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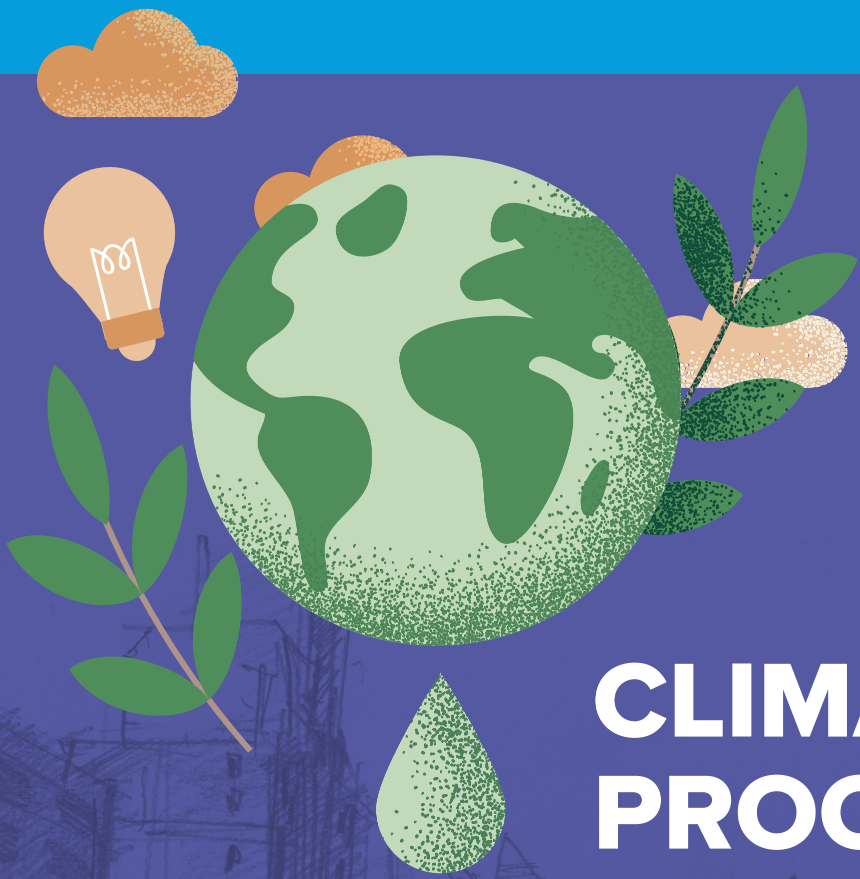

# CLIMATE PROOFING TOOLKIT

## FOR BASIC URBAN INFRASTRUCTURE, WITH A FOCUS ON WATER AND SANITATION

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COORDINATORS: Andre Dzikus and Hezekiah Pireh, UN-Habitat

LEAD AUTHOR: Prof. George Krhoda, University of Nairobi, Kenya

PEER REVIEWERS: Ms. Mara Mendes, Former Expert, United Nations Framework Convention on Climate Change (UNFCCC), Mr. Sergey Makarov, Adviser, Green Climate Fund, GIZ and former expert, UNFCCC, Dr. Kodwo Andah, Former Scientific Coordinator, Water Resources Research and Development Centre, University of Foreigners of Perugia.

DESIGN AND LAYOUT: Michael Lusaba

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# Table of Contents

## List of Boxes



## List of Figures

## List of Tables

# Preface

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

Climate change is not a crisis waiting to happen. It is happening now and we are getting accustomed to more devastating news of extreme events linked to these phenomena. From the largest drought-induced municipal water emergency in Cape Town, South Africa, the unprecedented tropical cyclones Idai and Kenneth hitting Mozambique in one season, to Hurricanes Katrina and Harvey, the most costly Atlantic hurricanes on record, as well as the ongoing consequences on sea-level rise in the Small Islands Developing States are great reminders. To echo the United Nations Secretary-General António Guterres' remarks to the 2019 Climate Summit Preparatory Meeting, *"the world is facing a grave climate emergency and climate disruption is progressing even faster than the world's top scientists have predicted."*

Hosting more than a half of the global population, cities are becoming increasingly vulnerable to the adverse effects of climate change. By one estimate, 530 cities are already reporting the devastating effects of climate change, subjecting up to 517 million urban residents to tropical diseases and lost livelihoods, destroying infrastructure, limiting access to water and food, and undermining the capacity of local governments to provide basic services to their citizens. Estimates project that by 2050, 800 million urban residents in over 570 low-lying coastal cities will be impacted by sea level rise and coastal flooding. It is also estimated that up to 650 million people in 500 cities will experience decreasing water supplies due to climate change by 2050.

However, cities are not just at risk of climate change. They emit a significant portion of greenhouse gases, estimated to be 75 per cent of global carbon dioxide emissions. Water and sanitation infrastructures are, therefore, playing a key role to mitigate risks, limit the development of water-borne diseases and water scarcity to ensure resilience. Consequently, cities must be vital actors in actions aimed at tackling climate change.

At UN-Habitat, we have prioritized "*Strengthened Climate Action and improved Urban Environment"* as one of the four pillars of our 2020–2023 Strategic Plan. Through our flagship programme, *"RISE-UP: Resilient Settlements for the Urban Poor"*, we are working with our partners to leverage large-scale investment to improve services, build communities' resilience, and adapt the global hotspots of vulnerability to climate change. In that sense, focusing on water and sanitation may help cities to tackle challenges and enhance sustainable development while integrating climate resilience actions.

This *Climate Proofing Toolkit for Basic Urban Infrastructure, with a focus on Water and Sanitation* is part of our efforts to provide practical guidance to policymakers, planners and service providers on how to integrate climate actions and responses into infrastructure planning and investment.

It is my hope that the key messages and tasks outlined in this toolkit will inspire leaders, policymakers, planners and service providers to factor potential climate change impacts in the design, construction, location and operation of current and future basic urban infrastructure related to water and sanitation. I thank the Government of Norway for supporting the development of this toolkit and enabling the organization to share its experiences to build a better urban future.

# Key Messages

1. The Climate Proofing Toolkit is a set of steps, tasks and tools to provide guidance to policymakers, planners, practitioners, engineers and utility managers to ensure that the potential climate change impacts are factored in the design, construction, location and operation of current and future basic urban infrastructure, with a focus on water and sanitation. Thus, as a toolkit it does not propose a one-size-fits-all solution.

2. Despite data challenges on estimating the magnitude of climate change, socioeconomic data for sensitivity and vulnerability assessments, and future climate scenarios do exist, the use of historical meteorological data is encouraged. In fact, in present examples, climate proofing investments to observed climate variability are an appropriate step towards ensuring the climate resilience to the infrastructure.

3. The toolkit incorporates metrics for calculating exposure, sensitivity, adaptive capacity and vulnerability assessment and a whole set of identification and assessment options, information and data provided by stakeholders while participating in screening, data provision, all types of assessment and decision-making.

4. The instruments suggested in the toolkit include sustainable development policies, planning and programming at all levels. The toolkit works better if implemented at the project planning stage so that climate change impacts are considered, appropriate tools are applied, and risks reduced to acceptable levels through long-lasting, environmentally sound, economically viable, and socially acceptable changes implemented at planning and design stages of the project cycle.

5. For purposes of sustainable development, the toolkit requires contributions from climatology, demography, disaster risk sciences, environmental sciences, geography, informatics, urban planning, economics, ecology, architecture, anthropology, hydrology and statistics as well as many other stakeholders.

6. Users are invited to use the toolkit according to their particular circumstances, clear understanding of climate proofing initiatives for developing proposals on water infrastructure projects. Establishing plausible lower and upper bounds of climate change to allow testing for the possible impact of climate change on the project's costs and benefits notwithstanding, the final decision may be the cost implications of climate proofing.

## Main sources of information for the development of the toolkit

The material presented in this toolkit draws from UN-Habitat's experiences supporting countries at the national, subnational and community levels with climate change mainstreaming and adaptation initiatives. It also captures key lessons and findings of other organizations on similar issues.

Below are organizations that have contributed to information used for developing the toolkit:

- Asian Development Bank
- African Development Bank
- The Organization for Economic Co-operation and Development/Development Assistance Committee
- United Nations Framework Convention on Climate Change
- Intergovernmental Panel on Climate Change
- United Nations Environment Programme
- United Nations Institute for Training and Research
- World Bank
- Danish International Development Agency (DANIDA)
- German Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit.
- International Institute on Sustainable Development
- International Institute for Environment and Development
- Stockholm Environment Institute
- International Union for Conservation of Nature
- Oxfam International

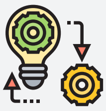
# Acronyms

| | |
|---|---|
| ADB | Asian Development Bank |
| AfDB | African Development Bank |
| AHN2 | Actueel Hoogtebestand Nederland |
| AR | Assessment report |
| CBA | Cost-benefit analysis |
| CEA | Cost-effectiveness analysis |
| CIF | Climate Investment Fund |
| CIVI | Coastal Infrastructure Vulnerability Index |
| COP | Conference of Parties |
| CP | Climate proofing |
| CREAT | Climate Resilience Evaluation and Awareness Tool |
| CRED | Centre for Research on the Epidemiology of Disasters |
| EM-DAT | The International Disaster Database |
| EUFIWACC | European Financing Institutions Working Group on Adaptation to Climate Change |
| FEMA | Federal Emergency Management Agency |
| GHG | Greenhouse gases |
| GDP | Gross domestic product |
| GIS | Geographic information system |
| GTZ | Deutsche Gesellschaft für Technische Zusammenarbeit |
| HDI | Human Development Index |
| ICT | Information and communications technologies |
| IFAD | International Fund for Agriculture and Development |
| IIED | International Institute for Environment and Development |
| IPCC | Intergovernmental Panel on Climate Change |
| KfW | Kreditanstalt für Wiederaufbau |
| MCA | Multi-criteria analysis |
| MDBs | Multilateral development banks |
| MIWD | Metro Iloilo Water District |
| M&E | Monitoring and evaluation |
| MSMEs | Medium, Small and Micro rated Enterprises |
| NAP | National adaptation plan |
| NAMA | Nationally appropriate mitigation actions |

| | |
|---|---|
| NAPA | National adaptation programme of action |
| NCCAP | National Climate Change Action Plan |
| NDCs | Nationally determined contributions |
| NGOs | Non-governmental organizations |
| NPV | Net present value |
| PACJA | Pan-African Climate Justice Alliance |
| PAGE | Partnership for Action for Green Economy |
| PCA | Principle Component Analysis |
| RCP | Representative Concentration Pathway |
| REDD | Reducing emissions from deforestation and forest degradation |
| SCF | Strategic Climate Fund |
| SEI | Stockholm Environment Institute |
| UCCAR | Urban climate change adaptation and resilience |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNFCCC - | United Nations Framework Convention on Climate Change |
| UN-Habitat | United Nations Human Settlements Programme |
| USAID | United States Agency for International Development |
| USD | United States dollar |
| WASH | Water, sanitation and hygiene |
| WHO | World Health Organization |

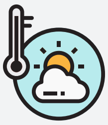
## Definitions

**Adaptation –** The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC Glossary AR5).



**Adaptive Capacity** - Ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences (Modified from Millennium Ecosystem Assessment, 2005).

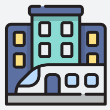
**Climate change –** A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (United Nations Framework Convention on Climate Change. Article 1: Definitions)



**Climate mainstreaming –** Integration or incorporation of priority climate change responses into development projects, strategies, policies and measures (either at the national level or within development agency programming) to reduce potential risks (OECD, 2009, p. 60).

**Climate Change Performance Index** –An independent monitoring tool of countries' climate protection performance that compares protection efforts and progresses made by individual countries (www.germanwatch.org/en/ccpi).

**Climate proofing** – A process for identifying risks to a development project, or any other specified natural or human asset, as a result of climate change and variability, and ensuring that those risks are reduced to acceptable levels through long-lasting and environmentally sound, economically viable, and socially acceptable changes. (ADB, 2005). In other words, integrating climate change risks and opportunities into the design, operation, and management of infrastructure.



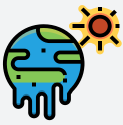
**Critical infrastructure –** The physical or virtual assets, systems, networks and functions so vital that their disruption would have a debilitating impact on security, the economy, public health and safety, or any combination of those matters. Key resources are publicly or privately controlled resources essential to operation of the economy and the government (http://www.dhs.gov/what-critical-infrastructure).

**Evaluation –** Systematic and objective assessment of a completed or ongoing action aimed at providing information about design, implementation and performance (Kusek, J.Z and Rist, R.C. 2004).

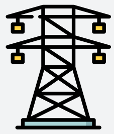
**Exposure –** The presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected (IPCC AR5).

**Impacts –** The effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts and sea level rise are a subset of impacts called physical impacts (UNFCCC. https://unfccc.int/resource/docs/publications/impacts.pdf).

**Hazard –** The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. In this toolkit, the term hazard usually refers to climate-related physical events or trends or their physical impacts (Adapted from: Seventy-first session Agenda item 19 (c) Sustainable development: disaster risk reduction, 2016).



**Heatwave** is defined as temperatures above 32 degrees Celsius with 80 per cent humidity sustained for at least 48 hours (American Red Cross,  https://www.redcross.org/ n)



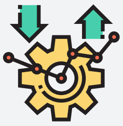
**Infrastructure –** A comprehensive term that includes traditional types of infrastructure—energy, public transport, buildings, water supply and sanitation wastewater—and nature-based infrastructure (such as forest landscapes, wetlands and watershed protection) that are essential for national and economic security, public health and safety as well as to the overall well-being of residents (Adopted from UNDP, 2011).

**Mitigation –** A human intervention or effort to reduce the sources or enhance the sinks of greenhouse gases (AR5-IPCC).

**Monitoring –** A continuous or periodic process in which data on specific indicators are systematically collected to provide information about performance of a project (Kusek and Rist. 2004.

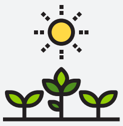
**Participation –** A process by which individuals and groups come together in some way to communicate, interact, exchange information, provide input around a particular set of issues, problems or decisions, and share in decision-making to one degree or another (Ashford et al. 1999).

**Resilience –** The ability of a system to absorb climate induced shocks or disturbances while either retaining the same basic structure and ways of functioning or bouncing back better. The central element required to building resilience is boosting adaptive capacity of people or the ability to adjust to a climate stimulus (ODI, 2010).

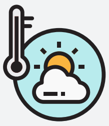


**Risk –** The potential for loss, damage or destruction of an asset as a result of a threat exploiting a vulnerability. Lying at the intersection of assets, threats (actual, conceptual, or inherent), and vulnerabilities, risk is a function of threats exploiting vulnerabilities to obtain, damage or destroy assets. Thus, there is little or no risk if there are neither vulnerabilities nor threat. Risk can be broadly defined as the combination of likelihood and consequence; the latter measured as vulnerability to greenhouse-induced climate change.

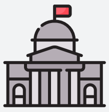
**Risk assessment –** A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend (UN, 2004).



**Sensitivity –** Degree to which a system or species is affected, either adversely or beneficially, by climate variability or change (IPCC Glossary SAR). The effect may be direct (for example, change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (for example, damages caused by an increase in the frequency of coastal flooding due to sea level rise) (ADB, 2013).



**Socioclimatic exposure –** A measure of the severity of climate change, economic capacity, and assets at risk calculated as an aggregated index of the product of climate change, population, wealth and poverty indexes (Diffenbaugh, N. S., F. Giorgi, et al. 2007).



**Urban governance –** Refers to the processes and structures that allow all local actors participating in the decision-making process and influencing public policies and strategies for improved urban planning, management and development. It focuses on the relationship between citizens and the local government, and requires adequate and efficient legal, policies, administrative and operational frameworks (UNESCAP & UN-Habitat, 2010: 211–12; 2015).

**Urban resilience** – The capacity of individuals, communities, institutions, businesses and systems (for example, infrastructure) within an urban area to adapt when exposed to hazards (for example, floods, disease outbreaks, terror attacks), stresses (for example, inefficient service delivery, high unemployment and slowed economic growth), or systemic change in order to maintain an acceptable level of functional organization (European Union, 2016. Urban Resilience A concept for co-creating cities of the future).

**Vulnerability** – The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is the propensity, degree, or predisposition to be adversely affected by climate change including climate variability and extremes, and a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC Third Assessment Report (TAR) (IPCC, 2001).

**Vulnerability assessment** – An endeavour to assess the propensity of a system to get adversely impacted through identification and quantification of factors and mechanisms (called biophysical and socioeconomic drivers of vulnerability) that compromise its capacity to resist change and remain resilient and adaptable. Two main approaches used in the present toolkit are to identify the potential impacts (reducing exposure or sensitivity, or both) and to measure the adaptive capacity (increasing adaptive capacity) (Expanded from ADB, 2013)

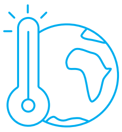
**Vulnerability Index –** A Climate Vulnerability Index is a metric characterizing the vulnerability of a system, typically derived by combining, with or without weighting, several indicators assumed to represent vulnerability. (IPCC AR5 WGII Glossary 2014). Infrastructures that have high adaptive capacity, low sensitivity and exposure can tolerate impacts to a greater degree and, therefore, have an overall low Vulnerability Index, while those that have high sensitivity and exposure as well as low adaptive capacity are more susceptible to impacts, and therefore have an overall high Vulnerability Index.

# CHAPTER 1:

# CLIMATE CHANGE TRENDS AND REFLECTIONS

## 1.1 Introduction

Cities are dynamic landscapes that have been changing rapidly in the last three decades. Urban growth, as the expansion of a metropolitan or suburban area into the surrounding environment or increased densification by population, is an indicator of the state of a country's economic development. The immediate cause of urbanization is migration from rural to urban areas due to concentration of new investment and economic opportunities in particular urban areas. This is so in low- and middle-income countries. By 2016, 68.9 per cent of the world's gross domestic product was generated by industry and services, most of which came from urban-based enterprises. Additionally, around 65 per cent of the world's economically active population was working in industry and services (World Factbook, 2018). Africa, Latin America and South-East Asia are estimated to house nearly 82.15 per cent of the global urban population in 2019 (World Population Review, 2019).



**68.9%**

of the world's GDP was generated by industry and services by 2016

With burgeoning population growth and concentration of economic activities in urban areas, public services such as water supply and sanitation, energy, and other urban infrastructures are stretched to limits. The impact of climate change becomes an additional influence in infrastructure development. There are barriers, limits and costs that are attributed to urban pressure and climate change that increase risk and vulnerability to livelihoods, especially in informal settlement areas, which are not fully appreciated. Present vulnerability to climate change is exacerbated by the presence of stresses such as population growth, weak institutions, inappropriate policies and poverty, while future vulnerability depends both on climate impacts and on present choices of sustainable development pathways. Climate proofing is one strategy of reducing climate risks and vulnerability, thus ensuring high performance of urban infrastructures.

The strategic goals for climate proofing urban infrastructures are, first, to integrate extreme climate change considerations effectively into sustainable development policies, planning and programming at all levels. Second, and most importantly, is to develop and strengthen institutions, processes and capacities at national, subnational and local levels in building resilience to climate hazards. Climate proofing also incorporates vulnerability reductions methods, especially by using flexible options including nature-based infrastructure.

## 1.2 Scope and objectives of the toolkit

The overall goal of the toolkit is to ensure that climate-related risks and impacts are factored in the design, construction, location and operation of current and future basic urban infrastructure. The toolkit outlines current capacity gaps and proposes specific actions for climate-resilient infrastructure (planning, designing, building and operating) that anticipates, prepares for and adapts to changing climate conditions. The toolkit's development was guided by current thinking on the anticipated climate change impacts on basic urban infrastructure, UN-Habitat's own learning and experiences gained in climate change-related programmes, and the experiences and practices of other development partners.

The toolkit covers different programme levels including the national (for example, cross sectoral policies, development plans and public funding), sectoral (plans, strategies, investment programmes) project as well as the local (projects and programmes, land use planning), leading to improved understanding of climate change impacts. The basis of the toolkit is that the impacts of climate change will increase and at the same time vary regionally. Each year damage worth tens of billions of United States dollars are caused by extreme weather events in high-income nations whose populations are served by protective infrastructure and good-quality buildings. Climate proofing is very likely to impose net annual costs, which will increase over time as global temperatures increase as indicated in the Intergovernmental Panel on Climate Change's (IPCC) 4th Assessment Report (AR4).

The strategic goal for climate proofing of urban infrastructures is to integrate extreme climate change considerations, effectively, into sustainable development policies, planning and programming at all levels. The integration will enhance actions for disaster risk reduction and prevention, increase resilience and reduce vulnerability. Moreover and most importantly is the need to develop and strengthen institutions, processes and capacities at national, subnational and local levels in building resilience to climate hazards. The climate proofing also incorporates nature-based infrastructure for vulnerability reductions.

Climate proofing infrastructure reduces loss of lives, physical damages and interruptions in critical services. It promotes poverty reduction and a more balanced regional development, increases energy security and greenhouse gas mitigation, and enhances biodiversity conservation. However, climate proofing infrastructure needs to be explored by each water and wastewater service provider because additional costs may be incurred when identifying and selecting adaptation options. Additionally, new solutions may be considered when selecting new adaptation options. A wide array of adaptation options is available, but climate proofing requires a more extensive application than is currently practiced to reduce vulnerability to future climate change impacts. The process of applying this toolkit is complex and multidisciplinary; it requires contributions from climatology, demography, disaster risk sciences, environmental sciences, geography, informatics, urban planning, economics, ecology, architecture, anthropology, hydrology and statistics as well as many stakeholders.

## 1.3 Target audience

The target audience of this toolkit consists of policymakers who—upon understanding the nature of risks posed by climate change—have the authority to make decisions as to whether society's scarce resources shall be allocated to increase the climate resilience of investment projects. The answer to "how, how much, and when" ultimately belongs to decision makers of the borrowing countries. The climate proofing options aim to be a guide in this decision-making process. A second target audience comprises planners and service providers who must account for the possible impacts of climate change on water and sewerage projects and other urban infrastructures. It is expected that there will be a clear understanding of climate proofing initiatives for non-governmental organizations (NGOs), community-based organizations and local communities (direct local beneficiaries) that seek to develop proposals for community-based projects. UN-Habitat has prepared this toolkit to support this process.

## 1.4 Toolkit structure

The toolkit offers guidance to policymakers, planners and service providers on how to undertake climate change sensitivity and vulnerability assessments and to identify possible ways of integrating climate actions and responses into infrastructure planning and investment. The toolkit proposes a participatory approach which draws strength from the mix of perspectives to provide an opportunity to engage a wide range of different stakeholders, from high-level decision makers to local population, in discussions about climate change. Even though the issue of climate change is not easy to deal with, the methodology adopted is easy to understand and, following the "form follows function" principle, can be adapted to any context. The process begins with screening and hazard identification at which the risk as a result of climate change is identified. If the risk is identified and new or additional measures are required, then stakeholders' assessment is carried out to determine exposure, adaptive capacity and vulnerability to the risk expected from participatory processes, historical record and climate change models. The main toolkit therefore incorporates exposure, sensitivity, adaptive capacity and vulnerability assessment and a whole set of identification and assessments options. The toolkit is in Chapter 3 and organized in 7 steps; some of them separated with tasks and work tables.

TOOLKIT STEPS

**STEP 1:** Screening, hazard identification and levels of exposure

**STEP 2:** Sensitivity measures

**STEP 3:** Adaptive capacity analysis

**STEP 4:** Vulnerability assessment for infrastructure

**STEP 5:** Options for identification and assessment of climate proofing

**STEP 6:** Governance, infrastructure, and capacity-building

**STEP 7:** “Soft” climate proofing options for general infrastructure

**STEP 8:** Implementation of climate proofing measures

The core activities related to project design fall under hazard assessment, exposure and sensitivity analysis, and vulnerability assessment. Finally, the process ends with defining implementation arrangements and monitoring and evaluation frameworks in Chapters 4 and 5, respectively.

Aerial view of Medellin City, Colombia. **© UN-Habitat/Julius Mwelu**

CHAPTER 2:

# CLIMATE CHANGE HAZARD AND CHALLENGES TO URBAN INFRASTRUCTURE

## 2.1 General reflections on climate change and water resources

The reality of climate change caused principally by anthropogenic factors is well known. In the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change, global and regional data records clearly show that land surface air temperatures and sea surface temperatures have increased over the last century. Records also show that maximum and minimum temperatures over land have increased since the mid-20th century. Furthermore, each of the past three decades has been warmer than any previous decade in recorded history (IPCC 2013). Records show that the mean rate of global averaged sea level rise has increased from 1.7 mm/y over the period 1901–2010, to approximately 3.2 mm/y over the period 1993–2010. More specifically, the Fifth Assessment Report concluded that the averaged combined land and ocean surface temperature data show a global warming of 0.65 to 1.06°C 2 over the period 1880 to 2012, and that this trend is expected to persist with a 1.8 to 4°C warming predicted for the current century based on various estimation of the IPCC's Representative Concentration Pathway. Warming will vary by region and be accompanied by significant changes in local precipitation, sea level rise and changes in the frequency and intensity of some extreme events (IPCC. 2019, 1.5°C Report).

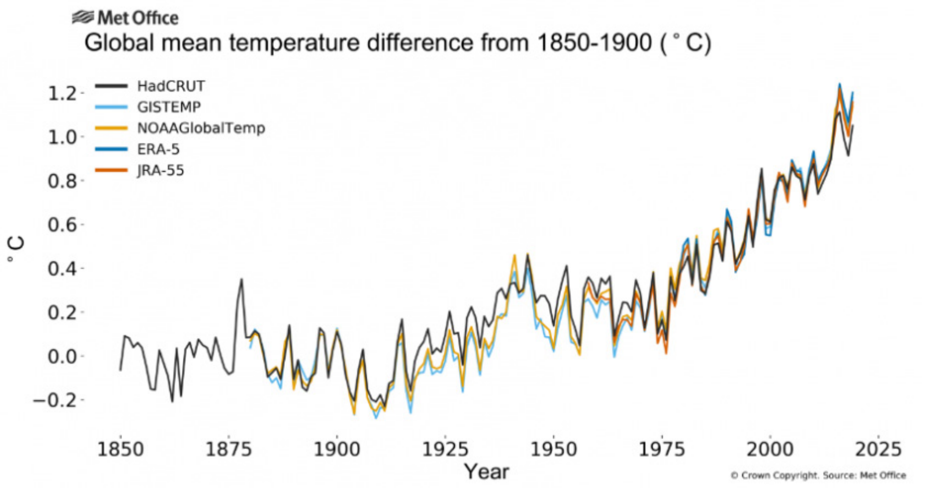
Local evidence of climate change also exists. The average temperature in Uganda between 1960 and 2010 increased by 0.28°C per decade, with January and February most affected. The warming trend averages an increase of 0.37°C per decade (Republic of Uganda, 2015). Sea level rise projections range from approximately 0.4 to 0.7 m, with a maximum projection of 0.98m by 2100 (IPCC AR5, 2014). The IPCC's AR5 notes the particular challenges of densely populated and low-lying areas where adaptive capacity is relatively low, and which already face other challenges such as tropical storms or local coastal subsidence – problems associated with climate change.  It also notes how adaptation will be more challenging in low-lying and middle-income nations, due to high levels of vulnerability and constraints on adaptation options.

There is sufficient evidence that climate change impacts have extensive implications on water resources and may increase the proportion of the world population exposed to a climate change-induced water stress by up to 50 per cent. The most recent modelling studies estimate that for each degree of global warming, approximately 7 per cent of the global population is projected to be exposed to a decrease of renewable water resources of at least 20 per cent. Countries continue to experience socioeconomic losses from flooding due to greater exposure and vulnerability. Climate change is likely to increase the frequency of meteorological droughts (less rainfall) and increase the frequency of short or flash hydrological droughts (less surface and groundwater).

Climate change negatively impacts ecosystems services by altering stream flow and water quality. It poses risks through increased temperature and increased sediments, nutrient and pollutant loadings due to heavy rainfall. During droughts the pollutants similarly are reduced by dilution. Climate change may also lead to disruption of water supply and wastewater treatment facilities during floods. Additionally, climate change-associated sea level rise will negatively affect small islands, low-lying coastal areas and deltas, leading to the risks associated with saltwater intrusion into freshwater systems. The cost magnitudes are extensive. The importance of "climate proofing" infrastructure through measures such as elevating road embankments to safeguard against flooding, relocating water intake and treatment facilities away from vulnerable areas, and improving design and maintenance of all infrastructure has become very urgent. It is estimated that Asian countries, for example, need to invest USD 1.7 trillion a year in infrastructure to maintain growth, and 16 per cent of the funds are required for climate change adaptation and climate proofing of infrastructure (ADB, 2017).

Figure 2.1 shows the global mean temperature difference between 1850 and 1900. Globally, extreme temperature events are observed to be increasing in their frequency, duration and magnitude. Heatwaves will increase with temperature. The Fourth Assessment of the Intergovernmental Panel on Climate Change concludes that heatwaves will “very likely” increase over most land areas over the course of this century

**Figure 2.1: Global mean temperature difference 1850–1900 (degrees Celsius).**




Source: Meteorological Office, via World Meteorological Organization, 2019. Available at https://www.unep.org/news-and-stories/story/who-turned-temperature-climate-change-heatwaves-and-wildfires

An overview of Kigali, Rwanda. **© UN-Habitat/ Julius Mwelu**

The potential impacts of climate change on water resources, water supply and sanitation infrastructure are summarized in table 2.1.

