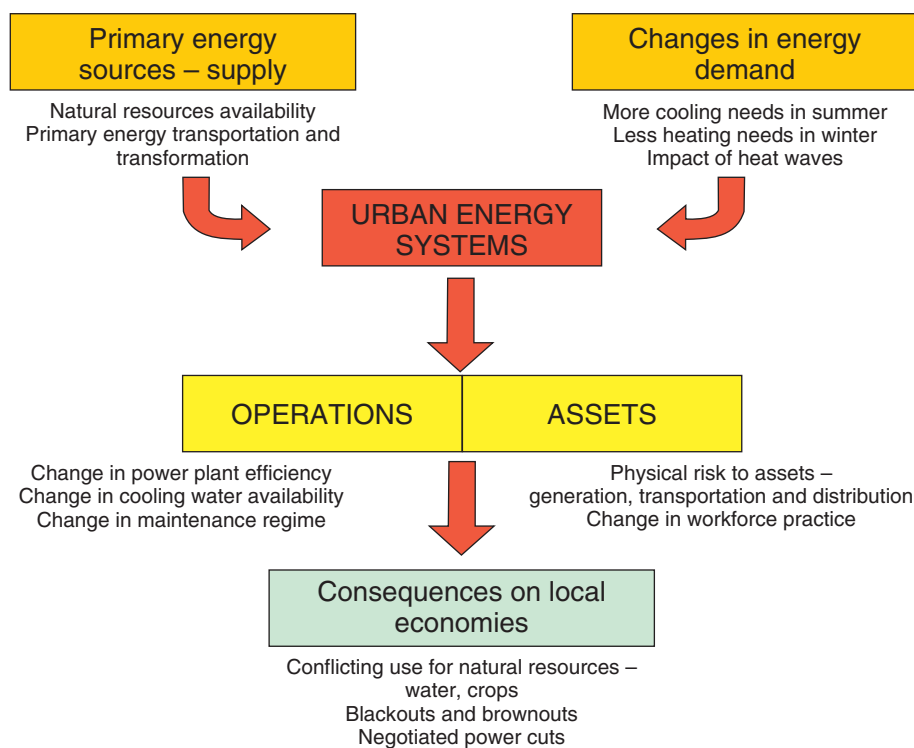


Figure 1.2: Impacts of climate change on urban energy systems.

* Million tons of oil equivalent

revised every 5–10 years as climate science progresses and data improve (Chapter 5). What is needed as well is the development of a new culture of water value, use, and consumption, based on balanced perspectives of its economic, physical, ecological, social, political, and technical dimensions.

Supply, demand, and quality in informal water supply systems in poor cities need to be better understood, with the purpose of improving these systems and their resilience in the context of climate change. More information on comparative performance among cities, as well as on city and regional hydrologic budgets, is required to guide efficient resource allocation and climate change responses in the urban water sector. Integrated water management includes supply, quality, and wastewater treatment both in cities and in their surrounding regions, and effective planning links beyond the water sector to other sectors, such as energy and disaster risk reduction.

The roles of institutions managing formal and informal water resources in urban areas should be analyzed and reassessed, to ensure that institutions are appropriate to changing challenges, including climate change impacts. This may include collaboration between informal and formal sectors where possible. Urban governance issues regarding water supply and demand in both the formal and informal sectors are likely to become increasingly important and contested, and may require changes in water law and management practices.

In regard to immediate adaptation strategies, programs for effective leak detection and repair and the implementation of stronger water conservation/demand management actions – beginning with low-flow toilets, shower heads, and other fixtures – should be undertaken in formal and, to the extent relevant, informal water supply systems. As higher temperatures bring higher evaporative demand, water reuse also can play a key role in enhancing water-use efficiency, especially for landscape irrigation in urban open spaces. Urban-scale water marketing through the informal private sector can be a mechanism by which to increase efficiency, improve system robustness, and facilitate integration of multisector use in some urban circumstances. Water banking (in which water in wet years is saved in, for example, aquifers for use in dry years) by urban water system managers is a way of hedging against uncertainties and improving system robustness. Rainwater capture can also be undertaken as a conservation adaptation to reduce pumped groundwater and related energy use.

