ADAPTING URBAN WATER SYSTEMS TO CLIMATE CHANGE

A handbook for decision makers at the local level

SWITCH
SIXTH FRAMEWORK PROGRAMME
ICLEI Local Governments for Sustainability
IWA International Water Association
UNESCO-IHE Institute for Water Education

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www.switchurbanwater.eu

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Key messages

- Adaptation is not new – city and water managers are used to dealing with uncertainty and change.
- Adaptation can help improve quality of life and the functioning of urban systems – cities should capitalise on the benefits that adaptation can offer.
- Adapting to climate change can happen at different scales, from the household level through to major infrastructure – no matter the scale, what is important is to take action now.
- The urban water system is highly vulnerable to climate change – without foresight and strategic planning, the consequences can be severe.
- It is often the most vulnerable people that bear the brunt of climate change – urban water system responses to climate change must take their needs into account.
- Climate change will not always happen in a gradual or linear way – cities have to be prepared to deal with the possibility of abrupt change.
- Cooperation with researchers and local experts is essential – decision makers need their expertise to better grasp the implications of uncertainty and take effective action.
- The urban water cycle cannot be adapted in isolation – the close linkages between urban systems such as energy, transport and health require integrated management.
- Sound water management needs to take all pressures on water systems into account – including those unrelated to climate change such as population growth, land use changes and pollution.
- Many cities are adaptation champions – other cities can learn from their experience and take action themselves.

Contents

Refers to another section of the handbook where more information can be found

SWITCH — Refers to SWITCH resources available on the SWITCH Training Desk website (*www.switchtraining.eu*)

Refers to a case study available on the handbook's website (*www.adaptationhandbook.org*)

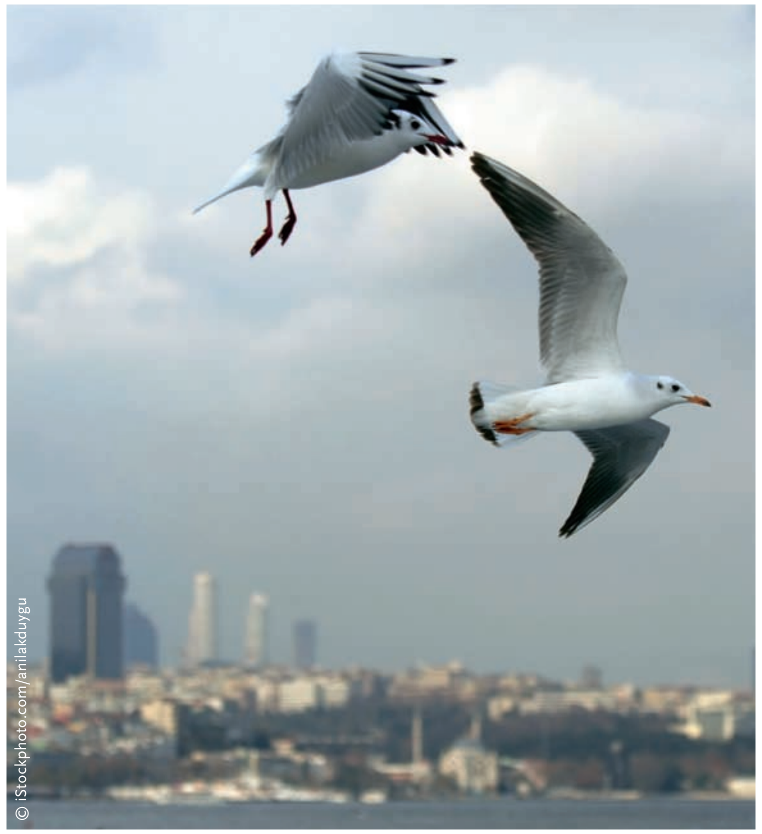
Refers to an external source of information that is not found on the websites above

Introduction

This handbook on adaptation of urban water systems to climate change is an initiative of the SWITCH project[1] and the result of a collaboration between ICLEI – Local Governments for Sustainability, the International Water Association (IWA) and the UNESCO-IHE Institute for Water Education. It draws on the research and findings from the SWITCH and PREPARED[2] EU Framework Programme projects. This handbook is a "living" document that is envisaged to be updated yearly with new information and experiences and is complemented by a website with additional information (*www.adaptationhandbook.org*).

An adaptation handbook for cities

Adaptation to climate change is the subject of increasing interest and research efforts. As a result, large amounts of information, studies and reports are available about topics such as climate projections, vulnerability assessment or practical adaptation options. However, there is a lack of guidance for decision makers at the local level who wish to proactively prepare for and adapt to climate change. Missing is also single 'home' for this information.



Building upon the wealth of knowledge within ICLEI, IWA and UNESCO-IHE as well as the vast quantity of information that has been or will be assembled during the SWITCH and PREPARED projects, this handbook – and its accompanying web pages – aims to be that home. The handbook will provide local governments and utilities with up-to-date information as well as access to resources and good practice examples. This will enable them to increase their awareness of how the potential impacts of climate change will affect their urban water systems and to build their capacity to develop a long-term strategy for adaptation in the water sector.

Climate change will disproportionately affect cities since these concentrate populations and economic activity and are mostly located in climate-sensitive areas such as floodplains and coastal zones. The urban water system – which includes water supply, wastewater and stormwater – is particularly at risk because climate change will mainly manifest itself through alterations in the water cycle. More variability and the increased occurrence of extreme weather events are predicted with a reasonable amount of confidence, in spite of some uncertainty. Some of these changes are already happening, and require cities to take urgent action.

[1] 'SWITCH – Managing Water for the City of the Future' was an action research project, implemented and co-funded by the European Union and a cross-disciplinary team of 33 partners from 15 countries around the world. The project ran from 2006 to 2011, and its aim was to bring about a paradigm shift in urban water management away from existing ad hoc solutions towards a more coherent and integrated approach.

[2] 'PREPARED Enabling Change' is a project running from 2010 to 2014 that will work with a number of urban utilities in Europe and worldwide to develop advanced strategies to meet anticipated challenges in the water supply and sanitation sectors brought about by climate change.

Luckily, it is possible for cities to increase their ability to adapt to climate change while at the same time increasing their overall sustainability and quality of life. This handbook illustrates some of the options that are available to make this happen.

The handbook does not aim to cover all aspects relating to adaptation or to present a complete picture of the origins and consequences of climate change, but rather aims to distil the most relevant aspects for urban water management. For example, the handbook details the main anticipated impacts of projected climatic variations on urban water systems and services, but does not go into scientific explanations about the causes of climate change. For this and other topics, the necessary background information is readily available if needed – some links are provided on the handbook's website.

Target audience

This handbook is aimed at local governments and utilities in cities of all sizes in both developed and developing countries. Certainly, much of its content has been drawn from the experiences of larger developed country cities, due to their greater familiarity with adaptation planning and implementation. However, the methods and concepts laid out in this handbook are applicable at all scales and levels of economic development, since adaptation is not merely a matter of available finances but also of knowledge and sound planning. A lot can also be achieved through the accumulation of individual adaptive actions.

The handbook will be most useful for mid-level managers and strategic planners within utilities or relevant local government departments who are responsible for taking decisions in the area of urban water management. Indeed, such managers and planners possess the necessary background both to understand the wider implications of climate change and to grasp the practical realities of adapting to it, and are thus able to initiate real change but also to wield influence at the political level.

About the handbook and its supporting website

This handbook is the cornerstone of a wider effort: indeed, it is accompanied by a website containing a wide range of supporting resources, which include copies of the full case studies that are summarised in the handbook. It is envisaged that both the handbook and website be regularly updated to include new research results, examples from cities and in-depth analysis of selected focus areas. Since the handbook and website are intended to meet practical needs, suggestions on what could be added or changed are welcome (contact: *water@iclei.org*).

The structure of the handbook seeks to answer a logical sequence of questions: What are the problems? How can they be overcome? What are others doing to overcome them? Section 1 outlines the key areas of vulnerability to climate change within urban water systems, while strategic planning based on stakeholder involvement is explained in Section 2. Finally, Section 3 presents the highlights from a series of case studies which showcase cities that have already planned for adaptation or implemented specific actions aiming at increasing their resilience to climate change. Annex 1 defines some of the key terms that will be used throughout the handbook.

❶ Vulnerability of urban water systems in the face of climate change

Climate change will mainly manifest itself through sea level rise and an intensification of the hydrological cycle, which will entail more frequent and intense rainfall as well as extended dry periods. As a result, a city's water supply, wastewater and stormwater systems will be particularly affected. Climate change's impacts on the urban water system typically has knock-on effects on other urban systems since water plays such a fundamental role in the functioning of such systems as well as in maintaining quality of life in a wider sense.

This section of the handbook draws out the main sensitivities of urban water supply, wastewater and stormwater systems to climate change. It presents a brief review of climate change then shows how the main climate change hazards that are anticipated might affect urban water systems. Finally, it outlines some of the institutional and social dimensions of climate change.

1.1 Climate change: a summary

The energy balance of the earth, which determines the functioning of its climate system, depends on a number of factors. Some are natural, such as variations in solar energy, and some are anthropogenic in origin, such as changes in the quantity of greenhouse gases present in the atmosphere. Carbon dioxide is the main greenhouse gas released by anthropogenic activities; others include methane and nitrous oxide. The greenhouse effect means that increased concentrations of these gases in the atmosphere prevent the release of some thermal infrared radiation into space and lead to increased temperatures in the earth's atmosphere and at its surface.

For an authoritative and in-depth summary explanation of the scientific basis for climate change, including its underlying causes, see the Summary for Policymakers of the IPCC's Working Group I (IPCC, 2007).

According to the Intergovernmental Panel on Climate Change (IPCC) there is very high confidence that greenhouse gases emitted because of human activities since the Industrial Revolution have led to the observed warming effect (IPCC, 2007). Although the term 'global warming' is not technically a misnomer, it has been applied in misleading ways and should be used sparingly, since it does not reflect the range of impacts of climate change. One of the main consequences of the change in the earth's energy balance is that the global hydrological cycle will be intensified and accelerated, a fact with specific implications for water management, as will be shown in Section 1.2.

In discussing climate change manifestations and impacts, it is vital to bear in mind the implications of uncertainty and variability. Also, system pressures that are not related to climate change should be given appropriate recognition. These points will be discussed in the next three sub-sections.

Uncertainty

The uncertainty related to climate change science derives from a number of factors, including:

- regional data gaps;
- deficiencies in the understanding of natural systems;
- the fact that predictions of climate change are based on the use of models that cannot consider all factors linked to climate systems; and
- the limitations of emissions scenarios which can only estimate future greenhouse gas emission levels.

The confidence in IPCC projections is also lower at smaller spatial scales and for certain manifestations such as precipitation. For water managers, the usefulness of global climate models is limited by the spatial and time resolution of their data, which is often not available at the catchment scale (Bergkamp, Orlando & Burton, 2003).

Working with uncertainty is one of the 10 guiding principles for good practices in adaptation developed by the ETC/ACC; these are in line with the concepts developed in this handbook (Prutsch, Grothmann, Schauser, Otto & McCallum, 2010).

Nevertheless, the uncertainty inherent within climate change science should not be confused with scepticism about the anthropogenic causes of climate change. Warming of the climate system has been unequivocally proven, attribution of warming to human activities is almost certain and some impacts can already be observed. Climate models are constantly being refined and supplied with additional data, meaning uncertainty does not remain constant but is reduced with time.

Uncertainty linked to climate change science should not be regarded as a barrier to action. Instead, it should be one of the numerous factors to consider when undertaking any planning exercise. Uncertainty linked to many other factors, such as population growth, is already allowed for within water management.

Despite this future uncertainty, plans still need to be developed. This implies a certain risk; however, there are ways to minimise it. In terms of adaptation, for example, a city can begin with no- or low-regret actions that can minimise costs, disruption and side effects without entailing major investments. This handbook presents this and other approaches for managing uncertainty.

Regional and temporal variability

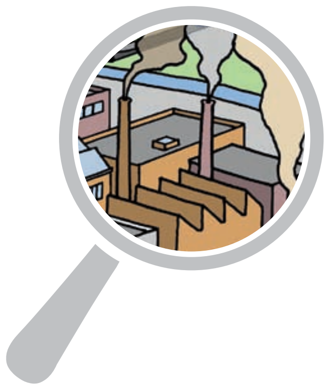
Discussions about climate change are often accompanied by generalisations: 'heat waves will be more common' or 'rainfall will increase.' However, the difference between global mean levels and specific local manifestations should be kept in mind. Examples abound: While global mean surface air temperature is indeed expected to increase, this increase will be subject to regional differences, with land surfaces and high northern latitudes experiencing the greatest warming. Globally averaged mean precipitation is also projected to increase but that in the subtropics to decrease.

A regional breakdown of climate change impacts on water resources can be found in the IPCC's Technical paper on climate change and water (Bates, Kundzewicz, Wu and Palutikof, 2008).

Some regions will also experience multiple manifestations: for example, mean precipitation will decrease in subtropical and mid-latitude regions, but, since the intensity of rainfall will also increase, longer periods will pass between rainfall events (Bates, Kundzewicz, Wu & Palutikof, 2008). A city might therefore be confronted with both flooding and drought within a relatively short time span. These examples of regional variability highlight the need for cities to make use of projections downscaled to a more precise scale: see Section 2.1 for more information.

Perth's experience of non-linear climatic change and its approach to dealing with variability are presented in Section 2.1.

Variability will also manifest itself on a temporal scale: long-term trends will interact with short-term ones, and greater climatic variability will lead to an increase in the frequency of extreme events (UN-Water, 2010). In addition, climatic variability will not always occur in a gradual linear way. Instead, the predictability of climate change is reduced by the fact that step changes can and do happen, with climatic conditions shifting from one state to another radically different one in a short period of time. As a result, although long-term climatic predictions are useful, cities should also prepare for the possibility of abrupt change as part of their planning.