**Table 2.1: Potential impacts of climate change on water resources, water supply and sanitation infrastructure**

| Hazard | Impacts on Water Resources |
|---|---|
| Sea level rise | Increased saline intrusion into groundwater aquifers<br>Increased salinity of brackish surface water sources |
| Warmer temperatures | Increased glacial melting, decreased seasonal snowpack formation, and earlier spring snowmelt may alter summer flows in surface waters and summer levels in reservoirs<br>• Changes in watershed vegetation may alter the recharge of groundwater aquifers and change the quantity and quality of runoff into surface waters<br>• Increased evaporation in surface sources of water<br>• Increasing biological and chemical degradation of water quality<br>• Changes in watershed vegetation and increased wildfire and pest risks in watershed areas<br>• Changes in watershed agricultural practices and in the resulting pollution loads from agriculture<br>• Increased frequency and/or intensity of droughts |
| More frequent or intense extreme weather events or both | • Increased turbidity and sedimentation of surface water<br>• Changes in nature of rainfall pattern leading to inadequate infiltration and groundwater recharge resulting in reduced flow or yield of water, or both<br>• More frequent or intense flash floods, or both, damaging infrastructure and disrupting services<br>• Potential loss of reservoir storage as a result of increased erosion in watershed<br>• Increased loading of pathogenic bacteria and parasites in reservoirs<br>• Operational challenges to aquifer storage and recovery and water reclamation facilities<br>• More frequent overflow events of combined sewer systems |
| Changes in precipitation | Reduced replenishment rates of groundwater resulting in declining water tables where net recharge rate is exceeded |
| | Impacts on Water Supply Treatment and Infrastructure |
| Sea level rise | • Assets on the coasts or in floodplains may be at increased risk from flooding, storm damages, and coastal erosion<br>• Increasing seawater intrusion into coastal aquifers |
| More frequent or intense extreme weather events or both | • Increased risk of direct flood damage to treatment plant, pumping and conveyance, and outfall<br>• Increased risk of landslide which may damage infrastructure |
| | **Impacts on Wastewater Treatment and Infrastructure** |
| Sea level rise | • Assets on the coasts or in floodplains may be at increased risk from flooding, storm damage, and coastal erosion<br>• Increased risk of operational impairment of outfalls including reduced ability to discharge wastewater into coastal waters<br>• Changes in treatment and compliance requirements as a result of altered biology and chemistry of receiving waters |
| Warmer temperatures | • Increased operating challenges to biological and chemical processes of treatment facilities<br>• Increased temperatures and increased evaporation in receiving water bodies, changing chemical balances and increased eutrophication<br>• Reduced capacity to meet wastewater treatment requirements and standards |
| More frequent or intense extreme weather events or both | • Increased risk of direct flood damage to treatment plant, pumping and conveyance, and outfall<br>• Increased risk of untreated sewage overflows contaminating water supply sources<br>• Changes in quantity and quality of watershed runoff and in the resulting non-point source pollution loads to receiving waters |

Sources: Cromwell, Smith, and Raucher (2007); Water Environment Research Foundation (2010); O'Neill (2010); Major et al. (2011).

## 2.2 Cities and climate change

The concentration of people in urban centres increases paved surfaces and restricts vegetation and green spaces. The consequences of these are risks associated with heat islands and floods, which degrade public health, water availability and quality, energy consumption and essential infrastructure. Climate change-related hazards and slow onset events include rising sea levels and storm surges, heat stress, extreme precipitation, inland and coastal flooding, landslides, drought, increased aridity, water scarcity and air pollution.[1] These result in widespread negative impacts on people's health, livelihoods and assets as well as on local and national economies and ecosystems. The risks are increasing in frequency and are amplified in magnitude for those who live in urban informal settlements and in hazardous areas, and either lack essential infrastructure and services or where there is inadequate provision for adaptation. The degree of impact varies in different urban areas as well as intra-urban differences, thus requiring involvement of many stakeholders. Climate proofing responds to these impacts on a broad spectrum of urban infrastructure systems (water and energy supply, sanitation and drainage, transport and telecommunication), on the built environment and on ecosystem services, thus mitigating health and livelihood risks.

## 2.3 UN-Habitat role in climate change

UN-Habitat, a key player in the United Nations system and on cities, works with international climate bodies and global city networks to influence climate policy and action, promoting the role of cities and human settlements in mitigation and adaptation. The main goal of UN-Habitat's resilience work is to support local governments and relevant stakeholders to transform urban areas into safer and better places in which to live. Additionally, supportive tools have been prepared to improve capacity to absorb and rebound quickly from all potential shocks or stresses, leading cities towards sustainability.

UN-Habitat's Climate Change Initiative is a flagship initiative supporting cities in emerging and developing countries to mitigate climate change and find how to increase their resilience. Being part of the Sustainable Urban Development Network (SUD-Net), UN-Habitat promotes collaboration by local authorities and their associations in global, regional and national networks to bring about policy changes; and enhances policy dialogue, awareness, education and capacity-building in support of climate change strategies. The initiative has developed a set of tools for capacity-building, especially by using the pro-poor innovative approaches and methodologies that put managers and practitioners in a better position to cope with climate change.

Cities are the major contributors to climate change. According to UN-Habitat, cities consume 78 per cent of the world's energy and produce more than 60 per cent of greenhouse gas emissions. Cities occupy 2 per cent of the Earth's area but represent high concentrations of financial, infrastructure and human assets and activities that are vulnerable to climate change impacts. In the 2011 Cities and Climate Change Global Report on Human Settlements, urban areas are recognized as the pivotal player in climate change mitigation and adaptation. Accordingly, the report identifies strategies and approaches for strengthening this role. UN-Habitat is poised to play an increasing role in supporting cities to deal with the escalating crisis caused by climate change. In its strategy for the period 2014–2019, UN-Habitat planned to focus on the mainstreaming of adaptation to and mitigation of cities. This was followed by integrating Climate Change into city development strategies (UN-Habitat) (2015b) and sustainable urbanization in the Paris Agreement (UN-Habitat) (2017b). UN-Habitat's

1 A warming climate will lead to more severe air pollution.

2020–2025 Strategic Plan aims to “advance sustainable urbanization as a driver of development and peace to improve living conditions for all”. Such a transformative and integrative strategy will contribute to the achievement of the global frameworks, including climate resilience.

The development of appropriate tools—such as a set of guides, steps and practical means that enable different stakeholders reach a desired goal of improving understanding and making appropriate decisions or providing required services for a complex science such as climate change— is paramount. Tools, such as the Urban and Territorial Planning Guidelines, were developed for city planners to better understand, assess and act on climate change at the local level (UN-Habitat, 2015b). The Cities and Climate Change Initiative prepared a strategic, values-based toolkit for planning for climate change. Additionally, a guide to mainstream climate change using a simple planning process based on understanding long-term climate change impacts, urban development challenges and the needs of citizens is being rolled out by UN-Habitat. The climate action plans address mitigation and adaptation (UN-Habitat, 2012). The City Resilience Action Planning (CityRAP) tool enables local governments to plan and undertake practical actions to strengthen the resilience of their cities. The tool is built on participatory methods and consensus building techniques to involve all concerned stakeholders with the aim to identify entry points to start building the city’s resiliency with minimum external support.

UN-Habitat, for many years, has provided guidance on climate such as “Guiding Principles for City Climate Action Planning”. UN-Habitat is working with partners and city leaders on climate action, lobbying to ensure that there is a cap on global emissions levels, and promoting necessary actions to reduce carbon emissions and transition to climate-resilient development pathways. The “Infrastructure, Cities and Local Action” engaged to identify the most transformative ideas to decarbonize, enhance the resilience of infrastructure, and strengthen adaptive capacities of communities across the world. Partnering with other institutions including city governments, UN-Habitat, as part of the Global Covenant of Mayors, is guiding cities establish robust climate agendas to ascertain risks and contribute to reduction of emissions. The Urban Low Emission Development Strategy project, in partnership with Local Governments for Sustainability is accelerating urban low emission development and climate resilience in more than 60 cities worldwide by exploring a multilevel governance approach to urban climate action.

A regional guide for integrating climate change concerns into urban-related policy, legislative, financial and institutional frameworks is a step towards climate proofing. Such measures can range from preferentially adapting to nature-based infrastructure, especially in water resources management, coastal resource management or protecting mangrove and natural reef ecosystems. Climate proofing of infrastructure, including storm-drainage systems, water supply and treatment plants, as well as the protection or relocation of energy or solid waste management facilities, are considered in the present toolkit.

Sustainable urban development entails the implementation of the New Urban Agenda (UN-Habitat, 2016), in which the Member States committed to integrate climate change adaptation and mitigation considerations into urban and territorial development and planning processes by 2036. The Agenda recognizes the importance of how cities and human settlements are planned, financed, developed, governed and managed for sustainable urban development.

## 2.4 Trends in urban disasters associated with extreme weather events

Climate change is expected to increase the frequency and intensity of current hazards, increase the number of extreme events and spur the emergence of new hazards such as sea level rise. Additionally, climate change-induced drought and resource conflict may force the pace of rural-urban migration, water scarcity, breakdown of environmental services, flooding and the subsequent waterborne disease, and malaria epidemics combined with a rapid rise in health expenditures.

Certain trends described above have obvious implications for climate proofing. These are as follows:

- Rapidly increasing urban populations – and rapidly increasing numbers of people living in informal settlements lacking basic infrastructure and services
- Rapidly increasing concentrations of economic activities and investments in urban areas
- Most of the growth in the world's population over the next 10–20 years being likely to occur in urban centres in low- and middle-income nations

**BOX 2.1: EFFECTS OF RAINFALL CHANGES**

Changes to rainfall can:

- Influence freshwater inflows
- Increase flood frequency
- Change salinity regimes of oceans (including stratification and circulation patterns)
- Change water balances and alter sedimentation and erosion rates
- Change water quality, such as altering nutrient loads due to changes to the transformations of nitrogen and phosphorus, which occur within areas of high turbidity from catchment-derived sediments
- Change flushing and residence times, particularly for intermittently open estuaries
- Impact ecology through altered water quality and changes to the frequency and magnitude of freshwater flows

Table 2.2 show some of the cascading events associated high rainfall intensity associated with climate change.

**Table 2.2: Global extent and impacts of certain disasters by hazard type, total 1990–2017**

| Number of events | No. of events | Mortality (thousand) | Economic damage (USD million, 2005 prices) |
|---|---|---|---|
| Avalanches/landslides | 191 | 7 864 | 1 801 |
| Extreme temperatures | 168 | 60 249 | 5 703 |
| Floods | 1 310 | 90 237 | 1 292 989 |
| Windstorms | 917 | 62 410 | 326 252 |

Source: EM-DAT, International Data Base. CRED, University of Louvain, Belgium.

There has been a very large increase in the number of natural disasters since 1950, mostly due to extreme weather events (EM-DAT). The latter's intensity and frequency are likely to increase as well.

**BOX 2.2: THE FLOODS IN MOZAMBIQUE**

Mozambique experienced heavy flooding during the rains of January to February 2015, the worst since 2000. The hardest hit areas were in the Limpopo River basin and the northern province of Nampula. About 326,000 people were affected; 140 were killed, about 30,000 houses, 2,362 classrooms and 17 health units were either partially or completely destroyed; 104,430 ha of crops were lost during the event, impacting 102,000 farmer household. In Gaza Province alone at least 150,000 people were displaced. Additionally, Maputo Municipality estimated USD 29 million worth of damage to infrastructure; mostly to housing and drainage. Key power lines were damaged, slashing power exports to South Africa from 1,500 to 650 megawatts.

A full 58 per cent of Mozambique's population is at risk of water-related hazards. Furthermore, it is estimated that gross domestic product growth has been reduced by 1.1 per cent annually (USD 105 million) due to flooding. The international community sought USD 30.6 million; the United Nations Central Emergency Response Fund had disbursed USD 5.13 million to United Nations agencies in the response effort.

Source: Global Facility for Disaster Reduction and Recovery https://www.gfdrr.org/updates-field-responding-floods-mozambique

The Adapt Cost Project (Watkiss, et. al. 2010) funded by the United Nations Environment Programme indicates that the economic costs of climate change in Africa could equal an annual loss in GDP of 1.5–3 per cent by 2030 under a business-as-usual scenario (PACJA, 2009), and these costs could rise rapidly. As an indication, the Policy Analysis of the Greenhouse Effect Model run as part of the Adapt Cost study and used in the *Stern Review on the Economics of Climate Change* indicates that these costs could rise to 1.7 per cent in 2040, 3.4 per cent by 2060 and almost 10 per cent of GDP lost by 2100 (PACJA, 2009). Aggregate models run in Rwanda and Kenya indicate that the additional net economic costs (on top of existing climate variability) imposed by climate change could be equivalent to a loss of almost 1 per cent of GDP each year by 2030 in Rwanda (though this excludes the future effects of floods and other extremes), and almost 3 per cent of GDP each year by 2030 in Kenya (SEI, 2009). In Namibia, it is estimated that expected climate impacts on the country's natural resources will cause annual losses of between 1 per cent and 6 per cent of GDP (IIED, 2009). In Cameroon, a 14 per cent reduction in rainfall is predicted to cause losses of up to USD 4.65 billion, and a 7 per cent reduction in rainfall could slash the country's net revenue by 6.5 per cent per hectare (Molua & Lambi, 2006).

Climate change is not a risk per se; rather, climate changes and related hazards interact with the evolving vulnerability and exposure of systems and thereby determine the changing level of risk. Extreme weather events or other changes are impactful when improperly factored into the programme and project design, such as undersized culverts in a road project that lead to road erosion and damage during excessive rains. The outcomes of investment are reduced or rendered ineffective due to external impacts like changes in rainfall patterns and health impacts that can be estimated and mitigated. For example, a facility designed to process certain crops may no longer be profitable if the crop mix in its service area changes as a response to climate change. Finally, there may be direct and indirect impacts on the target population due to their vulnerability to climate change for which mitigation or adaptation measures may be used to improve project performance life. An effective climate change policy for urban infrastructure that includes both mitigation and adaptation is essential.

**Table 2.3: Impacts on basic infrastructure resulting from climate change**

| Climate element | Climate change impacts |
|---|---|
| Increases in very hot days and heatwaves | Deterioration of pavement integrity, such as softening, traffic-related rutting, and migration of liquid asphalt due to increase in temperature<br>Thermal expansion of bridge expansion joints and paved surfaces |
| Increases in very hot days and heatwaves and decreased precipitation | Corrosion of steel reinforcements in concrete structures due to increase in surface salt levels in some locations. Increases in temperature in very cold areas |
| Increases in temperature in very cold areas | Changes in road subsidence and weakening of bridge supports due to thawing of permafrost<br>Reduced ice loading on structures such as bridges, a later onset of seasonal freeze and earlier onset of seasonal thaw |
| Later onset of seasonal freeze and earlier onset of seasonal thaw | Deterioration of pavement due to increase in freeze–thaw conditions in some locations<br>Reduced pavement deterioration from less exposure to freezing, snow and ice |
| Sea level rise and storm surges | Damage to highways, roads, underground tunnels and bridges due to flooding, inundation in coastal areas, and coastal erosion<br>Damage to infrastructure from land subsidence and landslides<br>More frequent flooding of underground tunnels and low-lying infrastructure<br>Erosion of road base and bridge supports<br>Reduced clearance under bridges<br>Decreased expected lifetime of highways exposed to storm surges |
| Increase in intense precipitation events | • Damage to roads, subterranean tunnels and drainage systems due to flooding<br>• Increase in scouring of roads, bridges and support structures<br>• Damage to road infrastructure due to landslides<br>• Overloading of drainage systems<br>• Deterioration of structural integrity of roads, bridges and tunnels due to increase in soil moisture levels |
| Increases in drought conditions for some regions | • Damage to infrastructure due to increased susceptibility to wildfires<br>• Damage to infrastructure from mudslides in areas deforested by wildfires<br>• Water stress. For example, Cape Town in 2018 was forced to take extraordinary measures to ration what little it had left in its reservoirs<br>• Increased groundwater withdrawal causing sinking cities. For example, Mexico City, Dhaka, Bangladesh |
| Increase of storm intensity | • Damage to road infrastructure and increased probability of infrastructure failures<br>• Increased threat to stability of bridge decks<br>• Increased damage to signs, lighting fixtures and supports |
| Increase in wind speed | • Suspension bridges, signs and tall structures at risk from increasing wind speeds<br>• Impact coastal erosion and accretion and aeolian sediment delivery<br>• Impact coastal flooding due to storm surge and cyclones lead to secondary implications due to increased fire hazards and subsequent sediment and nutrient influxes<br>• Alter coastal and estuarine wind set up |

Source: ADB, 2014

Climate proofing is designed to support the integration of climate change impacts, as well as awareness of the challenges and opportunities, in development planning at national to local levels. Climate proofing aims to make development measures more efficient and resilient. The tool can be applied at the very beginning of a planning phase or later during the revision stage. It complements other risk analysis instruments, such as the Strategic Environmental Assessment, and especially when working with longer planning horizons. Climate proofing helps to identify and enhance inherent adaptation value of a project, contributes to a reduction of vulnerabilities as well as actively promoting adaptation where appropriate. Because of the huge cost of infrastructure development, it is prudent to ensure that the country minimizes maintenance costs, ensure full life of the infrastructure, and improves efficiency. Climate proofing ensures that project results will not be hampered by potential climate change.

Although the cost of new decisions listed in table 1.4 are not presented in the toolkit, it is noted that questions of limited budgets will be raised by stakeholders. Three cost-related decision levels are the following:

- Coping with change by assessing operational flexibility to meet the changed operating parameters driven by the climate threat, and the costs associated with adaptation options may be minimal.
- Operating beyond design or current capacity without making large changes to the system for which operations and maintenance costs may increase, but shift will remain less costly than making infrastructure changes.
- Going beyond the limit of utility capacity to absorb climate impacts and hence augmenting or optimizing capacity through adoption of new practices and resources; the latter typically involves a higher level of capital investment.
- In all of these levels, costs of climate proofing need to be compared with cost of inaction and risks associated with the climate change, as well as upside co-benefits that would come with implementation of climate-proofing decisions. Since on average 50 percent of the cost associated with water supply is related to energy, it is preferred that low-carbon options be selected for climate proofing.

UN-Habitat pilot shelter project in Kalobeyei new settlement in Turkana, Kenya. **© UN-Habitat/ Julius Mwelu**

**Table 2.4: Climate-proofing options for water supply and sanitation investment projects**

| Infrastructure | Climate-proofing Options |
|---|---|
| Water supply | • Demand-side management with a view of decreasing water demand<br>• Reduction of nonrevenue water<br>• Water metering and water tariffs (which can contribute to reducing water demand)<br>• Low water use applications<br>• Diversification of water sources<br>• Enhancing storage capacity<br>• Water reuse and desalination<br>• Aquifer recharge using recycled water<br>• Relocation of flooded infrastructure<br>• Impounding reservoir to store freshwater |
| Water treatment and quality | • Protection of the water source and treatment of wastewater discharges<br>• Integrated water resources management<br>• Prevention of saltwater intrusion into coastal zones |
| Water distribution | Adjustment to operation below design capacity |
| Wastewater collection | • Prevention of sewer overflow<br>• Adjustment to operation below design capacity<br>• Relocation of flooded sewers |
| Wastewater treatment | • Adjustment of treatment technology to new effluent composition<br>• Adjustment of treatment level to revised dilution capacity of discharge point<br>• Relocation of flooded wastewater treatment facilities |

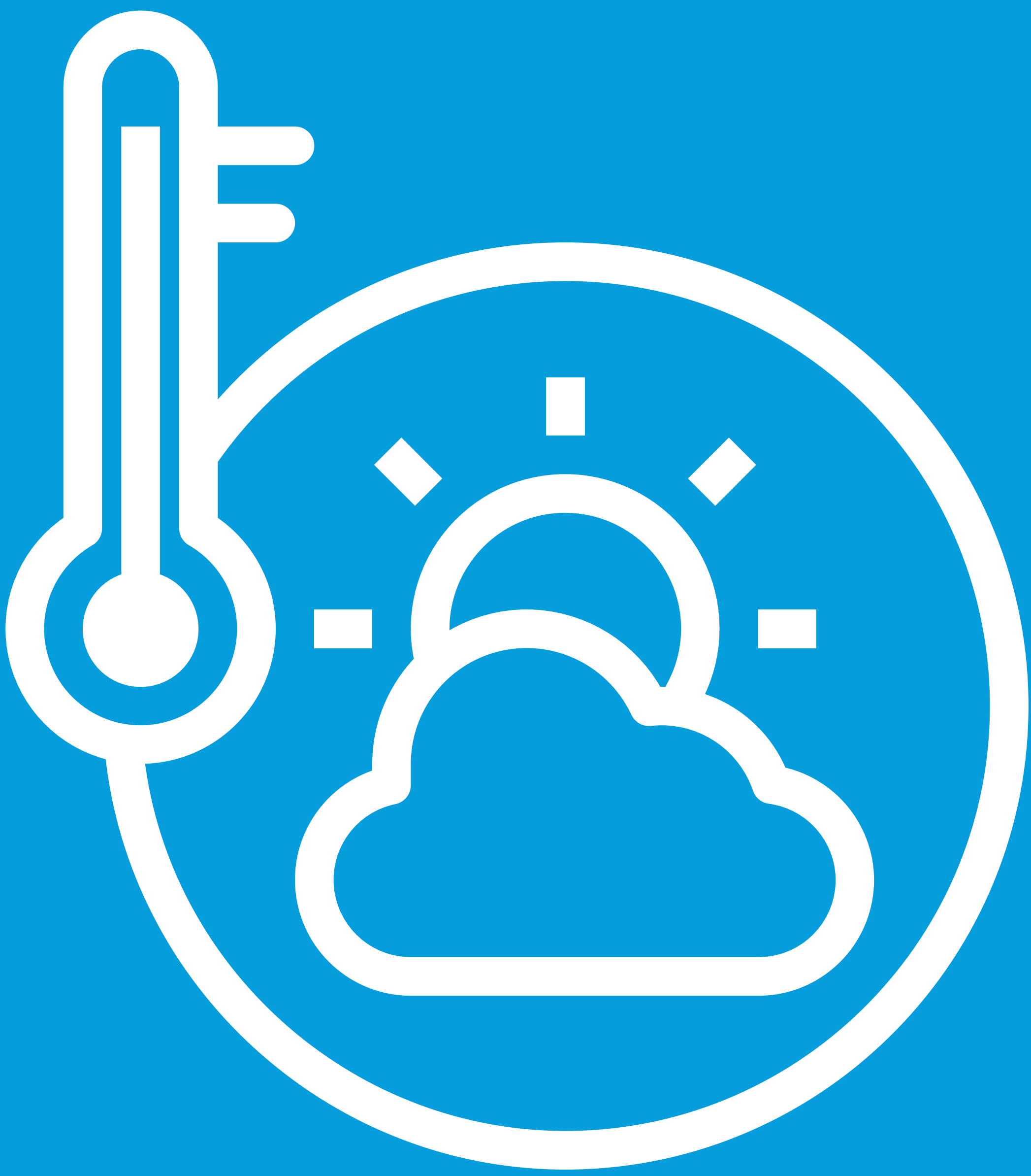
The climate proofing toolkit is intended to ensure that urban infrastructures will not be adversely affected by climate change, that inherent adaptation value of a project or programme is identified and enhanced and that there will be no maladaptation from the projects because of the comprehensive consideration of all steps towards vulnerability assessment.

A section of Port-Au-Prince, Haiti. **© UN-Habitat/ Julius Mwelu**

Aerial view of the residential area of the suburb of Nizhnevartovsk during the flood of 2015.

# CHAPTER 3:

# SETTING STAKEHOLDER PARTICIPATION



## 3.1 Role of stakeholders in climate proofing

Engaging a wide range of stakeholders early in the climate proofing process is crucial to successful implementation. Climate proof measures can be integrated into other policy but require interdisciplinary collaboration. It is especially important to ensure the participation of stakeholders from government institutions, the most vulnerable sectors of the economy and groups particularly vulnerable to climate change. Stakeholders can participate in the screening, data provision, all types of assessment and decision-making. They are also fundamental to the success of the implementation and they can be ambassadors of the process within their organizations or communities.  Stakeholders can be involved in basically all steps and most of the tasks of the process.

**Table 3.1: Climate proofing activities and the type of stakeholder**

| Step of the climate proofing process | Activity/data | Type of stakeholder |
|---|---|---|
| Vulnerability assessment | Climate data (historical and modeling) | Government agencies and academic institutions |
| | Climate observations (\|for example, frequency and consequences of extreme events) | All stakeholders, including the community |
| | Review inputs and outputs | All stakeholders, including community |
| Options identification | Determine objectives and identify options | All stakeholders, including community |
| Options assessment | Screen, assess, and prioritize options | All stakeholders, including community |
| Implementation | Climate proofing implementation plan | All stakeholders |
| | Mainstreaming climate proofing | Selected stakeholders |
| | Finance for climate proofing | Selected stakeholders |
| Monitoring and evaluation | | Selected stakeholders |
| Improvement | | All stakeholders |

Note: If the climate proofing is specific for only one or very few facilities, the level of stakeholder involvement and the entire process of climate screening can be shortened as indicated in existing recommendations for projects and facilities (UNDP 2009, ADB 2017).

## 3.2 National and subnational institutional framework for planning climate proofing

National and subnational institutions in charge of environment include sectoral ministries and departments, state institutions of environmental management, depending on governance structure, and private and non-governmental organizations. The ministries involved in climate change and on urban infrastructures are those mandated with functions of environment, land, spatial planning, infrastructure and services, housing and urban development (see table 3.2). Additionally, for each ministry there are national authorities whose mandate includes national and regional planning.

**Table 3.2: Types of national and subnational institutions involved in climate change**

| Governmental/parastatal institutions | | |
|---|---|---|
| **Institution/Sector** | **Mandate** | **Shortfalls** |
| Environment and natural resources and established National Climate Change Council, National Environment Management Authority, National Drought Management Authority | • Climate change policies and plans, including national adaptation plans (NAPs), nationally determined contributions, national climate change action plan<br>• Environmental management<br>• Disaster risk management<br>• Integrated coastal zone management | • Planning in many countries is heavily sectoral and each sector plans and implements in silos<br>• Lack public participation and outreach<br>• Limited capacity at the government to enforce and monitor compliance of adaptation or mitigation actions |
| Water and sanitation | • Policy on domestic water supply and improved sewage systems, enhanced irrigation and drainage to increase agricultural and livestock production, effective transboundary water resources management, and flood mitigation<br>• Promotion of public awareness on water conservation | |
| Transport, infrastructure and public works | Policies, regulations and investments on transport infrastructure, port facilities, roads, railways and bridges | • Implementation split between national, subnational and local jurisdictions |
| Information and communication technologies | • Support climate change technology and promotion of climate technology centres<br>• Codes and regulations to promote low-carbon climate-resilient technology choices<br>• Promote research and development to ensure appropriate technologies use and development and to share such information for climate proofing | • Developing countries lack data on key climatic parameters. No support to infrastructure (roads, railways, marine, aviation, buildings, information and communications technology |
| Lands, physical planning and housing<br>National Land Commission | • Land tenure, land-use policy and planning, zoning | |
| Energy* | • Energy generation and distribution. It includes the generation of renewable energy, such as solar power, wind energy, hydroelectric energy, geothermal energy and bioenergy | |

| | | |
|---|---|---|
| **Private sector organizations** | | |
| Private sector organizations | • Investment and financing, underwriting in insurance<br>• Awareness raising and information sharing | |
| Media | • Promote climate-friendly technologies, awareness raising and information sharing | |
| **Research and international organizations** | | |
| Research institutions | • Research partnerships, international research institutes, national research institutes, regional research NGOs, and universities | |
| Development institutions/ intergovernmental organizations | • International and national NGOs | |

*Note: Depending on the country, the energy sector is under the government or the private sector. In this table, the energy sector is presented under the government.

In order to engage national stakeholders, the process can be started by setting consultation workshops and by engaging the ministries, agencies and other institutions, such as table 2.1, which:

- define relevant policies, plans and projects related to urban infrastructure
- manage the relevant weather and climate data (current and historical), and perform climatic modeling, such as climatology departments, universities

Even at national level, it will be important to bring sectoral and local stakeholders (local government, local infrastructure representatives) as well as representatives from society to contribute to the process. Ways in which to engage these stakeholders is discussed in the following sections.

## 3.3: Local institutional arrangements

Integrating climate change into planning at the local level is particularly important for the following reasons (Hahn and Fröde, 2010):

- Climate change affects local livelihoods and environment.
- Climate vulnerability and adaptation are determined locally.
- Options for action are often best identified at the local level.

Implementing options for action at this level often makes local people the main actors in the implementation process when, for instance, it is a matter of improving their own housing. Donors can play an important role in providing training for programme staff and raising awareness about the opportunities and challenges of climate change among the local population.

**Table 3.3: Role of local and subnational government on planning**

| | |
|---|---|
| **Urban governments** | • Providing infrastructure and services<br>• Guiding land-use planning to avoid disasters such as floods, fires, landslides<br>• Regulating building design and construction, especially those building within low-income settlements)<br>• Regulating hazardous activities that can produce disasters (including industries and transport)<br>• Influencing land-use management through land-use regulations, zoning and bureaucratic procedures for buying or obtaining land and what can be built on it<br>• Encouraging and supporting household and community action that reduces risk<br>• Providing "law and order", which should also act to protect low-income groups from risk<br>• Coordinating and supporting links between disaster avoidance and disaster preparedness |
| **Subnational and urban areas** | • Physical planning, land-use planning, by-laws and regulations |

Climate proofing can be an important tool at the project level as (1) project goals may be directly affected by the effects of climate change, and (2) project results may increase or decrease the climate vulnerability of biophysical and socioeconomic systems. Climate proofing can be applied during project identification and during the project design phase.

## 3.4 Sectoral level

At the sectoral level, climate proofing can be especially important in planning sectoral policies or physical investments, for instance. In this case, the planning horizon of such investments is of particular relevance. Climate proofing can also be integrated as an important part of strategic environmental and social assessments. On the other hand, the ideal entry point is during the sectoral policy formulation or sectoral planning stages. Priority is usually given to development initiatives that are costly to modify later. Climate proofing can also be used to generate an overview of the sectoral impacts of climate change. Donors can play an important role regarding sector-level budget support and sector-wide approaches, as well as in providing training for key actors on climate change adaptation (Hahn and Fröde, 2010).

## 3.5 Stakeholders' engagement

Stakeholder participation is a key element in modern public administration and decision-making. With clear record keeping in the decision-making process that will support future engagement and improve trust in the process, decision makers invest time on issues which range from legal, rights- and duties-based arguments to arguments for equity, efficiency, effectiveness and sustainability. The stakeholders' processes support transparency and access to information. There are various methods to involve stakeholders, including cognitive mapping, expert judgment, brainstorming or checklists, and via interviews or surveys.

Application of context-specific and culturally-sensitive climate change adaptation tools is gaining traction in many programmes. Current best practices include the use of a livelihood approach to engage communities; the explicit acknowledgement of the local cultural dos and don'ts; the recognition of local champions appointed from within the local community; the identification and prioritization of vulnerable stakeholders; and the implementation of a two-way climate change risk communication instead of a one-sided information sharing approach.