1.4.5 City transportation systems

Urban transportation comprises the facilities and services to move people and materials throughout the city and its surrounding region. Cities encompass many modes of transport, including personal vehicles traveling on surface roads and public transport via bus, rail, and airplanes (Chapter 6). Rail transit systems are often critically important in urban areas, with very large extents and high rates of passenger service. For instance, the Metro-North railway in New York City serves 1.5 billion

passengers annually. In coastal cities, rail transit systems contain many points of climate change vulnerability to enhanced flooding from sea level rise, such as public entrances and exits, ventilation facilities, and manholes. These facilities are vulnerable to inland flooding as well. Most importantly, large portions of transit networks are of a hub-and-spoke design and converge on single points giving relatively little flexibility if any one area is disabled during extreme events, which are projected to increase in the future.

Surface transportation refers to both road-based transit (e.g., buses) and vehicular travel, much of which has high-volume traffic and key infrastructure located near coasts and rivers in many cities and thus vulnerable to sea level rise and inland flooding. Tunnels, vent shafts, and ramps are clearly at risk. Flooding necessitates the use of large and numerous pumps throughout these systems, as well as removal of debris and the repair or replacement of key infrastructure, such as motors, relays, resistors, and transformers.

Besides sea level rise and storm surge vulnerability, steel rail and overhead electrical wire associated with transportation systems are particularly vulnerable to excessive heat. Overheating can deform transit equipment, for example, causing steel rail lines to buckle, throwing them out of alignment, which potentially can cause train derailments. Heat can also reduce the expected life of train wheels and automobile tires. Roadways made of concrete can buckle, and roads of asphalt can melt. This is especially dangerous under congested conditions where heavy vehicles sit on hot surfaces for long periods of time, adding to the stress on materials.

Urban transportation adaptation strategies can focus effectively on both usage and technology. Usage strategies involve the ability to provide alternative means of transport during the periods in which acute climate impacts occur. These include being able to substitute roadways and rail lines for similar facilities in other areas, if possible. Examples of types of adaptation strategies for specific impacts are: changing to heat-resistant materials; sheltering critical equipment from extreme rainfall and wind; raising rail and road lines; increasing the deployment and use of pumps; installing drainage systems to convey water from facilities rapidly; and installing barriers such as seawalls at vulnerable locations.

Urban transportation systems also play an important role in mitigation of greenhouse gas emissions. Such mitigation actions can be implemented via transport and land use policies; transport demand management; and supply of energy-efficient transport infrastructure and services.

1.4.6 Climate change and human health in cities

Climate change can best be conceptualized as an amplifier of existing human health problems, attenuating or aggravating multiple stresses and, in some cases, potentially pushing a highly stressed human health system across a threshold of sustainability (Figure 1.3) (Chapter 7). Protection of the health of the

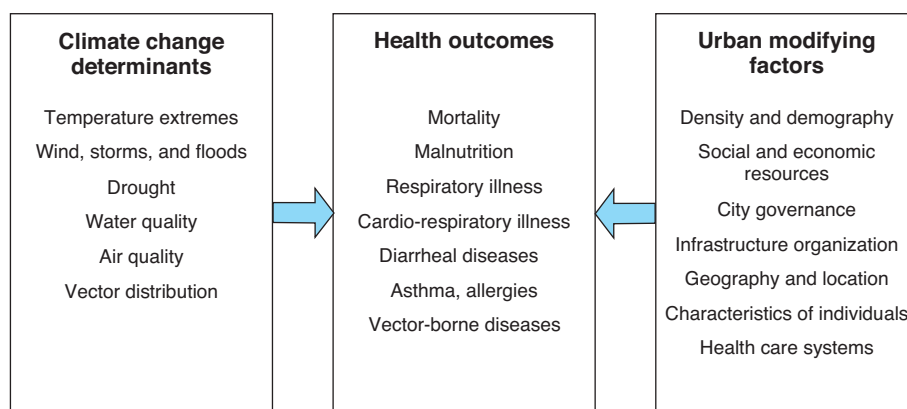


Figure 1.3: Climate change determinants and urban modifying factors on health outcomes in cities.

world's urban populations requires the involvement of all groups (government, business, academia, and communities), levels of government (international, national, regional, and local) and diverse disciplines (health, planning, engineering, meteorology, ecology, etc.).

Since the infrastructure for health protection is already swamped in many developing country cities, climate change adaptation strategies should focus on the most vulnerable urban residents. Such strategies need to promote “co-benefits” such that they ameliorate the existing and usually unequally-distributed urban health hazards, as well as helping to reduce vulnerability to climate change impacts. This involves health programs developed in partnership with public and private organizations and agencies to guide investments and technology choices that benefit the current health of urban residents at the same time as preparing for and responding to climate change.