Other pressures on water systems

Although the public and decision makers have become more aware of climate change, it is vital not to lose sight of the dominant role of the impacts of other human activities on freshwater and related systems. In many cases, the effects of other anthropogenic interventions are hard to separate from the effects of variations in climate. For example, river flows are substantially affected not only by climate-related precipitation and temperature patterns, but also by human activities such as dam building, land use changes and pollutant loads. Similarly, observed decreases in groundwater levels should first and foremost be attributed to overabstraction rather than climate-driven changes in recharge rates (Bates, Kundzewicz, Wu & Palutikof, 2008).

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Human activities can exacerbate the negative impacts of climate change by increasing the vulnerability of systems to a changing climate (Bates, Kundzewicz, Wu & Palutikof, 2008). While this handbook only focuses on adaptation to the impacts of climate change on the water cycle, it takes as a central assumption that sound planning should take all driving forces into consideration. In some cases, placing the focus exclusively on climate change may lead a city to miss more obvious leverage points, which might be more cost-effectively addressed and lead to better results and greater co-benefits. Attribution of impacts to driving forces should therefore be a key exercise within a city's assessment of its baseline situation.

1.2 Sensitivity within urban water systems

Cities concentrate population, infrastructure, economic activity and wealth, and will therefore be disproportionately affected by the local impacts of climate change. In addition, cities located in coastal areas and/or on the banks of rivers are particularly vulnerable to sea level rise and flooding. Cities are also characterised by the predominance of impermeable surfaces – which are less capable of absorbing increased rainfall and therefore increase the intensity of rainfall runoff – and are prone to the urban heat island effect which amplifies heat waves.

Finally, as population growth will overwhelmingly take place in cities, urban water managers will face a growing challenge to maintain safe and adequate water supplies and wastewater services for urban residents. Urban population growth in the next decades will take place at a very rapid scale and mostly in developing countries, exacerbating many of the problems linked to urban poverty, increasing the size of vulnerable populations in cities and placing additional pressure on dwindling supplies of resources such as water (Pageler, 2009).

The vulnerability of urban water supply, wastewater and stormwater systems to climate change is outlined in this section. These systems will be strongly affected by the various manifestations of climate change, with impacts primarily relating to their physical infrastructure but also to their functionality.

This section is supported by the table in Annex 2 which presents a selection of examples of the impacts of some predicted climate change manifestations. The table mainly focuses on urban water but also touches upon other urban sectors which are strongly related to water, such as energy, health, food production and green spaces. Annex 2 is intended as an illustration of the variety of impacts which can be anticipated and of the links between the water sector and other urban sectors. This section of the handbook is also accompanied by the illustration on pages 28 and 29, which shows some of the main challenges of climate change for cities.

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Water supply

Water supply will suffer from most of the anticipated manifestations of climate change, whether in terms of water quantity or quality. Flows into rivers, lakes and reservoirs as well as groundwater will be affected:

- Sea level rise can reduce the availability of potable water through saltwater intrusion into aquifers and estuaries.
- Water supply will be reduced by altered precipitation patterns and increased temperatures (which increase evapotranspiration).
- Security of supply is negatively affected by droughts both directly, since these reduce streamflow and inflows into reservoirs, lakes and groundwater, and indirectly, for instance through the increased occurrence of wildfires. In Australia for example, wildfires followed by vegetation regrowth significantly reduce catchment yields (Howe, Jones, Maheepala & Rhodes, 2005).
- The seasonality of water supply levels may change, particularly in regions where spring snowmelt is the main source of water. Reduced winter rainfall will affect the recharge period of groundwater, lakes and reservoirs. Many Latin American countries dependent on snow and glacier melt have already seen reductions in available water. In Peru for example, freshwater availability at the coast, where over half of the population is concentrated, has seen a reduction of 12% over a period of 35 years (Bates, Kundzewicz, Wu & Palutikof, 2008).

Turbidity increases: a big concern?

The increased occurrence and intensity of rainfall events can cause erosion within lake or river catchment areas and raise the turbidity levels of water. This turbidity can affect water quality even if the eroded soil is not particularly polluted. Turbidity affects drinking water production by interfering with disinfection processes, by requiring greater expenditure for coagulants and handling of solids and by overloading process functionality. It is a particular concern for cities such as New York City that do not filter their drinking water supply, as it can require the very costly installation of filtration systems if alternative means to control erosion are not put in place (Zwolsman et al., 2009).

Water quality is an important component of water supply, since it determines to what extent water needs to be treated prior to its use for drinking or other purposes such as irrigation. Changes in water quality therefore affect water users but also increase the cost of services. Water quality will be affected by flooding, through erosion and consequent turbidity increases, increases in non-point pollution, but also through damage to wastewater treatment plants and consequent bacterial contamination of water. It will also be affected by increased temperatures, which have an effect on the chemical and biological characteristics of water bodies, and by decreased precipitation which concentrates pollution. Consequences for certain water sources will have knock-on effects on others: precipitation decrease and its impact on surface water will result in increased water abstraction from groundwater and from sources with lower water quality (Bates, Kundzewicz, Wu & Palutikof, 2008).

The physical infrastructure of water supply will be negatively affected by flooding, through direct damage to pipelines and facilities, sedimentation of reservoirs as well as overloading of capacity. For example, infrastructural damage resulting in power cuts affects the ability to pump water. Climate change can also reduce the functionality of drinking water treatment, by for example lessening the effectiveness of treatment processes such as chlorination or causing overly high disinfection by-product levels in distribution systems (Zwolsman et al., 2009).

Functionality is affected by increased temperatures, which favour the proliferation of equipment-clogging algae and lead to greater expense for treatment to remove the taste and smell linked to bacterial and fungal growth. Unanticipated colder temperatures also affect functionality by freezing water in pipes which then leads to cracks and leaks, as happened in Ireland during the winter of 2010/2011. Pipes can also crack because of the drying of soils during drought conditions. Moreover, certain management decisions made as a response to climate change events can have consequences for water supply: for example, setting aside reservoir capacity as a flood absorption buffer can decrease drinking water availability.

Water supplies will also be affected by climate change driven alterations in water demand. Increased temperatures will increase water demand for all consumptive uses – barring efficiency improvements – and might therefore lead to stronger competition for water resources or require the sourcing of alternative water supplies. Water use in New York City for example increases by 11 litres per degree centigrade once temperatures go above 25°C (Protopapas et al., as cited in Kundzewicz et al., 2007). A related point is that in the context of reduced water availability, meeting any existing minimum ecological flow requirements will become more challenging, and could put into question drinking water production licence renewals (Zwolsman et al., 2009).

Wastewater systems

Much like water supply, the integrity and functionality of wastewater treatment infrastructure will be affected by climate change. The infrastructure of collection lines and wastewater treatment, including outfalls, pipelines and tanks, can be physically damaged by coastal flooding linked to sea level rise and also by flooding caused by increased precipitation. The functionality of wastewater treatment can also be reduced by flooding: in the case of cities with combined sewer systems, heavy rainfall events can overwhelm wastewater treatment capacity, which usually results in increased overflows. Coastal flooding can increase the salinity of influent and thereby disrupt biological processes and potentially affect the re-use of treated wastewater. Extreme events can challenge wastewater treatment plants by diluting or concentrating inflows, in the case of floods or droughts respectively.

Functionality is also impaired by increased temperatures: these can have both positive and negative consequences for wastewater treatment (Bates, Kundzewicz, Wu and Palutikof, 2008). Higher temperatures coupled with reduced rainfall can lead to increased pipe breakage due to drying of soils as well as increased deterioration of pipes due to corrosion from hydrogen sulphide build-up (Zwolsman et al., 2009; Howe, Jones, Maheepala and Rhodes, 2005). Wastewater management can also be indirectly influenced, for example if increased temperatures affect the oxygen levels of receiving water bodies and therefore lead to more stringent wastewater treatment requirements in order to stabilise these levels so as not to endanger ecosystems.

Stormwater and drainage systems

Drainage or stormwater systems will be most affected by the increased occurrence and intensity of precipitation. As rainfall becomes more intense, surface runoff levels can exceed the capacity of stormwater entry points or cause sewer overflows in combined sewer systems. This can cause street flooding, with associated health dangers due to contamination, but can also increase the cost of meeting related regulatory requirements. Combined sewer overflows are a problem linked both to stormwater and to wastewater: excess stormwater causes overflows, but the conveyance of wastewater by means of combined pipes is also at the root of the problem. In London, for example, discharges from combined sewer overflow outlets into the Thames River can occur between 50 and 60 times per year, and heavy rainfall can lead to over a million tonnes of a combination of untreated sewage and rainwater entering the city's rivers (Greater London Authority, 2009).

In addition, drying and shrinking soils caused by droughts can generate cracks in stormwater drains and sewers. This can lead to problems of contamination but also increases maintenance costs. Changes in vegetation and soil characteristics due to increased temperatures and higher rates of evapotranspiration can also change attenuation and infiltration rates, affecting soil retention capacity.

Increased heavy precipitation and more frequent and severe cyclones can cause riverine and coastal flooding and overwhelm city defences. Although the link between these two events and climate change has not been proven, the 2011 flooding in Queensland, Australia, and the hurricane-driven storm surge in 2005 in New Orleans, U.S.A., serve as reminders of the catastrophic impact of extreme weather events on urban areas and society in general. Hurricane Katrina cost New Orleans $30 billion in damage, destroying over 160,000 homes (Waggonner & Sternad, 2010). The costs and consequences of flooding are increased by growing population density and economic activity in at-risk areas, as well as by the existence and spread of informal settlements in developing countries. The dominance of impermeable surfaces in cities exacerbates the problems caused by heavy rainfall.

Sensitivity within water-reliant systems

Apart from water-related infrastructure, cities are also supported by a number of other systems which are at least partly reliant upon water. These include transportation, energy supply, health, food production and green spaces. Some impacts will be caused by the systems' direct reliance upon water: one example within the energy supply system is hydropower, whose ability to produce energy is governed by the availability of water. Another example is the food production system which is dependent upon the timely availability of sufficient quantities of water. Both of these systems will be altered by projected changes in the quantity, seasonality and geographical distribution of precipitation.

Other impacts will be caused by indirect effects, where climatic events damage the infrastructure – production, distribution or other – related to urban systems. Flooding for example can harm health infrastructure components such as hospitals, creating indirect health effects by preventing provision of and access to health services, and can also affect food distribution by damaging the transport network.

The links between the water sector and other sectors also work in the reverse direction: for instance, effective wastewater treatment is strongly reliant upon the regular and affordable provision of electricity, which may be affected by climate change. The strong links between urban management sectors build the case for management of urban water that features flexibility and integration, as shown in Section 2.1.

For more examples of the connections between water and energy, see the box on the water-energy nexus within Section 2.1.

1.3 Social and institutional dimensions of climate change

The social and institutional dimensions of climate change are often neglected in the debate; however, water managers should take them equally into account since they have a direct – even if not always obvious – link to urban water planning and management. This section gives a brief overview of some of these dimensions.

Migration

The impacts of climate change are likely to increase human migration, particularly since large numbers of people live in coastal regions and floodplains or are dependent for their livelihood on sectors that will be disproportionately affected by climate change, such as agriculture. According to the UN's World Water Development Report, anywhere from 24 to 700 million people could become displaced for environmental reasons (United Nations World Water Assessment Programme, 2009). This displacement could lead to negative social impacts not only for the displaced populations but also for those regions they relocate to. In the case of rural people dependent on agriculture, their migration to urban areas will place added strain on urban water management.

Equity

Equity here can be thought of as fairness: fairness both in terms of which groups will suffer most from climate change impacts and in terms of the differing capacity of these groups to adapt to them. Developing countries are responsible for a far smaller amount of greenhouse gas emissions – both currently and historically – but paradoxically bear the brunt of climate change hazards and have less adaptive capacity to deal with them. Equity also considers differences in socio-economic levels as a key factor in determining vulnerability, with the less developed economies of developing countries rendering them more susceptible to climate change than developed countries.

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Socio-economic equity is however a consideration in all countries, since the most marginalised segments of society within both developing and developed countries will be disproportionately affected. These include women, the elderly and sick, racial minorities and the poor. The increased vulnerability of these groups is linked both to their sensitivity, since they tend to live in areas that are more easily affected by natural disasters, and to their lack of adaptive capacity. For example, racial minorities in the U.S.A. tend to live in inner cities, which are more affected by the urban heat island effect. Poor people are also more likely to live on lower-value land such as flood-prone areas or steep hills that suffer from landslides, such as those in cities like Caracas or Rio de Janeiro (Wilbanks et al., 2007).

Overall, the poor devote a higher proportion of their income to basic necessities such as food, energy and water, and are therefore hit harder when scarcity drives the price of these resources up. As freshwater becomes scarcer, it can become more costly and access to it becomes a function of the wealth of an individual or a community. Climate change can therefore compound the problems linked to poverty, which creates a vicious circle where diversification or relocation becomes impossible. Finally, women in developing countries are overwhelmingly responsible for sourcing water for their households, and will be more affected by increased scarcity.

Multi-stakeholder involvement is a way to increase the likelihood that the needs of all water users are sufficiently considered, regardless of their income level or political power. For more information, see Section 2.2.

Water allocation

Another aspect linked to water is that of the water rights that govern its allocation. Although water rights are not usually determined at the city level, they do strongly influence the availability and management of water for urban areas, since water rights underlie the services provided by water management infrastructure as well as the institutions that manage it (Ludwig & Moench, 2009). Catchment-scale water management principles push for the allocation of water towards its most economically efficient use, particularly in the context of water scarcity, which means that cities will often be given priority.

The societal implications of this should be kept in mind; for instance, since agriculture tends to use water in the least technically and economically efficient way, it should theoretically be the sector that sees water allocation reductions in scarcity situations. This can have important consequences for communities dependent upon agriculture, and can result in diversification (where possible) or in rural-to-urban-migration. Shifts in allocation can be done in a planned way, as in Melbourne, Australia, where water trading takes place between the city and agricultural users of the Murray-Darling Basin.