The stakeholders' engagement is a participatory process and hence requires the following conditions:

- Having clear objectives and expectations
- Use of different methods – modelling, scenario building, community mapping
- Provide platform for exchange of information and experience
- Support information on policy and research
- Create ownership of climate adaptation action plans

The considerations for preparation and planning the participatory stakeholders' process for climate proofing need to include the following tasks:

- Identify stakeholders
- Establish stakeholders` advisory group
- Establish the procedures of the advisory group
- Determine if a broader community will be engaged, when and how

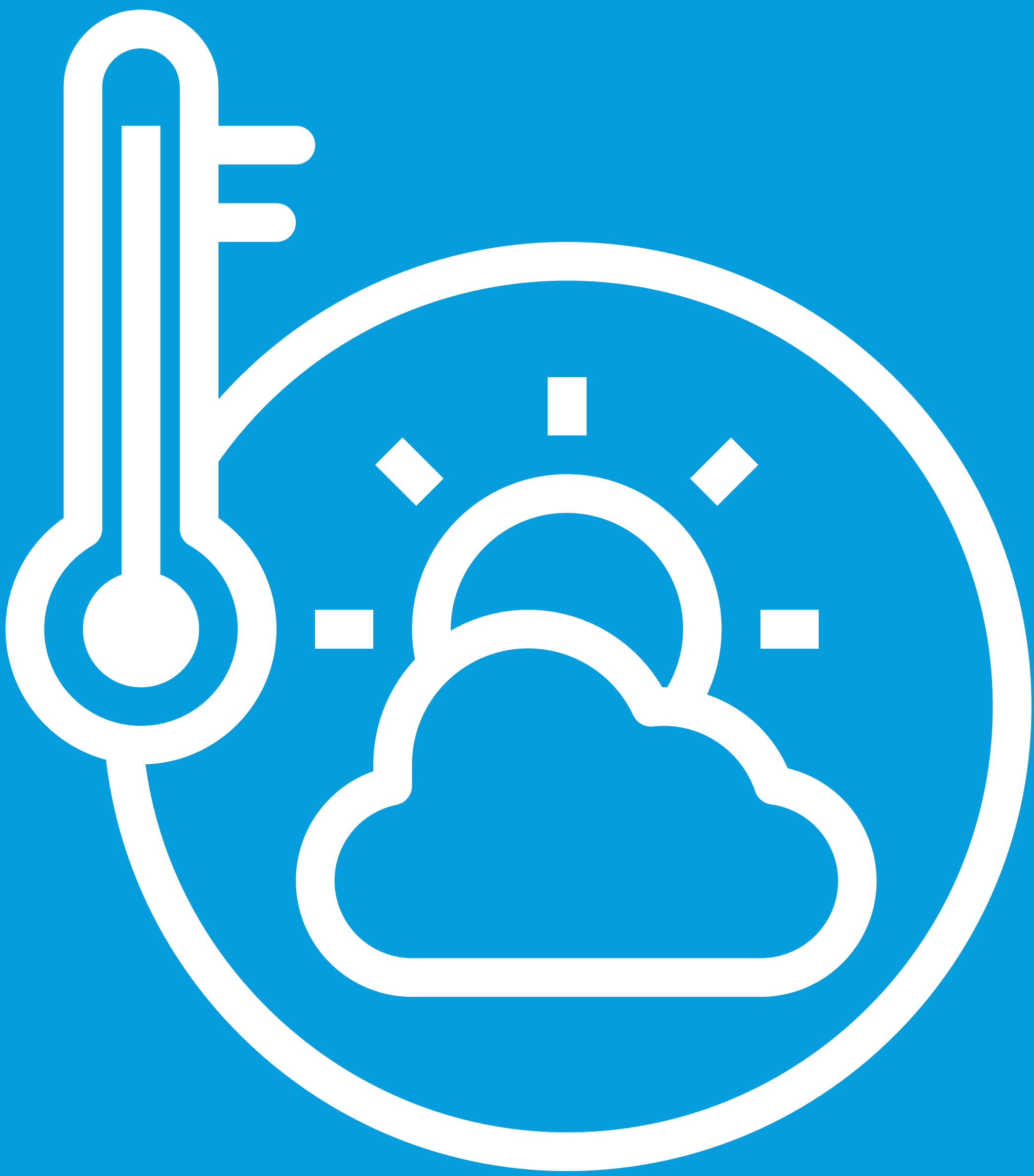
The stakeholder identification is one of the main steps for climate proofing, as it will be important in the identification of hazards, in the determination of adaptive capacity, the vulnerability assessment, and in the implementation and monitoring. Broad, representative consultation is important to ensure a wide range of perspectives. The broader the stakeholders' advisory group, in terms of participation of different government agencies, universities, NGOs and representatives from sectors and from communities, broader will be support to the process. Quite often it is important to select from some of the most relevant institutions involved in resources planning and climate change. Table 3.2 shows institutions whose stakeholders are important for the climate proofing process. As an example, specifically for water-related infrastructure, the following institutions represent a broad cadre of such representatives:

- Water resources research
- Water utility managers
- Consumers groups, community- and non-governmental-based organizations
- Climate change experts

Waterway to prevent flooding Montreal, Quebec, Canada. © **Shutterstock/ Sukpaiboonwat**

# CHAPTER 4:

# CLIMATE PROOFING TOOLKIT



# STEP 1: Screening, hazard identification and levels of exposure

## 4.1 Screening, hazard identification and levels of exposure

### 4.1.1 Integration of climate change variable

Climate proofing, being a multidisciplinary undertaking, will always require climate change information in databases, impact or vulnerability assessments, local knowledge about climate change, and so on. For rapid sensitivity screening, the two types of information from the utilities are adequate. Project preparation to evaluate potential risks, determine the need for further exploration or evaluation of an ongoing infrastructure require expert opinion and judgment based on awareness and knowledge of climate change and hazards. First, basic information is needed about each infrastructure, such as design, main components and target population; and basic climate change information (precipitation, wind, flooding, drought), including current climate variability and projected climate change, local impacts (changes in drainage, changes in groundwater, impacts of slope stability) and best practices for adapting to climate change that have been applied in similar conditions.

The approaches adopted in the present toolkit are as follows: The first part presents the *problem assessment*. This is demonstrated by examining climate data sources and reviewing stakeholders' analysis as a bottom-up approach. The second part presents *stakeholders consultations* that are planned to discuss the climate change science and scenarios, and the extent of the consequences caused by climate hazards. Third is dynamic vulnerability assessment. This is presented by a series of activities; namely, exposure analysis, sensitivity and adaptive capacity assessments.

Detailed current and historical climate trends provide an explanation of how climate is projected to change in the future and in which ways.[2] The consequences of climate change include extreme weather conditions with increases of various magnitude and frequency. While climate models provide general trends for large areas, downscaling the predictions is very difficult and wrought with many inaccuracies. It is imperative to identify thresholds and boundaries (physical and operational) based on performance, operations history, service reliability, past decisions, on cost-benefit analysis. It should also be able to establish climate responses based on trends and extremes already experienced. The screening process (see table 4.1) involves systematically examining activities (or projects, programmes, policies, technologies) with the aim of identification of levels of exposure and risk.

Table 4.1 presents an example of a checklist and scoring for identification of levels of exposure that can be used at project level. For each of the five questions presented in the checklist, the scoring is 0 for not likely, 1 likely, and 2 very likely. Add all scores together. A total score of 0 indicates a project has no or low risk to climate change, 1, 2, 3, or 4 indicates a project at medium risk to climate change, provided that no individual question has received a score of 2. A score of 2 to any individual question indicates a project at high risk to climate change. Similarly, a total score of 5 or more (the maximum score being 10) indicates a project at high risk to climate change.

2 U.S. EPA. BASINs 4.0 Climate Assessment Tool (CAT): Supporting Documentation and User's Manual (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/088F, 2009.

**Table 4.1: Checklist for identification of levels of exposure**

| Step | Screening Questions | Score | Remarks |
|---|---|---|---|
| Location and Design of Project | Is siting or routing or both of the project (or its components) likely to be affected by climate conditions, including extreme weather-related events such as floods, droughts, storms, and landslides? | | |
| | Would the project design (for example, the clearance for bridges) need to consider any hydrometeorological parameters (for example, sea level, peak river flow, reliable water level, peak wind speed)? | | |
| Design, materials and maintenance | Would weather, current and likely future climate conditions, and humidity hydrometeorological parameters likely affect the selection of project inputs over the life of project outputs | | |
| | Would weather, current and likely future climate conditions, and related extreme events likely affect the maintenance of project output(s)? | | |
| Performance of project output | Would weather and climate conditions and related extreme events likely affect the performance of project output(s) throughout their design lifetime? | | |
| **Total Score** | | | |

For climate proofing of overall urban infrastructure, a comprehensive risk-based vulnerability assessment is recommended. Since the Intergovernmental Panel on Climate Change 2014 Framework, climate change risk is understood as a function of hazards, exposure and vulnerability. The next sections of this chapter cover hazard identification and exposure. Vulnerability is understood as a function of sensitivity and adaptive capacity. The next steps to deal with methods and tools are to estimate sensitivity and adaptive capacity. Stakeholders' knowledge and experience is fundamental for identifying hazards, exposure and assessing sensitivity and adaptive capacity.

### 4.1.2 Hazard identification

Three broad categories of hazard may be identified (Brooks, N. 2003):

1. **Category 1:** Discrete recurrent hazards, as in the case of transient phenomena such as storms, droughts and extreme rainfall events.

2. **Category 2:** Continuous hazards; for example, increases in mean temperatures or decreases in mean rainfall occurring over many years or decades (such as anthropogenic greenhouse warming or desiccation).

3. **Category 3:** Discrete singular hazards; for example, shifts in climatic regimes associated with changes in ocean circulation.

Risk assessment, an approach not fully explored in the present toolkit, results from the interaction of vulnerability, exposure, and hazard (IPCC 2014, ADB, 2014)). Hazard approach that is adopted here, is often represented as probability of occurrence (likelihood of occurrence) or trends multiplied by the impacts (or consequences) if these events or trends occur. Climate change generated hazards such as sea level rise, increased frequency (likelihood) of inundation (a hazard) of an area during a storm event can put the structural integrity of a nearby infrastructure, such as a road, at risk. In the context of climate change, hazard refers to any potential occurrence of a natural or human-induced physical event that may cause damage to property, infrastructure, livelihoods, service provision, and environmental resources. As an example, as sea level rises, increased frequency of inundation of an area during a storm is a potential hazard for a low-lying coastal community. Risk is the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values.

The hazard assessment takes the outputs from the climate assessment and integrates that data into traditional hazard models. The hazard models are run using future conditions from the climate models. There are different types of hazard assessment approaches and tools; however, they usually involve a mapping component. The objective of the hazard assessment is to understand where the hazard could occur and identify probable characteristics. Three hazard assessment examples include the following:

- **Historical:** High-water marks could be collected for a recent storm and used with a digital elevation model to document the extents and depths of flooding. This could be used for response and recovery and to validate modelling efforts
- **Scenario-Based:** These assessments will not describe an actual event but might look at a series of potential events
- **Probabilistic:** This is a risk-based map developed using a probabilistic analysis. These maps are typically developed using historical hazard information to identify an event and assign likelihood to that event occurring in the future

Hazard assessment tasks include the following:

- Analysis of climate variability and climate change hazard
- Estimate the impact of the hazard
- Evaluate the hazard

The first step in characterization and assessment of hazard is to identify the hazard(s) that is likely to impact the system. Such identification is followed by characterization and assessment by developing the information about nature, strength, frequency, time of occurrence and probability of occurrence of hazard(s). Often the stakeholders have first-hand knowledge about the extent to which climate stressors affect development. However, this information may be subject to bias, especially if it is not readily accessible to participants in consultations or the expertise is not available to assess the information, independently.

**Task 1:** Collect historical weather and climate data (for example, local climate type, temperature, precipitation, extreme weather events), as well as climate projection and scenarios. The sources of climate data can include institutions such as:

- National Statistical Bureaus
- National meteorological bureaus
- World Meteorological Organization (http://www.wmo.int)
- National/Regional/Local Water Resources Board(s)
- Global Change Master Directory
- PAGES Past Global Changes Data Portal[3]
- National Climate Data Centre
- Climatic Research Institute, University of East Anglia, United Kingdom Datasets available for temperature and precipitation
- Global Historical Climatology Network, 1900 - Contains gridded precipitation anomalies calculated for monthly precipitation data set. The data are formatted by year, month, latitude and longitude
- National Climatic Data Centre, Monthly Climatic Data for the World 1948 - contains monthly mean temperature, pressure, precipitation, vapour pressure, and sunshine for approximately 2,000 surface data collection stations worldwide and monthly mean upper air temperatures, dew point depressions, and wind velocities for approximately 500 observing sites

3 http://www.pastglobalchanges.org/

**Table 4.2: Sources of data**

| Data needed | Purpose | Sources of data |
|---|---|---|
| Past weather and climate data (for example, local climate type, temperature, precipitation, extreme weather events) | Demonstrate trends and existing weather | • Government weather stations and agencies<br>• Meteorological departments (national/subnational/local)<br>• Environment ministry or department (national/subnational/local)<br>• Climate change officer or equivalent<br>• Municipality profile<br>• Other studies |
| Climate scenario/projections | Illustrate trends and their likelihood over 10, 30, 50 years | • National and subnational government (for example, environment departments)<br>• Academic institutions<br>• IPCC global projections |
| Impact report of previous climate-related disasters | Identify potential climate change hazards and their impacts | • Disaster management centre or equivalent (national/subnational/local)<br>• Social service department/ministry or equivalent<br>• Agencies and statistics related to disaster risk reduction (https://www.unisdr.org) |

**Source:** UN-Habitat (2014)

**Task 2:** Identify any record of occurrence of climatic hazard in the past in the area, existence of any risk management strategies in place to tackle any future occurrence of that hazard.

The location of hazards, the most vulnerable populations and climate change element are most frequent to be determined. A 30-year period, depending on data availability, would be sufficient to provide adequate history of the hazard. Precise and well-documented information will be most appropriate, such as time periods (hours/days/weeks) for which services (intake, treatment, bulk supply, distribution, sewage disposal) were disrupted on account of (a) excessive precipitation (or extreme dry weather), (b) high temperatures, (c) power failures on account of typhoons and storms, and (d) flooding as a result of sea level rise and storm surges. These disruptions should be accompanied by corresponding disruption of operation or service, for example, shortfalls in supply of distributed water (water planned for bulk distribution less water actually distributed).

Ariel view of Kalobeyei Turkana, Kenya.
**© UN-Habitat/ Julius Mwelu**

### BOX 4.1: USE OF HISTORICAL DATA IN CLIMATE POLICY FORMULATION

Historical records of Uganda's glaciers show that the ice caps on the Ruwenzori Mountains have shrunk significantly in the last 100 years. The percentage of ice loss is highest on Mount Baker (96 per cent), followed by Mount Speke (91 per cent). Mount Stanley has the lowest percentage of ice loss (68 percent). The primary cause of the decline in the area covered by glaciers is considered to be rising air temperatures that have amplified ice losses by evaporation and melting. These alpine wetlands, lakes and streams are supplied, in part, by snowfields. They support aquatic environments, like the headwaters of the River Nile, and are home to a diverse range of flora and fauna. To overcome these challenges, the policy priority is to support ongoing efforts to ensure that climate change concerns are integrated into national efforts for sustainable and long-term conservation, access and effective utilization and management of water resources.

Specific strategies for tackling water policy priority are the following: ● Promote and encourage water harvesting and efficient water utilization among individuals, households, institutions and sectors. ● Ensure availability of water for production in water dependent sectors in order to increase their resilience to climate change impacts. ● Promote and strengthen the conservation and protection against degradation of watersheds, water catchment areas, river banks and water bodies. ● Promote Integrated Water Resources Management (including underground water resources), including contingency planning for extreme events such as floods and drought. ● Ensure that all guidelines for infrastructure and hydraulic works (that is, water for production, piped water supply schemes and conditional grants guidelines for support to point sources protection) mainstream climate change. ● Improve and strengthen transboundary cooperation regarding water resources management. ● Support institutional and human capacity-building in water resource use, development and management. ● Strengthen water resource monitoring networks and flood warning systems.

Source: Republic of Uganda. 2015. Uganda National Climate Change Policy Theme: Transformation through Climate Change Mitigation and Adaptation. Ministry of Water and Environment. https://www.mwe.go.ug/sites/default/files/library/National%20Climate%20Change%20Policy%20April%202015%20final.pdf

**Task 3:** Identify any record of occurrence of climatic hazard in the past in the area under consideration, screen to narrow down the list of hazards (relevant to the infrastructure):

- Determine the consequence of that event.
- Are there any risk management strategies in place to protect previously affected systems from future occurrence of that hazard?
- Understand and identify residual risk of a given system (that is, risk that remains even after putting a risk management strategy in place).

In order to anchor climate proofing on a need basis, finding the gaps in data collection, compilation and analysis in current programmes and projects and suggesting a new adaptation planning for the future is important.

**Table 4.3: Example of local observation template**

| CC Hazard | Extreme event or trend? | Historical trend: local or regional data | Historical trend: stakeholder observation | Climate model scenario |
|---|---|---|---|---|
| Flooding | Low-lying areas | | | |
| Mean sea level rise, increased storms surge heights, coastal flooding and erosion | • Areas already at or below sea level<br>• Coastal zones and islands<br>• Offshore locations | | | |
| Average temperature rise, and increased risk of heatwaves | Urban centres, where the "Urban Heat Island" effect will exacerbate high temperature. | | | |
| Droughts | Areas of high precipitation variability. | | | |

**Task 4:** Monetize the impacts and record financial data at prevailing tariffs alongside the volumetric data, if available.

- Identify and list the associated remedial measures (whether short- or long-term).
- Indicate the costs (nominal prices).

**BOX 4.2: PERU HIT BY DRINKING WATER SHORTAGE AS DEATH TOLL IN FLOODING UP OVER 70**

There has been shortage of water due to landslides of mud and stone that have fallen into the Rimac River and other tributaries on which Lima, the capital of Peru, relies. The solid residue has overwhelmed the city's La Atarjea treatment plant's ability to process its drinking water because of turbidity. As a result, 72,115 people have lost their homes, 567,551 people have been affected, and 119,084 buildings have been damaged. The water situation has become critical.

**Source:** Xinhua | Updated: 2017-03-20 09:05. China Daily, March 27, 2017

**Task 5:** Using information of assessment on past hazard in the target area, list the system components (for example, assets) affected in the past events.

- What was the consequence of those events? (Qualitative or quantitative estimation).
- Are there any risk management strategies in place to tackle any future occurrence of that risk?
- Understand and identify residual risk of a given system (in other words, risk that remains even after putting a risk management strategy in place).

**Table 4.4: Summary table for climate change impacts and costs**

| No. | Date of disruption | Associated climate change variable | Cost of impacts (USD) | Cost of remedies (USD) | Type and impact of disruption | Action taken | Cost of action (USD) |
|---|---|---|---|---|---|---|---|
| 1. | | | | | | | |
| 2. | | | | | | | |
| 3. | | | | | | | |
| 4. | | | | | | | |

**Table 4.5: Template for assessing flood disaster**

| No. | Assessment criteria | Year | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| | Affected area ($km^2$) | | | | | |
| 1. | Population affected | | | | | |
| 2. | Houses | | | | | |
| 3. | Roads (km) | | | | | |
| 4. | Electricity (hours of disruption) | | | | | |
| 5. | Water supply (number of persons/ households affected) | | | | | |
| 6. | Conservation area ($km^2$) | | | | | |
| 7. | Assets destroyed (USD million) | | | | | |
| 8. | GDP (current) | | | | | |
| 9. | Assets destroyed as % GDP | | | | | |
| 10. | Hazard return period | | | | | |

### 4.2.1 Hazard mapping

Climate proofing of infrastructure shall also consider integration with land-use management, environmental and socioeconomic impacts, and various institutions. Mapping is particularly important for natural risk management. Hand-drawn maps, developed in group settings, can be useful for gathering input for participatory hazard mapping. A community hazard map (box 4.3) can include the following elements (Kienberger, 2014):

- Land-use and land cover classification (based on satellite imagery)

- Community infrastructure (houses, school, location of the flood response kit, health facilities, water wells, market, accommodation centres, and paths). Data can be collected through various sources and with additional community input during the mapping exercises (box 4.2), as well as global positioning system collections

**BOX 4.3 CREATING A COMMUNITY MAP OF FEATURES AND KEY LANDMARKS**

A community-made mapping of features could cover features and landmarks such as the following:

- Community boundary
- Neighbouring communities
- Risk Zones (high risk/low risk/safe areas)
- Lower and higher elevated areas and areas close to the river
- Special infrastructure of the community (such as wells, markets, schools, assembly points, accommodation centres; sacred places should only be mapped if community members agree)
- Settlement area
- Naming of areas and natural features

**Source:** Kienberger, 2014

- Community boundary
- Houses and settlement area
- Flood hazard zones
- Results of vulnerability identification (such as a list and as a tree map,[4] scoring results)
- Buffer zones indicating the distance to the safe areas (GIS analysis)
- Analysis of exposure (spatial analysis and distance queries; number of houses in risk zones, distance to safe areas, statistical data on the community and an estimation on people living in risk zones)

To determine and map the hazard at the subnational level, one needs to identify projected hazards (flooding, landslides, hurricanes, sea level rise, heatwaves, drought, and wildfires) and perturbations under climate change, future temperature patterns (average and variance), rainfall events (average and variance), and frequency or magnitude or both of extreme events (such as droughts, floods or cyclones). For hazard mapping, tools such as geographic information system tools (for example, 3Di tool model, see box 4.4) can be used to develop hazard maps. The existing sectors of society (population, agriculture, water, energy, tourism, fisheries, health, and biodiversity) affected by hazards and perturbations, current socioeconomic trends that interact with these sensitivities (and in particular run the risk of amplifying them) and the level of adaptive capacity are to be estimated. In summary, a hazard map will include a base map, a hazard record map that shows the location of events occurring based on geological and scientific evidence and historical data, and a hazard forecast map illustrating the location, severity, and likelihood of occurrence of hazardous phenomena (see box 4.5).

4 A tree map is a visualization of hierarchical data with nested rectangles. The size of the rectangles displays the weight of the representing factor. This type of visualization allows for easy capturing of the structure and the weight of the different factors.

**Table 4.6: Housing - Inundation mapping for housing**

| No. | Level of Inundation (m) | Baseline Scenario | | Climate Change Scenario | | Change due to Climate Change | |
|---|---|---|---|---|---|---|---|
| | | km² | % total inundation | km² | % total area | km² | % total area |
| 1. | Flood free | | | | | | |
| 2. | F0 (0.1-0.3m) | | | | | | |
| 3. | F1 (0.3-0.9) | | | | | | |
| 4. | F2 (0.9-1.8m) | | | | | | |
| 5. | F3 (1.8-3.6m) | | | | | | |
| 6. | F4 (>3.6m) | | | | | | |
| 7. | F1+2+3+F) | | | | | | |

Although urban infrastructures and urban systems are often viewed individually–transport or water supply or wastewater and drainage–in fact they are usually highly interactive and interdependent. Table 4.6 on level of inundation may also be used for tabulating vulnerable populations. The results of a study in Mathare informal settlement in Nairobi, Kenya, indicate that not only the elevation of the land is important for vulnerability assessment but that the building structural type with mud wall and mud floor is the most vulnerable structure to flooding, while the structural type with stone walls and concrete floors is least vulnerable.[5]

**BOX 4.4 ESTIMATES OF FLOODING USING THE 3DI AREA MODEL**

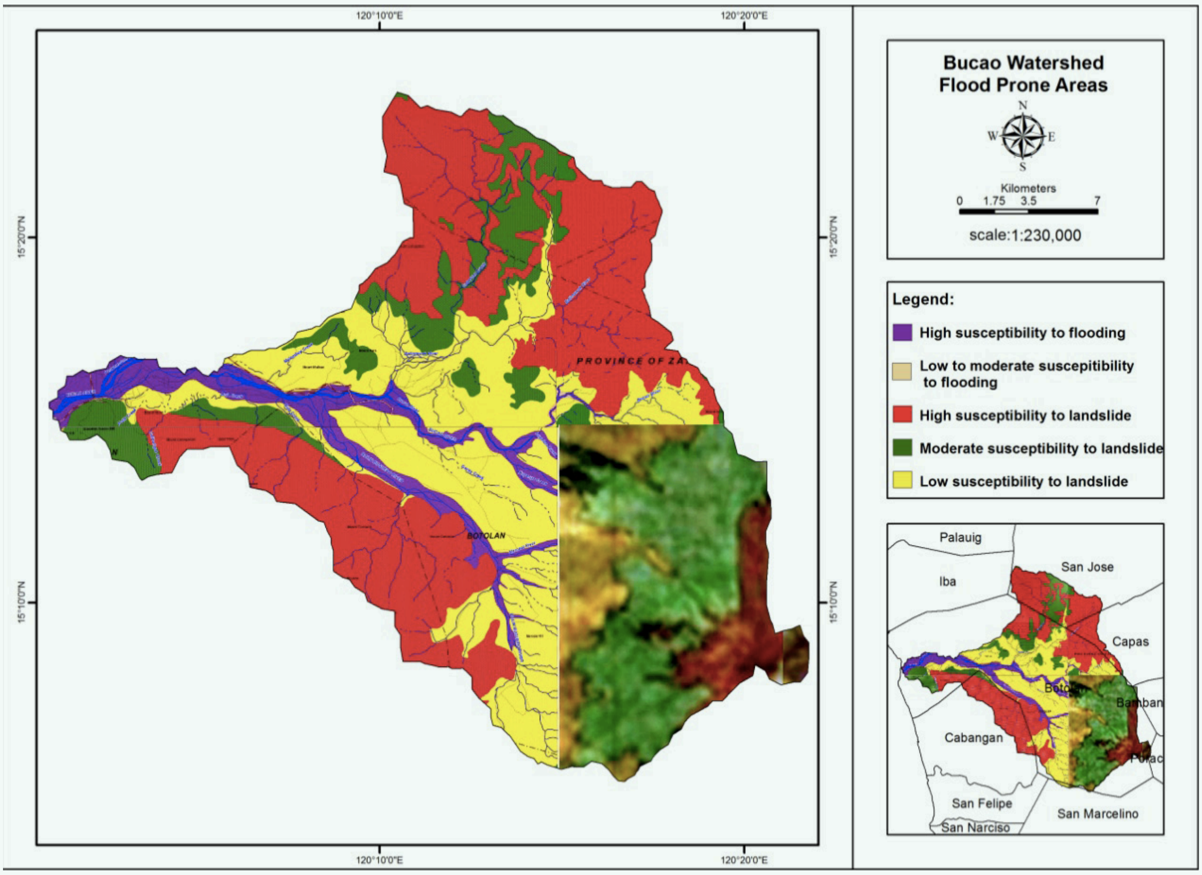
The 3Di area model is a tool that offers insight into how vulnerable an area is to flooding. It can also be used as an assessment tool, whereby the effects of changes to the system can be shown interactively on a touch screen during a work session. Because the spatial resolution is very high and the calculation speed is a factor 1,000 faster than comparable instruments, calculations can be made 'at the table' during the decision-making process. The 3Di model makes it possible to chart quickly and accurately where, to what extent, and how quickly extreme rainfall leads to water hindrance and pluvial flooding. Using the extremely detailed actual height model of the Netherlands (AHN2) database, it becomes easy to see how much water there will be vital or vulnerable objects, networks and groups (roads, properties and gardens) and where this water will go shown interactively on a touch screen during a work session.

Because calculations can be paused, adjusted and restarted means that all those involved, including non-specialists, can "try out" climate adaptive measures. Thus, consensus can be reached quickly about the use and necessity of measures, and worthwhile measures can be separated from those that are not worthwhile.

**Source:** Climate Proof Cities Consortium (2014). https://edepot.wur.nl/351021

5 Gitonga, J.K. 2017. Risk Analysis of Flood Physical Vulnerability in Residential Areas of Mathare Nairobi Kenya. Available at https://www.Researchgate.Net/Publication/321070479 Risk Analysis Of Flood Physical Vulnerability In Residential Areas of Mathare Nairobi Kenya [Accessed Nov 04 2019].

**BOX 4.5. FLOOD HAZARD MAP: BUCAO, THE PHILIPPINES**




Relevant information can be obtained from disaster management department. Under the Sendai Framework for Disaster Risk Reduction, several studies are being developed and several tools are being made available online (for example, www.preventionweb.net).

**Source:** PHIL-Lidar (2019)

### 4.1.3 Exposure measures

Rapid population growth has challenged the rate of infrastructure development, especially in developing countries. On the one hand pollution increases due to low sanitation coverage, especially in water-scarce areas, and on the other hand water demand increases for all uses resulting from rapid economic growth, increase in food production, and challenges of climate change. Climate change will influence the nature of the climatic hazards to which people and ecosystems will be exposed. The phenomenon will also contribute to deterioration or improvement of coping and adaptive capacities of those who will be exposed to these changes. While exposure is distinct from vulnerability, exposure is an important precondition (IPCC, 2015) for considering a specific climate risk. If a system is neither at present nor in the future exposed to hazardous climatic trends or events, the risk to such hazards is not relevant in the current context. Exposure is high in centres that contain a high concentration of the urban population that have close relationship between agriculture and urban development, and "rural" development of farmers and rural households, and workers in industry or services. Thus, maintaining the two-way flows of food, biomass, water and livelihoods, products and services continuum makes such communities vulnerable to a myriad of hazards, especially the intimate connectedness between livelihoods and drought, biomass and energy security.

Exposure is increased by the level of poverty and influenced by gender characteristics. The degrees of poverty will influence exposure levels to almost all hazards, although there is considerable variation within "low-income" urban dwellers in regard to their exposure to climate change forcing elements. There are large variations between settlements in terms of housing quality provision and risks to settlements from flooding or landslides. Within informal settlements, tenants living below the poverty line of USD 1.90 per day are often most at risk. This is especially so where landlords do not live on the premises, thus removing the link between those responsible for the quality of the housing and those tenants who are at risk. The houses are usually built without any plans and operate without regulation to enforce health and safety standards. Tenants who are seasonal or temporary migrants have less interest in risk reduction with longer-term concerns or to infrastructural improvements.

There are also large variations in the asset bases that different low-income individuals or households can call on to help cope with emergencies and in the quality and extent of safety nets on which they can draw. There are obvious variations in the speed with which different gender and the disabled minorities can move in response to impending risks and in the possibilities of them being reached by appropriate public information on what to do.

**BOX 4.6 GREEN BOOK: ADAPTING SOUTH AFRICAN SETTLEMENTS TO CLIMATE CHANGE**

The Council for Scientific and Industrial Research, South Africa, has developed an innovative set of guidelines, called the Green Book, to support the processes of adapting existing and future South African settlements to climate change. The book presents evidence for adapting settlements to climate-related risks and vulnerabilities, as well as the necessary guiding principles to do so. The guidelines focus on aspects such as disaster risk reduction; spatial structuring; land-use management; bulk services and critical infrastructure; municipal service delivery; mobility networks; public transport; public health; social facilities; ecosystem services; and food security.

**Source:** Van Niekerk, W. and Pieterse, A. The Adaptation Network, August 2017.  The Green Book available at www.greenbook.co.za

### 4.1.4 Exposure analysis

Exposure analysis assesses how climate change hazards affect people, places, infrastructure and overall economic sectors. Analysis of the nature, frequency and duration of hazard at a location characterizes exposure at that location. Exposure can be assessed on spatial and temporal dimensions. The advisory group can evaluate how climate change hazards affect people and sectors, then organize them, for instance, in a matrix such as the example shown in table 4.7.