1.4.7 Urban land use and climate change

Urban land factors that affect climate change risk include the natural features of a city's geography, e.g., coasts and flood plains; its urban form, e.g., is the city compact or characterized by “sprawl”; and the nature of the built environment, e.g., what

is the extent of impervious surfaces that can exacerbate runoff (Chapter 8). A city's urban planning and management structure also affects its ability to respond to climate change, since planning and management agencies and organizations can contribute greatly to the development of efficient and effective processes for both mitigation and adaptation (Table 1.1). Through urban planning and management, cities determine their land use, neighborhood densities, character of the built environment, parks and open spaces, as well as public infrastructure and facilities. Planning and management departments administer public services and regulate and provide incentives for private infrastructure providers and land markets. A key climate change response mechanism relates to property rights and land tenure. For example, how property rights and land tenure are structured in a city will play a key role in responding to the threat of sea level rise in regard to its coastal development.

1.4.8 City governance

Climate change presents city governments with several challenges, including the need for political and fiscal empowerment at the local level to deal with local impacts and specific mitigation measures; the presence of multiple jurisdictions among cities, metropolitan regions, states, and nations; and often weak planning and management structures (Chapter 9). These challenges highlight the need for science and evidence-based policy formulation in regard to climate change. However, data and measurement capability are often lacking, especially in cities in developing countries. Beyond the need to develop specific near-term adaptation and mitigation measures, city governments face the challenge of addressing deeper and enduring risks and long-term vulnerabilities. Since city administrations tend to be rather short-lived, long-term risks are often ignored. A final governance challenge involves the need to be inclusive of all communities in an urban area, especially since vulnerability to climate change varies widely among socio-economic groups. To answer these climate change challenges successfully, city governments need to enhance the potential for science-based policymaking, effective leadership, efficient financing, jurisdictional coordination, land use planning, and citizen participation.

Table 1.1: Urban planning strategies for climate change hazards.

Climate hazards	Major urban planning strategies
Temperature, heat waves	Change building codes to withstand greater energy loads.
Precipitation, floods, and droughts	Restrict development in areas prone to floods, landslides, fires; change building codes to encompass more drainage.
Sea level rise and storm surge	Restrict development in coastal areas; change building codes to reduce impact, e.g., elevate buildings, build protective works. For existing urban areas subject to coastal areas where protection efforts not feasible, develop plans for retreat and new settlements.

1.5 Conclusion

The form and function of the ARC3 is designed to be multi-dimensional. While the core of the effort reflects a cutting-edge climate change assessment focused on cities, it has emerged out of a process that explicitly aims to link on-the-ground scientific expertise in the service of the needs and requirements of local city decision-makers. The presentation and organization of the assessment are designed to bridge the science-policy divide in a range of urban contexts. Key dimensions are the development of risk assessment and management frameworks that take urban climate hazards, sensitivity, adaptive capacity, and agency into account, interactive consideration of mitigation and adaptation in critical urban sectors – energy, water, transportation, and human health – and the inclusion of overarching integrating mechanisms of urban land use and governance. Throughout, the goal is to contribute to effective, ongoing, and beneficial processes in the diverse cities of the world to respond to the risks of current climate extremes and future climate changes. These responses include effective planning to safeguard all urban inhabitants from climate risks equitably, while mitigating greenhouse gas emissions and thus contributing to reduction of the magnitude and impact of future changes.

REFERENCES

- Collins, W. D., *et al.* (2006). The Community Climate System Model Version 3 (CCSM3). *Journal of Climate*, **19**, 2122-2143, doi: 10.1175/JCLI3761.1
- IEA (2008). *World Energy Outlook 2008*. International Energy Agency, OECD Paris.
- IPCC (2007). *Climate Change 2007: Impact, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, Eds., Cambridge, UK: Cambridge University Press.
- IPCC (2011). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. Special Report (in preparation, due late 2011).
- Mehrotra, S., C. E. Natenzon, A. Omojola, *et al.* (2009). *Framework for City Climate Risk Assessment*. Commissioned research, World Bank Fifth Urban Research Symposium, Marseille, France.
- Nakicenovic, N., *et al.* (2000). *Special Report on Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.
- New York City Panel on Climate Change (2010). *Climate Change Adaptation in New York City: Building a Risk Management Response*. eds. C. Rosenzweig and W.D. Solecki. Prepared for use by the New York City Climate Change Adaptation Task Force. In *Annals of the New York Academy of Sciences*, 2010. New York, NY. 354 pp. <http://www.nyas.org>.
- Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge, UK: Cambridge University Press.
- Urban Climate Change Research Network (2008). *ARC3 Progress Overview and Stakeholder Input*. Unpublished manuscript.