Insurance

The core business of insurance involves the prediction of probabilities of loss. Climate change increases the likelihood, location and magnitude of extreme weather events and also decreases the predictability of weather. Consequently, the viability of methods used to estimate risk and calculate loss used by the insurance industry will be put into question. The insurance industry also tends to use historical data as a basis for decisions, and is moreover less able to rely on the use of climate models, since these cannot help in the production of quantitative risk assessments based on probabilities.

In sum, insurance institutions will play a reduced role in spreading risk in society. As private companies with profit as a main motivation, they may withdraw from high-risk areas, leaving governments – and ultimately taxpayers – as insurers of last resort (Ludwig & Moench, 2009). Cities may choose to buy out uninsured (or uninsurable) riverside landowners rather than face important costs in case of floods, as is being done in the city of Moorhead, Minnesota (Federal Emergency Management Agency, n.d.).

Encouraging exposure reduction: The Lloyd's approach

Some insurers think the insurance industry has an important role to play in encouraging the climate-proofing of society (Lloyd's, 2006). They promote:

- Moving away from pricing risk based on historical trends.
- Building incentives for the appropriate management of risk within insurance policies by for example placing limits on contents insurance so that steps are take to protect valuable property.
- Finding ways to restrict population concentration in risk-prone areas.
- Being able to adequately price risk, free of regulatory action, while recognising that the future pace of climate change may ultimately limit insurability of climatic hazards.
- Being open to withdrawing or restricting insurance cover in overly risk-prone areas.

Other institutions

Institutions, particularly those at the governmental level, will be affected by climate change mainly because of the increasing demands for resources and services – such as health care, energy and emergency response – that climate change will place on them. They will also have to handle the increasing expenditure that dealing with climate change manifestations can involve. Such costs might have to be met through increases in revenues or decreases in other services, and may place further stress on already overextended institutions (Wilbanks et al., 2007). These facts strengthen the case for strategic and integrated planning using flexible and lower-cost options and technologies, as reviewed in Section 2.

Financing adaptation in cities

A significant proportion of the average costs of adaptation to climate change will include costs linked to cities, largely because of the expense required to adapt – or build new and resilient – infrastructure and services. Although exact figures are not yet available, it is clear that a large amount of additional investment will be needed if adaptation is to be seriously addressed. In addition, many of the costs of adapting cities – particularly upgrading housing stock – will be borne by private individuals. Estimates based on the costs of adapting infrastructure thus do not represent the total cost of adaptation. At present, the scale of funding available falls far short of what is needed, and what little exists gives unsatisfactory attention to urban areas.

While enhancing financial capacity seems to play a role in driving current adaptation responses, it is to a lesser degree than could be expected: several cities around the world have started to initiate adaptation, often irrespective of national frameworks being in place. City networks are also being set up: these can stimulate national policies and act as a positive example, providing an important venue for the transfer of knowledge and technology. City networks exchange good practices on a wide range of issues: one example is Connecting Delta Cities.* Ultimately, the success of adaptation in cities critically depends on the availability of necessary resources, not only financial and natural, but also linked to knowledge, technical capability, institutional resources and targeted tools (Bakker, 2010).

* *http://www.rotterdamclimateinitiative.nl/nl/delta_cities_website/home*

To conclude Section 1, it can be said that although uncertainty remains regarding the expected manifestations of climate change, the likely impacts of climate change on urban water systems are important enough that they cannot be ignored by water managers. Section 2 highlights the importance of applying a planning process that is based on forecasts and scenarios and is designed to deal with uncertainty and changing conditions.

❷ A strategic planning framework for adaptation

It can be hard for a city to know where to begin its process of adaptation. Strategic planning provides the necessary framework for taking an integrated, flexible and long-term approach to water management and for the planning and implementation of successful adaptation actions.

2.1 Addressing climate change vulnerability through integration

Flexible and future-oriented urban water management

In responding to the twin challenges of planning in times of climate change – the uncertainty of climate predictions and the fact that a greater diversity and higher frequency of outlying weather events will have to be considered – the current approach to water management is at a disadvantage and renders water systems more vulnerable to climate change. Indeed, the typical approach tends to address existing problems through large investments in a limited range of long-established technologies. This hard infrastructure, and the inflexible institutions that underpin them, are not well designed to cope with changing and uncertain conditions. Conversely, a flexible system based on long-term planning is more readily compatible with the characteristics of climate change and the requirements of adaptation.

'Stationarity is dead'

Taking a long-term view is certainly not a new approach within water management; indeed, given their big price tags, planning for the future is a necessary component of infrastructure projects. A guiding principle of water management is that of stationarity, which assumes that natural systems are subject to fluctuation that nonetheless remains within the bounds of a defined range of variability; this fluctuation is used as a basis for decision making. The range of variability is determined based on historical data and observations. It has been argued that the unprecedented scale of anthropogenic climate change and its predicted impacts have rendered stationarity obsolete as a management principle (Milly et al., 2008).

In general, the design of urban water supply, wastewater and stormwater infrastructure builds in spare capacity to account for future growth in demand. Local governments and utilities will therefore most likely be able to cope with short- and medium-term changes, unless the rate of change is too rapid and/or exceeds or goes below the planned buffer capacity. In the long term however, built-in margins will be exceeded. Many utilities throughout the world are facing these problems and trying to integrate them into planning practices (Perth is one example: see box on opposite side).

Forgoing stationarity in Perth, Australia

In the city of Perth, dramatic reductions in streamflow have led the Water Corporation to change the length of historical record used for planning purposes. Perth has recognised that the long term average does not represent likely future streamflow conditions. Perth now uses a combination of climate projections from climate modelling for long-term planning of 50 years, together with a 10 year streamflow average for medium-term planning. Using the climate scenario the city has adopted as well as estimates of population growth, the Water Corporation estimates that the additional water required by the city by 2030 will be equivalent to more than 40% of current annual water use.

Figure 1 illustrates the steep drop in inflows to dams in the last ten years compared to the averages that governed the best part of the 20th century, providing a stark reminder of the sometimes non-linear shifts that can occur because of climate change.

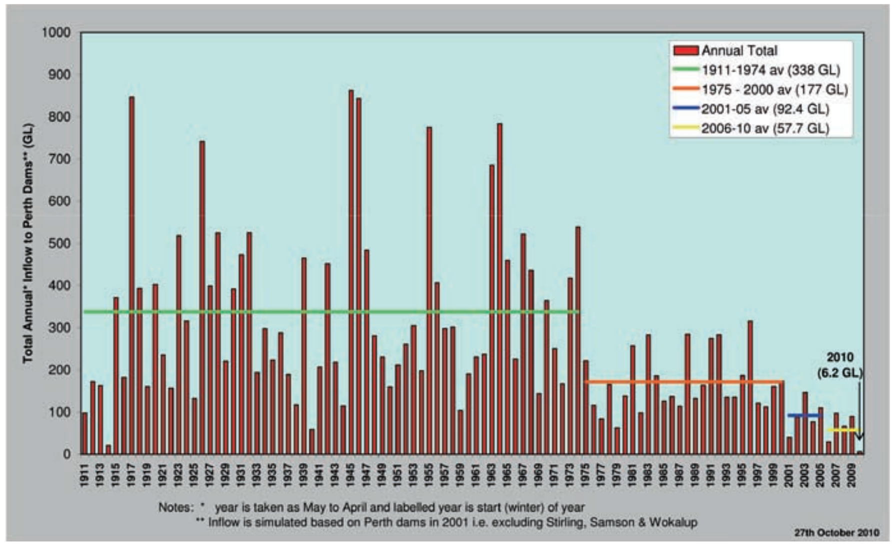

Figure 1: Impact on water availability in Western Australia – reduced inflows to dams (Source: Water Corporation)

Unless temporary or more long-term reductions in water supplies are planned for, water managers may be forced to implement measures such as rationing or supply interruptions. Such measures are not only unpopular but also costly, since the hydraulic shocks associated with intermittent supply damage water supply infrastructure – decreasing the lifespan of equipment – and lead to increased maintenance and repair costs (Danilenko, Dickson & Jacobsen, 2010).

In contrast to the limitations imposed by stationarity, more flexible and sustainable management involves making decisions and choices while considering a range of scenarios. It leads to the selection of management options and technologies with fewer negative impacts on the long-term sustainability of the system as a whole. For example, solutions that target demand reductions and the use of alternative sources rather than resource development and infrastructure expansion are less vulnerable to inaccurate forecasts.

SWITCH

Further information on the flexible solutions given in Table 1 as well as other flexible solutions can be found in Modules 3 (water supply), 4 (stormwater management) and 5 (wastewater management) of the SWITCH Training Kit (ICLEI European Secretariat, 2011).

Choosing flexibility

Current water management infrastructure tends to be inflexible to changing circumstances, yet projections of climate change show that variability can change capacity requirements either regionally or across the year. More sustainable urban water management systems are designed to cope with varying and unpredictable conditions, and achieve this through the implementation of flexible and often decentralised options and technologies that take into account a range of future scenarios.

A flexible system is one that is characterised by its ability to adapt to changing requirements. Table 1 gives some examples of how a flexible urban water system would respond to changing conditions versus how a typical system would do so. The design of a flexible system and the choice of options and technologies can be facilitated through the strategic planning process that will be introduced in the next section.

Table 1: Conventional versus flexible system responses to changing conditions (Source: ICLEI European Secretariat, 2011)

Urban water management aspect	Non-exhaustive examples of climate change impacts	Current system response example	Potential responses to changing conditions from a flexible system
Water supply	Reduced water supply, either seasonally or throughout the year	Increasing water supply through additional infrastructure such as dams, boreholes, desalination facilities or bulk supply transfers	Demand reduction through efficiency increases, active leakage management, behaviour change or pricing policies
			Sourcing of alternative supplies for non-potable demand: rainwater harvesting or treated wastewater effluent reuse
			Increasing sustainable storage capacity, for example through Aquifer Storage and Recovery
Wastewater management	Increased inflow of pollution, caused by flooding	Improving treatment technology	Control of pollution at source and use of natural treatment techniques
	Flooding of wastewater treatment plants located near rivers or coasts	Construction of protective barriers or lifting of equipment	Use and appropriate siting of decentralised natural treatment techniques
Stormwater management	Increased stormwater flows and combined sewer overflows	Improving and extending the infrastructure conveying stormwater away from the city	Attenuation of runoff through the use of Sustainable Urban Drainage Systems options, for example green roofs, porous paving, swales, rainwater harvesting, and detention ponds and basins

The flexibility of non-conventional urban water systems is often related to their decentralised solutions. Decentralisation decreases sensitivity by spreading risk; indeed, it is easy to understand the heightened risk faced by a city dependent on one or more large wastewater treatment plants versus a city that operates several smaller-scale natural treatment systems located in different areas.

In addition, decentralised solutions are often quicker to install and more cost-effective to build and maintain. These considerations are particularly important in the face of changing conditions, which can easily render large investments in new treatment facilities or water supply infrastructure redundant.

COFAS - A water management decision-support tool

The selection of appropriate adaptation measures requires innovative tools that help understand the flexibility of different options. COFAS (Comparing the Flexibility of Alternative Solutions), for example, goes beyond the conventional multi-criteria analysis and also visualises the inherent ability of a potential solution to respond flexibly under different scenarios.

Source: Ingenieurgesellschaft Prof. Dr. Sieker mbH, Germany

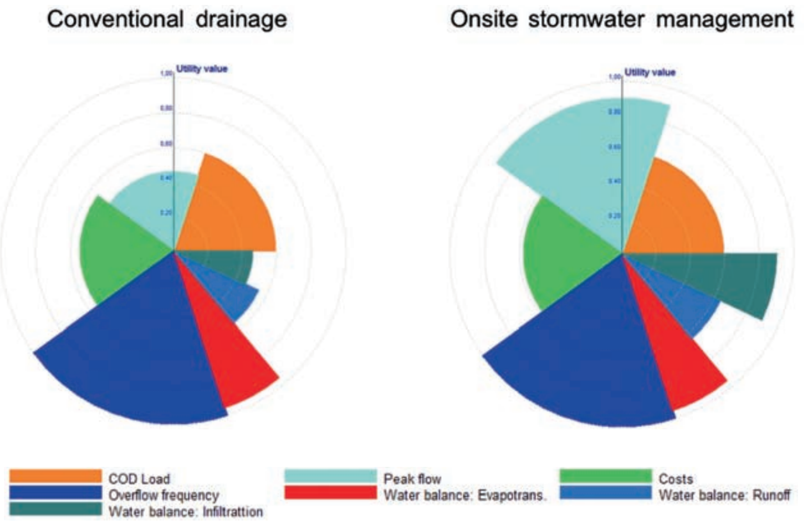

Figure 2: Applying COFAS to compare two solutions for urban drainage in order to select the most flexible one

Fostering integration across urban management sectors

As shown in Section 1, the impacts of climate change will be felt in a cross-cutting manner across different elements of the urban water cycle, but also across all urban management sectors. Current approaches to urban water management are often fragmented, with the design, construction and operation of the various elements carried out in isolation from one another, and with little coordination with other urban management sectors and institutions.

This fragmented approach often results in unsustainable practices, for instance when technical choices have unintended impacts in other parts of the urban system. For example, the structural means of flood protection applied to the Elbe River in Germany negatively affect ecosystems (Weschung et al., 2005 as cited in Kundzewicz et al., 2007). It is also inadequate in terms of responding to the challenges posed by climate change.

SWITCH

Integrated Urban Water Management (IUWM) is a widely recognised integrated planning approach. Further information on IUWM can be found in Module 1 of the SWITCH Training Kit (ICLEI European Secretariat, 2011).

The water-energy nexus in the context of climate change

Multiple and complex links exist between water and energy. Water management is heavily reliant on energy for activities such as pumping, transportation, desalination, domestic water heating and the treatment of drinking water and wastewater. Water is also integral to energy production, through hydroelectric dams but also steam turbines and fossil fuel processing.

The links between the two resources are becoming ever more apparent, particularly in the context of increasing resource scarcity and climate change. At a time when many cities are trying to reduce greenhouse gas emissions to mitigate climate change, the intensive energy use of classic water infrastructure can be a drawback.