**Table 4.7: Example of an overview of exposed people, places, institutions**

| Climate change hazard | Hazard area/location | Hazard area – exposed features | Exposed sectors |
|---|---|---|---|
| Drought | Citywide | • City reservoir, residents, business | • Water/Sanitation<br>• Economy (formal & informal)<br>• Health |
| Flooding | Low lands | • Flood plain<br>• Bridges X, Y, Z<br>• Informal communities A, B | • Agriculture<br>• Housing<br>• Transport<br>• Economy (formal & informal) |
| Heatwaves | Citywide | • Elderly and young<br>• Power plant (energy consumption)<br>• Water treatment (water consumption) | • Health<br>• Energy<br>• Water |
| Sea level rise | Coastal zone<br>River estuary | • Informal communities C, D<br>• Fishing port<br>• Estuary ecosystem | • Fisheries<br>• Housing<br>• Environment Ecosystems |

**Source:** UN-Habitat (2015)

Socioclimatic exposure is a measure of the severity of climate change, economic capacity and assets at risk. In general, the people most at risk from climate change are those living in affected areas who are:

- least able to avoid the direct or indirect impacts (for example, by having good-quality homes and drainage systems that prevent flooding, by moving to places with less risk or by changing jobs if climate change threatens their livelihoods)
- likely to be most affected (for instance infants and older groups who are less able to cope with heatwaves)
- least able to cope with the illness, injury, premature death or loss of income, livelihood or assets caused by the kinds of impacts

The aggregated exposure index is calculated as the product of the climate change, population wealth, and poverty indexes (Füssel, H-M. 2009). Poorer groups get hit hardest by this combination of greater exposure to hazards (for example, a high proportion living in makeshift housing on unsafe sites), lack of hazard-removing infrastructure and inadequate capacity.

| Table 4.8; Exposure assessment in water supply and sanitation infrastructures | |
|---|---|
| **Climate Stressor** | **Impact and Risks** |
| More frequent, intense rainfall events | • Increased sedimentation and turbidity<br>• Loss of reservoir storage capacity for water supply or flood control due to sedimentation accumulation<br>• Challenges to water treatment performance; increased turbidity will require additional chemicals or changes to treatment technology<br>• Direct storm and flood damage to water supply and water management facilities<br>• Landslides and washouts can impact water pipelines; intake structures can also be impacted |
| Sea level rise | Increased saline intrusion and possible need for expensive treatment options:<br>• In groundwater aquifers, salt water intrusion may impact aquifers and wells<br>• Brackish surface water sources may become saltier, requiring relocation or new treatment technologies<br>• Direct storm and flood damage to water supply water management facilities, flooding of facilities will require protection or even relocation |
| Warmer, drier seasons. | Vegetative changes in watersheds and recharge areas:<br>• Increased risks of wildfire; invasive species will impact rainfall runoff characteristics<br>• Changes in quantity and quality of groundwater; recharge may decrease<br>Increased water temperatures:<br>• Eutrophication and changes in aquatic species may impact surface water quality<br>• Evaporation losses from surface waters and reservoirs may increase, resulting in less available water for domestic consumption or agriculture<br>Increased water demand:<br>• Increased irrigation demands (longer growing seasons)<br>• Increased urban demands (dry spells, heatwaves)<br>• Potential groundwater depletion and in-stream flow reductions |

**Sources:** WHO (2009): The Resilience of Water Supply and Sanitation in the Face of Climate Change, Summary and Policy Implications, Vision 2030, WHO, Geneva

### 4.1.5 Role of technology in water supply and sanitation

In many cases, technology and management tend to interact with local circumstances such as water availability and demand to determine the vulnerability and adaptive capacity of water supply and sanitation services. For water supply and sanitation, technologies were categorized according to their climate change resilience, taking account of vulnerability to climate changes (determined by engineering and environment) and adaptive capacity (ability to be adjusted or managed so as to cope in response to different climate conditions). Drinking water technologies have a wide range of potential climate change impacts on water supply technologies, including flood damage to infrastructure, increased contamination, deteriorating water quality, increased treatment requirements and reduced availability.

Besides preparations that may occur before the disruption occurs, the proceeding way of putting the system back to normalcy is paramount. The water source area (catchment, spring, and borehole), water treatment plant, distribution network, consumer points and waste water treatment plant are crucial. These points require enhance technology in order to avoid system collapse.

# STEP 2: SENSITIVITY MEASURES

## 4.2 Sensitivity measures

### Introduction

Sensitivity assessment is a reflection of bottom-up vulnerability and thresholds-first approach. It is also a recognition that the most effective strategy for climate proofing is to integrate climate change adaptation into policies, plans, programmes and projects at all levels of urban infrastructure in a rather more integrated manner by involving all stakeholders on all institutional levels. The exposure includes people, places, infrastructure and institutions impacted today, and the degree to which they would be impacted in future. Different infrastructure and human systems will be exposed to significant climatic variations (exposure to climate factors) and therefore considered to be external. For example, a quarter of humanity faces looming water crises today (Somini Sengupta and Weiyi Cai, 2019). More than a third of major urban areas with more than 3 million people with a combined population of over 255 million are under high or extremely high-water stress, which has repercussions for public health and can cause social unrest (Hofste, et al, 2019). From India to Iran to Botswana, 17 countries around the world are under extremely high-water stress, meaning they are using almost all the water they have. By 2030, the number of cities in the extremely high stress category is expected to rise to 45 and affect nearly 470 million people.

### 4.2.1 Sensitivity assessment

#### 4.2.1.1. Relation between adaptive capacity and sensitivity

Sensitivity is the "degree to which a system is affected, either adversely or beneficially, by climate-related stimuli" (sensitivity to change (IPCC. 2007. Working Group II: Impacts, Adaptation and Vulnerability). In the present toolkit, sensitivity is interpreted as the degree to which an infrastructural system will be affected by or responsive to climate stimuli, either positively or negatively. Even though a particular infrastructure may be considered as being highly exposed or sensitive to climate change, it does not necessarily mean that it is vulnerable. This is because neither exposure nor sensitivity account for the infrastructure's adaptive capacity, whereas vulnerability is the net impact that remains after adaptation is taken into account.

#### 4.2.1.2 Sociodemographic sensitivity assessment

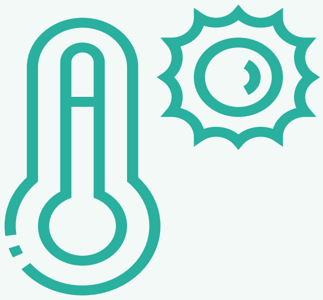
Demographic composition is important in sensitivity analysis, which is rarely due to a single cause. Rather, democratic composition is a product of intersecting social processes that result in inequalities in socioeconomic status and income, as well as in exposure. Such social processes include, for example, discrimination on the basis of gender, class, ethnicity, age, disability and fitness.

Children, as a group, will be affected by extreme events and longer-term climate change, in particular, in more extreme ways than the population as a whole. This is because of their greater physiological and psychosocial vulnerability to a range of associated stresses. Disruptions to water supplies and sanitation systems for instance, are far more likely to result in diarrhoeal illness for infants and young children than for other age groups, and repeated episodes can have long-term implications for their physical growth and even cognitive functioning. Young children also have less capacity to cope with heat stress, deteriorations in urban air quality, threats to food supplies and the increases in certain vector-borne diseases associated with climate change. There are also the particular vulnerabilities that many older men and women face that need consideration – for instance, the greater risks that heat stress poses or limitations in the capacity to move rapidly away from rising floodwaters. The vulnerability of older people may also be linked to their isolation.

The heatwave that occurred in Europe affected the elderly compared with other demographic groups. Over all, gender mainstreaming into adaptation and mitigation programmes is key to ensure that the vulnerability of women and men, boys and girls is reduced and their adaptive capacity is strengthened.

**BOX 4.7: HEATWAVE IN EUROPE**

A heatwave struck large parts of Europe during the last week of June 2019, breaking several historical records at single locations in France, Switzerland, Austria, Germany, the Czech Republic and Spain. The all-time temperature record at a station in metropolitan France (old record 44.1°C in Conqueyrac, Gard) was broken on 28 June, with a new record of 45.9°C, more than 1.5°C above the previous set at Gallargues-le-Montueux, Gard, near the city of Nîmes.



**Source:** van Oldenborgh, et al, 2019)

#### 4.2.1.3 Sensitivity mapping of places

Sensitivity is the measurable ability of the urban infrastructure, with its users, to maintain continuity through all shocks and stresses. Community-based sensitivity mapping in more vulnerable areas may be guided by activities and data sources shown in table 4.1. The effect of climate change may be direct or indirect.

**Table 4.9: Data types and analysis**

| No. | Assessments | Activity | Data sources |
|---|---|---|---|
| 1. | Past and Present Climate Trends and Risks | Existing and recent historical climate extremes. Time series, seasonality, parameters | National meteorological records |
| 2. | Past and Present Sensitivity by Sector | Determine the sensitivity of various infrastructure – spatial distribution | Archives, disaster reports, electricity consumption, water stoppages, etc |
| 3. | Future Exposure to Climate Hazards and Perturbations | Uncertainty increases with the record. Scenarios are storylines of future demographic, social, economic, technological and environmental conditions, and are used to represent how society may unfold in the future | Computer-generated climate models |
| 4. | Future Sensitivity to Climate Change | Making predictions about the development and evolution of society | Socioeconomic data on projected pathways of development is critical for determining future sensitivity to climate change |

Rainwater harvesting in storage tanks, public drinking water distribution in Namibia, southern Africa.

#### 4.2.1.4 Sensitivity of water supply and sewerage services

The water supply and sanitation in urban areas are fairly mixed of various forms, situated in various parts of a city and with differing population. The components of water supply and wastewater treatment are catchment area, storage reservoir, raw water collection, and water purification, distribution network, pumping station, and power supply and access road. In considering drinking water supply, included are piped water, public standpipes, protected wells, protected springs and rainwater collection. Sanitation broadly includes a piped sewer system, septic system and pit latrines including ventilated improved pit latrines, pour–flush latrines, pit latrine with slabs and composting toilets. Other climate-generated aspects are, for example, coastal inundation, saline intrusion, and vectors of disease, emergency responses and indirect effects of climate change. Typical vulnerability areas are damage to physical assets, reduced service, life span of asset, and reduction in reliability, interruption of services, increased input costs, increased operation and maintenance cost, and reduction in efficiency. Table 4.3 shows that damage to the infrastructure, scarcity and water pollution are main areas of concern

**Table 4.10: Sensitivity of components of water supply and sanitation**

| Climate change impact | Sensitivity areas | Aspects of vulnerability |
|---|---|---|
| Water quality response to storms and other extreme rainfall events | Increased loads of sediments and pathogens, as well as other pollutants; suspended solids (turbidity) in lakes and reservoirs | Additional stress on water treatment systems; increasing coagulant demand, reducing the working period of the multi-stage filters and increasing the chlorine demand, reduced efficacy of the treatment process |
| Infrastructure responses to storms and other extreme rainfall events | Damage to water systems, inundated by floods<br>Damage to energy sources and power lines | Disruptions to water treatment chemicals and energy supplies, and reduced performance of wastewater treatment plants |
| Responses to droughts | Intermittent supply, source dries up (Cape Town), size of the population affected by the disruption of utility | Low water quality |
| Protected wells include boreholes and dug wells | Dug wells are at higher risk of becoming contaminated than deeper wells | Ingress of contaminated surface water |
| Protected springs | Droughts impact on water levels. Poor maintenance of the spring protection | Increasing groundwater recharge |
| Rainwater collection | Collection and storage during heavy rains. | Contamination |
| Combined sewer systems | Storms and other extreme rainfall events lead to sewer overflow, contributing to increased contamination of surface water.<br>Land movement or erosion around buried sewer pipes, or if sewer pipes above ground are washed away by the flood waters | Major disruption of services, severe damage to buildings |
| Sea levels rise | Water levels in the sewers may rise; wastewater to back up and flood | Sewer outfalls discharge into the sea.<br>Damage |
| Septic tanks and cesspits | Effects of increased rainfall and storms in areas of high groundwater tables | Overflow. Floods can also cause structural damage to septic tanks |
| Pit latrines | Rising groundwater or by inundation of surface water; flood-prone areas | Destroying pit latrines, leading to widespread contamination of groundwater and surface water |

**Table 4.11: Format for measuring sensitivity of water supply and sanitation**

| | Components | Risks by each hazard | Identifies and validates the location | Options for implementation | Reviews |
|---|---|---|---|---|---|
| **Water supply** | | | | | |
| 1. | Catchment | | | | |
| 2. | Water treatment | | | | |
| 3. | Water distribution | | | | |
| 4. | Consumer services | | | | |
| **Sanitation** | | | | | |
| 5. | Combined sewer | | | | |
| 6. | Storm drainage | | | | |
| 7. | Septic tanks and Cess pit | | | | |
| 8. | Pit latrines | | | | |

Tables 4.10 and 4.11 should be read simultaneously. The scoring is 0 for not likely, 1 likely, and 2 very likely for each climate change hazard. Adding all scores together, a total score of 0 indicates a component has no or low risk to the relevant climate change hazard, 1, 2, 3, or 4 indicates a project at medium risk to climate change, provided that no individual question has received a score of 2. A score of 2 to any individual question indicates a project at high risk to climate change. Similarly, a total score of 5 or more (the maximum score being 10) indicates a project at high risk to climate change.

**Table 4.12: Estimation of sensitivity analysis**

| Sector | Sensitivity assessment | Calculation of socioeconomic costs of disruptions |
|---|---|---|
| Water supply and sanitation | 1) Median of the projected change in precipitation.<br>2) Standard deviation of the projected change.<br>3) Median of the projected change in runoff. | Disruptions of services. |
| Coastal zones and their populations | 1) Percentage of land area below 1 m elevation.<br>2) Percentage of population below 1 m elevation.<br>3) Percentage of land area below 5 m elevation. | |

**Source:** Based on two studies by the World Bank (Buys et al., 2007; Dasgupta et al., 2007 and PLACE-II dataset (SEDAC, 2007)

Complete urban surveys are generally required in order to characterize the urban area into socioeconomic groups, settlement density and types of water buildings. These groups also access services very differently. Additionally, sanitation in slum is poor as most dwellers use pit latrines which are shallow due to the height of the water table in the flood plains or steep slopes where they live. These sanitary facilities get flooded and become inaccessible during the rainy season, leading to contamination of water sources. Even after disasters, risk reduction is often ineffective. Since external support is often readily available during reconstruction following a disaster, constraints still persist because humanitarian agencies have limited developmental skills or approaches that support and encourage local participation, leading to ineffective and inappropriate investments. Emergency funding budgets from donors often have to be spent in a short time period, usually within 12 months, and are not available to support longer-term development processes.

| Table 4.13: Measures of socioeconomic sensitivity - different degrees of aspects of urban poverty | | | |
|---|---|---|---|
| **Degrees of poverty** | **Aspects of poverty** | | |
| **Destitution** | **Extreme poverty** | **Poverty** | **At risk of being poor** |
| Income | Income below the cost of a minimum food basket. | Income just above the cost of a minimum food basket but far too low to allow other necessities to be afforded. | Income below a realistic poverty line but enough to allow significant expenditure on non-food essentials. |
| Housing with access to infrastructure and services | Homeless or living in a very poor-quality shack with no provision that is no-cost – or close to no cost. | Very little to spend on housing – often renting a room in tenement or illegal or informal settlement shared with many others. | More accommodation options – for example, slightly more spacious, better-quality rental housing or capacity to self-build a house if cheap or free land is available. The extent and quality of low-cost housing options is much influenced by government land, infrastructure and services policies and investments. |
| Assets | Typically, none or very little (although membership of a community-based savings group may provide access to small amounts of credit for emergencies). | Often some capacity to save, especially within well-managed savings and credit schemes; housing the most valuable asset for those who manage to "get their own home" even if it is illegal. | |

#### 4.2.1.5 Sensitivity thresholds analysis

The terms sensitivity thresholds or tipping points have been used interchangeably. The Intergovernmental Panel on Climate Change AR5 defines a tipping point as an irreversible change in the climate system. It states that the precise levels of climate change sufficient to trigger a tipping point remain uncertain, but that the risk associated with crossing multiple tipping point increases with rising temperature. A broader definition of tipping points is sometimes used as well, which includes abrupt but reversible tipping points (Lenton, 2011). In order to determine the sensitivity thresholds or tipping points of tolerable impacts of climate change, one needs to answer the following questions:

1. How high is the inter-annual variability of climate variables?
2. What is the frequency, intensity, timing and duration of extreme events?
3. What are the observed key climatic hazards in the system of interest?
4. Where are the hotspots; that is, where have the largest changes occurred in climate variables from past to present conditions?
5. How trustworthy is the information available for answering these questions?

Thresholds or tolerable rates are common term usage regarding reaction of communities to a hazard (Petersen, et al, 2017). These two terms are community-defined based on their adaptive capacities. Tolerable rates of disruptions and outages resulting from extreme climate events need to be developed to ensure the planned infrastructure, economic and technical feasibility.

A tipping point in the climate system is a threshold that, when exceeded, can lead to large changes in the state of the system. The adaptation tipping point approach gives insight into how much pressure a system (physical or social) can absorb, what the acceptable limits are for impacts and when they are reached. The impact level is defined as reaching a threshold when the impact indicator exceeds the acceptable limit for the physical or social system. Tipping point infrastructure vulnerability is a case in which a small increase in climate extremes above thresholds or regional infrastructure “tipping points” have the potential to result in large increase in damages to other existing infrastructure and increase disaster risks. Since infrastructure systems, such as buildings, water supply, flood control and transport networks often function as a whole or not at all, an extreme event that exceeds an infrastructure design or tipping point may result in widespread failure and a potential disaster.

When dealing with thresholds, tipping points and the like, the questions change from potential impacts of climate change tangible and locally relevant, and include the following:

1. How does climate and weather affect your job, the people you serve, and your family and community?

2. When does weather go from being a nuisance to a problem?

3. What are the impacts of extreme weather, climate variability, and climate change in urban infrastructure and or other water-related departments?

#### 4.2.1.6 Sensitivity summary

The important message in sensitivity assessment is that the presence of uncertainty about climate change does not invalidate the conduct of the sensitivity analysis of urban infrastructure, nor does it require new tools of analysis. The presence of uncertainty does require a toolkit that will assist in comparing climate proof project and enhance learning to contribute to decision-making processes in which technical and economic expertise combine to present decision makers with the best possible information on the economic efficiency of alternative designs of investment projects.

Hard to circulate situation at Ho Chi Minh city when flood tide, flooded water on street, vehicle traffic in Vietnam. **© Shutterstock/ xuanhuongho**

# STEP 3: ADAPTIVE CAPACITY ANALYSIS

## 4.3 Adaptive capacity analysis

### 4.3.1 Adaptive capacity of sociological and socio-ecological systems

Adaptive capacity is the ability of a system to adjust to or to moderate potential damages or be damaged to take advantage of opportunities, or to cope with the consequences of climate variability and climate extremes (IPCC, 2014). The adjustments include taking advantage of opportunities or coping with the consequences, which all reflect the ability of the internal system.

Conceptually lying between sensitivity and vulnerability analyses, adaptive capacity inherent in a system represents the set of resources available for adaptation as well as the ability or capacity of that system to use these resources effectively in the pursuit of adaptation. Such resources may cover a wide range of sectors, geographic locations and scales of analysis. These include social networks, economic, financial, political, technology, infrastructure, information, skills and management, and institutional systems to adjust to change, moderate potential damage, take advantage of opportunities, and coping with the consequences of the hazard. Indicators may be derived from the resources mentioned above. Income, for example, is a very important indicator that measures the adaptive capacity of households to climate hazards. Low-income groups have more limited adaptive capacities to cope with climate change, although disaggregated data to support this assertion that reflect the specific implications of climate change to incomes and gender is often missing. But it is possible to extrapolate from existing knowledge in a number of related works on environmental health, on disaster responses and on household coping strategies.

Other indicators of capacity to adapt includes awareness of risks, willingness of people to move, availability and affordability of housing in less exposed areas and ability of local authorities to impose fines on developers building in flood-prone areas or failing to incorporate measures to make new buildings more resilient. In certain developing countries where people build their own dwellings, the affordability and availability of the materials required to build more flood-resistant housing will be an indicator of their capacity to adapt, as will a knowledge of appropriate building design.

The adaptation process requires the capacity to learn from previous experiences to cope with current climate and to apply these lessons to cope with future climate phenomenon, including surprises. The climate hazards faced by a society–both historical climate data and that from scenarios of future climate change–are key to enhancing adaptive capacity. Adaptive capacity, therefore, depends on the ability of a society to act collectively and to resolve conflicts between its members – factors that are heavily influenced by governance.

The steps in mapping of adaptive capacity include:

- Defining climate systems and identifying hazards (who adapts to what hazard).
- Identifying the range (options) of adaptations.
- Prioritizing adaptations based on their efficacy, feasibility and acceptability.
- Selecting low carbon options.
- Methods for removal of barriers to adaptation.
- Identifying who is to act for planned adaptations.

Nature-based climate proofing options need to be kept in mind for application in any opportunity that may arise. The nature of the landscape becomes very important for such purposes.

**BOX 5.1: IDENTIFYING INDICATORS TO ASSESS ADAPTIVE CAPACITY AND BARRIERS TO ADAPTATION TO FLOODING SPECIFIC CLIMATE CHANGE VARIABLE**

- Using the question-based approach, identify the groups most vulnerable to flooding in a particular community or region (for purposes of nature-based climate proofing)
- Determine the options - a combination of relocating certain groups to less exposed areas, and introducing and enforcing stricter building codes
- Determine combination of quantitative and qualitative indicators required to assess the actions
- Determine external barriers to adaptation, in other words the lack of new land available for relocation, or limitations placed on local authorities by central government, preventing the introduction and enforcement of building regulations
- Population density might be a quantitative indicator of such barriers, and political autonomy
- Internal barriers to adaptation might be the unwillingness of people to move away from flood-prone areas (due to the nature of their livelihoods), the high prices of land or property, or a lack of awareness of the risk of flooding under anticipated changes in climate
- Addressed internal barriers through the provision of social housing, loans or grants, and awareness-raising (education and illiteracy, economy, livelihoods, food security, low awareness) Using the question-based approach, identify the groups most vulnerable to flooding in a particular community or region (for purposes of nature-based climate proofing)
- Determine the options - a combination of relocating certain groups to less exposed areas, and introducing and enforcing stricter building codes
- Determine combination of quantitative and qualitative indicators required to assess the actions
- Determine external barriers to adaptation, in other words the lack of new land available for relocation, or limitations placed on local authorities by central government, preventing the introduction and enforcement of building regulations
- Population density might be a quantitative indicator of such barriers, and political autonomy
- Internal barriers to adaptation might be the unwillingness of people to move away from flood-prone areas (due to the nature of their livelihoods), the high prices of land or property, or a lack of awareness of the risk of flooding under anticipated changes in climate
- Addressed internal barriers through the provision of social housing, loans or grants, and awareness-raising (education and illiteracy, economy, livelihoods, food security, low awareness)

Adaptive capacity assessment tools include:

- Full scope social assessment or extensive consultations or both. This approach uses key informant surveys, focus group discussions, community surveys.
- Rapid Social Assessments.6 It is drawn from full scope assessments and sector findings to narrow down community assessments and provide more efficient ways of obtaining necessary information.
- Field-testing project management tools such as community assessments that use computer-based tools such as the Community-based Risk Screening Tool – Adaptation & Livelihoods (CRiSTAL).

### 4.3.2 Determinants of adaptive capacity

Adaptive capacity is the ability of a system to adjust successfully to climate change to: (i) moderate potential damages; (ii) to take advantage of opportunities; and (iii) to cope with the consequences (IPCC, 2014). Adaptive capacity comprises adjustments in behaviour (socioeconomic factors, institutions, governance and management) and in resources and technologies. Adaptive capacity is a property of the system to adjust its characteristics or behaviour in order to expand its coping range under existing climate variability or future climate change. In most cities, the urban poor:

- Live in the riskiest urban environments – floodplains or other areas at high risk of flooding or unstable slopes and have limited resources to relocate.
- Have problematic relationships with local government – which is meant to be the institution that acts to reduce these risks and to the extent have limited communication channels with local administration.
- Live in informal settlements (including many on land occupied illegally) and work within the informal economy (and thus not within official rules and regulations).
- Governments may clear them off land sites deemed to be vulnerable to (for instance) floods, with very inadequate or no provision for finding alternative accommodation that meets their needs.

## Task 1: Analysis of adaptive capacity

Task 1 is an assessment of risks to water infrastructure that can be set out as a “traffic light” scorecard, using documented indicators of vulnerability and expert judgment. Climate change and uncertainties in climate projections present, perhaps, an entirely rational barrier to prioritization, at least for simple systems with a design life of 10–20 years. However, this is more difficult to justify given the widely perceived impact current climate variability already has on the sector results. Floods undoubtedly cause sanitation systems to overflow, result in damage to infrastructure and create widespread health problems. Existing seasonality of rainfall affects the performance of springs and shallow wells tapping smaller groundwater systems with low storage, leading to water rationing and use of unsafe sources. And environmental degradation exacerbated by intense rainfall events clearly impacts on infrastructure and poses a longer-term threat to the resource base. Dealing with issues such as catchment protection, water resources management and the lack of basic knowledge on resource conditions and trends will take longer, but is essential as climate change accelerates and competition for water grows.

6 See the Resources section of the Participation and Social Assessment Tools and Techniques, World Bank, 1996, for more information on Rapid Social Assessments and Participatory Rural Appraisal tools).

## Task 2: Extent to which a water infrastructure programmes address key risks and vulnerabilities

Risk screening process shows that existing political and institutional bottlenecks hamper service delivery and sustainability. National governments are important for adaptation because of direct role in allocating resources and setting incentives, while local governance delivers services or oversees their provision by others. However, capacity constraints continue to block the ability to supervise construction and enforce standards, and the ability (and incentive) to build and use a knowledge base on local climate, water resource conditions and pressures, and environmental conditions more generally.

## Task 3: Assess the determinants of adaptive capacity

In many circumstances, current levels of adaptation are far from adequate given the high costs imposed by variations and extremes in climate. The adaptive capacity of society, while impossible to measure directly, is principally determined by various social factors. These factors including incomes, the asset base, institutions and entitlements, knowledge and information, innovation and technology, and flexible forward-looking decision-making that are conducive to adaptive capacity, gender, class and age. Since these determinants are imprecise, it is expected that practitioners describe in detail their meanings as in table 5.1. The determinants of adaptive capacity are generally operative at local levels; and stakeholder groups are best placed to evaluate and describe them, how each determinant is characterized, and how it will be related to climate adaptation and to climate proofing. Together, these socioeconomic factors tend to give rise to differences in levels of education, health, financial capital, access to governance and institutions, which in turn affect ability to anticipate, cope with, and respond to change. The development of water infrastructure considers the impacts on risk generated from other non-water infrastructures such as flood risk resulting from increases in paved surfaces, urban drainage, and so forth.

**Table 5.1: Determinants of adaptive capacity**

| Determinant | Description | Relation to climate planning and proofing |
|---|---|---|
| Economic wealth and financial capital | Assets, incomes, tools, etc. | Flexible decisions (availability of key assets that allow the system to respond to evolving circumstances) |
| Access to information | Knowledge, best practices, information | Adaptability to change or ability to collect, analyse and disseminate knowledge and information in support of adaption activities |
| Material resources and infrastructure | Natural systems, land use | Option and alternative support systems |
| Human resources and capacity | Education, gender, belief systems, behaviour and organizational structure | Able to anticipate, incorporate and respond to changes with regards to its governance structures and future planning |
| Organizational and social capital | Supporting (formal and informal) institutions, legitimacy, accountability inclusion and fairness leadership coordination and collaboration, social networks | Flexible decision-making (allows fair access and entitlement to key assets and capitals) |

Adaptive Capacity Index (ACI) may be calculated from the aggregation of the parameters of natural capacity, physical capacity, human resource capacity, and economic capacity.

## Task 4: Assess the adaptive capacity of the infrastructure

The adaptive capacity (information capacity, social and institutional, human and financial capacity) provides mechanisms for integrating climate actions and responses into infrastructure planning and investment. Adaptive capacity also reflects the intrinsic qualities of a system that make it more or less capable of adapting, for example, the cooperative relationships between species in an ecosystem, the presence of effective leaders and organizers in a community, or the relative abundance of shaded parks in an urban environment). Adaptive capacity can also reflect the abilities of an organization responsible for managing an ecosystem or leading a community to collect and analyse information, communicate, plan and implement adaptation strategies that ultimately reduce vulnerability to climate change impacts.

The following questions provide a guide for estimating adaptive capacity.

- What is the country's Human Development Index?
- What is the local level dependency ratio?
- What is the percentage of female-headed households?
- What is the percentage of households caring for orphans?
- What is the percentage of households claiming a disability grant and other cash transfer indicating vulnerability?
- What is the level of the resources within the subnational territory?
- What is the savings and investment capacity of the population?
- What is the structure of institutions and decision-making authorities?
- Is there a strong and well-capacitated local government structure?
- What is the level of human capital in the subnational territory?
- What is the level of education?
- What is the health status?
- What is the level of public perception of risks, including climate change?
- What proportion of the population is dependent on primary industries (farming, fishing and forestry) for the bulk of their livelihoods?
- What is the level of early warning and disaster preparedness?

**Table 5.2: Determinants and dimensions of adaptive capacity**

| Dimensions of adaptive capacity | Determinants of adaptive capacity | Indicators | Sources of data |
|---|---|---|---|
| **Awareness of the problem** | Knowledge, information and awareness. | • Level of education | • Expert judgment |
| | | • Skills | • Stakeholders' analysis |
| | | • Attitudes towards climate change | • Participatory roundtable and invite representatives from relevant sectors |
| | | • Willingness to change and adapt | |
| | | | |
| **Ability to take action** | Technology | • Resource to access technology | • A participatory roundtable and invite representatives from relevant sectors |
| | | • Flexibility of a system to change in response to climate stimuli | |
| | | • Innovation/Patents | • Review reports and documents |
| | | • Capacity | • Stakeholders' analysis |
| | Infrastructure | • Water supply and sanitation | • Participatory roundtable and invite representatives from relevant sectors |
| | | • Transportation | |
| | | • Energy/Power | |
| | | • Housing | |
| | | | |
| **Action taken** | Institutions | • Government effectiveness | |
| | | • Democracy | |
| | | • Participation | |
| | Economic resources | • Income per capita | |
| | | • Unemployment | |
| | | • Age dependency | |

**Source:** Juhola, S. and Kruse, S. 2015. *A framework for analysing regional adaptive capacity assessments: Challenges for methodology and policy making,* January 2015. Mitigation and Adaptation Strategies for Global Change, 20:99-120. DOI: 10.1007/s11027-013-9481

***1. Identify the impacts on infrastructure***

Determine the climate change factors that impact on a specific infrastructure, such as water shortages during the dry season, flooding during the wet season, river bank erosion, institutional challenges, as well as other factors (see table 5.2). The indicators of the various subcomponents of water supply and sanitation are shown in table 5.3.