In planning mitigation and adaptation actions, cities must keep the connection between energy and water in mind, to reduce the likelihood of unintended impacts. For example, the excessive water consumption of some bioenergy crops is one of the main reasons cited by those who oppose their use as part of mitigation strategies. Many of the sustainable water management options outlined in Table 1 have the added advantage of reducing energy consumption, although in some situations more decentralised solutions can actually increase energy consumption, highlighting the need for constructive dialogue between water and energy managers (Kenway, 2010).

A more sustainable approach to water management involves not only integrated management of the different elements of the urban water cycle, but also the coordination of actions with other urban management sectors, which can help identify synergies but also address conflicts. In the context of climate change, whose impacts are likely to be felt across a range of urban sectors and services, such an integrated approach can be particularly valuable for adaptation planning. In addition, flexible options and technologies can also benefit other urban sectors: examples of co-benefits are given in Annex 4. An integrated approach can be applied through the development of a continuous, regularly evaluated procedure with ongoing choices designed to cope with changing circumstances, through strategic planning.

Strategic planning for adaptation to climate change

What is strategic planning?

SWITCH

Further information on strategic planning can be found in Module 1 of the SWITCH Training Kit, from which much of the content of this section has been derived (ICLEI European Secretariat, 2011).

Strategic planning is a structured framework for the development and implementation of a long-term strategy for integrated urban water management. Strategic planning is not a process that has been specifically designed to plan for adaptation to climate change. Rather, it is a process intimately linked to urban water management as a whole, and one which covers climate change – and adaptation to it – as one of many relevant aspects to be considered. However, because the strategic planning process has been designed to plan for variable and unknown conditions, and since it entails taking a long-term perspective and enables consideration of the linkages between urban water sectors and with other urban sectors, it is actually perfectly suited to plan for climate change adaptation in the context of urban water management.

Strategic planning for adaptation

The strategic planning process consists of a number of phases, which are visualised in Figure 3. This figure highlights the adaptation-specific considerations within the strategic planning process. Each phase is described in more detail below, while the vulnerability assessment process is covered in the next section.

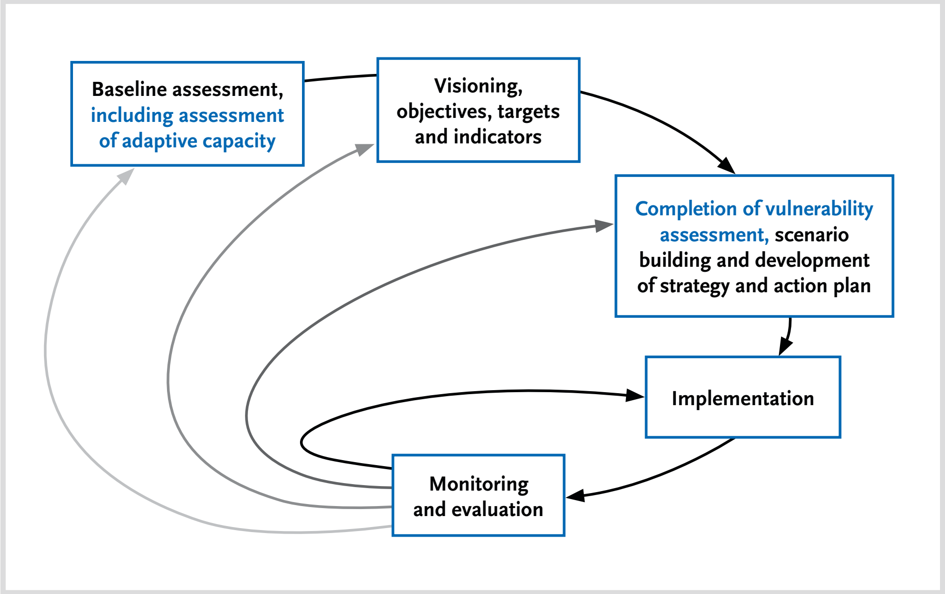

Figure 3: The strategic planning process, incorporating adaptation considerations

Figure 3 presents strategic planning as a logical sequence of phases, but in reality the order of tasks can vary and the different phases should be regularly revisited. In particular, the outcome of the vulnerability assessment and scenario building may require that the targets or other previous phases be subjected to a reality check. Indeed, forecasts may show that the vision as has been set previously would not be reachable under strongly altered climatic conditions.

Strategic planning phases

Baseline assessment, including assessment of adaptive capacity
Before entering into a process of change, a city needs to know its starting point. A *baseline assessment* is an initial collection and analysis of information to gain up-to-date knowledge about factors affecting systems. *Assessment of adaptive capacity* should form an integral part of the baseline assessment, since it requires a city to take stock of the existing characteristics of a system that will determine to an extent how it responds to hazards, as shown in the next sub-section.

Visioning, objectives, targets and indicators
A *vision* is a concise description of a desired future state, containing the broad goals that give the overall direction for the strategic planning process. *Objectives* are a more detailed and concrete breakdown of a vision into sub-goals that specify what changes in state need to be achieved for the vision to become reality. *Indicators* are tools to measure and/or visualise progress towards the objectives, while *targets* are aspired indicator values, usually expressed in specific figures.

"Scenario building is not about 'knowing the future', or always being right; it is about trying to minimise the chances of being seriously wrong" (Batchelor and Butterworth, 2008).

Completion of vulnerability assessment, scenario building and strategy development
Assessing vulnerability is a process that consists in balancing sensitivity against adaptive capacity. This can be done as part of the scenario building/strategy development phase, and is explained in greater detail below. *Scenario building* is a way to minimize and overcome the risk associated with uncertainty, and involves the identification of the factors most likely to have an impact, and the estimation of how these will develop over time. The aim of the *strategy* is to define the main avenues through which the city will, under a range of scenarios, achieve the identified objectives.

Action planning and implementation
The *development of an action plan* is the compilation of programmes, projects and other measures that match the selected strategy and are designed to achieve the objectives and targets within a defined time and budget frame. The *implementation* phase enables physical progress towards the vision.

Monitoring and evaluation
Monitoring involves measuring indicator values against the targets that have been set, and *evaluation* of these monitoring results enables analysis and communication of the outcomes of the planning process.

The vulnerability assessment process

Vulnerability assessment is both a process and an output. The process of vulnerability assessment includes three main steps, summarised in Figure 4.

Step 1: Reviewing adaptive capacity.

Step 2a: Determining exposure to climate change hazards.

Step 2b: Assessing the sensitivity of the system(s) under review.

Step 3: Conducting the vulnerability assessment itself (the output). This will involve determining to what extent adaptive capacity provides a counterweight to sensitivity, and what the resulting vulnerability will be.

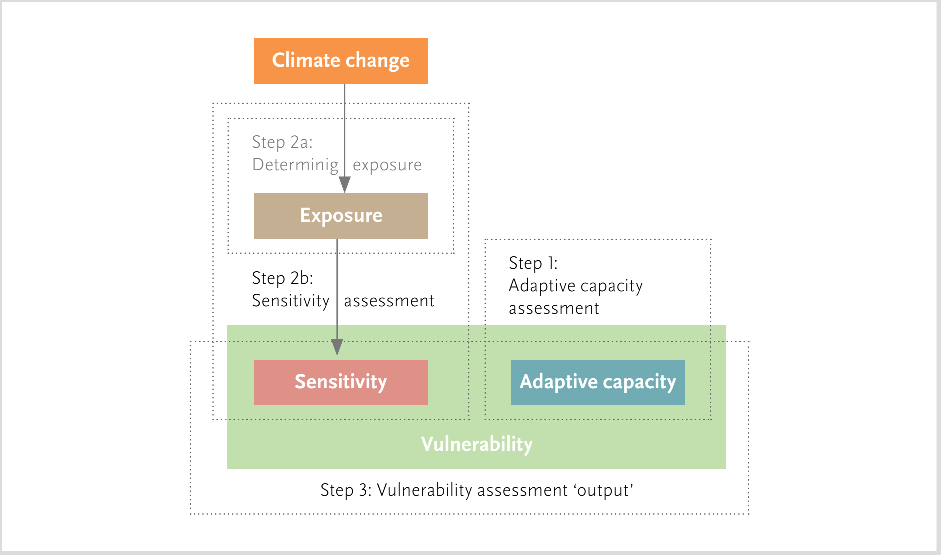

Figure 4: The vulnerability assessment process

Step 1: Adaptive capacity assessment

Determining the adaptive capacity of a system can be a complex, subjective and time-consuming task; how thoroughly a city will be able to conduct its adaptive capacity assessment will therefore strongly depend on its resources. For the purposes of this handbook, a more in-depth approach following the logical principles of strategic planning is laid out, though a more rapid and targeted approach to such an assessment is also possible. In this case, a city or utility would seek to identify the features of adaptive capacity within a specific system that moderate its response to a given climate change hazard.

An in-depth and holistic approach to adaptive capacity assessment, on the other hand, seeks to consider all of the determinants of adaptive capacity within a city that exist regardless of climate change. This ensures a more thorough approach is taken. Indeed, reviewing this 'generic' adaptive capacity means that the analysis will not be blinkered by any particular expected hazard and is likely to produce more wide-ranging results that take into account the links between urban sectors. Moreover, knowing the general state of adaptive capacity for the urban area under consideration means that vulnerability to all types of hazards can more easily be identified, which is particularly important in the context of uncertain and imprecise climate change predictions. The flip side of this is that assessment of generic adaptive capacity is more time-consuming and complex.

A typical approach to adaptive capacity assessment involves the selection of proxy indicators that serve to evaluate adaptive capacity determinants. Annex 3 defines four categories of determinants (economy, society, governance and ecosystems) and gives some examples of elements that can be looked at in conjunction with these categories, without aiming to provide a complete list or selecting indicators. For example, when looking at economic determinants of adaptive capacity, a city might want to think about economic development as one area of interest, and it could select for example GDP per capita and GDP growth rate as indicators with which to represent and quantify economic development.

The selection and interpretation of indicators is not straightforward; it is location-specific, and should therefore be conducted locally (Schauser, Harvey, & Schneiderbauer, 2010). However, such an approach is still valuable as it is the most easy to apply and understand; it can greatly benefit from the involvement of stakeholders. In terms of interpretation for example, it is hard to evaluate the way in which values obtained against indicators affect adaptive capacity; e.g. what is the cut-off point for deciding whether an indicator reveals high or low adaptive capacity?

Step 2: Sensitivity assessment

Step 2a: Assessing exposure
Determining exposure forms a natural part of the scenario-building phase of the strategic planning process, since it involves determining what hazards the city will be exposed to. Exposure of a city to climate change hazards can be determined at different scales of precision, depending upon the city's location and the resources that are available to it. Cities can rely upon predictions of climate change that have been made at the international level (the IPCC being the main source for these) or upon downscaled predictions that have been made at a continental, national, or even regional scale, if these exist (Kropp & Scholze, 2009). Such predictions can generally be accessed through the websites of the environmental or meteorological agencies of national or regional governments as well as those of research institutes. If a city has sufficient time, skills and financial resources, it may choose to do its own downscaling of climate models, using publicly available data.

Collaboration with the research community can be particularly valuable for generating more locally-specific predictions; see the box on Learning Alliances in Section 2.2.

This usually involves running data through General Circulation Models (GMCs, also known as Global Climate Models) under a range of emissions scenarios that have been produced by the IPCC. It can be done using internal scientific capacity or subcontracting the task to universities or other research institutions, as was done in New York City for example (NYCDEP, 2008).

Step 2b: Sensitivity assessment
Conducting a sensitivity assessment entails detailing how each urban sector may be affected by climate change hazards and the type of impact that will ensue. A city should first assess the present status of each relevant system with regard to the external pressures faced, also considering relevant historical data that has impacted the functionality of the system, such as demand peaks, sudden changes, climate conditions, demographics, or the political situation. Then, based on the scientific understanding of expected climate change impacts, a city should identify which climate change hazards may threaten each system's functionality as well as how they would do so, i.e. undertake a separate analysis of systems. Impacts should be classified under one of the following categories: potential for infrastructural damage or impairment; potential for reducing or interrupting the system's ability to function properly, including system overload and underuse; and potential for negatively impacting human health, social interactions or causing human casualties (Schauser, Harvey, Robrecht & Morchain, 2010). Examples of potential impacts on urban systems are show in the illustration on pages 28 and 29.

Finally, the analyses of each system should be merged into one unified picture, delivering a holistic sensitivity assessment for the city. Separate system analysis allows a detailed consideration of each system and is mainly intended as a working tool for the team involved in the adaptation process. A holistic analysis of systems is more of a communication tool, considering its lower technical level/language, and hence its easier accessibility by non-expert readers.

Assessing sensitivity in Melbourne, Australia: a collective exercise

In Melbourne, a series of meetings involving a variety of participants resulted in a "virtual" sensitivity assessment, with participants walking through the systems they were familiar with in their minds and determining the sensitivity of these to different climate hazards. Bringing together a mix of people allowed Melbourne Water to first understand the impact that higher temperatures, lower rainfall or other climate parameters might have on each section of their system – from the outer drinking water catchments all the way through to discharge or recycling of wastewater or stormwater. Good facilitation allowed a collective decision on what was most important to address and what options for adaptation would be most effective. Eventually this prioritised set of adaptation actions was built into the Melbourne Water Corporation's business and strategic plans and adopted by the Victoria State Government.

Understanding risk and prioritising adaptation actions can be more effective if a variety of people with different types of knowledge or experiences are involved in the process. Strategic thinkers and outside experts contribute the system's bigger picture and provide an "outside the box" perspective. Utility or local government operators can bring in detailed knowledge of how an area's water, wastewater and drainage systems work, including their experiences with extreme events. Academics can bring in knowledge of innovations and global experiences. Regulatory and public health experts come in from a perspective focusing on people and the economy. This mix of knowledge and experiences stimulates discussion and understanding.

Step 3: Conducting an assessment of vulnerability

The vulnerability assessment 'document' or output (to distinguish it from the overall vulnerability assessment process, which covers all three steps) combines the findings of both the adaptive capacity assessment and the sensitivity assessment. Of course in practice it is not always easy to distinguish between the two (Schauser, Harvey, & Schneiderbauer, 2010). Because of the dynamic and complex nature of aspects affecting a system's vulnerability, vulnerability assessments should be conducted periodically. They also need to be revisited taking into account the impact of both adaptation and mitigation actions whose aims are, after all, to reduce vulnerability.

Running a vulnerability assessment is a mostly qualitative exercise based on the two assessments mentioned above, which will provide guidance on system and community needs, identifying the most vulnerable systems and social groups. An appropriate vulnerability assessment should serve as a solid base for developing an adaptation plan (UNECE, 2009). However, it is not a straightforward formula that combines adaptive capacity and sensitivity using some mathematical formula, producing a final result. The vulnerability assessment remains, rather, a normative analysis of the combination of the adaptive capacity and sensitivity of systems. Stakeholder engagement is therefore the cornerstone of an appropriate and accurate vulnerability assessment, since it will ensure that all relevant issues and local knowledge are included in the analysis. It will also enhance the chances of a successful implementation of corresponding adaptation measures.

A useful approach to vulnerability assessment would be to focus on each urban sector and determine its sectoral vulnerability. Considering the 'total' adaptive capacity of the city, as presented in Annex 3, the more specific sectoral adaptive capacity and the sectoral sensitivity, each sector should determine how the potentially negative effects (sensitivity) and positive effects (adaptive capacity) 'add up.' Then, creating a general, aggregated picture combining all the sectors (while always keeping in mind the city's total adaptive capacity), would offer a holistic view of the city's vulnerability. Vulnerability assessment is vital to adaptation planning; however, a bridge between the two still needs to be built, using risk assessment. This step involves evaluating the likelihood and outcome of events, and allows for the prioritisation of targeted adaptation actions that will most reduce vulnerability.

Examples of potential effects of climate change at the urban level

Climate hazard: Decreased precipitation
Impact: Water scarcity
Vulnerable system: Food production
How this could affect a city: Reduced availability of irrigation water and yield decreases

Climate hazard: Higher temperatures
Impact: Reduced water oxygen concentrations and altered mixing
Vulnerable system: Water supply (lakes/reservoirs)
How this could affect a city: Reduced water quality for example through algal blooms, increase in treatment requirements

Climate hazard: Increased heavy precipitation
Impact: Increased erosion and sediment transport
Vulnerable system: Water supply (reservoirs)
How this could affect a city: Sedimentation and decrease in water storage capacity and turbidity increase

Climate hazard: Decreased precipitation
Impact: Water scarcity
Vulnerable system: Urban green space
How this could affect a city: Reduced biodiversity and ecosystem services

Climate hazard: Decreased precipitation
Impact: Reduced streamflow
Vulnerable system: Energy supply
How this could affect a city: Disruption of thermal power plant cooling processes

Climate hazard: Decreased precipitation
Impact: Water scarcity
Vulnerable system: Human health
How this could affect a city: Malnutrition and increase in waterborne diseases

Climate hazard: Sea level rise
Impact: Storm surges, flooding
Vulnerable system: All
How this could affect a city: Damage to all coastal infrastructure

Climate hazard: Higher temperatures
Impact: Increase in bacterial and fungal content of water
Vulnerable system: Water supply infrastructure
How this could affect a city: Increase in treatment requirements to remove odour and taste

Climate hazard: Higher temperatures
Impact: Snow and ice cover change
Vulnerable system: Water supply (rivers)
How this could affect a city: Change in peak flow timing and magnitude

Climate hazard: Increased heavy precipitation
Impact: Flooding
Vulnerable system: Transportation
How this could affect a city: Damage to transport infrastructure

Image by: Loet van Moll – Illustraties Aalten, Netherlands | *www.loetvanmoll.nl*

Climate hazard: Sea level rise
Impact: Saltwater intrusion into coastal aquifers
Vulnerable system: Water supply (groundwater)
How this could affect a city: Salinisation of groundwater, abandonment of source

Climate hazard: Increased heavy precipitation
Impact: Flooding
Vulnerable system: Wastewater
How this could affect a city: Flooding of facilities causing damage and contamination of water bodies

Climate hazard: Decreased precipitation
Impact: Reduced streamflow
Vulnerable system: Food production
How this could affect a city: Negative impact on coastal fisheries due to decreases in the outflow of sediment and nutrients

2.2 Strengthening the planning process

Four factors are indispensable to the undertaking of a strategic planning process: strong political backing, appropriate coordination between relevant departments and institutions, support from research bodies and multi-stakeholder involvement. These should be in place prior to the start of the process and should also be maintained for its duration.

Political commitment

Although evidence of an anthropogenic influence on present-day climate patterns is mounting, climate change in general is thought to be a long-term process, with many of the more extreme predicted impacts likely to be felt by future generations. This, as well as the uncertainty associated with climate change, creates a real barrier to securing formal political commitment to support the implementation of responses to climate change.

Political commitment is important for any adaptation process for several reasons. First, water managers have a limited degree of influence over legislation and regulations, which are important for adaptation: land use planning requirements or mandated water efficiency targets are some examples. Secondly, the implementation of adaptation measures requires funding which must be approved by politicians. Finally, the existence of political support for adaptation can act as a real motivating and awareness-raising factor at all levels of urban water management and beyond. Strong political backing helps confer legitimacy and credibility to the strategic planning process, particularly vis-à-vis stakeholders.

A non-exhaustive list of examples of co-benefits is provided in Annex 4.

Often, it is important for water management units to think about and make available information about the different benefits of flexible water management, which frequently extend beyond water. These can be used by politicians to promote the implementation of sustainable water management in a way that is tailored to the concerns and priorities of their constituents.

Internal coordination

The strategic planning process requires the participation and cooperation of various departments and institutions. There are different ways through which to approach such internal coordination. Cooperation is most easily facilitated through the establishment of a coordination unit, which could either consist of a separate office or individual, or of a unit within or linked to an existing department or institution. Local governments, due to their broader responsibility for local development as a whole, are a logical home for such a unit.

Coordination of adaptation in New York City

New York City's Long Term Planning and Sustainability Office is the city's coordination unit for the implementation of its sustainability strategy. A Climate Change Adaptation Task Force has been set up as an element of this strategy, and involves the direct participation of a range of stakeholders. These include relevant city agencies, state-wide bodies and private companies involved in energy, transport and communications. For more information, see the New York City case study (*www.adaptationhandbook.org*).

Stakeholder involvement through coordination in London

The Greater London Authority has set up the London Climate Change Partnership as its coordination unit for climate change. The partners consist not only of relevant government departments, but also of other key stakeholders such as insurance companies, non-governmental organisations and private utilities. For more information, see the London case study (*www.adaptationhandbook.org*).

Cities can also establish specific coordination units to take a broad view of management of all urban sectors in the face of climate change. Water management, arguably the most vital urban system and potentially one of the most affected by climate change, naturally forms one of the main areas of concern of these units. Often, and ideally, these units or the sub-groups they form become arenas for multi-stakeholder involvement. In principle, urban water managers are also able to develop plans without such internal coordination, while taking climate change into account; however, the resulting adaptation actions are likely to be less effective.

Collaboration with research

The complexity and uncertainty inherent to both climate change manifestations and associated adaptation responses requires having the best possible knowledge of current conditions and likely long-term changes. Because of this, active collaboration with researchers is vital. Scenario building is a phase for which research input is particularly important, as the plausibility of these scenarios (as well as a sound assessment of the degree of confidence in them) will determine to a great extent the outcome of the city's water management strategy. Researchers can also help with the development of innovative solutions.

Learning Alliances: Bridging the gap between research and practice

Learning Alliances are a type of action research which attempts to bridge the gap between the scientists and experts on one hand, and water users as well as other stakeholders on the other. In the course of the SWITCH project, they have been set up and tested in a number of cities worldwide. The logic of the Learning Alliance requires that the starting research agenda itself be formulated in conjunction with stakeholders and address their main concerns. The research itself is not solely conducted by experts but shared with the stakeholders. Solutions resulting from an organised joint learning process such as this are more likely to be adopted in practice.

Stakeholder involvement

Stakeholders are individuals or entities that have interest in a particular decision or process, either because they are affected by it or because they can influence it in some way themselves. Multi-stakeholder involvement is the process of engaging with these stakeholders in a collaborative manner. Although it is certainly technically feasible – as is demonstrated in many urban areas – to manage an urban water system without stakeholders, the sustainability and adaptive capacity of the system can significantly be strengthened through their involvement. If not, the costs of mismanagement are transferred from one actor to another, and the overall efficiency of water management is restricted. Multi-stakeholder involvement is therefore necessary to make the most of strategic planning as well as to realise integration in urban water management more generally.

SWITCH

This section does not provide information on how to establish, facilitate or evaluate a stakeholder involvement process. More detailed guidance on these topics can be found in Module 2 of the SWITCH Training Kit (ICLEI European Secretariat, 2011).

It should be noted that the stakeholder process does not replace but rather complements the governance of the urban water system. The actual power of decision making – and thus the accountability – for performing good water services still lies with the public and private entities that have an official mandate for managing water. An effective stakeholder process will however ensure that important decisions are taken in consensus with all key actors and that these in turn develop a sense of responsibility and willingness to support the official entities within the limitations of their own capacities. In order to make integration a reality, stakeholders play a varying but continuous role throughout the strategic planning process. Early involvement is advisable to gain and strengthen their ownership and thus their motivation right from the beginning. Stakeholders are identified as part of the baseline assessment, ideally at the beginning of that process, so that they can also give their input to the vital information collection exercise.

Evaluating adaptation options through a participatory process

Hermosillo, Mexico, was the setting of a participatory exercise aimed at defining, evaluating and prioritising adaptation options. A preliminary list of adaptation options was generated based on informal interviews with a range of stakeholders; these options were then discussed at a formal stakeholder workshop which resulted in the choice of five options. A research team then took on the detailed analysis of the proposals, the results of which were debated during another workshop. Participants proposed evaluation criteria, qualitatively assessed the options against these, and were asked to prioritise the options both in terms of how they met current water challenges and of how they would help cope with two possible future climate scenarios.

The pilot project succeeded in introducing the issue of climate change into to the already heated debate surrounding the city's water resources. Many decision-making agencies were represented in the stakeholder workshops, hopefully sowing the seeds for the incorporation of climate change adaptation into policies. However, the process was hampered by the limited participation of stakeholders from the agricultural sector: as the city's main water users, their participation would have been essential to build a holistic picture and reduce conflict (Eakin et al., 2007).


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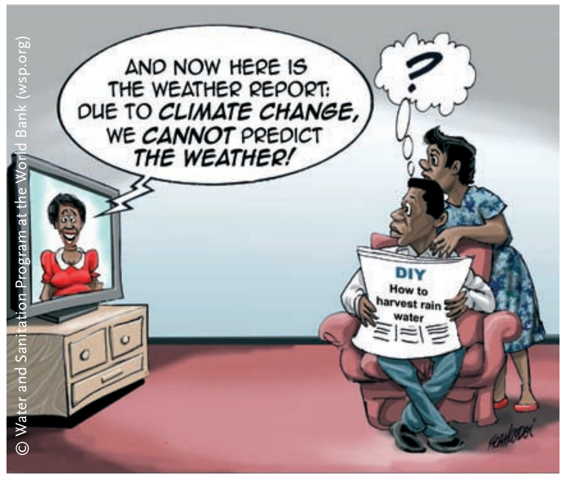
Strategic planning that specifically includes climate change as one factor under consideration is likely to come across certain difficulties in its involvement of stakeholders – these can be addressed through good facilitation and knowledge sharing (Gardner, Dowd, Mason & Ashworth, 2009).

- Gaps in knowledge: Providing information can help address lack of understanding and misconceptions.
- Uncertainty: Acknowledging uncertainty is vital, as is presenting climate change adaptation as a response to risk rather than events that might or might not be occurring presently.
- Scepticism: Being open about scientific work, putting the emphasis on the inherent rationality of taking a risk management approach and highlighting the co-benefits of adaptation can help overcome scepticism or at least put it aside.
- Emotional reactions: The strategic planning approach, which has at its core action planning and implementation, can help surmount feelings of helplessness and encourage participation.

2.3 Communicating climate change adaptation

Stakeholders are central to the implementation of adaptation, and failure to adequately communicate with them about climate change can put barriers in its way. First, almost all adaptation actions will impact stakeholders to some degree, be it through a visible change or through expenditure of tax revenue. If the reasoning behind such impacts is not explained or does not resonate with stakeholders, these are likely to oppose planned projects. This can be the case for some of the technologies and options outlined in this handbook, since these are not yet widespread and are based on some concepts that can trigger preconceived notions, for example the recycling of human waste. Secondly, a lot of the flexible solutions for urban management rely heavily on decentralised solutions which can require the active support and participation of the public for their wide uptake, to a much greater degree than typical centralised water management infrastructure – green roofs and rainwater harvesting are some examples.

Communicating climate change



© Water and Sanitation Program at the World Bank (wsp.org)

The stakeholders linked to urban water management are a disparate group, with varying levels of knowledge about water and climate change. Generally, stakeholders outside of the scientific community and of the institutions directly involved with urban water management can be presumed to have some knowledge gaps in these areas. As part of the strategic planning process, it will be necessary to communicate about such issues with these stakeholder groups.

The Centre for Research on Environmental Decisions (CRED) has identified eight principles of climate change communication: knowing one's audience, getting its attention, translating scientific data into concrete experiences, not overusing emotional appeals, addressing uncertainties, taking advantage of the audience's group affiliations, encouraging group participation and fostering environmentally-positive behaviour (CRED, 2009). Although it is not within the scope of this handbook to help cities define a complete climate change communication strategy, the first principle – knowing one's audience – does merit to be reviewed in more detail.