## Task 5: Hazard-specific adaptive capacity assessment

It makes little sense to talk about a system's vulnerability and adaptive capacity without specifying the hazard to which it is vulnerable and to which it must adapt. Once we accept that risk, vulnerability and adaptive capacity are hazard-specific. We must then recognize that there are many different kinds of climate hazard, operating over a variety of different timescales and requiring a variety of adaptation responses. A system may have the capacity to adapt to certain types of hazard but not to others. Most studies linking climate modelling to impacts have focused on long-term changes—generally beyond the 2050s—with relatively little work on near-term changes, impacts and the practical needs of decision makers. The local water balance (how rain falling at a particular place becomes divided between surface runoff and infiltration, and then between evapotranspiration and groundwater recharge) is very sensitive to changes in climate and to those in soil properties and vegetation cover. Hence untangling the climate signal from the many other direct and indirect factors influencing water resource conditions, and the services they support, remains challenging, especially given the lack of meteorological and hydrological data in many developing countries. Vulnerability and risk assessment per cent annual chance event (commonly referred to as the 100-year event) and other methods of estimating return period of climate events, including Monte Carlo simulations, assign a return period to an event of a particular magnitude.

**Table 5.3: Indicative risks associated with diverse infrastructures**

| Infrastructure | Associated climatic event |
|---|---|
| Rail/Road | • Extreme temperatures (medium risk)<br>• Intensity of rainfall leads to flooding (high risk)<br>• High rainfall impacts on track foundations |
| Electricity | • Intensive wind events<br>• Thermal/temperature events<br>• Cyclones/hurricanes<br>• Bushfire, lightning, dust storms |
| Construction | • Heat (temperature >30o C stops work)<br>• Flooding |
| Ports: air and sea | • Sea level rise<br>• Inundation (tides, storm surge)<br>• Wind, heat |
| Transport | • Coastal surge Extreme storms<br>• Floods and bushfires |
| Telecommunications | • Floods, hurricanes/cyclones<br>• Bushfires |
| Water supply and sanitation | • Drought<br>• Flooding<br>• Groundwater recharge<br>• Wind storms and bushfires (immediate risks)<br>• Inundation (long-term risk) |

**Table 5.4: Summary of indicators of vulnerability of subcomponents in water supply and sanitation**

| Main Components | Subcomponents | Definition and selected indicator |
|---|---|---|
| **Exposure** | Water availability | • Calculate available water through assessing future river flow under different climate scenario<br>• **Indicator:** River flow ($m^3/s$) |
| | Water demand | • Agricultural, domestic, industrial and in stream water demand increase the sensitivity for the study area<br>• **Indicator:** Total water demand, which is the aggregation of agricultural, domestic, industrial and in-stream water demand ($m^3/s$) |
| **Sensitivity** | Infrastructure pressures at upstream | • Sensitivity induced by alterations of the river flow at upstream deriving from dams, etc., which may increase the sensitivity<br>• **Indicator:** Hydroelectrical installed capacity (MW)<br>• Data from the development plans of the electricity authority |
| | Forest cover upstream | • Strategies for controlling runoff and erosion risks, thus limiting the probability of flood events downstream<br>• **Indicator:** Area forest cover ($km^2$) |
| **Resilience** | water resource and water services | • An activity that contributes to the sustenance of the resource and supply with positive potential for limiting the impacts of climate change |
| **Adaptive capacity** | Governance | • The status of water governance can determine the capacity for the management of various problems of water resources<br>• **Indicator:** Perceived trend of composite water governance (use scores, i.e., numeric value between 0 and 1) |
| | Poverty | • GDP, HDI, here derived from the projections of the indicator "incidence of poverty" |

***2. Use appropriate tools***

The development of the tools will vary according to different cultures and level of scrutiny. In addition, workshops constituted of plenary discussions and breakout sessions are useful in teasing out socioeconomic issues and developing priorities. Having different professional inputs assist in the identification of possible adaptation options and even set initial priorities.

***3. Adopt a scoring method***

The six dimensions of adaptive capacity includes human, social (institutional, organizational, and individual), natural, physical, and financial capital (Gupta et al. 2010), and scoring criteria rated on a 5-level scale (very high, high, medium, low, very low). Stakeholders could evaluate the adaptive capacity framework using the same categories representing a numerical score of 5, 4, 3, 2 and 1 respectively.

***4. Determine adaptive capacity***

Qualitative ranking (high, medium, low) may not always convey realistic and bankable decisions but they are informative and depict community interests.

# STEP 4: VULNERABILITY ASSESSMENT FOR INFRASTRUCTURE

## 4.4 Vulnerability assessment for infrastructure

### 4.4.1 Vulnerability of the infrastructure

Vulnerability, according to this toolkit, is considered to be the degree to which an infrastructure is susceptible to, and unable to cope with adverse effects of climate change, including climate variability and extremes. It has been shown that vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity (McCarthy et al., 2001). Exposure, sensitivity and adaptive capacity have been presented earlier in the toolkit. Local factors—such as climate, topography, temperature, income, access to health services and dependency—are important in determining the underlying vulnerability of a population. An assessment of vulnerability provides an understanding of how robust the infrastructure is to departures from design assumptions. This kind of assessment also identifies critical thresholds of vulnerability past which the project fails to perform as designed. There are two types of approaches to climate vulnerability assessment of which the first is based on projected impact on a vulnerable region, sector or nation. In general, these types of studies utilize climate change and precipitation scenarios that are based on scientific simulation models. The second type is based on the qualitative analysis of climate change impacts using a matrix of participatory process. The so-called “bottom-up” approach has been commonly used for this type of local vulnerability assessment.

Vulnerability refers primarily to characteristics of human or social ecological systems exposed to hazardous climatic (droughts, floods, etc.) or non-climatic events and trends (increasing temperature, sea level rise). Basic infrastructures that have high adaptive capacity and low sensitivity and exposure can tolerate impacts to a greater degree and, therefore, have an overall low vulnerability. Conversely, infrastructure with high sensitivity and exposure and low adaptive capacity are more susceptible to impacts and, therefore, have an overall high vulnerability. Assessing vulnerability to climate change is therefore more complicated than simply assessing the potential impacts of climate change, due to the “adaptive capacity” component.

Contextual vulnerability (also known as starting-point interpretation or internal social vulnerability) is rooted in political economy. It is determined exclusively by internal characteristics of the vulnerable system or community that determine its propensity to harm for a wide range of hazards. Outcome vulnerability (also known as end-point interpretation or integrated cross-scale vulnerability), on the other hand, represents an integrated vulnerability concept that combines information on potential climate impacts and on the socioeconomic capacity to cope and adapt (Fussel, 2009). There are two approaches to vulnerability assessment, namely, qualitative and quantitative methods. Qualitative vulnerability assessment produces results that are not always easy to compare or even to check for accuracy, but are reliable and answer some questions that quantitative measures cannot (for example, how and why) by involving the key stakeholders. Quantitative assessments, however, are often requested by decision makers as they are considered more reliable than those that are qualitative: they can be compared, leave less room for misinterpretations and are easy to communicate.

There is increasing need to demonstrate an integrated approach to tackling climate-related and wider socioeconomic challenges in vulnerable urban environments. Quantitative vulnerability assessments incorporate a wide range of geospatial data to characterize exposure and sensitivity of assets across geographic units. Such assessments have difficulty in incorporating context-specific knowledge of system sensitivity and adaptive capacity. In order to mainstream climate proofing in existing projects, project will retrofit “green and blue” infrastructure, wherever it is found appropriate. Generally acceptable examples for climate proofing include sustainable urban drainage systems, rain gardens, drought-resilient planting and micro green roofs supported by rainwater harvesting. The green and blue infrastructure will provide effective, affordable and socially acceptable alternatives to heavy engineering approaches and achieve environmental and economic goals such as reducing freshwater demand. As discussed earlier, the components of vulnerability are the following:

- Exposure, interpreted as the direct danger, and the nature and extent of changes to a region’s climate variables (temperature, precipitation, extreme weather events)
- Sensitivity, the human and environmental conditions affected by the hazard, ameliorate the hazard, or trigger an impact
- Adaptive capacity, the potential to implement adaptation measures that help avert potential impacts

**BOX 6.1: REDUCING VULNERABILITY THROUGH STORM WARNING IN MOZAMBIQUE COASTAL CITIES**

With more than 60 per cent of the population living in coastal communities in Mozambique, cyclones and floods consistently cause extensive damage. Since November 2016, people have been able to prepare better to deal with dangerous storms by accessing pertinent weather information through a mobile-based service.  The service, called 3-2-1, provides free access through short message service (for short SMS) or calls providing information needed to safeguard against storms and other impending weather events.

To receive a storm warning, people use a mobile phone (either basic or smart) to dial 3-2-1, toll free, at any time of day. Callers hear a message in one of three local languages—Portuguese, Changana, or Macua—that guides them to a menu of topics with weather information. Messages include information such as timing for a cyclone or storm, areas of potential flooding, and ways to protect individuals and property. The service is operated by Human Network International in partnership with one cellular phone company and the National Disasters Management Institute of Mozambique. The Network creates the messages and uploads them to the service; regular updates are posted twice a week, while severe event information is posted as needed.

The Network’s procedure complements the Institute’s early-warning system by adding a data-collection component — community networks share pre-disaster warning messages and collect real-time post-disaster data using Data Winners, a data-collection platform. It is the first two-way warning system in Mozambique to use cellular phones, making it a low-cost and innovative solution for community members who have access to cell phones.

With more than

**60%**

of the population living in coastal communities in Mozambique, cyclones and floods consistently cause extensive damage.

**Source:** USAID’s Mozambique Coastal City Adaptation Project. Compiled from https://www.chemonics.com/impact-story/storm-warnings-mozambique/  and https://www.chemonics.com/impact-story/saving-lives-cell-phones-mozambique/ (accessed on 26 August 2019).

### 4.4.2 Vulnerability assessment tools

Vulnerability assessment defines two streams of assessment of vulnerability: the contextual vulnerability assessment and the outcome vulnerability assessment. The contextual form mainly assesses vulnerability in a constructional approach, obtaining a qualitative picture of vulnerability with the help of survey instruments and case studies. The outcome vulnerability assessment utilizes a reductionist approach, using quantitative techniques such as modelling and dose-response functions. The current method of vulnerability assessment is index-based. There is no single method of assessing climate risks to a programme or activity. The methodologies range from basic screening that highlights overall risks to a robust assessment that provides in-depth analysis of when, how and to what extent climate variability and change may impact programming.[7] Several tools discussed herein provide an excellent sample of tools used in vulnerability assessments.

The outcome vulnerability assessment utilizes a reductionist approach, using quantitative techniques such as modelling and dose-response functions.

7 World Bank, Climate Risk Screening, Climate Resilient Development, Climate Change and Disaster Risk, Climate Change

**Tool 1: Vulnerability Index**

The present toolkit uses the Intergovernmental Panel on Climate Change definition of vulnerability, which is “the degree to which a system is susceptible to or unable to cope with adverse effects of climate change, including climate variability and extremes.” There are three main components of vulnerability as defined by the Intergovernmental Panel: exposure, sensitivity and adaptive capacity. An index-based approach is used where a set of indicators[*] that represent key components of vulnerability (water supply, rail and road, energy, etc.) is selected using the statistical techniques. The impacts of climate change on key urban infrastructure as represented by the changes in the indicators can be derived from impact assessment models.

In this section, the general procedure for constructing a Vulnerability Index for any sector is described. For each of the components of vulnerability, formal indices can be constructed and combined. Methods of aggregating across sectors and scales have been developed in other contexts (for example, the Human Development Index) and are beginning to be applied to climate change. The Vulnerability Index for a specific infrastructure is typically based on a number of indicators that determine the vulnerability of that infrastructure to climate change. Construction of Vulnerability Index for each component involves the following general methodology shown in table 6.3.

* Vulnerability indicator captures the ability to anticipate, avoid, plan for, cope with, recover from and adapt to (evolving) stresses and shocks.

**Table 6.1: Tasks in vulnerability assessment**

| Step | Vulnerability indicators |
|---|---|
| Identifying and defining the indicators | Indicators are selected according to assumptions, baseline considerations and limitations for each sector |
| Quantification of indicators | Indicators are quantified based on secondary data sources, observations or measurements and stakeholder perceptions |
| Normalization | For aggregation purposes, each indicator is normalized to render it as a dimensionless measure or number |

The Vulnerability Index is numerical scale calculated from a set of selected variables for a specific infrastructure and used to compare them with one another or with some reference point. Computation of regional assessments such as the Coastal Infrastructure Vulnerability Index (CIVI) applied to the Aberystwyth coast (Kantamaneni, 2016) demonstrates how the coastal infrastructure comprising indicators such as population, commercial and residential properties were valuated. Construction of the Vulnerability Index consists of the selection identifying and defining the indicators of an infrastructure, which is affected by various climate change elements. For each infrastructure, a set of indicators is selected for each of the three components of vulnerability. The indicators can be selected based on the availability of data, personal judgment or previous research. Vulnerability Index is constructed in such a way that it always lies between 0 and 1 so that it is easy to compare regions. Sometimes the index is expressed as percentage by multiplying it by 100.

### Tool 2: Principal component analysis

The multiple biophysical and socioecological indicators of vulnerability that express exposure, sensitivity and vulnerability can produce spatially explicit vulnerability indices. Such indices reduce the amount and complexity of the information that must be communicated while providing an indication of the interaction of multiple, spatially homogenous indicators through a single aggregated vulnerability score. Principal component analysis identifies the significant indicators and eliminate non-significant ones from a set of interrelated indicators. It involves a mathematical procedure that transforms a number of possibly correlated indicators into a smaller number of uncorrelated variables called components. Each component is a geometric combination of the indicators. In the analysis, a set of components are extracted using a criterion, whereby the eigenvalue of each component that is extracted is greater than 1. Generally, indices are created out of an arithmetic or geometric combination of the indicators that are present in the extracted components.

The weights for the urban infrastructure Vulnerability Index can be decided to be equal across indicators on consultation with experts. A similar approach was adopted for the forest sector also by providing equal weights to all the indicators used in developing the Forest Vulnerability Index. The weights for the Water Vulnerability Index can be calculated from the eigenvalues of the analysis.

### Tool 3: Vulnerability profile

Climate change profile is designed to help integrate climate actions into development activities. Vulnerability profile provides an overview of sector vulnerabilities and the necessary adaptation actions. Assessment of vulnerability by identifying the potential impacts (= reducing exposure and/or sensitivity), and by measuring the adaptive capacity (= increasing adaptive capacity). The infrastructure is especially vulnerable to changes in precipitation patterns that impacts water, ecosystem and hydropower energy production. Floods and landslides are common in highlands, often triggered by heavy rains, while droughts are also becoming more frequent.

Graphic vulnerability profiles are presented either as pentagrams or radar charts.
In a radar chart, the spokes of the plot typically represent indicators of which one with a high score (higher vulnerability) is plotted farther away from the centre. It is essential that acceptable risk levels be defined and tolerance levels of thresholds demarcated as it is neither feasible nor advisable to reduce climate-based risks to zero. Integrating climate change risks and opportunities into the design of infrastructure should aim to reduce infrastructure risks to a quantifiable level, accepted by the society or the economy. In practice, it might mean identifying the types and duration of service interruptions that can or cannot be accepted. A wide variety of non-structural and structural options exist to reduce risks to agreed acceptable levels. Non-structural measures are any measures not involving physical construction, such as building codes, land-use planning laws and their enforcement, research and assessment, information resources and public awareness programmes. Structural measures are any physical construction to reduce or avoid possible impacts of hazards, such as flood levees and ocean wave barriers. The potential to generate additional development benefits will be critical in the weighting regional options.

One of the Bugesera housing project supported by UN-Habitat and ONE UN in Rwanda.
**© UN-Habitat/Julius Mwelu**

**BOX 6.2: FLOODING IN THE MEKONG DELTA AND RURAL ROAD DEVELOPMENT IN CAMBODIA**

Many parts of Cambodia experience regular and severe flooding. The government has produced flood vulnerability maps that identify segments of the Asian Development Bank (ADB) transport project area as being priority for attending to flood problems. The project aims to rehabilitate and pave 505.4 kilometres of rural roads of 5–6 metres in width to improve rural connectivity to pave national and provincial road networks. A mixture of loan and grant from ADB, Export-Import Bank of Korea, Nordic Development Fund total USD 67 million went to the climate change adaptation component of the project. While flooding is a more obvious challenge in the project area due to recent floods, droughts are at the same time getting more intense. A possible adaptation strategy would combine engineering, environmental and policy-oriented tools to deal with increased variability. A combination of measures has been suggested. These include (i) elevating vulnerable segments of the road; (ii) using materials that accommodate greater moisture content; (iii) improving flood management through revegetation, using more flood- and heat-tolerant indigenous species; and (iv) developing a vulnerability map and early warning system. Nature-based options that conserve and redistribute water from times of excess to times of shortage would complete a package of climate proofing measures.

**Source:** ADB. 2010. Proposed Loan Kingdom of Cambodia: Rural Roads Improvement Project. Report and Recommendation of the President to the Board of Directors, Manila.

## Task 1: Determining the vulnerability of infrastructure

Vulnerability increases as the level of sensitivity increases and decreases as adaptive capacity increases. Reducing vulnerability can happen through any combination of reduced sensitivity, reduced exposure, or increased adaptive capacity. The definition used in these guidelines incorporates three main variables: exposure to climatic variations, sensitivity and adaptive capacity of a system to various stressors. The drivers of increased vulnerability to climate change urban infrastructures are:

- drivers of urbanization and urban change
- policy and regulatory failures
- weaknesses and incapacities of governments
- development and expansion of cities in high-risk sites

In developing countries, the critical populations and elements in any urban area most at risk are:

1. Informal and slum dwellers, who often reside in the most vulnerable locations
2. Buildings that are especially vulnerable to wind, water and geological hazards
3. Water utilities including intake points, treatment plant, roads and sewerage works
4. Other infrastructure including roads, bridges, railways, ports, airports and other transport systems; energy and related pipelines; drainage, flood and coastal defence systems; telecommunications and critical social infrastructure such as hospitals, schools, fire service, police stations, and first responders' infrastructure

5. Nature-based infrastructure especially wetlands, riverine, estuarine and coastal ecosystems, surface and groundwater systems

The vulnerability assessment methodology involves assessing the project's exposure, sensitivity and adaptive capacity. The first step is to define the project's assets. These assets could be the infrastructure itself (for example, manufacturing facility or hydropower plant), but they could also be coral reefs or beaches for tourism-based projects. Coral reefs and beaches are considered the basis for the crucial tourism industry and nurseries for marine life and as protection from storm surges (NOAA 2013). Coral reefs are affected by ocean warming or acidification as a result of higher dissolved carbon dioxide levels, and die-offs or bleaching has been extensively documented over the past decade. Because of warming temperatures, models predict significant risk to coral reefs, with substantial loss in the worst-case scenarios. Beaches in the Caribbean have been eroding over the past two decades, with higher rates of erosion for islands hit by hurricanes. Greater erosion is expected under future sea level rise scenarios. Reduction, or even complete loss, of beach area in some regions could have a major adverse effect on tourism infrastructure and future potential.

## Task 2: Measuring vulnerability to climate change

Traditional assessments of vulnerability, and of adaptation options, have many limitations compared to a risk-based approach, such as:

- no formal assessment of the likelihood of future extreme events or variations in climate or of baseline conditions
- a focus on individual events (for example, an extreme rainstorm or a cyclone) or on a future date, rather than on an aggregation of the anticipated climatic conditions over a specified time period into the future
- inability to differentiate between the costs of current climate extremes and variability and the future costs of those events plus any systematic trend (that is, unable to evaluate the incremental costs of climate change)
- difficulty of incorporating economic, social and wider environmental scenarios into the assessment procedures
- no functional link between the vulnerability and adaptation assessments
- no formal procedures for prioritizing adaptation options on the basis of cost and other measures of efficiency and effectiveness

## Task 3: Calculate the Vulnerability Index

All quantitative vulnerability concepts specify the vulnerable infrastructure, the hazards to which they are exposed, the attributes at risk from this exposure, and the time period considered. Vulnerability indices are applied for many scientific purposes (for example, for identifying causal processes and explaining attributes of vulnerable systems, for linking system attributes to vulnerability outcomes, and for mapping, ranking and comparing vulnerability across regions). These indices are also applied at many scales (from local to global) and with different policy objectives (for example, more realistic assessment of climate change risks, aiding the allocation of resources across regions, monitoring the progress in reducing vulnerability over time, and identifying suitable entry points for interventions).

The development of aggregated vulnerability indices requires substantial normative choices in the selection and aggregation of diverse information across time, affected systems and regions, and impact metrics, which largely determine the resulting vulnerability ranking. The vulnerability of an infrastructure to climate change cannot be measured directly. Even if the decision context is clear, legitimate normative differences may strongly influence the combination of diverse information sources into an aggregated Vulnerability Index. Normative challenges include the aggregation of future and current climate risks; of monetary, human health and other non-market impacts of climate change; of high-certainty and low-certainty impacts; and of beneficial and adverse impacts occurring in different sectors or regions or both.

## Task 4: Compile vulnerability maps

The maps developed in previous chapters, such as hazard mapping, can be the basis for vulnerability mapping. The existing sectors of society (population, agriculture, water, energy, tourism, fisheries, health, and biodiversity) that are likely to be affected by these hazards and perturbations, current socioeconomic trends that interact with these sensitivities (and in particular run the risk of amplifying them) and the level of adaptive capacity estimated are all reflected in the vulnerability maps. Society's coping mechanisms and management changes are required. The latter is needed in the form of changes through policies and activities that minimize adverse impacts (or make the most of the opportunities presented), or increase their vulnerability.

Based on the activities described on chapters 3 to 5, it is possible that there will be several maps as outcomes (based on various scenarios of exposure, sensitivity, and socioeconomic adaptive capacity).

| Table 6.2: Data collection tools for vulnerability mapping | | |
|---|---|---|
| **No.** | **Tools** | **Source of data** |
| 1. | Data collection and analysis | Existing and primary data about the location, operation and performance of the infrastructure |
| 2. | Geographic Information Systems[8] | Overlay physical hazards data with socioeconomic adaptive capacity data<br>Determine most vulnerable components of the system – where there is an intersection of high exposure to hazards and perturbations and low socioeconomic adaptive capacity |
| 3. | Expert judgment and tracing paper | Expert team of professionals to support the mapping process |

### BOX 6.3: RISK PERCEPTIONS TOWARDS FLOODING IN LOW-INCOME HOUSEHOLDS' ADAPTATION TO FLOODING IN INDORE, INDIA

In many low-income communities in Indore, flooding is perceived as a natural, seasonal event, and households take steps to limit its damage. Those who live on land sites adjacent to small rivers that are also key storm drains are particularly at risk. But these sites have the advantage of a central city location. They have economic advantages because they are close to jobs or to markets for the goods these households produce or collect (many earn a living collecting waste). The land is cheap and because it is in public ownership residents are less likely to get evicted.

These sites have social advantages because they are close to health services, schools, electricity and water. Most inhabitants have strong family, kinship and community ties with other inhabitants. Some residents have noted that the sites are considered safer for children because the narrow streets make them inaccessible to motor vehicles. Households and small enterprises have made temporary and permanent adaptations to flooding. These include raising plinth levels and paving courtyards, using landfill, using materials which resist flooding, choosing furniture that is less likely to be washed away and ensuring that shelving and electric wiring are high up the walls, above expected water levels. Roofing may not be attached to a house so it can be quickly removed if the structure is in danger of being swept away. Many households also have suitcases ready, so valuables can be saved. Residents have also developed flood-prediction and protection systems, and contingency plans for evacuating persons and possessions. In one settlement (Shekha Nagar), residents' first response to the threat of severe floods is to move the elderly, children and animals to higher ground. Then they move electrical goods such as televisions and radios. Then other lighter valuables and cooking utensils are moved, with clothes being moved last as these are more easily replaced and not damaged by flooding. The more established residents have also learnt how to use the state system of compensation for flood damage, and this can provide a perverse incentive for residents to build houses in the most vulnerable and dangerous areas.

**Source:** Stephens, Carolyn, Rajesh Patnaik and Simon Lewin (1996) *This is My Beautiful Home: Risk Perceptions towards Flooding and Environment in Low-income Urban Communities: A Case Study in Indore, India,* London School of Hygiene and Tropical Medicine, London, 51 pages

8 GIS is particularly useful as it enables different data layers to be presented together in the same map, and the scales of data collection do not need to be identical.

## BOX 6.4: ECONOMIC DEVELOPMENT AND ECOSYSTEM CHANGE IN THE GULF OF MEXICO

The coastal states around the Gulf of Mexico are home to more than 55 million people. These states have many critical ecosystems such as wetlands, sea grass beds, mangroves, barrier islands, sand dunes, coral reefs and marine forests. These are obviously influenced by the heavy concentration of economic activities: petroleum production, fisheries, agriculture, forestry and tourism. The Gulf concentrates a high proportion of offshore oil production by United States companies and of Mexico's total oil production; chemical production, oil field equipment dealers, cement suppliers, caterers, divers, platform fabrication yards and shipyards. The main drivers for wetland conversion in Mexico are large-scale tourism development, urbanization, and agriculture. In addition, wetlands are extremely sensitive to sea level rise; adaptation should mean maintaining their functions and productivity. For some people, adaptation is only possible if there is room for them to migrate inland. For those unable to migrate due to topographical or other natural constraints, space should be provided for the creation of new wetlands.

**Source:** National Research Council. 2013. An Ecosystem Services Approach to Assessing the Impacts of the Deepwater Horizon Oil Spill in the Gulf of Mexico. Washington, DC: The National Academies Press. https://doi.org/10.17226/18387.

UN-Habitat pilot shelter project in Kalobeyei new settlement in Turkana, Kenya.
**© UN-Habitat/Julius Mwelu**

# STEP 5: OPTIONS FOR DETERMINATION AND ASSESSMENT OF CLIMATE PROOFING

## 4.5 Options for determination and assessment of climate proofing

### 4.5.1 Determination of options for climate proofing

Having identified vulnerability in the previous steps, the logical next step is to decide on adaptation interventions and consider the effect they will have on that vulnerability. Adaptation interventions need to respond to known risks and the uncertainty of possible climate change futures. This step introduces the idea of setting up a system to evaluate the changes in vulnerability as climate changes under different socioeconomic scenarios of development. It also outlines decision-making tools that permit prioritization of interventions (for example, between sectors). Due to the intensely normative nature of this effort, stakeholder consultation and participation is imperative. Given that adaptation choices require a long-term view of how the urban territory will look in the future under alternative (ranging from conservative to extreme) scenarios, consultation processes should even be extended to the general population at large.

The identification of options for climate proofing urban infrastructure takes into consideration the goals and objectives set for the climate proofing undertaking. The relevant steps include the following:

- Use expert judgment in identification of climate proofing options (early warning systems, evacuation plans, and financial support to microinsurance schemes, building dikes) with inputs of sector representatives.

- Review the existing policies, plans and strategies and evaluate if they were implemented or if they are relevant to be considered as options to be implemented.

- A range of technically feasible adaptation options to reduce climate risk to the project or target area or city are identified and the nature of these options vary across technical features of the investment project itself and across the geophysical characteristics of its location.

- Organize the options. These can be organized by sector or theme, such as governance, infrastructure, capacity-building and by time frame (short-, medium- and long-term)

- Use Multi-Criteria Analysis to rank and select preferred options to be developed into concrete actions.

- Scrutinize the preferred list of climate proofing actions with stakeholders.

When it comes to selecting and prioritizing appropriate adaptation options for implementation, a prudent approach begins by recognizing that there are several viable options and their combinations for effective adaptation. Some of them will be better suited to minimize the risks associated with implementation even in the face of associated uncertainties regarding the risks and benefits. These options are referred to as the following:

- "No-regrets adaptation options" that are worthwhile whatever the extent of future climate change will be

- "Low-regrets options" that are adaptive actions for which the associated costs are relatively low and for which the benefits, although primarily realized under projected future climate change, may be relatively high

- "Win-Win options" are adaptation actions that deliver the desired result in terms of minimizing the climate risks or exploiting potential opportunities but also have significant contribution to another social, environmental or economic goal
- "Flexible or adaptive management options" are those options that can be adjusted easily (and with low cost), if circumstances change compared to the projections made initially
- "Multiple-benefit options" provide synergies with other goals such as mitigation, disaster risk reduction, environmental management or sustainability (for example, ecosystem-based approaches usually provide such multiple benefits)

**Table 7.1: Summary of steps for identifying options for climate proofing**

| No. | Steps | Activity | Source of information |
|---|---|---|---|
| **1.** | Identify adaptation options | Compiling a list of all possible adaptation options, without consideration to their efficiency; adaptation is a new challenge and new and innovative strategies have to be promoted | Expert Judgment<br><br>Spatial Analogues |
| **2.** | Assess adaptation options | Draw from lessons learned from infrastructures and regions that already experience similar conditions | Cost-Benefit Analysis<br><br>Risk Assessment |
| **3.** | Review vulnerability and adaptation options | Recognize that climate risks and adaptive capacity may change over the lifetime of an investment project<br>Examine co-benefits between climate change adaptation and other economic or social objectives | Demographic changes.<br>Consult with affected stakeholders to identify risks, benefits, and lessons from past experiences |

### 4.5.2 Cost-benefit analysis of climate proofing options

The economic analysis of climate proofing enables the costs and benefits of each adaptation option to be assessed against other options and the cost of inaction. The climate proofing of infrastructure can be conceptualized from an economics standpoint as insurance against the adverse impacts of climate change. Determining the right amount of climate proofing requires consideration of the costs and benefits. Incorporating climate proofing of infrastructure projects seeks to reduce vulnerability to increased extreme or variable climatic conditions, such as avoided damages to property, forgone economic activity as a result of damages, effects on health and human life, and impacts on environmental services. Typically, these benefits are not straightforward to monetize because they are not observable through market transactions and are not priced (see box 7.1). Their quantification, therefore, usually requires some form of non-market valuation.

**BOX 7.1: OPTIONS FOR WATER SECURITY, CLIMATE CHANGE AND DEVELOPMENT IN ILOILO, THE PHILIPPINES**

- Evaluate resources
  a. Long-term water security and climate change monitoring.
  b. Evaluate and enhance groundwater.

- Improve knowledge management
  a. Enhance monitoring networks for supply, quality and flooding.
  b. Develop an information clearinghouse for all water-related data.
  c. Develop capacity for information-based management decisions.