Any good marketing or communication plan should begin with an assessment of the target market or audience for the product, service or campaign. In the case of climate change, this involves assessing stakeholders' level of knowledge of, and opinions about, climate change and adaptation. This may involve undertaking a survey on the perception of climate change among the stakeholders identified as part of the strategic planning process. Such a survey can help identify any gaps in knowledge and barriers to effective collaboration, for example in the event of widely varying and conflicting opinions between and within stakeholder groups. It may reveal that the implementation of a particular adaptation solution would need to be preceded by a public education exercise. For example, the reuse of treated wastewater effluent or the use of sewage sludge as a fertiliser can raise concerns relating to public health, which need to be addressed prior to implementation.

Getting to know your audience: water and energy at the household level

The UK's Energy Saving Trust and Waterwise have launched a pilot initiative on energy and water targeted at consumers. One of its first steps was a baseline survey of consumer perceptions of the link between water and energy. The survey revealed that consumers lacked awareness of the link itself and certainly of its nature. Since 90 percent of the energy use linked to water occurs within the household, mainly for heating water, the survey revealed a real need to change perceptions in order to drive behaviour change (Energy Saving Trust, 2010).

Communicating adaptation: some unique challenges

Climate change has only relatively recently become the subject of widespread discussion, is the subject of uncertainty, and is a complex phenomenon that takes place at timescales that are often beyond those considered by individuals and institutions. These are some of the many challenges that face those wanting to communicate climate change to stakeholders.

Uncertainty

Predictions regarding future manifestations of climate change are fraught with uncertainty. The scientific community has precise means with which to deal with uncertainty but the communication of this uncertainty and its consequences for decision making has not functioned as well as it should. An example of this is the "climategate"[3] email hacking incident which has put the focus on some of the underlying assumptions and data gaps within climate change science.

Active and open participation of the scientific community within the strategic planning process can help address the issue of uncertainty. As long as the gaps and assumptions within predictions are made obvious, and as long as the implications this has on scenario ranges are clarified, then uncertainty should not be a barrier to planning or implementation of actions. Indeed, uncertainty as a general concept is one that is familiar to individuals, businesses and institutions, since it features in their own planning activities.

Extended timescales

The anticipatory and planned adaptation entailed in this handbook is more than just a response to current climate events such as droughts or flooding: it is also a response to anticipated future events. Often, these anticipated events may occur beyond the time horizons people or organisations tend to think about. Communicating the need to plan now for actions which are aimed at benefiting future generations – particularly if they entail financial costs – can be a challenge. People and hence organisations tend to focus on imminent threats, and getting them to relate to climate change might require linking it to personal experience. In practice, this is often done by highlighting recent extreme weather events as examples of what is to come. This approach can be problematic in that it over-simplifies complex biophysical processes, sometimes ignores non-climate causal links and finally can create a sense of fear and lack of empowerment within stakeholder groups. It is an approach that should be used in moderation, while recognising the importance of taking advantage of the moments of opportunity that are sometimes created by such extreme events.

[3] "Climategate" is the label given by the media to the scandal surrounding the hacking of emails from the University of East Anglia's Climate Research Unit in 2009, which revealed private messages from scientists and was pointed to by those sceptical about climate change as evidence of data manipulation on the part of scientists. See: *http://www.nytimes.com/2009/11/21/science/earth/21climate.html*

Emphasising co-benefits

The stakeholder involvement process will entail the participation of groups that may not necessarily be directly implicated in the management of urban water. Communicating with these groups about adaptation may require emphasising the co-benefits of water-related adaptation actions. Such an approach can also help ensure the participation of groups or individuals who are sceptical about climate change and the need for adaptation.

As shown in previous sections, the urban water cycle is intimately connected to a wide range of other urban sectors, and also plays a central role in ensuring urban quality of life. Adaptation actions linked to water management can therefore almost invariably be linked to improvements in other urban management sectors and/or to tangible improvements in people's lives such as health, quality of life and economic benefits. Being able to point to these co-benefits is therefore valuable. Annex 4 presents a non-exhaustive list of examples of the co-benefits of sustainable water management technologies and options. Of course, in some situations it will not be possible to identify any co-benefits. In these cases, the risk management perspective will have to be the main focus of the strategic planning communication process.

❸ Adapting the urban water system: city examples

Section 3 presents highlights from 10 case studies of cities that are seeking to adapt their water system to climate change; the case studies themselves are available online on the handbook's accompanying website (*www.adaptationhandbook.org*). The case studies cover cities in both developed and developing countries: Durban (South Africa), Hanoi (Vietnam), Infanta and General Nakar (The Philippines), Lima (Peru), London (U.K.), Melbourne (Australia), New York City (U.S.A), Rotterdam (The Netherlands), Semarang (Indonesia) and Toronto (Canada).

The cities profiled are at different stages of the adaptation process: some have implemented specific adaptation actions, while the majority have adopted or at least initiated an adaptation strategy. The case study cities face a variety of climate change challenges, and their responses are equally diverse. Some prioritise a single type of adaptation response, such as strengthening governance in Durban or improving infrastructure in Semarang. Others rely on a portfolio of responses which include the previous two as well as the use of economic incentives and natural systems.

Overall, the city examples provide an ideal illustration of the main concepts outlined in this handbook. Most place strong emphasis on the importance of involving stakeholders at all stages of the process and of integrating quality of life considerations into adaptation plans. Some have even built adaptation strategies that are integrated across all urban sectors and prioritise flexible and sustainable management options.

Prepared
enabling change
www.prepared-fp7.eu

How PREPARED are cities for the impacts of climate change?

The EU-funded PREPARED project focuses on urban water and sewerage strategies, technologies and tools to better cope with the impacts of climate change. All the PREPARED project cities also link their activities to energy technology and consumption in order to improve their carbon footprint. Fourteen cities/utilities cooperate in PREPARED, and focus on the following:

Barcelona, Spain:	Adaptation strategies to adapt to water resource scarcity and extreme rainfall events.
Berlin, Germany:	Remedying the two major challenges for the city – water supply security and increased concentration of mining-related substances in the water.
Eindhoven, The Netherlands:	Developing water cycle safety planning for integrated risk management in order to plan and remedy current system shortcomings.
Genoa, Italy:	Decision support and monitoring systems to plan for drought and extreme rainfall periods.
Istanbul, Turkey:	Alternative water supply (rainwater harvesting) and greywater management for areas of the city suffering from severe water stress.
Gliwice, Poland:	Integrating the city's land depression reservoirs in the overall water management system through improved rainfall monitoring systems and forecasting capabilities.
Lisbon, Portugal:	Combating water scarcity and quality through improved water cycle safety planning, early warning and disinfection systems.
Lyon, France:	Improving rainfall measurement in order to develop effective climate change adaptation strategies.
Oslo, Norway:	Combating the city's two major challenges: combined sewer operation and the deterioration of raw water quality.
Simferopol, Ukraine:	Developing a water cycle safety plan and a hazard database for risk reduction options to improve the city's potable water.
Århus, Denmark:	Improving rainfall monitoring, integrated control of sewers and wastewater treatment plants.
Melbourne, Australia:	Taking remedial action to improve water security, waterway pollution, flood mitigation and improved resilience and sustainable living.
Seattle, U.S.A.:	Assessing the impacts of climate change on the hydrologic cycle and developing adaptation strategies.
Principality of Wales, U.K.:	Developing tools and frameworks to build capacity in the partner cities to use adaptive water and sanitation systems, and then to effect this transition so as to deliver systems with greater resilience.

Mainstreaming adaptation through a cooperative process
Durban, South Africa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Climate change in Durban is expected to cause more intense and erratic rainfall, more hot days and heat waves, higher mean sea levels as well as higher mean and extreme temperatures. In order to achieve a greater resilience to climate change, a Municipal Climate Protection Programme (MCPP) has been developed to gain insight into climate change impacts and possible adaptation measures.

One aspect of Durban's MCPP is the use of multi-criteria analysis for prioritising the most promising measures in Municipal Adaptation Plans. In this analysis, criteria such as flexibility, emission impact, ease of implementation, cost-benefit ratios and potential externalities are considered in order to assess potential climate adaptation solutions. The multi-criteria analysis process itself is valued more highly than its actual outcomes since it stresses the importance of stakeholder participation and cooperative decision making.

Existing institutions proved to be incapable of implementing holistic and cross-sectoral government initiatives. In order to achieve some of the measures, it therefore became necessary to make institutional changes, such as embedding climate change issues in various departments of the municipality as well as attracting funds and skilled personnel.

Full case study available at *www.adaptationhandbook.org*

CITY IN PROFILE

Size:
Megacity ☐
Large ☑
Medium or small ☐

Economy:
Developed country ☐
Emerging economy ☑
Developing country ☐

Climate classification:
Tropical ☐
Dry ☐
Temperate ☑
Continental ☐
Polar ☐
Alpine ☐

Projected climate change challenges faced:
Sea level rise ☑
Increased heavy precipitation ☑
Decreased precipitation ☐
Increased temperature ☑
Wind storms ☐

Adaptation response:
Economic incentives ☐
Infrastructure improvement ☐
Use of natural systems ☐
Strengthening governance ☑
Other ☐

Has the city developed an adaptation plan or strategy?
Yes ☑
No ☐

Integrated river basin management for climate resilience
Hanoi, Vietnam


© iStockphoto.com/Kristall

Hanoi distinguishes itself from other major urban areas with climate change problems in that it is not situated on the coast. This limits the direct influence of sea level rise, although backwater curves can still have a significant effect on water levels in the Red River which flows through the city centre. Climate change projections anticipate an increase in the frequency and intensity of typhoons and tropical storms, increased precipitation volumes and intensity and moderate sea level rise, suggesting an increase in the flood risk for urban areas.

A project involving the cooperation of the Hanoi city administration, the Ministry of Natural Resources and Environment and the World Bank was implemented in order to reduce Hanoi's vulnerability to climate change. The project takes an integrated approach to redesigning the Red River basin's water management.

The climate resilience programme entails hard and soft adaptation initiatives to ensure the system's resilience in the near future. These initiatives include a revision of current flood protection infrastructure, the creation of additional water retention capacity in the form of reservoirs, institutional strengthening to respond to dike emergencies and finally new flood discharge regimes that incorporate socio-economic considerations.

Full case study available at *www.adaptationhandbook.org*

CITY IN PROFILE

Size:
Megacity ☐
Large ☑
Medium or small ☐

Economy:
Developed country ☐
Emerging economy ☐
Developing country ☑

Climate classification:
Tropical ☐
Dry ☐
Temperate ☑
Continental ☐
Polar ☐
Alpine ☐

Projected climate change challenges faced:
Sea level rise ☑
Increased heavy precipitation ☑
Decreased precipitation ☐
Increased temperature ☐
Wind storms ☑

Adaptation response:
Economic incentives ☐
Infrastructure improvement ☑
Use of natural systems ☐
Strengthening governance ☑
Other ☐

Has the city developed an adaptation plan or strategy?
Yes ☑
No ☐

Community-based early warning system
Infanta and General Nakar, The Philippines

In 2004, a devastating flash flood in Infanta and General Nakar sparked interest in the development of adaptation measures to mitigate and reduce the effects of natural disasters induced by local climate change on the part of the Philippine government, donor agencies and the local population. In cooperation with the local community, municipality officials and donor agencies, a plan was developed for the implementation of a community-based early warning system. The system utilises two-way radio communication technology, local knowledge and hydrological equipment to provide weather forecasting and early warning of impending flash floods.

The radio signal was preferred over the cellular network due to the latter's unreliability in remote locations and during disasters. Transferring climate forecasting and warning systems to the local level allowed local stakeholders to directly learn and benefit from the added security to their environment. The project required the close involvement and interaction of stakeholders and the local community, which by itself has made a significant contribution to institutional strengthening. Apart from significantly reducing local flood risk, the project has demonstrated that effective climate adaptation and resilience projects do not by definition require significant investments, and that much is to be gained from making use of local knowledge.

Full case study available at *www.adaptationhandbook.org*

CITY IN PROFILE

Size:
- Megacity ☐
- Large ☐
- Medium or small ☑

Economy:
- Developed country ☐
- Emerging economy ☑
- Developing country ☐

Climate classification:
- Tropical ☑
- Dry ☐
- Temperate ☐
- Continental ☐
- Polar ☐
- Alpine ☐

Projected climate change challenges faced:
- Sea level rise ☐
- Increased heavy precipitation ☑
- Decreased precipitation ☐
- Increased temperature ☑
- Wind storms ☐

Adaptation response:
- Economic incentives ☐
- Infrastructure improvement ☐
- Use of natural systems ☑
- Strengthening governance ☑
- Other ☐

Has the city developed an adaptation plan or strategy?
- Yes ☐
- No ☑

Developing a strong framework for adaptation planning
London, United Kingdom

In London, all of the elements that make up successful strategic planning are in place. First, political support: two consecutive mayors have placed climate change at the top of their agenda and adaptation considerations are integrated into all major areas of responsibility. Second, coordination: the London Climate Change Partnership (LCCP) has been in place since 2001 and ensures coordination of climate change planning across government levels through its leadership role. Third, collaboration with research: London benefits from scientific outputs such as high resolution downscaled models. Finally, stakeholder involvement: this takes place primarily through the LCCP.

In addition, the city has allocated discrete funding for adaptation and has made a particular effort to ensure transparency, notably through its website and the use of the media and public consultations. London therefore has many enabling factors in place, paving the way for the adoption of its draft adaptation strategy. Thames Water is planning a combined sewer overflow conveyance tunnel; this end-of-pipe solution can be seen as being at odds with sustainable water management, since it does not concentrate on the implementation of flexible and decentralised options and technologies. However, such an approach needs to be assessed based on local conditions and on how it performs in the long run.

Full case study available at *www.adaptationhandbook.org*

CITY IN PROFILE

Size:
- Megacity ☑
- Large ☐
- Medium or small ☐

Economy:
- Developed country ☑
- Emerging economy ☐
- Developing country ☐

Climate classification:
- Tropical ☐
- Dry ☐
- Temperate ☑
- Continental ☐
- Polar ☐
- Alpine ☐

Projected climate change challenges faced:
- Sea level rise ☑
- Increased heavy precipitation ☑
- Decreased precipitation ☑
- Increased temperature ☑
- Wind storms ☐

Adaptation response:
- Economic incentives ☑
- Infrastructure improvement ☑
- Use of natural systems ☑
- Strengthening governance ☑
- Other ☐

Has the city developed an adaptation plan or strategy?
- Yes ☑
- No ☐

Wastewater reuse for irrigation in the urban context
Lima, Peru

Precipitation in Lima is extremely low, making the city almost entirely dependent on its surface and groundwater supplies. At the same time, climate change projections suggest a steady increase in temperatures which causes melting of glaciers, resulting in even more water scarcity.

To address scarcity, multifunctional use of water sinks has been considered by the local government through involvement in the SWITCH project. For instance, recycling treated wastewater is seen as an alternative for irrigation water. This means that less clean water is needed for irrigation and as a result that more potable water is available for higher value uses such as drinking water.

Overall, the project aims to raise awareness, develop national policy guidelines and strengthen local government capacity to design integrated systems. These efforts have been proven to be successful as new national policy guidelines and the new national law on water resources specifically recognises the potential of using treated wastewater for productive purposes. Although the project was not formulated entirely with climate change in mind but more as a response to scarcity issues, it shows that existing efforts and plans can bring opportunities to contribute to climate resilience.

Full case study available at *www.adaptationhandbook.org*

CITY IN PROFILE

Size:
- Megacity ☐
- Large ☑
- Medium or small ☐

Economy:
- Developed country ☐
- Emerging economy ☑
- Developing country ☐

Climate classification:
- Tropical ☐
- Dry ☑
- Temperate ☐
- Continental ☐
- Polar ☐
- Alpine ☐

Projected climate change challenges faced:
- Sea level rise ☐
- Increased heavy precipitation ☐
- Decreased precipitation ☐
- Increased temperature ☑
- Wind storms ☐

Adaptation response:
- Economic incentives ☐
- Infrastructure improvement ☑
- Use of natural systems ☐
- Strengthening governance ☑
- Other ☐

Has the city developed an adaptation plan or strategy?
- Yes ☐
- No ☑

Becoming water-sensitive to respond to a changing climate
Melbourne, Australia

In Melbourne, population growth and urban sprawl combine with the challenges of climate change to create new incentives to build a city that is simultaneously resilient to future shocks, sustainable and also liveable.

Events such as droughts, floods and wildfires highlight the need for a more flexible planning approach that allows the city to adapt to new conditions. Water managers no longer assume that historical rainfall and stream flow data provide a dependable guide to the future, or that rainfall will be the sole water supply source. The city has diversified its water supply system with a desalination plant as well as other local scale rainwater and recycled water reuse schemes. Although not 'least cost' according to traditional assessments, these options diversify the system and add a level of redundancy to cope with a broad range of conditions.

Melbourne aims to become a water-sensitive city, integrating water management with urban design, energy use and major infrastructure such as transport and telecommunication systems. This involves working with the urban planning sector and developers to change city design, and embedding water sensitive urban design into new building stock and other infrastructure to maximise the yield of local scale urban water reuse systems and reduce the impacts of waste discharges on receiving waterways.

Full case study available at *www.adaptationhandbook.org*

CITY IN PROFILE

Size:
- Megacity ☐
- Large ☑
- Medium or small ☐

Economy:
- Developed country ☑
- Emerging economy ☐
- Developing country ☐

Climate classification:
- Tropical ☐
- Dry ☐
- Temperate ☑
- Continental ☐
- Polar ☐
- Alpine ☐

Projected climate change challenges faced:
- Sea level rise ☑
- Increased heavy precipitation ☑
- Decreased precipitation ☑
- Increased temperature ☑
- Wind storms ☐

Adaptation response:
- Economic incentives ☑
- Infrastructure improvement ☑
- Use of natural systems ☑
- Strengthening governance ☑
- Other: Integrated planning ☑

Has the city developed an adaptation plan or strategy?
- Yes ☐
- No ☑

Planning for adaptation in a megacity with ageing infrastructure

New York City, United States of America

New York City's vulnerability to climate change is determined both by its exposure to several climate change threats – including rising temperatures, sea level rise and increasing rainfall – and by its sensitivity. In the arena of water management, this sensitivity is mainly driven by the age of its water infrastructure and its lack of redundancy, by the city's dependence on an inherently clean source of freshwater, and by its coastal location.

The size of the city's carbon footprint justifies its efforts to reduce its exposure by implementing mitigation measures. New York City is also working to adapt to unavoidable climate change impacts, following an integrated planning approach. Its adaptation planning is driven by a multi-stakeholder involvement process which has placed special importance on the role of scientific research, particularly in the steps linked to forecasting climate change impacts and assessing vulnerability.

Recognising and planning for uncertainty is one of the mainstays of the city's adaptation approach. It is taking a phased approach, with immediate adaptive action being taken where it can be done cost-effectively and will deliver benefits in other areas where the city is improving sustainability. In parallel, the city is assessing the suitability for implementation of all adaptation options.

Full case study available at *www.adaptationhandbook.org*

CITY IN PROFILE

Size:
- Megacity ☑
- Large ☐
- Medium or small ☐

Economy:
- Developed country ☑
- Emerging economy ☐
- Developing country ☐

Climate classification:
- Tropical ☐
- Dry ☐
- Temperate ☐
- Continental ☑
- Polar ☐
- Alpine ☐

Projected climate change challenges faced:
- Sea level rise ☑
- Increased heavy precipitation ☑
- Decreased precipitation ☐
- Increased temperature ☑
- Wind storms ☐

Adaptation response:
- Economic incentives ☑
- Infrastructure improvement ☑
- Use of natural systems ☑
- Strengthening governance ☑
- Other ☐

Has the city developed an adaptation plan or strategy?
- Yes ☑
- No ☐

Using adaptation to create a more attractive city

Rotterdam, The Netherlands

The consequences of climate change are already being felt in Rotterdam, with heavier rain showers causing excess water or flooding. In the long run, the low-lying delta city will also be confronted with rising sea levels and exceptionally high or low river levels. Furthermore, rising temperatures will affect increasing numbers of people through heat stress.

In order to confront the challenge of climate change as an opportunity rather than a threat, the City of Rotterdam has set up the Rotterdam Climate Proof programme. The programme aims to make Rotterdam climate change resilient by 2025, and plans for permanent protection and accessibility of the Rotterdam region. Its central focus is to create additional opportunities to make Rotterdam a more attractive city in which to live, work, relax – and invest.

Trendsetting research, innovative knowledge development and decisive implementation of suggested measures are expected to result in strong economic incentives. Collaborating with prominent partners, Rotterdam aims to become the most important innovative water knowledge city in the world and an inspiration to other delta cities. Rotterdam Climate Proof is a part of the Rotterdam Climate Initiative. Rotterdam is thus addressing both the causes of climate change (mitigation) as well as its consequences (adaptation).

Full case study available at *www.adaptationhandbook.org*

CITY IN PROFILE

Size:
- Megacity ☐
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Economy:
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- Emerging economy ☐
- Developing country ☐

Climate classification:
- Tropical ☐
- Dry ☑
- Temperate ☐
- Continental ☐
- Polar ☐
- Alpine ☐

Projected climate change challenges faced:
- Sea level rise ☑
- Increased heavy precipitation ☑
- Decreased precipitation ☐
- Increased temperature ☑
- Wind storms ☑

Adaptation response:
- Economic incentives ☑
- Infrastructure improvement ☑
- Use of natural systems ☑
- Strengthening governance ☑
- Other ☐

Has the city developed an adaptation plan or strategy?
- Yes ☑
- No ☐

Water level control in the Semarang test polder

Semarang, Indonesia

Semarang's coastal location makes it extremely vulnerable to climate change, most notably to the threat of sea level rise and floods from storm surges and extreme rainfall. Additionally, flood risk is amplified by extreme land subsidence linked to urban groundwater abstraction in the context of rapid population growth and economic development.

Since it is impossible to relocate most of the area's population in the short term, other adaptation measures were needed to deal with the problem. With help from the Dutch government and engineering consultants, plans have been drafted to create a test polder in Semarang. This polder allows for direct control of water within the designated area by artificially maintaining the water level through a complex configuration of pumping systems and dikes. This allows the city administration to adapt to changing hydrologic conditions within a few hours when necessary.

Applying the traditionally Dutch concept of polders to Indonesia has proven to be challenging. Local soil characteristics, water fluxes and climate all are fundamentally different from those within The Netherlands. Pump capacity, structural integrity and even the institutional context of the polder required engineers to rethink the typical design requirements to make the polders a truly sustainable solution for the local context.

Full case study available at *www.adaptationhandbook.org*

CITY IN PROFILE

Size:
- Megacity ☐
- Large ☑
- Medium or small ☐

Economy:
- Developed country ☐
- Emerging economy ☑
- Developing country ☐

Climate classification:
- Tropical ☑
- Dry ☐
- Temperate ☐
- Continental ☐
- Polar ☐
- Alpine ☐

Projected climate change challenges faced:
- Sea level rise ☑
- Increased heavy precipitation ☑
- Decreased precipitation ☐
- Increased temperature ☐
- Wind storms ☐

Adaptation response:
- Economic incentives ☐
- Infrastructure improvement ☑
- Use of natural systems ☐
- Strengthening governance ☐
- Other ☐

Has the city developed an adaptation plan or strategy?
- Yes ☑
- No ☐

First out of the starting blocks: Prioritising adaptation actions

Toronto, Canada

Toronto's approach to adaptation planning is to start with short-term adaptation actions while at the same time laying the groundwork for what the city understands needs to be implemented: a more comprehensive and long-term strategy.

The city has worked out a ranking system for prioritising short-term adaptation actions. Actions are ranked highly if they meet certain financial considerations – economic benefit generation, low cost, external financing – if they address identified climate risks, if they contribute to mitigation efforts and if they can measurably increase the city's resilience. This corresponds to a 'no regret' approach to adaptation.

Many cities and communities around the Great Lakes have started implementing mitigation plans, but adaptation strategies are less widespread. Toronto is a good example of an early adapter, and the lessons it learns from the development of a strategic approach to adaptation will help urban areas in the entire region. These have joined forces as part of the Great Lakes and St. Lawrence Cities Initiative.

Full case study available at *www.adaptationhandbook.org*

CITY IN PROFILE

Size:
- Megacity ☐
- Large ☑
- Medium or small ☐

Economy:
- Developed country ☑
- Emerging economy ☐
- Developing country ☐

Climate classification:
- Tropical ☐
- Dry ☐
- Temperate ☐
- Continental ☑
- Polar ☐
- Alpine ☐

Projected climate change challenges faced:
- Sea level rise ☐
- Increased heavy precipitation ☑
- Decreased precipitation ☐
- Increased temperature ☑
- Wind storms ☐

Adaptation response:
- Economic incentives ☑
- Infrastructure improvement ☑
- Use of natural systems ☑
- Strengthening governance ☑
- Other ☐

Has the city developed an adaptation plan or strategy?
- Yes ☑
- No ☐

Conclusion

Decreasing vulnerability to climate change can go hand in hand with creating a more liveable and sustainable city. Rather than solely relying on massive infrastructure projects, adapting to climate change should combine flexible options and technologies with 'soft' approaches such as stakeholder involvement, awareness raising and education.

In this handbook, the strategic planning process is presented as a framework that facilitates the shift to more integrated policies, governance structures, practices and technology choices for more sustainable water management. As well as increasing the overall sustainability of cities, sound planning based on a strategic and integrated approach is also a framework suitable for adaptation to climate change.

Strategic planning is a process able to deal with uncertainty and changing conditions, imperative in the context of climate change. Its integrated approach, taking stakeholders into account during all phases of the process, ensures that the cross-cutting consequences of both climate change and responses to it are also considered. The flexible and decentralised water management options presented in this handbook are also better equipped to cope with changing climatic conditions, bring co-benefits for other urban sectors and also enhance urban quality of life.

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The methodical and integrated approach laid out in this handbook should encourage cities to take a positive view of their ability to cope with climate change.

- Adaptation has always been necessary:
  Dealing with uncertainty and change has always been a part of city and water planning – in this case, it will just mean dealing with rather more uncertainty and increasing rates of change, in a slightly different way.

- Adaptation is always a winning approach:
  Cities can take the challenge of climate change as an opportunity to improve the functioning of their urban systems and the lives of their citizens.

- Acting now is vital:
  Many initial options that increase the adaptive capacity of cities and quality of life can be put in place at little cost and with few disruptive consequences.

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The adaptation handbook website

Supporting resources can be found on the handbook's accompanying website; these include the full case studies whose highlights are presented in Section 3. Visit the website (*www.adaptationhandbook.org*) to download case studies, get access to links and other resources and to download an electronic version of this handbook. Regular updates to both the website and the handbook are planned, so make sure to check back regularly for the latest on adaptation to climate change in the water sector.

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Annex 1: Definitions

'Adaptation', 'mitigation', 'adaptive capacity', 'sensitivity' and 'vulnerability': these are some of the recurring terms in climate change literature. What follows are definitions of selected key words as applied by the authors in this handbook. Figure 5 visualises the connections between the different terms, overlain by the DPSIR (Driving forces, Pressures, State, Impacts and Responses) framework.