- Augment water supplies
  a. Community-based options
  i. Implement rainwater harvesting in the Metro Iloilo.
  ii. Develop community-based potable water supplies.
  iii. Pursue demand-side management in the Metro Iloilo.
  b. Metro Iloilo Water District (MIWD) options
  i. Reduce MIWD non-revenue water.
  ii. Conduct a feasibility study of MIWD treatment of Jalaur Water.

- Improve water quality and sanitation
  a. Evaluate point-of-use source water treatment for near-term potable water provision.
  b. Improve compliance and enforcement capacity to achieve water quality goals.
  c. Develop a sanitation information and education campaign.
  d. Analyse Metro Iloilo options for treating wastewater.

- Reduce flood risks
  a. Promote enhanced land-use planning for water security.
  b. Investigate improvement of Flood Early Warning Systems.
  c. Analyse capacity of Iloilo's flood management system to cope with potentially enhanced floods under climate change.

- Reform sector governance
  a. Improve water sector accountability and coordination.
  b. Build civil society capacity to advocate for water security.
  c. Analyse options for public-private partnerships in support of water security.

- Demonstrate cross-cutting solutions
  a. Conduct an urban and rural Water, Sanitation, and Hygiene study.

**Source:** USAID Adapt Asia-Pacific

There is an additional cost to climate proofing that needs to be justified for every project proposed. The objective of a cost-benefit analysis is to estimate the net benefits of climate-proofing measures. At the project level, it is important to distinguish between (i) the costs of climate change and (ii) the benefits of climate proofing.

Cost-benefit analysis (CBA) relies on a framework to compare the economic costs and benefits of the impacts of climate change with the economic costs and benefits of adaptation. To do this, the model of the economic framework is centred on a "do nothing scenario" with no adaptation beyond business as usual and incorporates the projected changes in the climate. Adaptation options are drawn from alternative ones. The selected options are compared against business as usual case and the computation provide a net present value (NPV) for each chosen point. Subsequently, the framework is iterated to choose adaptation strategies that maximize the NPV.

The economist's task is to monetize the impacts of climate change and of the adaptation options that have been identified and quantified by other experts. The costs and benefits of adaptation options must be assessed by identifying and quantifying the climate change impacts along two scenarios of which the first is the expected impacts of future climate change on basic infrastructure if no adaptation measures are in place. The second represents the expected impacts of future climate change on the transport infrastructure if adaptation measures are in place. In the calculations, the cost-benefit analysis estimates and totals up the equivalent monetary value of the benefits and costs of projects to the subnational region to establish whether they are worthwhile in the context of other criteria. The economic decision-making tool will in particular address:

- whether the interventions proposed, future climate change possibilities as well as future socioeconomic possibilities are realistic

- the extent to which the probability of occurrence of all possible outcomes has been met by the cost-benefit analysis

- how the losses that do not necessarily have a market price have been addressed by cost-benefit analysis (economic tools and instruments for valuing the loss of landscape, the loss of biodiversity, health impacts, and so forth, although estimation of a number of components of benefits and costs are rather unclear, difficult and time-consuming)

Some basic principles are required for the effective application of cost-benefit analysis as a decision-making tool; these include the following:

- Unit of measurement should be in a common basic denominator — usually in monetary terms

- The revealed preferences of stakeholders, including consumers and producers, must be taken into account. This is usually measured through their actual or likely behaviour (based on observed information)

- Market choices are used as proxies for measuring benefits

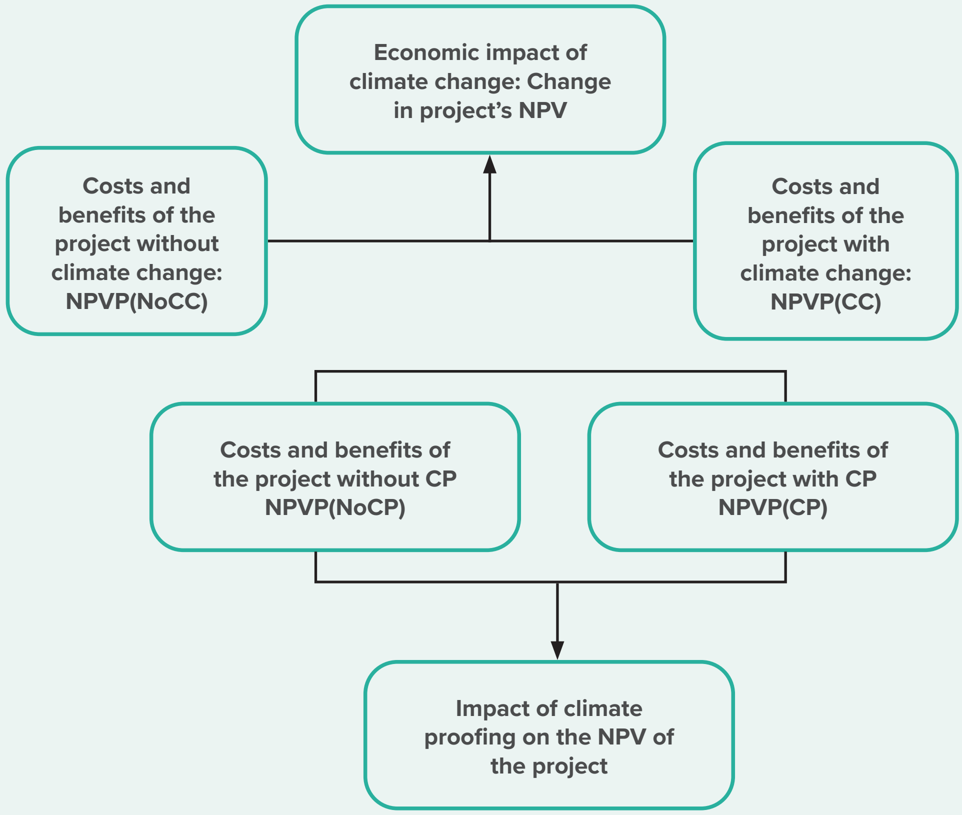
- A counter-factual analysis is necessary (that is to say with or without an intervention)

- Double counting must be avoided

- Discounting is necessary but is fraught with political issues, such as those that are intergenerational

In figure 7.1, the scenario given is that with climate change, the impact of climate proofing is estimated as the difference between the NPV of the project without climate proofing (NPVP [NoCP])—where CP stands for climate proofing) and the NPV of the project with climate proofing (NPVP [CP]) —where NPVP (CP) includes the cost of climate proofing. Provided the above notation, note that NPVP (CP) stands for the NPV of the entire investment project, and not solely of the climate-proofing measure. In figure 7.1, NPVP includes the costs and the benefits of the project and the climate-proofing measure, while NPVP (CP) is assumed to include all economic benefits resulting from the adoption of the climate-proofing measure, including ancillary or co-benefits.

**Figure 7.1: Impact of climate change and of climate proofing**




While the overall framework presented above remains simple, a key issue is related to the treatment of risk and uncertainty in the cost-benefit analysis. The outputs from table 7.1 suggest the preferred timing to implement the adaptation measures. The trade-off between the loss of benefits in terms of the economic screening (see table 7.2) aims to determine the following climate proofing investment options.

**Table 7.2: Economic screening of climate proofing options**

| No. | Decision criteria | Scores (1-very high/much, 5 not at all) | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 1. | Climate change impact the estimated costs and benefits of the project | | | | | |
| 2. | Climate proofing the project desirable from an economic efficiency view | | | | | |
| 3. | Climate proofing should take place at the time of infrastructures implementation (built into project design) | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4. | Climate proofing should be delayed to a later point in time | | | | | |
| 5. | Benefits associated with climate proofing be included in the project economic analysis | | | | | |
| 5. | Which of them should be recommended multiple technically feasible and economically desirable climate-proofing options | | | | | |
| 7. | Expected impacts of climate change on the project in the future when no climate-proofing measures in place now | | | | | |
| 8. | Economic analysis of climate proofing projects differs from the economic analysis of any project | | | | | |

Decisions are easy to make under the following conditions:

- Flexibility - meaning that adjustments to infrastructure can easily be made to adapt to climate change. An example is coastal flood protection through beach nourishments.
- Resilient - meaning that negative consequences of climate extremes can be restored easily, such as electricity connections after a storm.
- Compartmentalizing - is about making compartments with respect to a threat such that a disaster is limited to a certain area.
- Infrastructure is redundant when there are spare facilities that compensate for the failing of other infrastructure, such as water reservoirs in the urban environment that store the water of heavy downpour with which the sewage system cannot cope.

### 4.5.3 Probability (or risk) analysis using Monte Carlo simulation

Conducting a "probabilistic cost-benefit analysis" involves attaching a probability distribution for the possible value of any given specific cost or benefit component of the project instead of attaching a single deterministic value. Such probability distributions may be constructed using historical data. Probabilistic (or risk) analysis allows selecting multiple variables that can all be varied simultaneously according to the specific probability distribution attached to each variable. This process, known as a Monte Carlo simulation analysis (GIZ. 2013) involves the following steps:

- Randomly generating a specific value for each individual variable (cost component or benefit component) according to the specific probability distribution attached to each variable.
- For any given draw of specific values, the net present value of the adaptation option is calculated.
- Repeat many thousands of times using a computer.

The decision rule guiding the selection of adaptations are as follows:

- If only one technically feasible adaptation option exists, then the decision is to recommend implementing the adaptation option based on the outcome of the economic analysis.

- If expected NPV < 0, then recommend rejecting the adaptation option do not do anything.

- If more than one technically feasible adaptation option exists, then the decision rule is to select the option with the largest expected NPV.

- If all adaptation options yield a negative expected NPV, then the best option is do not do anything.

### 4.5.4 Cost-effectiveness analysis (CEA)

A CEA, considered a costing analysis of alternatives, can rank and thus prioritize climate change adaptation options. A prerequisite of using a CEA to compare different adaptation options is that their benefits can be expressed in the same unit. It determines how a well-defined objective can be achieved in the most cost-efficient way. There are two data sets required:

- Costs need to be quantified in monetary terms.

- If it is impossible to assign a monetary value to benefits of adaptation options.

Quantifying (monetary) costs and (non-monetary) benefits means that the unit costs can be calculated as the ratio of total (discounted) costs to total benefits. The output indicator of a CEA is, therefore, also a cost benefit-ratio (CBR) of which the most cost-efficient option is the one with the lowest CBR costs per unit of benefit. The inverse of CBR, a benefit-cost-ratio (BCR), can also be taken as an indicator; in the latter, the highest BCR directly indicates the most economically promising adaptation option. If more than one type of benefit results from an adaptation option, a CEA can still be conducted as long as benefits can be expressed in the same unit. For example, consider an adaptation option in the health sector resulting in multiple adaptation benefits, such as better sanitation, lower risk of diseases and healthier nutrition. If these benefits can all be measured in the same unit, for example an improved health status of the local population, then these benefits can be added to form an overall benefit indicator of the adaptation option. If, on the other hand, an adaptation option will result in diverse benefits that cannot be measured in the same unit (for example, better human health and protected habitat for wildlife) then these benefits cannot be accounted for in one CEA calculation because the outcomes cannot be numerically compared.

### 4.5.5 Multi-criteria analysis for climate proofing

When benefits cannot be measured quantitatively or when multiple diverse benefits cannot be aggregated a multi-criteria analysis (MCA) can be used. Similar to a CBA and CEA, MCA is able to rank and thus prioritize among multiple adaptation options. The ranks resulting from MCA are not based purely on economic calculations on an (qualitative) assessment of criteria such as feasibility.

The rules for the assessment of climate proofing options are agreed upon according to a set of criteria in ranking options, including a qualitative expert judgment to fill any information gap. The present toolkit favours simple scoring methods ranging from 1 to 10 and each attributed to each criterion. Criteria may be given different weights according to their relative importance. The weights finally add up to 1.00 (that is, 100 per cent). Use of Microsoft Excel tools is suggested.

### 4.5.6 Economic decision criteria for climate proofing options

Two types of decisions may be examined in order to assist in assessing financial risks of climate proofing:

**Decision of Type 1** or a **low-regret** approach

Invest in climate proofing the infrastructure at the time of design or implementation because the present estimated costs are relatively small while the estimated benefits are very large. At a later point in time, climate proofing costs are expected to be prohibitive or is technically not possible, or a set of climate-proofing options selected will deliver net positive economic benefits regardless of the nature and extent of climate change, including the current climate conditions. A "no-regrets approach" is, essentially, where there will be a full-scope programme of remediation and adaptation that incorporates all of the infrastructure's needs to provide high-quality service already included in the budget as well as additional programmes to consumers in a long-term framework.

**Decision of Type 2** or **adaptive solution or management**

Do not invest now but ensure that the project is designed in such a way as to be amenable to be climate proofed in the future if and when circumstances indicate this to be a better option than not climate proofing. In the construction of river or sea dykes suitable to projected higher sea level and stronger storm surges in a distant future, the sea dyke base may nonetheless be built large enough today to accommodate future heightening of dyke but "ready" to be climate proofed if required. This concept is akin to the real options approach to risk management.

**Decision of Type 3**

Make no changes to project design. Monitor changes in climate variables and their impacts on the infrastructure assets, and invest in climate proofing if and when needed at a later point. A decision of Type 3 results from the following circumstances:

1. Costs of climate proofing now are estimated to be large relative to the expected benefits.
2. Costs (in present value terms) of climate proofing at a later point in time are expected to be no larger than climate proofing now.
3. Expected benefits of climate proofing are estimated to be relatively small.

The most costly aspects of weather today—extreme storms such as hurricanes, typhoons, and windstorms—are the major insurance markets, thus making insurance companies the best financial litmus-test for climate proofing. It is also known that the choices that are made today in climate proofing affect future costs of operation and maintenance, longevity of the infrastructure and convenience (EOCD, 2016). However, there has been very little attempt to seek insurance to help quantify these costs of climate proofing.

For the economic analysis of climate proofing an investment project can help answer questions of the following nature:

- Do the benefits from this option for action promote climate proofing?
- Compared to the benefits, are the additional costs reasonable?
- Taking into account the costs and benefits, are the required funds available to implement this option?
- If not, what additional funding is available?
- Would the benefits of this option for action also occur in the long-term?
- Is the planning horizon for the option for action in line with the planning horizon for the climatic trends?
- Do the required technical skills to implement the option for action exist?
- If not, which skills have to be acquired?
- Calculate the total score.

### 4.5.7 Critical infrastructure

Critical infrastructure includes any physical or virtual assets, systems, networks and functions whose disruption would have a debilitating impact on security, the economy, public health and safety, or any combination of those matters. Natural disaster may appear to be local and yet the impact may be transboundary covering several jurisdictions. In the present toolkit, water supply and sewerage services, information and communications technology as well as transport may be considered critical infrastructure. Essential steps for identifying and protecting critical infrastructure are fairly distinct and protected in different ways in various jurisdictions. The essential steps include but are not limited to risk assessments and prioritizing of the assets, understanding interdependencies of key infrastructure, analyzing cross-sector cascading effects, and coordinating with private and public sectors to improve protection and resiliency. Governments have categorized these infrastructures into five levels, depending on importance to the county, city, region or state.

Risks are determined by the threats, including the likelihood of occurrence and the impact these threats would have on the immediate infrastructure and on interdependent systems and facilities. Critical infrastructure is not a distinct collection of physical entities. Instead, it is an interconnected system of systems, each part relying on and affecting the operations of other parts of the system. This is also known as a cascading impact. The best and most effective way of minimizing the impacts of critical infrastructures' system failures is to reach the highest possible level of resilience with respect to all its subsystems. Disruption in any part of the cross-sector may have a direct impact on the local, regional or state economic stability and the inability to provide vital lifeline services.

The critical infrastructure system has three hierarchical levels that constitute a vertical classification: system, sector and element levels. The system level is the basic classification of a critical infrastructure comprising of two areas: the technical and the socioeconomic infrastructure. Technical infrastructure includes sector producing and providing specific commodities (energy and water supply) or sectors providing technical services (transport or ICT systems). The socioeconomic infrastructure is composed of sectors that provide public social or economic services (health care, financial and currency markets, emergency services and public administration).

Following the work of Giovanni, et al; (2018), climate proofing steps will include:

- Identify and assess climate hazards.
- Determine the overall framework of critical infrastructure (physical assets and systems) and describe each specific component.
- Estimate the level of integration of infrastructure systems including the spatial and temporal variability.

- Determine the exposure levels and climate sensitivity of critical infrastructures.

- Estimate the overall multi-hazard multi-sector risks, the impacts at sector and infrastructures.

- Estimate the costs of climate proofing.

### 4.5.8 Identification of sector-specific climate proofing options

The urban basic infrastructure composed of water supply and sanitation, energy, transport and ICT are interconnected, although energy and ICT remain central in the assessment. It is imperative to examine how this interdependency may be exploited to reduce the cost of climate proofing of basic infrastructure. Wherever there is a failure in one there will be a cascading impact on the other sectors. Suggested measures may be integrated into current asset management, permit compliance, emergency response planning, capacity development and other decision-making processes at utilities.

There is a tendency to deny economic incentives to infrastructure firms because the economists may be looking at the short term while infrastructure is developed for 30 or so years. Savings may be made if the two establishments work together. There is currently no evidence of such partnership.

#### 4.5.8.1 Water supply, sanitation and storm water

While there is a high level of confidence in the processes linking emissions to global warming, much less is known about how warming will manifest itself at the local level through changes in rainfall, runoff, groundwater recharge and climate extremes. Water and wastewater issues that may be exacerbated by climate change are water availability from surface and groundwater resources; extremes in the form of flood and drought; and saline intrusion. The analysis is made difficult because programmes across sub-Saharan Africa prioritize service extension and rehabilitation, but do so with little if any evidence on performance or the causes of failure.

Risk assessment or a risk screening approach that can be identified and mitigated is thought to suffice in WASH, focusing more on system vulnerability and technical change. The technical emphasis preference is for concrete and more readily identifiable (and measurable) things, and the reduction of adaptation policy to lists of analytical, planning and delivery processes that need technical know-how to make them work. The first step is to set a scorecard, using documented indicators of vulnerability, and either expert judgment or community participation. Adaptation is expected to determine the extent to which a WASH programme focuses on key risks and vulnerabilities.

Undoubtedly, floods in informal settlements will cause pit latrines to overflow resulting in damage to infrastructure and creating widespread health problems. On a similar note, seasonality of rainfall will affect the performance of water sources from springs and shallow wells with low storage, leading to water rationing and use of unsafe sources. The water sources are degraded further by environmental damage exacerbated by intense rainfall impact on infrastructure. This poses a longer-term threat to the resource base. These bottom-up steps could mitigate some of these risks. Addressing issues such as catchment protection, water resources management and the lack of basic knowledge on resource conditions and trends will take longer, but is essential as climate change accelerates and competition for water grows.

**BOX 7.2: EXPLORING ADAPTATION OPTIONS FOR WATER INFRASTRUCTURE AT SEA LEVEL**

In the State of Massachusetts, Manchester-by-the-Sea's wastewater treatment plant is located right on the coast. The town's water utility is working with the Federal Environmental Protection Agency's Climate Ready Water Utilities Programme to consider its adaptation options.

The Water Utility Climate Adaptation Planning in the town of Manchester-by-the-Sea is a community of just under 6,000 residents located on Cape Ann, Massachusetts, approximately 20 miles (about 32.2 kilometres) northeast of the city of Boston. This coastal community—originally gifted by land grant to the Massachusetts Bay Colony in 1629—is now known for its picturesque harbour, beautiful beaches and restored sea captain's homes.

**Climate stressors and impacts:** Manchester's wastewater treatment plant is located right at Manchester Harbour. The harbour borders the Atlantic Ocean, and the plant is less than 3 metres above sea level. Because of its location, the plant is susceptible to flooding from extreme precipitation events, high tides, storm surges, and sea level rise. The plant site is within the Federal Emergency Management Agency's (FEMA) 100-year floodplain, indicating that it is at risk of inundation from flooding. During storms, it is common to see the parking lot adjacent to the treatment plant covered in 4–6 inches (about 10.2–15.2 cm) of water.

Nearly 18 years old, Manchester's treatment plant was built to process an average flow of 1.2 million US gallons (4.5 million litres) of water per day (MGD). It was designed for a maximum daily flow of 3.0 MGD, and an instantaneous maximum flow of 5.0 MGD. When intense precipitation events occur, the plant must handle high rates of water inflow and infiltration to the collection system. Flooding places the plant's pumps and chemicals stored in its headwork's building at significant risk for malfunction and contamination.

This aerial view of the wastewater treatment plant emphasizes how the site is exposed to water on two sides.

Evaluating the infrastructure of the utility and its resiliency to climate-related hazards is critical to safeguarding a community by the water, especially with an increased occurrence of extreme weather events and factors associated with a changing climate. Town Administrator Gregory Federspiel says, "One of our biggest motivations to try and get ahead of the impacts of climate change is really a financial concern. To anticipate that is going to be less costly than trying to repair in a crisis situation."

A wake-up call: In October of 2014, seven inches (15.2 centimetres) of rain fell in the area surrounding the treatment plant within 24 hours. Though the plant did not sustain significant damage, similarly intense rain events have led to street closures, public infrastructure and private property damage. Following the 2014 event, Manchester-by-the-Sea's utilities embarked on a project to work with the United States Environmental Protection Agency's (EPA) Climate Ready Water Utilities Programme. The heavy rain event provided motivation for them to evaluate the potential impacts of climate change to their utility, look at ways to deal with these impacts and prepare for the future.

Setting priorities and examining options: Using EPA's Climate Resilience Evaluation and Awareness Tool (CREAT), the utility was able to examine maps of projected changes at their site based on several scenarios. These scenarios enabled Manchester's water managers to analyse projected threats of heavy precipitation and flooding to the year 2035 and sea level rise and projected storm surge heights to 2060.

**Scenarios:** Based on "warm and wet" weather scenarios, water managers decided to focus first on building the resilience of their headworks building. They chose this building because it contains many of the influent (in-flow) and effluent (out-flow) pumps that would no longer be operable if flooded. Another factor in this decision was the building's location; it sits entirely within the FEMA 100-year and 500-year floodplain. With their top priority identified, utility staff used CREAT again to facilitate discussion on changes that could be implemented to protect the assets of the wastewater treatment plant.

The assessment and evaluation of the adaptation options process gave Manchester an opportunity to be proactive in its decision-making and look for ways to fortify the area around the plant, better, to keep it functioning. Based on what authorities learned, the utility is evaluating adaptation options, such as relocating to an area with higher ground or constructing a higher sea wall along the harbour. As Carol Murray, interim director of the Department of Public Works, says, "We have the opportunity to glimpse what the future may hold, but we also have the opportunity to change that."

**References:**

Manchester-by-the-Sea, Massachusetts, 2015: About Manchester-by-the-Sea. Accessed 10 August 2015; U.S. Environmental Protection Agency, 2015: Climate ready water utilities. Accessed 10 August 2015; U.S. Environmental Protection Agency, 2015: Climate resilience evaluation and awareness tool exercise report. Manchester-by-the-Sea, Massachusetts. 13 pp.

**Water safety plans:** The impacts of climate change on water quality need to be managed in order to ensure the consistent safety of drinking water. This has been done through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer. This is a preventative approach which aims to avert contamination before it happens by identifying and mitigating risks in advance rather than relying on end-of-pipe testing and ad-hoc measures. The plan ensures the safety and acceptability of a drinking-water supply. The water safety plan team implements the plan. The team consists of individuals from the utility and, where appropriate, from a wider group of stakeholders. They have the collective responsibility for understanding the water supply system and identifying hazards that can affect water quality and safety throughout the water supply chain.

**Land-use planning*:*** Land-use planning can substantially reduce the exposure and vulnerability of water infrastructures and associated disasters whenever plans are supported by reliable data on floods and droughts.

### 4.5.8.2: Ecosystem control and water management

Water managers have in the past monitored known hazards and risks in water resources planning. With climate change, it is prudent that, in addition to known risks and hazards, the unknown risks must be investigated through system research and determining the range and type of relevant uncertainties. Ecosystem protection and restoration, not only for watershed services but for nature-based infrastructure, is urgently needed to maintain and restore natural capacities that support the protection of people and basic assets, including infrastructures, against increased climate variability and extreme events.

For this to be achieved, wider stakeholder involvement and transparency is required to build political support for sharing the burden and benefits of the impacts of climate change with other industry players. Engineers, hydrologists, urban planners and many other professionals will need to invest in strengthening the ability of people to manage water resources more efficiently and equitably for human need and infrastructure. New institutional strengthening and individual capacities is critical in order to step in adapting to climate change.

Besides building the human and institutional capacity, there will be increased coordination and participation in adaptation efforts. Vulnerability to climate change depends on the capacity of societies to adapt to changing climate and increase social capital. A deliberate effort is needed to enlarge social capital by raising awareness, organizing special events, and securing financial and other support from community-based groups. Coalition building is needed to engage political leaders to support climate proofing in water supply and sanitation, and other basic infrastructure. Leaders in government, business and civil society will be needed to make adaptation a success.

The response to water supply and sanitation regarding climate proofing could be to implement water-use efficiency while reducing energy use, use of climate-smart water management tools, including groundwater banking and water recycling. Other response measures could prioritize mutually beneficial approaches in adaptation measures and flood management, as the latter is likely to increase in magnitude and frequency as a result of climate change. Each component of water use, from transport and treatment through distribution, could require energy. Therefore, energy consumption and efficiency need to be considered in response planning to ensure solutions are not exacerbating the basic problem of carbon emissions. Improved flood control and storm water management in urban areas could buffer climate-related impacts. Potential surface storage in urban green areas has the potential to increase infiltration and reduce flash floods.  Incorporate the need for flood management because most dams serve water supply and flood management roles. Thus, increasing downstream flood protection could enable existing dams to be operated for increased water supply.

**Nature-based infrastructure:** Ecosystems provide significant services in the hydrologic cycle. Nature-based infrastructure includes widening riparian buffers, watershed restoration, and a greenbelt network, larger culverts at road crossings, and more efficient and stable road design.

Water treatment plant in Quebec, Canada.
**© Shutterstock**

# STEP 6: GOVERNANCE, INFRASTRUCTURE, CAPACITY BUILDING

## 4.6 Governance, infrastructure, capacity-building

### 4.6.1 Role of policy and regulatory measures

The overall goal is to build climate-resilient infrastructure using water governance instruments such as policies, legislations and regulations, as well as trade-offs and barriers to climate proofing. Measures for adapting climate change will be considered in approval of development policies, strategies and plans in national, subnational and project levels. The revisions may take various forms; examples include but are not limited to the following:

- Revise and renovate the design standards for building, transport, water conservation construction and hydropower, considering the climate change impact assessment.
- Consider the policy revision of increasing migration from the coastal zone to the higher places and to the buffer zone due to sea level rise.
- Making infrastructure development adaptive to climate change.
- Consider climate change during water resources development, such as during reservoir management regulation and river integrated management.
- Raise awareness and community participation.
- Commit to strategic environmental assessment.
- Establish a natural disaster early warning system.
- Enhance the weather forecast system.
- Encourage low-emission technologies.

The result of the analyses of impact on infrastructures (loss, damage and operational challenges) identified and adaptation requirements as well as consequences on health and development raises the issues of stakeholders' participation and capacity-building in order to climate proof basic infrastructure.

### 4.6.2 Mainstreaming climate proofing through legal, policy and regulatory frameworks

The role of the national and subnational government is mainly legislative, policy direction and operational oversight. The legal and regulatory framework for climate change provides legitimacy, regulates conduct and establishes institutions, and provide sanctions that can ensure compliance and implementation of the climate proofing strategy. The relevant regulatory and policy institutions are to enact an overarching stand-alone climate change law, enact or amend sectoral laws to facilitate priority actions, establish a high-level National Climate Change Council to provide oversight and coordination, and establish a Climate Change Secretariat as the main technical mechanism to deliver on the Action Plan. Some countries have such legal, policy and regulatory frameworks while others do not. The absence of such a framework in Uganda, for example, is an obstacle in translating the identified policy priorities into implementable actions with tangible climate change benefits.

Climate change programmes and projects are implemented by lower-level institutions such as directorates. A key information gap exists in the linkage between national adaptation programmes of action and those that are local. Consequently, the current local programme is silent about urban areas despite their importance in climate change adaptation and mitigation. Deliberate attempts to embrace urban issues in to adaptation programmes is an essential feature for climate proofing for urban infrastructure.

Although there is no specific urban development policy, urban development is guided by legislation on the following:

- Town and Country Planning Act: inter alia, prescribes the procedure for declaring a locality as a planning area and the process for formulating spatial planning schemes as a framework for urban service provision.

- Public Health Act: inter alia, details building standards and requirements.

- Local Governments Act: in part, focuses on urban-wide provision of services, including street lighting, solid waste management, environment management, infrastructure development and governance

- The National Environmental Act: under which a number of vital environment management guidelines and regulations have been formulated and put into effect.

- National Urban Policy and National Urban Forum, Liberia, both policy and Guiding Policy Framework in 2016.  Kenya validated its urban development policy in 2015.

- Efforts that have been supported by UN-Habitat III Policy Unit 3 on National Urban Policies. These mitigation and adaptation intentions are based on a country's National Climate Change Policy, which is derived from the Constitution of the respective countries, and reflects country vision. The priorities in the Policy requires integration in some of the Second National Development Plan.

For example, the ministry in charge of infrastructure has the responsibility to develop and ensure integrated planning and management of transport and other physical infrastructure that build on insights from climate predictions. Similarly, the issues regarding biodiversity and ecosystem services are planned by the ministry in charge of environmental management, and whose responsibility includes attending effectively to the challenges posed by climate change impacts on biodiversity and ecosystems, so as to ensure ecosystem health and provision of ecosystem services that are crucial to sustainable and resilient development. The human settlements and social infrastructure and disaster risk management portfolios cover social planning for disaster mitigation and adequate preparedness for climate change induced risks, hazards and disasters.

Integrating climate change into planning at the local level is particularly important because climate change affects local livelihoods. Moreover, the environment, climate vulnerability and adaptation are determined locally, and options for action are often best identified at that level. Implementing options for action at this level often makes local people the main actors in the implementation process when, for instance, it is a matter of adapting agricultural production or improving their own housing. Donors can play an important role in providing training for municipal government staff and raising awareness about the opportunities and challenges of climate change among the local population.

Climate proofing can be an important tool at the project level as project goals may be directly affected by the effects of climate change and project results may increase or decrease the climate vulnerability of biophysical and socioeconomic systems. Climate Proofing can be introduced during project identification and during the project design phase by drawing out the interests of stakeholders in relation to the project's objectives, identifying actual and potential conflicts of interest, and viability other than in strictly financial terms (for example, includes social factors) to stakeholders who will be directly affected by, or who can directly affect the project implementation.

Aerial view of the modern skyline of Panama City, Panama with modern Highrise buildings.
**© Shutterstock/ Gualberto Becerra**

Adaptation calls for human-driven adjustment to economic, social, and environmental systems in response to climate impacts. By implementing adaption options, vulnerability, which is the degree of susceptibility to an adverse is reduced. Institutional entrepreneurs can help to connect different goals and ensure widely supported solutions for urban development and realizing cost savings simultaneously.

Climate proofing national strategic development plans enhance the enabling environment for adaptation; establish the requirement for climate proofing sector and subnational (for example, state, island and community) development plans, as well as individual development projects (that is to say, mainstreaming adaptation); and ensures that actions to reduce climate-related risks are an integral part of, and harmonized with, sustainable development initiatives.

### 4.6.3 Experiences with national policy and law; application of environmental safeguards

Ensuring that infrastructure is resilient to climate change can support the achievement of the Paris Agreement, including through increasing the ability to adapt to climate change and ensuring that financial flows are consistent with low emissions and climate-resilient development. Climate-resilient infrastructure can also support the efforts to achieve a number of the Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction. The Paris Agreement has the goal of holding temperature increases "well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels".

The United Nations Strategic Development Goal Target 1.5 states that by 2030, the world must "build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social, and environmental shocks and disasters" (UN 2016c). Additionally, Goal 13 focuses purely on climate change, calling on "urgent action to combat climate change and its impacts." Target 13.1 states that we must "strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries."

Overarching principles are as follows:

- The goal of pro-poor and pro-growth adaptation that encourages sustainable economic development and livelihoods in the face of climate change.
- The objective of climate-resilient development, including systemic changes to development processes.
- A key outcome is that climate change risks are integrated into national planning and poverty reduction efforts.
- Success will be measured using indicators and targets that reveal systemic and sector-wide policy changes.

Disaster risk reduction is more concerned with the present and is focused on near-term trends (disaster relief and prevention). Climate change adaptation is a long-term development effort aimed at attenuating the negative effects of climate change, including natural disasters. Climate change adaptation focuses on extreme events and on gradual changes in average climatic conditions and climate variability. Climate change adaptation encompasses disaster risk reduction in a longer time frame by attacking the root causes of vulnerabilities at the broader societal scale rather than focusing on singular extreme phenomena for immediate or short-term preparedness and response.

National governments may intervene in any of the following ways:

- Encourage and support patterns of private investment within national boundaries that are less concentrated in high-risk sites; the choice of "safer" city sites rather than hazard-prone areas
- Controlling population movements to high-risk sites

- Adopt policies that do not allow low-income households to return to their settlements after disasters, such as post-tsunami in Sri Lanka, to assess climate risks at a level of detail sufficient to develop approaches to address moderate and high climate risks adequately

### 4.6.4 Governance for climate proofing

#### 4.6.4.1 Role of governments

Governments and their development assistance partners should ensure that all proposed, new and upgraded development projects are "climate proofed" at the design stage. This should be part of good professional practice, with national and state climate risk profiles being used as the basis for "climate proofing" infrastructure, community and other development projects. Compliance with this requirement should be assessed as part of enhanced environmental impact assessment procedures. Governments should also undertake cost-benefit analyses of all major development projects, including determining the incremental costs and benefits of incorporating adaptation measures. If for a developing country the incremental costs are large, the government should request a donor of a developed country and other relevant agencies to fund the incremental costs. Governments should also ensure that all regulations (for example, building codes, public health regulations) are "climate proofed" as this will facilitate enforcement of policies and plans that should, themselves, be "climate proofed".

Climate change is considered a cross-cutting issue that has to be mainstreamed in all the sectors of the economy through the planning process. True as this may be, it is one of the greatest obstacles to serious planning of climate proof infrastructure because coordination requires Cabinet decision or a legal framework. Table 8.1 is intended to assist in determining the number of subnational entities budgeting and implementing climate proofing programmes.

**Table 8.1: Governance structure for vulnerability assessment**

| Governance | Policy | Legal and Regulatory | Capacity Development | Financial/Resources mobilization |
|---|---|---|---|---|
| Community-based involvement | Number of urban areas that have integrated climate proofing in the plans (NAPAs, NAPs, etc) | Participation | Population demanding water supply and sanitation | Level of support for community water infrastructure |
| Infrastructure development cases/ application using climate smart designs (energy, ICT, transport) | Programmes/projects incorporating nature-based infrastructure | Presence of regulations and enforcement of the same – design, materials, land suitability and preparation | Public servants trained on climate change | Institutional framework for approval of clime-resilient water projects |
| Functional climate change coordination structures | | Presence or absence of supporting legal framework | | Overall coordination of climate change at national and subnational levels |
| Climate change public awareness campaigns | | | Number of institutions supporting climate change initiatives | |

#### 4.6.4.2 National guidelines for mainstreaming adaptation to climate change

These actions can be assisted by preparing and implementing national guidelines for mainstreaming adaptation to climate change. One experience that relates to understanding institutional inertia is Grenada's National Adaptation Plan (NAP) process that had an opportunity to take stock of, coordinate and identify any gaps in ongoing sectorial efforts to integrate adaptation into strategies and plans but never did. For understanding the link between the NAP process and potential to access international climate funds and climate-proofing, the national development plan is a perquisite. The inclusion of cross-sector adaptation planning in Peru's Intended Nationally Determined Contribution provided the impetus of different levels of uptake of adaptation by different sectors and levels of government, which was a challenge due to complex system of governance and relatively low levels of awareness and lack a national priority. The NAP process is an opportunity to insert climate change adaptation in sectorial plans, as well as at the national, subnational and local levels, of development planning. When done in a participatory process, it ensures that national, regional and local actors, including households, consider adaptation strategies and practical adaptation measures.

Existing Guidelines outline some "guiding elements" that inform and sketch out the climate proofing process. However, they fall short of providing a structured framework. The guiding elements imply that the NAP process need to emphasize (1) a participatory approach involving stakeholders; (2) a multidisciplinary approach; (3) a complementary approach that builds on existing plans and programmes; (4) sustainable development; (5) gender equity; (6) a country driven approach; (7) sound environmental management; (8) cost-effectiveness; (9) simplicity; and (10) flexibility based on country specific circumstances. However, NAPs provide direction only, while implementation is left to different ministries and departments without any further reference to other stakeholders.

**BOX 8.1: OBJECTIVES OF THE KENYA'S NAP**

- Highlight the importance of adaptation and resilience building actions in development
- Integrate climate change adaptation into national and county-level development planning and budgeting processes
- Enhance the resilience of public and private sector investment in the national transformation, economic and social and pillars of Vision 2030 to climate shocks
- Enhance synergies between adaptation and mitigation actions in order to attain a low carbon climate resilient economy
- Enhance resilience of vulnerable populations to climate shocks through adaptation and disaster risk reduction strategies

**Source:** Republic of Kenya. 2016. Kenya National Adaptation Plan 2015–2030

# STEP 7: "SOFT" CLIMATE PROOFING OPTIONS FOR GENERAL INFRASTRUCTURE

## 4.7 "Soft" climate proofing options for general infrastructure

### 4.7.1 Methods for selecting climate proofing measures

For most environmental hazards, local governments can act to remove or lessen hazard impacts using by-laws and other regulatory measures. Adaptive capacity is the potential of a system or population to modify its features or behaviour to cope better with existing and anticipated stresses. So, adaptation is about enhancing resilience or reducing people's vulnerabilities to observed or expected changes in climate. Sustainable development may increase adaptive capacity and reduce the vulnerability of low-income groups. Adaptive capacity will influence adaptation (the actual adjustments made) although high adaptive capacity does not necessary translate into measures that reduce vulnerability. In terms of who has to adapt, discussions for urban areas highlight that this includes governments, enterprises and households. Organizations need to adapt their own behaviour, goals and practices and support progressive and proactive adaptation among other actors. Government agencies, and especially local government, are the most important for shaping the operating environment that influences the capacity for households and businesses to build adaptive capacity and undertake adaptive action. In most urban centres in low- and middle-income nations, community organizations and local NGOs also have a considerable role to play, especially where they are influential in the construction and management of homes and neighbourhoods, and in the provision of services within the informal or illegal settlements where government agencies provide limited infrastructure or services.

In this step 7, we explore how governance interfaces with communities' and households' responses, short- and long-term, to the impact of climate change so that it will be possible to determine options available for climate proofing of the basic urban infrastructure.

Ahmedabad Mayor and Members of Standing Committee painted a roof white to launch the city cool roofs initiative.
**© NRDC/Nehmat Kaur**

### 4.7.2 Creating a catalogue of relevant climate proofing governance options

In the first step in compiling flood proofing options for consideration, the overall approach and objectives of adaptation planning in the municipality may ask the following questions:

1. What are some of the "soft" climate proofing measures? Some examples are as follows: managerial, which introduce flexi-time work during heatwaves,; strategic, which commission new buildings with climate resilient design as part of planned urban building programme; and temporary measures, which use large umbrellas to reduce solar heat increases.

2. Are there any technical and ecological measures that can be adopted? Examples of the technical measures are to refurbish buildings and enhance physical flood defences; and ecological examples are the implementation or expansion of green infrastructure for water runoff.

Some of the most effective pro-poor actions to reduce vulnerabilities also come from partnerships between local government, development partners and community organizations. Many aspects of "development" increase adaptive capacity because they also increase local knowledge and local capacity to act, increase incomes and asset bases of poorer groups, as well as improve their health and reduce their vulnerability. Sustainable development should also increase poorer groups' capacity to influence local governments and so spur them to appropriate action too.

Climate proofing means identifying risks to a development project, or any other specified natural or human asset, as a consequence of current and future climate variability and extremes, and ensuring that those risks are reduced to an acceptable level. The stakeholders will highlight short- and long-term options (see table 9.1). Climate proofing interactions include green spaces, green roofs, urban agricultural gardens and permeable pavements to reduce runoff, greenhouse gas emissions, ambient air temperature, and increase infiltration of rainfall for groundwater recharge. The institutions managing infrastructure investments need to consider the financial risks associated with location of basic infrastructure as well as the opportunity created by nature-based infrastructure. The main defining moment is for spatial development planning as explained by rationale and clarity on concepts on climate proofing.

**Table 9.1: Examples of climate proofing in practice**

| Type of response to climate change | Autonomous (by households, communities and firms) | Policy driven |
|---|---|---|
| Short run | Making short-run adjustments. For example, reducing water use, spreading the risk of loss through insurance | Developing greater understanding of climate risks and vulnerabilities<br>Improving emergency response |
| Long run | Investing in climate resilience – much encouraged if future effects are relatively well understood and benefits are easy to capture for household, community organization or firm | Investing to create or modify major infrastructure. For example, larger reservoir storage, increased drainage capacity, higher sea walls.<br>Avoiding negative impacts. For example, land-use planning to restrict developments in floodplains and at-risk coastal sites |

### 4.7.3 Guidelines for water utilities

Given the context-specific nature of climate adaptation, the measures used to achieve this will vary widely. In some cases, no structural changes will be needed to achieve this. However, where changes are required, they can be grouped into two categories (EUFIWACC, 2016) in table 9.2.[9] The objectives of proofing will be to influence the costs of adaptation and the residual impacts. In the most general terms, adaptation can aim at maintaining a given standard of service, achieving a new "optimum" standard of service, or meeting some new service standard. This new service standard could be higher–because, for example, the threat of climate change increases risk aversion–or could be lower because of financial or feasibility constraints and will vary from place to place.

### 4.7.4 Nature-based infrastructure for climate proofing

Nature-based solutions tend to offer options for climate change adaptation and mitigation although they have no direct influence in infrastructure climate proofing. Globally, the cost of disasters has increased several-fold because more people and more valuable infrastructure have been located in vulnerable locations, and the vulnerability and the cost of disaster-related damage will increase resulting from climate change. Floods and hurricanes have caused major damage and loss to lives, livelihoods, human well-being and gross domestic product. These weather-related phenomena have also caused a rise in sea level, an increase in the frequency and intensity of hurricanes, disruptions in rainfall and reduced fresh-water availability, which significantly undermine sustainable development efforts.

**Table 9.2: Climate proofing options using technical guidelines**

| Measures | Climate proofing options |
|---|---|
| Structural measures | Changing the composition of road surfaces so that they do not deform in high temperatures<br>Building seawalls or using permeable paving surfaces to reduce run-off during heavy rainfalls<br>Ecosystem-based approaches using natural infrastructure to design adaptation measures are also key alternatives to be considered alongside structural adaptation measures |
| Management measures(non-structural) | Changing the timing of maintenance to account for changing patterns of energy demand and supply<br>Investment in early warning systems or purchasing insurance to cover the financial consequences of climate variability<br>Enhanced monitoring of existing assets to reduce the risk of failure as climate conditions change<br>Flexibility from the outset to monitor and adjust to changing circumstances over the asset's lifetime |

9 Climate –resilient Infrastructure. Policy Perspectives. OECD Environment Policy Paper no. 4. 2018.

The purpose of a spatial development plan is to improve utilization of the natural resource base and guide the organization and sustainable development of physical and social development of a region or county. The spatial framework is designed to promote optimal use of land and to achieve sustainable development by meeting rural urban development challenges in an integrated manner and exploiting opportunities in various sectors. It indicates how land use, transport planning, infrastructure and services provision should be coordinated to contribute to a competitive, economically robust, socially liveable and sustainable regions that meet the daily aspiration for prosperity of the residing population. In this regard, the planning process offers an opportunity for climate proofing infrastructure based on land-use controls in recognition of vulnerability of utilities to extreme climates. In Kenya, there are several guidelines that have missed opportunities for climate proofing infrastructure development.

### 4.7.3 Guidelines for flood-prone areas for nature-based infrastructure

Nature-based infrastructure provides protection, especially in flood plain and riverine zones. The guidelines for flood-prone areas identifies and maps them out; instructs on how to carry out afforestation, tree-planting, water and soil conservation in catchment areas and along water courses; discourages human settlement in flood-prone plains; and demonstrates how to create a buffer zone between the flood plain and human settlement as a contingency measure to ensure safety of the local community. Planting of water-logged tolerant crops (for example, rice, arrow root) in flood plains may be encouraged in addition to development of a flood early warning system. The activities will increase groundwater infiltration and sequestrate carbon dioxide.

Engineering options such as controlling flow of water along water courses through construction of flood control structures such as dykes and dams may be viable for retrofitting existing infrastructure. However, all land use is expected to undertake an environmental impact assessment for proposed construction of dykes and dams and involve the local communities in the construction of water-flow control structures.

### 4.7.4 Guidelines for landslide-prone areas

Landslides are associated with enhanced or above normal rainfall and steep slopes. The guidelines for landslide-prone areas include identification and mapping of these areas, discouraging human settlement in them, intensifying soil and water conservation measures in already settled landslide prone-areas, and siting of infrastructure in these areas to be determined by slope, soil characteristics and vegetation cover.

### 4.7.5 Guidelines on fire management

The climate change scenarios expected are a rise in temperatures, increased droughts and, therefore, high frequency of fires in forest and grassland. Climate change will increase the odds of such devastating wildfires in the coastal hospitality industry[10] in the tropics. It can be seen that the guidelines for fire management make no mention of the increased vulnerability resulting from climate change. Besides designation and development of fire breaks in identifiable fire-prone habitats[11] (such as forests, ranches, squatter land and slums) and urban areas, building and strengthening the capacity of responders (fire fighters) and conducting regular drills, there is little awareness that the frequency and intensity of these fires will increase as a result of climate change. While labelling and safety precautions are important and must be enforced, additional effort needs to be put in place to make these buildings and habitats climate proof.

10 Fire razed down Travellers Beach Hotel in January 30th 2002. Many cases have been reported and yet there is very little documentation.

11 Tanzania wildfires likely to affect annual wildebeest migration to Kenya, 6th July, 2018. About 750,000 wildebeests are expected to cross over into the Maasai Mara Game Reserve.

### 4.7.6 Guidelines for zoning of urban areas

Zoning specification should be developed, taking into consideration the different user types; for example, residential zones and densities, commercial zones and industrial zones as well as according to vulnerability of infrastructures in specific environmentally significant areas. Zoning of urban areas should take note of the prevailing meteorological conditions (for example, wind direction) and existing extreme climatic events that are expected to increase in magnitude and frequency in future. Such guidelines will reduce hazard risk and vulnerability of the infrastructure.

Although environmental and social impact assessment is undertaken for all projects, issues of climate change are not generally emphasized. Land-use planning concentrates on spatial plan to enhance inspection and monitoring to ensure compliance with the zoning specifications, provide designated locations for establishment of public utilities, social amenities such as kiosks, car wash (using appropriate water saving technologies), garages, public toilets and smoking areas taking into considerations the interrelationships between various land-use types rather than climate-related concerns. Amongst risk assessment issues are: dangerous substances, chemical spills and conservation areas (game parks and reserves) and noise.

### 4.7.7 Informal sector urban development

Promote measures to prevent proliferation of slums through the adherence to housing standards, the provision of low-cost quality houses and slum upgrading projects. Provide access to firefighting equipment and services through enforcement of fire drills and exits at commercial and residential buildings, and provision of sub fire stations with at least one fire tender and at least 30 staff members for a population of between 50,000 and 100,000. Review of local and regional development plans should be undertaken after a period of 10 years before which no piecemeal change of user and review should take place.

### 4.7.8 Guidelines for utility corridors and greenways

The poor in slum areas live in low-lying, flood-prone areas and are at particularly high risk of becoming unliveable — or at least uninsurable. Adaptation will probably be easier for the affluent than for the poor. Those who can afford to move to an area with more favourable impacts from a warmer climate presumably will. Utility corridors and greenways are required so as to provide for a distribution system throughout the country but are also useful as nature-based infrastructures for water resources, groundwater and recreation. For the utility corridors and greenways, sufficient easement width is needed for the major trunk lines

Fire razes a hotel in Malindi, Kenya.© **UN-Habitat** and transmission lines for utility systems. These should avoid areas that are likely to suffer gross inundation during floods and thus interrupting power supply. Appropriate planning will encourage coordination between utility companies, landowners, local authorities and the local community to ensure that safety, liability and maintenance issues are adequately addressed. Power lines are important to the national energy supply and should be indicated in regional land-use plans.

### 4.7.9 Guidelines for parks and recreation areas

For urban residential development, land for open space, recreational areas and green zones should be provided for reducing temperatures as well as providing other biodiversity services. Climate models consistently project that heatwaves frequency, severity, and duration will increase markedly over this century as a result of urban densification. For urban residents, the urban heat island effect further exacerbates the heat stress resulting from heatwaves. There is a 10 per cent open space requirement during land subdivision that may be used for enhancing infiltration and recharging groundwater as a mitigation to increased floods and droughts.

### 4.7.10 Guidelines for urban renewal

The following are the guidelines for urban renewal:

- Enhance the efficiency of all buildings through the provision of efficient management systems; that is, efficient use of water, energy, parking space, security, waste management and lighting among others as well as provision for persons with special needs
- Promote high-rise buildings as opposed to horizontal growth to save on available space Preserve buildings of historical and national heritage importance
- Undertake road widening and redesigning programmes to ease and discourage traffic congestion; and encourage pedestrian and non-motorized-oriented and friendly towns
- Decentralize ministry headquarters from Nairobi to other towns to reduce congestion, ease infrastructural pressure and encourage growth of other urban centres

Songyang, China.
**© UN-Habitat**

View of architectural street in Lujiazui Financial District, China.

## STEP 8: IMPLEMENTATION OF CLIMATE PROOFING MEASURES

## 4.8 Implementation of climate proofing measures

At this stage, the goal is to move from the ideas and options identified in previous Steps into actual implementation of the selected options for climate proofing. It is necessary then to establish arrangements for implementation. Depending on the scale, it will be either a matter of selecting some options to implement or maybe the case of designing an entire Climate Proofing Implementation Plan (depending if the process is being done at national, subnational or local level). Several plans had been designed that were never implemented, for reasons such as the following (adapted from UN-Habitat, 2014):

- Poorly written or difficult to use plan
- Too vague, without clear roles, responsibilities and timeline
- Lack of political will to act and implement the plan
- Changes in political or organizational leadership
- Lack of resources to implement the plan

It is also necessary to identify the needs for technical support, capacity-building and financial resources. For implementation of climate proof infrastructure, four elements of capacity are required: financial resources, cooperation and coordination of stakeholders, availability and quality of information on vulnerability and adaptation to climate change, and the level of understanding of climate change vulnerability and adaptation. These broad categories would derive several activities which need to be documented, analysed and archived for monitoring.

### 4.8.1: Establish arrangements for implementation

In order to guide developers, table 10.1 presents a worksheet to guide the implementation of the selected options or projects for climate proofing of urban infrastructure.

**Table 10.1: Climate proofing implementation worksheet**

| Description of option/action | Institutions involved | Project leader | Resources required | Budget (est) | Time frame (est) | Progress |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |

Table 10.2 shows the sectors, activities, implementing institutions and the actions applicable to climate proofing.

**Table 10.2: Action plan for climate proofing urban infrastructure implementation**

| Sector | Activities | Implementing institutions | Application to climate proofing |
|---|---|---|---|
| Stakeholders | Develop climate change awareness programmes<br>Disseminate climate change and early-warning information in local languages | Subnational governments<br>Project promoters | Provide information on the hazards, adaptive capacity and vulnerability of community |
| Water supply and sanitation | Design and plan with climate change in mind | National government responsible for fresh water<br>Subnational governments in charge of water supply | Application of the policies, legislation and regulatory |
| Transport and ICT | Establish insurance schemes | National and subnational governments | Low carbon options; non-motorized transport; cycling |
| Energy | Options are renewable energy | National governments | Low carbon strategies and options evaluated |
| Nature-based infrastructure | Investigate options | Subnational governments | |
| Housing | Revise and harmonize structural and building codes and standards<br>Training on such standards, taking into account the expected changes in climate<br>Improve disaster preparedness by increasing early warning | Number of well-equipped health facilities<br>Constructing dams and dykes in flood-prone areas, and improving disaster preparedness and management knowledge and skills<br>Strengthen housing development policies, including subsidies to low-income communities<br>Improve disaster preparedness by increasing the number of well-equipped health facilities | Cool roof initiative – 2017: Heat Action Plan12.<br>Cool roofs initiative<br>Install slum household roofs to cool roofs<br>Convert public buildings to cool roofs, including municipal buildings and government schools, as procurement criteria<br>Information, education and communication for awareness on cool roofs |
| Urban development | Promote and encourage proper planning of urban centres in order to have climate change-resilient urban areas | National and subnational governments | Formulating planning policies, legal and institutional frameworks |

12 Ahmedabad Municipal Corporation initiative 2017.

## 4.8.2: Funding for Implementation

### 4.8.2.1 Introduction

The needs of financial resources and funding sources will be identified. Below, a brief introduction to sources of finance is given. These sources are not exhaustive as new arrangements and new schemes are continuously being developed. It is important to take into account that several options can be developed locally with local resources.

Most international agencies deliberately want to invest in reduction of urban and rural poverty. Disaster management is generally relegated to other specialist disaster agencies, or have weak links between their disaster departments and development departments (for example, with development and disaster budgets kept separate). Acting to reduce risk often requires actions undertaken in collaboration with many different agencies. Effective risk-reduction strategies have to be locally determined but official development assistance agencies work primarily through national governments. Such strategies often involve long-term processes whose effectiveness may be hard to demonstrate. Each international agency has its own programmes, criteria for allocating funding, and project cycles (which helps to explain the poor integration among them).

The funding for the policy priorities will come from various public and private sources. The main sources and financial instruments will be costed in a detailed implementation plan. Limited financing options to sustain scaled-up adaptation measures remain a constraint. It is difficult for countries to learn from each other about their experiences with such different approaches to adaptation being implemented.

### 4.8.2.2 Local sources

It is important to start from the perspective that climate finance will come mainly from domestic sources, and that these should be thoroughly explored before going on to the more challenging pursuit of international financing, over which local governments have relatively little control. The users of the toolkit also need to know that almost all funding for local governments will pass through the budget (including funds from the national or state governments, part of which may come from international sources). Therefore, particular attention needs to be paid to budget processes and tracking climate finance through the budget by tagging climate expenditure or creating a specific chart of accounts for climate change expenditures. In most cases, transfers from higher levels of government (for example, provincial or national government transfers to the local level) are also relevant contributors to the local government. These transfers can be used to finance adaptation measures, but in many cases there will be guidelines and requirements associated with these transfers. Therefore, climate proofing mainstreaming is fundamental to assure funding from national or subnational government for adaptation and climate proofing at local or sector level. Existing sources of domestic funds for adaptation and climate proofing are the following:

- Operational budget surpluses
- Transfers from higher levels of government
- Loans, grants and bonds
- “Contingency reserve funds”
- Local taxes and fees include land development fee, land taxes, property improvement levies, permitting fees
- User fees include connection charges or development rights
- Operational budget surpluses include spillover from one year to the next
- Transfers from higher levels of government include sources such as international urban sector programmes, dedicated national urban development funds for transport or water supply infrastructure, or even climate funds

- Loans, grants and bonds include financial resources derived from borrowing or issuing municipal bonds, receiving direct grants from donors, or resources extracted from local balance sheets (property or assets owned by the city) as well as those obtained through private-public partnerships

- Local governments can create Contingency reserve funds for disasters (for example, a climate change trust fund would use this approach)

Innovative sources of funding for climate change adaption and climate proofing can include the following (adapted from the Urban Climate Change Adaptation and Resilience Training Course by USAID Adapt):

- Municipal green bonds

- Catastrophe bonds

- Contingency line of credit

- Insurance and reinsurance

- Programmes of activities

The developers and stakeholders involved in developing new adaptation or climate proofing projects that require large investment will need to use specific tools or frameworks for capital investment planning as any other project would. The World Bank has launched its *Guidebook on Capital Investment Planning for Local Governments* in 2011.[13]

#### 4.8.2.3 Green bonds

Considering the trillions of dollars of investment needed to establish a low-carbon and climate-resilient pathway, new climate finance instruments have the potential to help countries to overcome market, financial and regulatory constraints and unlock the mobilization of financial resources at scale for mitigation and adaptation. Green bonds are one climate finance instrument that public and private institutions can utilize to scale up the mobilization of climate finance by attracting investments at scale, including from large investment banks, institutional investors and pension funds. Green bonds may not be new and innovative in themselves but using the share of proceeds from them for mitigation and adaptation actions can be considered new and innovative. According to a representative of the Climate Investment Funds, the green bonds market had grown to USD 250 billion in 2018, far exceeding the record USD 155 billion of green bonds issued in 2017, a significant share of which is expected to cover climate projects.

Some of the main challenges and limitations associated with green bonds are the lack of common standards and criteria to determine whether or not a bond is green and the lack of a common monitoring and verification system to ensure the environmental and social standards of the underlying assets. Recognizing these limitations, multilateral development banks, following joint common principles for tracking climate finance, have started to report what they deem to be green with a view to establishing common criteria for green projects and bonds. Another challenge is that developing countries have difficulty in meeting the credit standards required to access the green bond market. There is a debate whether green bonds contribute to mobilizing new and additional climate finance and whether the proceeds generated by green bonds will cover adaptation and mitigation projects equally. Adaptation is a priority area for many developing countries, particularly for local communities.

Increasing the issuance of green bonds would require the following actions:

1. Mainstreaming climate considerations in the investment plans of public institutions and private businesses so as to encourage climate investments.

13 Available at:http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1169585750379/UDS13CIP.pdf

2. Adopting consistent standards and criteria for issuing green bonds as well as developing a common monitoring and verification system to ensure the environmental and social integrity of projects.

3. Scaling up the technical and financial support provided for building the capacity of developing countries. Climate-friendly national policies and enabling environments, such as a common taxonomy for sustainable finance and/or regulations on transparent financial disclosures by corporations, would also help developing countries to harness the full potential of green bonds.

#### 4.8.2.4 National budgets

National climate change funds attracted early interest, largely because they were established with independent governance structures that met high levels of transparency and inclusiveness and could channel finance quickly to projects suited to national circumstances that were aligned with national priorities. Working through coordinated national systems could also improve transaction efficiency. In practice, however, the impact of national trust funds on strengthening national ownership and coordination remains to be seen, and the sums of finance that these funds have raised are often modest. At the same time, many developing countries are beginning to incorporate climate risk into their national fiscal frameworks, and monitoring climate-related expenditure.

#### 4.8.2.5 National climate finance architecture

National climate funds contribute to building national capacity for the development and implementation of climate projects, and can benefit from sustainable, predictable and accessible financial and technical support. Challenges remain in meeting the criteria and requirements of resource providers in mobilizing the financial means to replenish national climate funds. Budgetary planning and devising climate investment plans facilitate the process of determining the expenditure required for climate projects, and identifying and attracting additional resources to cover any financing and investment gap. However, challenges remain in these following areas:

1. Mainstreaming adaptation and resilience considerations in sustainable development.

2. Identifying economic and social co-benefits of climate actions.

3. Engaging with national stakeholders on fully integrating their needs into budgetary planning and climate investment plans.

4. Gaining the necessary buy-in across ministries and relevant stakeholders.

Efficient access to the readiness support programmes of the multilateral climate funds and international support providers is a key factor in successful country planning, but currently access can be time consuming and complex. Better coordination among the support providers and a tailored approach to providing the services may help improve access. Moreover, many government authorities find it difficult to navigate the capacity-building and readiness support programme and to select the ones suitable for their capacity-building needs. This problem may be overcome through better matchmaking of the readiness support providers and national focal points.

#### 4.8.2.6 National climate funds

Several developing countries have established regional and national channels and funds with a variety of forms and functions, resourced through international finance and domestic budget allocations and the domestic private sector. The Indonesian Climate Change Trust Fund was one of the first of these institutions to be established. Brazil's Amazon Fund, administered by the Brazilian National Development Bank, is the largest national climate fund, with a commitment of more than USD 1 billion from Norway. There are also national climate change funds in Bangladesh, Benin, Cambodia, Ethiopia, Guyana, the Maldives, Mali, Mexico, the Philippines, Rwanda, and South Africa. Additional countries have proposed national climate funds in their climate change strategies and action plans. In many cases the United Nations Development Programme acted as the initial administrator of national funds, increasing donor trust that good fiduciary standards will be met, but many countries are now passing these tasks on to national institutions. Data on capitalization of national climate change funds, however, is not consistently available.

#### 4.8.2.7 International climate finance

Financial resources can be mobilized to fund actions that mitigate and adapt to the impacts of climate change. The international community has pledged public climate finance commitments under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) and other international agreements. In the 2009 Copenhagen Accord, and confirmed in the Cancun Agreements and Durban Platform, developed countries pledged to deliver finance approaching USD 30 billion between 2010 and 2012. In 2015, the Paris Agreement set a new collective goal for climate finance at USD 100 billion per year, taking into account the needs and priorities of developing countries.

**Table 10.3: Types of funds and schemes**

| Types of funds | Schemes, funds and sources | Examples of current funding |
|---|---|---|
| National and sectoral<br><br>Development plans and budgets | Taxes, social security funds, etc. | Climate change concerns are mainstreamed and leveraged through various development plans |
| Multilateral and bilateral development partners | • Agence Française de Développement (the French Development Agency)<br>• Japan International Cooperation Agency (JICA)<br>• European Investment Bank<br>• Kreditanstalt für Wiederaufbau KfW (Germany's government-owned development bank)<br>• Swedish International Development Cooperation Agency | Bangladesh, Cambodia and Mozambique funded by the Pilot Programme for Climate Resilience (PPCR) account for 86 per cent of this urban adaptation finance. These projects fund investments in infrastructure, primarily to improve protection to flooding, with varying combinations of concessional loans and grants |
| Multilateral Development Banks' (Climate Change Funds | Climate Investment Funds comprised of<br>• Clean Technology Fund<br>• Strategic Climate Fund<br>• Other funds by regional development banks: CLIMDEV Africa Special Fund | Pilot Programme for Climate Resilience<br>Scaling-Up Renewable Energy Programme<br>Forest Investment Programme |
| The funds under the CoP of UNFCCC | • Global Environment Facility Trust Fund<br>• Special Climate Change Fund and Least Developed Countries Fund: both are smaller Funds managed by the Global Environment Facility (GEF), and accessed through GEF approved agencies<br>• Adaptation Fund, established under the Kyoto Protocol and with funds already mostly spent<br>• Green Climate Fund operational since 2015 and is the largest fund covering climate change adaptation and resilience to be accessed by national governments | |

| | | |
|---|---|---|
| Bilateral donors | USAID – U.S. Agency for International Development<br>DfiD – Department for International Development (United Kingdom)<br>GIZ – Deutsche Gesellschaft für Internationale Zusammenarbeit, or commonly (known in English as the German Federal Enterprise for International Cooperation)<br>JICA<br>Global Climate Change Alliance, an initiative of the European Union; among others | |
| Bilateral funds | Canadian Cooperation Fund for Climate Change<br>International Climate Initiative, a funding instrument under Germany's Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety<br>Nordic Climate Facility<br>Nordic Development Fund<br>Danish Cooperation Fund for Renewable Energy and Energy Efficiency, and many others | |
| Private sector investments | Payment for ecosystem services schemes | Asian Sustainable Transport and Urban Development Programme of the GEF seeks to add value to large Asian Development Bank investments |
| Market-based mechanisms for climate-related actions | Benefit-sharing schemes under REDD+, emissions-trading revenues, tax incentive and tariff schemes<br>Clean Development Mechanism | |

**Sources:** Barnard, S. 2015. Climate finance for cities: How can international climate funds best support low-carbon and climate resilient urban development? ODI. June 2015

ADB/Government of Cambodia (2012). PPCR Project Approval Request – Cambodia: GMS Southern Economic Corridor Towns Development Project. Available at https://www.climateinvestmentfunds.org/cif/sites/ climateinvestmentfunds.org/files/Project%20Approval%20Request.pdf

UN-Habitat (2009). Guide to Municipal Finance. Nairobi: United Nations Human Settlements Programme.

Most of the funds listed in Table 10.3 may be accessed by national governments through accredited facilities, such as the MDBs, that is through the World Bank, the African Development Bank, the Asian Development Bank, and the Inter-American Development Bank. The list above is not exhaustive; many other funds and programmes are available. When planning to implement a climate proofing activity which may require accessing to international funding, it is recommended to involve representatives from ministries in charge of finance as they are usually the focal point to the Green Climate Fund, and to involve representatives from development banks as they are aware of several sources of funds available, such as specific funds for water and for infrastructure.

Organizations supporting climate change adaptation activities can, therefore, support climate proofing activities. The list is not exhaustive, as there as many other organizations and initiatives such as the following:

- UN-Habitat's Cities and Climate Change Initiative
- Cities Development Initiative for Asia
- Local Governments for Sustainability
- Secretariat of Pacific Regional Environmental Programme
- C40 Climate Leadership Group

- National development cooperation agencies, such as USAID, GIZ, DFID, NORAD

**4.8.2.8 Global Environment Facility**

Established in 1991, the Global Environment Facility is an operating entity of the financial mechanism of the UNFCCC, serving in the same function for the Paris Agreement, with a long track record in environmental funding. It also serves as a financial mechanism for several other conventions, including those of biodiversity and desertification. Resources are allocated targeting multiple focal areas, including climate change, according to the impact of money spent on environmental outcomes, but ensuring all developing countries have a share of the funding. GEF also administers the Least Developed Countries Fund and the Special Climate Change Fund under the guidance of the UNFCCC Conference of Parties (COP). These funds support national adaptation plan development and implementation, although largely through smaller-scale projects (with a country ceiling for funding of USD 20 million).

**4.8.2.9 Adaptation Fund**

The Adaptation Fund is financed through a 2 per cent levy on the sale of emission credits from the Clean Development Mechanism of the Kyoto Protocol. In times of low carbon prices the Fund has become increasingly reliant on grants from developed countries. It has been operational since 2009.

**4.8.2.10 Green Climate Fund**

At COP 16, the Standing Committee on Finance was established under the UNFCCC to assist the COP in meeting the objectives of the financial mechanism of the Convention. The Committee had been tasked with, among other things, preparing a biennial assessment of climate finance flows, the second of which was published in 2016 and detailed flows from 2013–2014 (UNFCCC, 2016). The Green Climate Fund of the UNFCCC was launched in 2011 at COP17 in Durban, South Africa; it became fully operational with its first projects approved at the end of 2015. Climate-resilient and low-carbon development in developing countries with a country-driven approach, and a commitment to an equal balanced allocation of finance to adaptation and mitigation will go a long way in spurring sustainable development. At this moment, the GCF has used its initial allocation of USD 10 billion and is undergoing its first regular replenishment process.

**4.8.2.11 Climate Investment Funds**

The Climate Investment Funds (CIFs) established in 2008 are administered by the World Bank, but operate in partnership with regional development banks. The CIFs supports the Clean Technology Fund and the Strategic Climate Fund (SCF). The SCF is composed of the Pilot Programme for Climate Resilience, the Forest Investment Programme and the Scaling-Up Renewable Energy Programme for low-income countries.

**4.8.2.12 Multilateral development banks**

Multilateral development banks play a prominent role in delivering multilateral climate finance, with climate finance commitments. The World Bank's Carbon Finance Unit has established the Forest Carbon Partnership Facility to explore how carbon market revenues could be harnessed to reduce emissions from deforestation and forest degradation, forest conservation, sustainable forest management and the enhancement of forest carbon stocks (REDD+). The World Bank also manages the Partnership for Market Readiness, aimed at helping developing countries establish market-based mechanisms to respond to climate change. Carbon Finance Unit also manages the Bio Carbon Fund, which is a public-private partnership that mobilizes finance for sequestration or conservation of carbon in the land-use sector. The European Investment Bank administers the European Union Global Energy Efficiency and Renewable Energy Fund.

**BOX 10.1: OTHER INTERNATIONAL FUNDS THAT CAN BE CONSIDERED FOR ADAPTATION AND CLIMATE PROOFING**

Regional Cooperation and Integration Financing Partnership Facility:

- Investment Climate Facilitation Fund
- Regional Cooperation and Integration Fund
- United Kingdom Fund for Asia Regional Trade and Connectivity

Urban Financing Partnership Facility

- Urban Climate Change Resilience Trust Fund
- Urban Environmental Infrastructure Fund
- Cities Development Initiative for Asia
- ASEAN Australia Smart Cities Trust Fund

The African Development Bank with other partners such as Canada, Denmark, and the Netherlands has funded programmes on renewable energy, energy efficiency and climate change, mainly on the promotion of renewable energy, energy efficiency and greenhouse gas; while the Canadian Cooperation Fund for Climate Change and the Danish Cooperation Fund for Renewable Energy and Energy Efficiency have been active in the energy sector. The African Development Bank also finances enhanced climate finance readiness in African countries through the German-funded Africa Climate Change Fund, whose first projects were approved in 2015. The African Development Bank is also the Trustee for the Africa Renewable Energy Initiative (AREI) and will house the AREI Trust Fund with expected USD 10 billion in resources.

The UN-REDD Programme, made operational in 2008, brings together UNDP, the United Nations Environment Programme and the Food and Agriculture Organization of the United Nations to support REDD+ activities, with the governance structure giving representatives of civil society and indigenous people's organizations a formal voice. The International Fund for Agriculture and Development administers the Adaptation for Smallholder Agriculture Programme that supports smallholder farmers in scaling up climate change adaptation in rural development programmes.

#### 4.8.2.13 Bilateral partnership programmes

Bilateral channels for climate finance, a significant share of public climate finance, is spent bilaterally and administered largely through existing development agencies, although a number of countries have also set up special bilateral climate funds. There is limited transparency and consistency in reporting of some bilateral finance for climate change, however, with countries self-classifying and self-reporting climate-relevant financial flows without a common reporting format or independent verification.

#### 4.8.2.14 Mitigation and adaptation market mechanisms

The Nationally Appropriate Mitigation Actions facility supports developing countries and emerging economies that want to implement ambitious mitigation measures. Germany, Denmark and the United Kingdom also support the Global Climate Partnership Fund, managed by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, and KfW, that focuses on renewable energy and energy efficiency through public-private partnership. Germany and the United Kingdom also support the USD 141 million REDD+ Early Movers Programme.

Norway's International Forest Climate Initiative has pledged USD 377 million each year since 2008 through bilateral partnerships, multilateral channels and civil society. Sizeable pledges have been made for REDD+ activities in Brazil, Guyana, Indonesia and Tanzania.

**Market mechanisms**

- Payment for ecosystem services schemes
- Benefit-sharing schemes under Reducing Emissions from Deforestation and Forest Degradation (REDD+)
- Clean development mechanisms (under the Kyoto Protocol)
- Mechanism for Mitigation and Sustainable Development, which constitute a new mechanism to be developed under the Article 6.4 of the Paris Agreement

**4.8.2.15 Role of UNFCCC funds, multilateral and bilateral institutions in delivering climate finance**

Article 4 of the United Nations Framework Convention on Climate Change requires developed countries to assist those developing that are “particularly vulnerable” to climate change in meeting costs of adaptation to its adverse effects. As a result, three funds have been established under the Framework Convention and the Kyoto Protocol to provide funds for assessing, planning and implementing adaptation measures in developing countries. Further adaptation funding is provided bilaterally and by multilateral institutions outside the Framework Convention. Several multilateral and bilateral institutions are aligning their strategies with the Paris Agreement and mainstreaming climate change in their operations and internal reporting. Multilateral and bilateral institutions have difficulty identifying fundable projects, while developing countries encounter challenges in designing quality projects and programmes. This situation creates a discrepancy between supply and demand in climate finance, particularly for adaptation.

**BOX 10.2 THE ADAPTATION BENEFIT MECHANISM**

The Adaptation Benefit Mechanism is an innovative mechanism being developed for mobilizing new and additional public and private sector finance for enhanced climate change adaptation action. It has the potential to speed up transformation to low-carbon, resilient and sustainable development of the host countries by giving value to resilience. It will contribute directly to the establishment of a new business model for adaptation and the achievement of the Sustainable Development Goals, adaptation goals of the Paris Agreement, and other national goals and needs expressed in the nationally determined contributions, NAPs, and so on.

The Mechanism will de-risk and incentivize investments by facilitating payments for delivery of adaptation benefits. The Mechanism will certify the social, economic and environmental benefits of adaptation activities. The value of adaptation action captured in these certificates, including the incremental costs of generating the benefits, will be promoted to potential investors or lenders. The expectation is that verified certificates of the benefits of specific adaptation activities issued by a reputable international organization and based on sound methodological and technical work, in consultations with stakeholders and with the approval of the host country government, will guarantee the credibility of the adaptation activities and increase their attractiveness to potential investors or lenders.

The Mechanism was developed theoretically by the African Development Bank in collaboration with governments from several African countries and various stakeholders. It will be tested in a pilot between 2019 and 2023.

**Source:** African Development Bank (2019)*

* Retrieved on August 2019 at: https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/adaptation-benefit-mechanism-abm

The discrepancy can be alleviated by the following measures:

1. Setting ambitious strategies and actions, in terms of both supporting institutions (supply) and countries (demand), through clear policies and targets.

2. Setting aspirational targets in relation to adaptation finance; clear policies and targets.

3. Further mainstreaming climate change in the agendas of public institutions and the private sector entities in developing countries to reflect commitment for action.

4. Enhancing the support provided to developing countries for designing and implementing quality projects and programmes, including through project preparation facilities and the facilitation of mutual cooperation and collective learning.

Multilateral climate funds consider the need to enhance the coherence of policies related to accessing funds, which would include standardizing requirements.

#### 4.8.2.16 New climate finance instruments

Although insurance is a risk-mitigating instrument, developing countries, and particularly the most vulnerable communities, often face internal and external barriers in accessing insurance and harnessing its potential, including high upfront costs, lack of the data required to assess risk levels, and general lack of access to the insurance market. Enhanced financial support and technical assistance, including from domestic, bilateral and multilateral institutions, could help developing countries to enhance their access to green financial markets over time and scale up the mobilization of financial resources through new climate instruments.

#### 4.8.2.17 Non-market approaches

The Article 6.8 of the Paris Agreement also foresees the development of non-market mechanisms. Based on demands from countries, some organizations are starting to develop and pilot such approaches and mechanisms.

### 4.8.3 National governance

A number of countries have governance structures in place that suit their national circumstances and ensure national and subnational coordination on climate change. However, additional opportunities remain for countries to continue to enhance and align domestic policy environments with their nationally determined plans and strategies. Strong political will and the articulation of climate change in national agendas could help to overcome barriers between ministries and enhance communication with subnational actors. Good practices and lessons learned in relation to overcoming national coordination challenges can be shared among countries, while acknowledging the specific national circumstances of each country.

Engaging a wide range of stakeholders is crucial for assessing the needs and priorities of subnational and local actors, as well as for preparing and implementing inclusive and well-informed climate change projects, taking into consideration the different governance structures and stakeholder engagement policies and regulations within countries. Stakeholder engagement may be enhanced by, inter alia:

1. Financial resources and dedicated budget lines for continuous engagement with relevant stakeholders.

2. A greater awareness of climate change and opportunities that can be harnessed through climate finance.

3. Long-term perspectives on engagement among the stakeholders involved.

4. Guidelines and toolkits on good practices for stakeholder engagement.

5. Joint indicators for demonstrating stakeholder engagement in the planning and implementing phases of programmes and projects.

Micro, small- and medium-sized enterprises (MSMEs) are important actors in the national climate finance architecture because they form the backbone of developing countries' economies. Support, including from domestic, multilateral and bilateral institutions, can help enable MSMEs access climate finance. Several tasks remain in scaling up MSME engagement in climate action and making international climate finance more accessible to them, including providing favourable national enabling environments that will help lower their risk profiles and de-risk investment in them.

Country ownership is key to ensuring that developing countries take the lead in forming and implementing climate projects to meet their needs and priorities. Ensuring country ownership requires a deep understanding of developing countries' needs and priorities on the part of multilateral climate funds and the relevant developing country authorities. In this context, multilateral climate funds and developing country authorities need to communicate closely with each other, including on strategies and approaches for achieving transformative change through country programming and on the latest policies and decisions of the funds.

### 4.8.4 Private sector

Public-private partnerships have been explored for long time in the area of infrastructure development and could be also considered when climate proofing the urban infrastructure are needed.  It is important to build public and private sector capacity and de-risk mitigation and adaptation.  Insurance and reinsurance and the development of new insurance packages would also involve the private sector.  Private sector would be also involved under the market mechanisms.

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# CHAPTER 5:

# MONITORING AND EVALUATION

## 5.1 Introduction

The purpose of monitoring and evaluation (M&E) is to track implementation modalities, demonstrate effectiveness and accountability of the interventions. However, the main challenges associated with M&E of infrastructure climate proofing are likely to be related to the long timescales of project performance and climate change and its impacts. In spite of the foregoing, M&E is critical in ensuring the long-term success of climate proof initiatives, plans and actions. Performance tracking of activities will include those involving stakeholders, pre-identified risk thresholds and trigger levels which were identified during project design. Additional tracking of proposed new actions and adjustments undertaken during project implementation period and determining whether planned outputs and outcomes have been achieved. M&E also demonstrates accountability of local government, industry and other regional managers to their constituents including funders' leveraging continued community support for climate proofing initiatives. It can also improve project performance through evaluation of efficiency and effectiveness thus supporting climate proof management.

## 5.2: Monitoring and evaluation plan for climate proofing infrastructure

There are three principal differences between M&E for traditional management purposes and for adaptation planning. The management time frame for M&E for infrastructure projects is associated with climate change. Climate proofing is the period the project takes as compared to traditional projects. Additionally, there is so much uncertainty associated with the magnitude and nature of climate change, especially at the local level where the scenarios tend to diverge considerably. Climate that is continually changing implies that traditional methods of measuring change, such as results based on static baselines, may not reflect an accurate result.

Each sector monitoring will be dependent on institutional clarity regarding monitoring and data collection. Systematic assembling of data on past and ongoing disaster events, with each event having records of dates, location, deaths, economic losses, number of people affected, and a suitable archiving system to maintain the records and allow easy access will be valuable. The overall goal is to ensure that interventions are moderating climate change impacts and enhancing beneficial project qualities. Recently, and mainly in disaster risk reduction interventions, there has been a trend to examine the change in the adaptive capacity of the community as well.

## 5.3 What to monitor: integrity of infrastructure, floods and drivers, weather, water quality, ecosystem

Developing an M&E plan, including selecting indicators, should take account of the feasibility (technical and expense) of the methods of measurement and the availability of information to calculate baselines and for monitoring. A holistic M&E has the following characteristics: integrated, equitable, sustainable, informed, and responsive. In order to obtain the maximum benefit from the use of the indicators, it is desirable to involve the stakeholders in dialogue on their interpretation and evaluation. The following tasks should be undertaken when developing an M&E plan:

**Task 1:** Establish a baseline. Effective M&E requires a baseline of information regarding the current hazard, exposure, sensitivity and vulnerability situations, in order to monitor changes. If there is no baseline, then incorporate data collection into the M&E plan.

**Task 2:** Methods of collecting information. Include secondary sources, the process for collecting primary information, how the baseline will be established, and how the information will be documented and stored.

**Task 3:** Frequency and timing of information collection and information processing, taking into account whether the primary data collection needs to take place at a particular time of year.

**Task 4:** Determine the location(s) and scale the information to be collected, and by whom.

**Task 5:** Determine who is responsible for information collection and for analysis.

**Task 6:** Who will use the information? And who should receive the information?

**Task 7:** Determine how feedback and evaluation will be monitored and evaluated.

**Task 8:** Determine the cost. Resources needed, costs sustainable or adjust the monitoring plan, ongoing, similar data collection processes that can be built upon.

The selection of indicators will depend on the type of infrastructure to be monitored. All the same, all indicators need to be specific, measurable and quantifiable to have value in a monitoring or assessment-oriented process. It is advisable to select a limited number of indicators that focus on the most essential aspects of the urban infrastructure, such as performance of activities undertaken during the development of climate proofing, identified risks threshold and trigger levels that identify climate proofing or no longer achieving its intended objectives, that is reduction in vulnerability, and determine whether the outputs and outcomes have been achieved. These indicators must be achievable, realistic and time bound to allow sufficient time for the appropriate planning, stakeholder engagement and funding to be achieved for the next action in the sequence. These thresholds can be determined through review of event and performance history, modelling of system performance, or inspection of assets or comparison with other similar projects. The selected indicators should be readily implemented and sustained over many years since climate and the environment of the project will be continuously changing.

Trigger indicators are used to determine when a particular threshold is met and there has been irreversible change. Trigger indicators identify when the specific adaptation action occurs. At this stage, an alternative adaptation action is required. The selected trigger indicators[14] can be physical, environmental, social or economic and may include all or some of the following:

- Physical – the number of flooding events over a certain period
- Environmental – the number of mangrove seedlings per square metre of saltmarsh
- Social – the level of satisfaction with beach visits
- Economic – the costs of insurance premiums

14 Trigger indicates uses words such as measures are quantitative or qualitative, a performance rating systems can be used for reporting purposes, e.g. meeting or exceeding desired outcome or trend, moving towards desired outcome or trend, limited changes towards desired outcome or trend, not meeting desired trend and showing signs of decline, or data unavailable for reporting period.

It is possible to select outputs, immediate and short-term outcomes and long-term outputs while considering scale of monitoring, time horizons and timing of data to allow comparability (Thomsen et al. (2014). For basic infrastructure, the scale for monitoring will be temporal (short, medium or long), management (policy, strategy, legislation) and landscape. There may be a few cases of transboundary issues in climate proofing although this may be too ambitious and costly. Most of climate proof projects are multidisciplinary and interdependent; it may be possible to categorize monitoring indicators in the form of whether they focus on knowledge and learning, capacity-building or focal area and technology based.

**Table 11.1: Categories of indicators applicable to climate proofing project**

| Project schedule | Examples of indicators | Purpose/Limitations |
|---|---|---|
| Pre-project activities | • Stakeholders' engagement on risks, vulnerability<br>• Data collection and analysis<br>• Tools used | To ensure that they can be improved in future learning |
| Threshold/trigger points during implementation | • Observed climate change variables, observed changes on the performance of the infrastructure | Trigger indicators need to be robust to natural climate variability and climate change |
| Performance and outcomes | • Measurable objectives, relationships and correlations | While baseline data may be useful, absolute information may be inadequate |

**BOX 11.1: MONITORING OF THE LIFE+ FUNDED PROJECT CLIMATE-PROOFING SOCIAL HOUSING LANDSCAPES, LONDON**

Groundwork London, in partnership with the Hammersmith and Fulham Council, received LIFE+ funding for the Climate-Proofing Social Housing Landscapes project in 2013. The project, which came to an end in September 2016, has demonstrated an integrated approach to climate adaptation in urban areas by undertaking a package of affordable, light-engineering climate change adaptation measures based around the retrofitting of blue and green infrastructure. The project implemented natural water retention measures (NWRM) such as green roofs, permeable surfaces, swales, rain gardens, infiltration basins.

**Monitoring parametres: Technical monitoring**

- Performance of measures during rain events (for example, infiltration rates) and the development of vegetation captured using fixed-point time lapse cameras at key locations near to the interventions
- Environmental conditions, including the timings and size of rain events, temperature, wind direction and speed, and humidity, monitored using weather stations; this enabled comparative analyses to be made with the fixed-point photo monitoring and other monitoring data
- Aspects such as rainwater inputs and infiltration times monitored using flowmeters at inlets (for example, downpipes from roofs) and pressure sensors in basins, in order to understand the impact of selected rainfall events on surface water run-off, and in turn calculate the amounts of water diverted from reaching the sewer network
- Thermal monitoring using a thermal imaging camera to understand the impact on the urban heat island effect, with a focus on key aspects such as green roofs on particularly hot and cold days, and comparisons made with untreated

surrounding areas. Biodiversity monitoring on the green roofs using vegetation surveys to understand the floral species diversity; percentage of vegetation cover was also monitored

- Photographic monitoring during site visits to create an archive of the development of biodiversity and to monitor elements as they develop and mature; residents were also encouraged to participate in this through a photography competition

- Simulated storm events to assess how selected interventions would perform in a 1 in 100-year storm event (as they were designed for), by pumping water into the intervention and monitoring data readings from the relevant monitoring equipment such as pressure sensors, as well as undertaking photographic documentation and visual assessment

Social Return over the Investment: This measured the benefit of the climate adaptation interventions to local communities beyond their immediate role of improving resilience to climate change - such as community cohesion, understanding of climate change, and awareness of its impacts.

Images: Before and after the implementation of NWRMs

**Source:** Natural Water Retention Project. http://nwrm.eu/case-study/climate-proofing-social-housing-landscapes

## 5.4 Regular review of vulnerability and adaptation options

The process of vulnerability identification and mapping should be an ongoing process, with the exercise repeated at regular intervals to take into changing scientific projections of climate change and socioeconomic development trajectories within the subnational territory. Similarly, adaptation is a dynamic and reflexive process where a strategy evolves over time rather than remaining static. It must co-evolve with many other policies and measures as well as reflect new information on vulnerability. The efficiency of many adaptation measures is still uncertain. An adaptation strategy, and the various options that it contains, should thus also be subject to a review process. Efficiency indicators should be defined and monitoring data collected in order to review change over time. The steering group leading vulnerability mapping and adaptation within the subnational territory should also schedule regular reviews that take into account co-costs and co-benefits. The suite of adaptation options being implemented may vary over time based on the results of the review or improvement process.

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# CHAPTER 6:

# FINAL CONSIDERATION AND WAY FORWARD

## 6.1 Conclusion

The present ongoing climate change has led to increased frequency and magnitude of extreme weather events resulting in flooding, landslides, and damage to property and infrastructure, devastation of agricultural crops, reduction of hydropower generation, and negative impact on human health. Climate proofing of urban infrastructure can be better planned and decisions made in ways that reduce physical exposure and vulnerability through better planning at the very early stages to start with an understanding of resilience-led and performance-based risk. The present vulnerability to climate change will be exacerbated by the presence of other stresses, while future vulnerability depends not only on climate impacts but also on a sustainable development pathway. This will result in a wide range of options being considered, before arriving at an appropriate design and construction. This will also need to ensure harmony between the urban infrastructure and other country, regional, city and sector strategies that are resilient and environmentally sustainable.

The toolkit contains useful technical steps to integrate climate change risks and opportunities into the design of urban infrastructure and key principles for making infrastructure more resilient. Naturally, there will be an increased cost to climate proof infrastructure, but the cost will be better spent here rather than budget for outages and expensive repairs.

The impacts of climate change are already resulting in huge economic, social and environmental damage, especially in urban areas of developing countries. The toolkit supports participation of stakeholders in planning and design of community infrastructure, and favours the enhancement of resilience of communities rather than providing projects based on economic investment rationale alone. From a practical point of view, this means governments and multilateral financial institutions will need to spend more for a climate-proof bankable project. This is required to plan properly for urban infrastructure that enhances resilience and that reduces any unintended maladaptation and further vulnerability to current and future climate risks.

Bridge in Songyang, China.
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# Annex 1: Indicative list of software packages and web applications for generating climate change projections steps for climate risk management

## Quantitative Risk Assessment System

Understanding risk and having the right strategies in place when an incident occurs is becoming more evident and essential. Increasingly, organizations are faced with the need to measure and reduce their risks. A successful and effective approach to risk management critically depends on the ability to answer key questions of the following nature:

- What are the most likely risk scenarios and how severe would the consequences be?
- What elements in our system or organization are the major contributors to risk?
- How will our risk be affected by changes to the system or organization?
- How confident are we about the answers to the above, and how can we increase our confidence?
- Do you have to analyse multiple or single factors to address the uncertainties when reducing your risk? Do you consider such factors as: systems, processes, organization, people, communication and unforeseen elements as part of your risk assessments?
- Do you need to construct scenarios with many elements or factors during your risk assessment?
- Do you consider elements that could adversely affect your organization's mission, proposal, production, finances, design, acquisition, schedule, requirements and management?
- Do these elements or factors pose a threat or potential risk on their own or have an effect on other parts of the organization?

ITEM Quantitative Risk Assessment System (iQRAS) can help identify the risks, find the major contributors, effective ways to reduce the risks, and improve your understanding. The initiating event integration with time lines, event sequences, failure probability characterization, risk ranking, and sensitivity analysis, provides you with a powerful, integrated, risk analysis environment. Other Probabilistic Risk Assessment tools cannot match the unique integration of capabilities in iQRAS.

## Annex 2: Additional materials

The toolkit deals with urban infrastructure especially in poor neighbourhoods. Additionally, country criteria have not been incorporated to flag risks of exposure, sensitivity and adaptive capacity. The aim was for replicability and the potential for transformative change. It is a similar approach to where screening is incorporated into a strategic environmental assessment.

For users who want more detail on analytical issues, this information can be found in a number of manuals, handbook and sourcebooks elaborated by international organizations and donor agencies. The list is not exhaustive but represents selected ones that have been referred to in the toolkit.

- UNFCCC's Handbook on Vulnerability and Adaptation Assessment (http://unfccc.int/resource/cd_roms/na1/v_and_a/index.htm)
- UNEP Sourcebook, 2008;
- Climate Proofing: A Risk-based Approach to Adaptation, ADB 2005;
- Adapting to Climate Variability and Change: A Guidance Manual for Development Planning, USAID 2007;
- OECD Guidance on Integrating Climate Change Adaptation into Development Cooperation, OECD 2008.
- What is Critical Infrastructure? Available at http://www.dhs.gov/what-critical-infrastructure.

Additional information on adaptation initiatives supported by the following organizations was also considered in the preparation of this toolkit.

- African Development Bank
- Asian Development Bank
- Organization for Economic Co-operation and Development/Development Assistance Committee
- United Nations Framework Convention on Climate Change
- Intergovernmental Panel on Climate Change
- UN-Habitat
- United Nations Environment Programme
- United Nations Institute for Training and Research
- World Bank
- Danish International Development Agency (DANIDA)
- German Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit)
- International Institute on Sustainable Development
- International Institute for Environment and Development
- Stockholm Environment Institute
- International Union for Conservation of Nature
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- UNDP Prioritization of Climate Change Adaptation Options. The Role of Cost-Benefit Analysis. Accra, Ghana October 25 to 28, 2016
- Economic framework for analysis of climate change adaptation options. Australian Department of Climate Change and Energy Efficiency

# Annex 3: Community-based Risk Screening Tool – Adaptation and Livelihoods

CRiSTAL is a project-planning tool that helps users design activities that support climate adaptation (that is adaptation to climate variability and change) at the community level. CRiSTAL stands for "Community-based Risk Screening Tool – Adaptation and Livelihoods."

- Community-based – CRiSTAL focuses on projects at the local community level
- Risk Screening – CRiSTAL helps users to identify and prioritize climate risks that their projects might address
- Adaptation and Livelihoods – CRiSTAL helps users to identify livelihood resources most important to climate adaptation (that is, adaptation to climate variability and change) and uses these as a basis for designing adaptation strategies

While climate variability and change may not always be the most important stresses affecting a specific community, they should always be considered when designing and implementing a development project, particularly in communities characterized by climate-sensitive and/or natural resource-dependent livelihoods.

Indeed, any activity that does not account for present and future potential climate risks may inadvertently increase a community's exposure and vulnerability. For example, a food security project may encourage dependence on a particular agricultural technology or crop species that may be negatively affected by climate change, thereby increasing local vulnerability in the longer term. CRiSTAL seeks to assess, systematically, the impacts of a project on some of the local determinants of vulnerability and exposure, so that project planners and managers can design activities that foster climate adaptation.

New versions of the CRiSTAL tool and the User's Manual are now available in English, Spanish and French. Available at https://www.iisd.org/cristaltool/

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