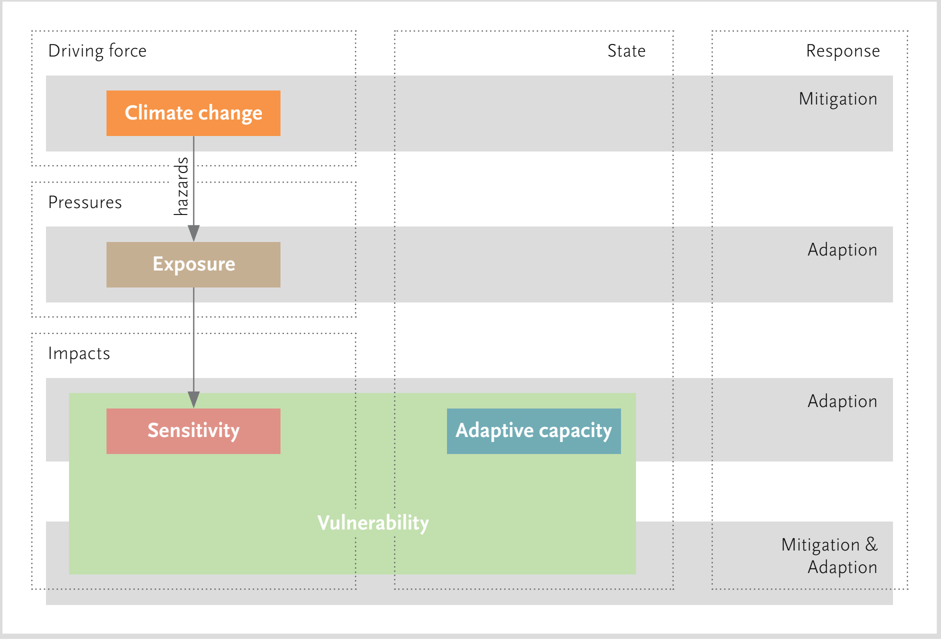

Figure 5: Key climate change terms

Key terms

Adaptation: Adaptation is one possible response to climate change (another being *mitigation*) that involves the adjustment of natural or human systems in response to expected climate *hazards* (Parry et al., 2007). Adaptation does not seek to influence or attenuate climate change itself, but rather to enable systems to adjust to those climate change impacts which are inevitable.

"Avoid the unmanageable" through mitigation and "manage the unavoidable" through adaptation (Kropp and Scholze, 2009).

Mitigation: Mitigation is the other main response to climate change apart from *adaptation*. Mitigation seeks to reduce expected climatic *hazards* by reducing emissions of greenhouse gases or enhancing sinks to absorb these gases (Parry et al., 2007).

Hazard: Actual or expected climate change manifestation.

Exposure: Contact of a system with climate change *hazards*.

Sensitivity: Extent to which a system is impacted by climate *hazards* once it has been *exposed* to them.

Adaptive capacity: Inherent ability of a system to adjust in response to actual or expected climate hazards.

Vulnerability: Degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change; it is a function of sensitivity, of adaptive capacity and of the system's exposure to hazard (Parry et al., 2007).

Understanding definitions in practice

To understand what these terms can mean in a practical context, and why they are important to differentiate, let us take recent examples of a natural disaster completely unrelated to climate change: earthquakes. In 2010, an earthquake with a magnitude of 7.0 shook the island of Haiti, and another of magnitude 8.8 struck Chile. In terms of energy released, the Chile earthquake was 500 times more powerful than the Haiti earthquake. However, this difference is not apparent in the casualties caused by the two earthquakes: over 200,000 people died in Haiti, versus approximately 500 in Chile. What factors can explain how Chile, though *exposed* to a *hazard* of a much greater magnitude, found itself less *vulnerable* than did Haiti? Simply put, Haiti's *sensitivity* to the hazard was greater and its *adaptive capacity* was lower, as shown in Figure 6.

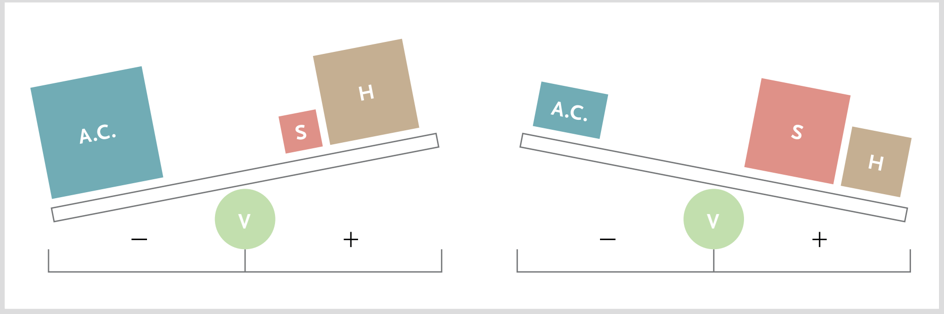

Figure 6: Adaptive capacity (A.C.), vulnerability (V), sensitivity (S) and hazard (H), for the Chile (left) and Haiti (right) earthquakes

Of course, this simplification may ignore other factors, such as the difference in the distances between the epicentres and major population centres, or the different underlying soil types which influence the degree of shaking. Nonetheless, the disparity in vulnerability between the two countries has mainly been attributed to the existence of building codes (or the enforcement thereof) and to the degree of preparedness of emergency services and of the population. Differences in national and per capital wealth and those linked to good governance (corruption is an example) also form the backdrop of these disasters. The poor condition of buildings made Haiti more *sensitive*, while the lack of governance reduced its *adaptive capacity*.

Though unrelated to climate change, this example helps to demonstrate the connection between terms: the magnitude of a hazard does not directly determine the vulnerability of a system. Rather, vulnerability is a function of how a system's sensitivity responds to the hazard and of how much adaptive capacity the system has. Adaptation is a means with which to reduce sensitivity and bolster adaptive capacity, thereby reducing overall vulnerability to – in this case – climate change.

Annex 2: Examples of impacts of climate change on urban sectors*

Vulnerable systems and services in cities – Water supply and wastewater services

	Climate change manifestations			
	Sea level rise	**Increased heavy precipitation and flooding**	**Decreased precipitation, water scarcity, drought**	**Increased temperatures**
Rivers	• **Saltwater intrusion** at river mouths, reducing the available potable water supply [a]	• Soil fluvial erosion, causing an **increase in suspended solids**.[a] This turbidity can impact water supply by interfering with disinfection processes, increasing the need for coagulant use, increasing handling costs, etc [j]	• Reduced streamflow, **decreasing water supply** [a] • Increased **pollution concentrations** [b] • **Saltwater intrusion** at river mouths [c] • Re-suspension of river bottom **sediments** and liberation of **compounds** [a]	• **Reduction of self-purification capacity** of rivers through reduced oxygen levels [a] • **Deterioration of chemical & biological river features** [b] • Snow and ice cover changes: **Reduced or earlier peak streamflows** and/or extension of the low flow period, and long-term decrease in river flows due to glacial melt [a] • Wildfires: Washoff of dissolved materials into receiving waters; **changes in turbidity and chemistry of water** [n] • Change from non-erosive snowfall to erosive rainfall, **increasing water turbidity** [a] • Indirect effect: Higher demand for cooling water in the energy sector leading to increased **thermal pollution** [a]
Lakes / Reservoirs		• Increased erosion and sediment transport, leading to **sedimentation of reservoirs** and decreased water storage capacity [a] • Drinking water **storage capacity decrease** because of the need to maintain more flood storage capacity [h] • Fluvial soil erosion, causing an **increase in suspended solids** [a]	• Reduced inflow from rivers **decreases lake levels**, even leading to the disappearance of endorheic lakes [b] • Re-suspension of lake-bottom **sediments** and liberation of **compounds** [a] • Increased **pollution concentrations** [b]	• Increased **evaporation** [a] • **Reduced water quality** due to reduced oxygen concentrations, release of phosphorus from sediments and altered mixing [f] • Increased occurrence of **eutrophication** and toxic algal blooms [f] • Change from non-erosive snowfall to erosive rainfall, **increasing water turbidity** [a] • Indirect effect: Higher demand for cooling water in the energy sector leads to increased **thermal pollution** [a]
Groundwater	• Saltwater intrusion into aquifers: **Salinisation of groundwater** and associated reduction in freshwater availability for human consumption and for irrigation [a]	• **Increased virus and pollution loading** in groundwater [a] • **Decrease in groundwater recharge** as heavy precipitation exceeds soil infiltration capacity and increases surface runoff [k]	• **Falling groundwater tables** due to reduction in recharge and decreased river flow [c&a] • Increased groundwater use as surface **water availability declines** [a] • Reduced precipitation decreases groundwater recharge, leading to **saltwater intrusion** into coastal or inland aquifers [a]	• Increased evapotranspiration and improved growth conditions **increase biomass**, which impacts groundwater [a] • **Salinisation of groundwater** due to increased evapotranspiration [a] • Snow and ice cover changes: **increased groundwater abstraction** to compensate for reduced summer river flows in snow-dominated basins [a] • Loss of glacier and snow cover: **decrease in recharge rates** [k]
Wastewater and water supply infrastructure	• **Sewer outfalls** into sea exposed to **damage** during coastal flooding [c] • Coastal wastewater treatment **infrastructure damaged** [h] • Coastal flooding: temporary **increases in salinity of influent** to wastewater treatment plants, leading to disruption of biological processes and corrosion of equipment [j]	• **Capacity overload** of water and wastewater treatment plants [a] • Combined sewer and pit latrine **overflows, causing urban flooding and contamination** of water [c] • **Non-point pollution**: Increased washoff of nutrients, pathogens and toxins, requiring more treatment [a] • Water treatment and abstraction facilities are likely to be located near rivers and are the first to be affected by flooding, causing **contamination** of water and **damage** [c] • **Erosion** of pipelines due to heavy rainfall [c]	• **Intermittent operation** of urban water supplies during drought periods, adversely affecting water quality [a] • Activities counteracting increased aridity will exacerbate **secondary salinisation** [a] • Increased water **withdrawals from low-quality sources** due to shortages will increase treatment requirements [a]	• Increased water demand, leading to **increased water abstraction** for irrigation, power plant cooling and direct consumption [a] • **Increase in bacterial and fungal content** of water, requiring additional treatment to remove odour and taste [a] • Increase in **algal growth** impacting on the reliability and operational costs of water systems [a] • Increased microbiological activity, leading to an **increase in disinfection by-product levels** [j] • **Impact on temperature-related wastewater treatment** processes, for example reduction of oxygen levels and transfer rates [j] • Reduced oxygen content in wastewater effluent receiving waters, leading to **more stringent wastewater treatment requirements** [j] • **Corrosion of sewers** [j]

* **Based on:** Schauser, Harvey, Robrecht & Morchain, 2010.
Note: The format of this table does not allow for a holistic presentation of the connections between manifestations and impacts, and does not reflect the local differentiation of impacts. Finally, while this table only considers negative impacts, some climate change manifestations may lead to positive ones: local governments and utilities should also be ready to take advantage of any positive effects as they occur. Overall through, in terms of freshwater, negative impacts will outweigh positive ones (Kundzewicz, 2007).

Vulnerable systems and services in cities – Water-reliant systems

	Climate change manifestations			
	Sea level rise	**Increased heavy precipitation and flooding**	**Decreased precipitation, water scarcity, drought**	**Increased temperatures**
Local energy supply	• Changing conditions affect coastal facility **siting decisions** [c] • Storm surges: **damage** to coastal energy **infrastructure**	• Physical **destruction** of transmission and distribution infrastructure [c]	• Reductions in streamflow **affect power plants** that use water for **cooling** [c] • Reductions in streamflow affecting **hydropower production** [c]	• Rising river temperatures **reduce the cooling efficiency** of thermal power plants [c] • Increased cooling needs, leading to **increased water withdrawal** for thermal power plant cooling [b] • Snow and ice cover changes: **Hydropower production is affected** by the timing of snowmelt [c] • Melting permafrost **threatening the stability** of oil and gas **pipelines** [c]
Urban green space	• Flooding: Impacts on species' composition and distribution, **habitat loss** [d] • **Salinisation of coastal** plant and animal **communities** inland due to higher water levels and increased estuarine salinity [d]	• **Ecosystems: Shifts** in plant and animal communities, with possible local **extinctions** [f]	• Urban green spaces: **less rain and irrigation water** • **Drying of wetland** ecosystems [b] • **Ecosystems: Shifts** in plant and animal communities, with possible local **extinctions** [f] • **Forest mortality** and potential decrease in resilience, accompanied by damage from pests and pathogens [f] • Decreased river flow **degrades habitat** for aquatic species [a]	• Higher water temperatures **degrade habitat** for aquatic species' such as salmon [a] • **Range expansion** of many invasive aquatic weed species and of insect pests affecting plants [b] • Wildfires: **Changes in plant community structures** [f] • Higher demand for cooling water in the energy sector leading to **increased thermal pollution** of water bodies and consequent impacts on freshwater biota [a] • **Ecosystems: Shifts** in plant and animal communities, with possible local **extinctions** [f]
Transport	• Flooding and storm surges: **damage** to and **degradation** of all **transport infrastructure** [b]	• Flooding and landslides **damage** all **transport infrastructure**: bridges, roads, subways and railways [b]	• **Disruption of river boat transportation** due to decreased river levels	• Higher temperatures cause **buckled rails and rutted roads** [c] • **Damage to roads** from permafrost thawing [b]
Human health	• Saltwater intrusion into aquifers: **Reduced access to potable water** in areas dominated by coastal groundwater abstraction [g] • **Injuries and mortality** from flood events [d]	• Flooding causing **contamination from sewage and other pollutants**, leading to health problems, including increases in infectious diseases [b] • Flooding can cause **damage to the health infrastructure** [b] • **Population displacement**, with associated health impacts [g] • Flood events: **Injuries and mortality** [d] and **negative mental health impacts** [j]	• Reduced river flows lead to **increased concentration** of pathogens and chemicals [b] • **Population displacement**, with associated health impacts [g] • **Increase in mortality, malnutrition**, and infectious, waterborne, water-washed and respiratory **diseases** [g] • Lack of alternatives leading to **consumption of water contaminated** by fluorine and arsenic [a] and other substances	• Changes in spatial distribution, intensity of transmission and seasonality of vector- and waterborne diseases, causing **morbidity and mortality** [b] • Increased occurrence of toxic **algal blooms** which are dangerous to human health [b] • Glacial Lake Outburst **Floods** pose a threat to human life [b] • Increase in the occurrence of **food poisoning** from seafood [g] • Worsening of **urban heat island** effects with consequent negative health impacts
Urban food production & supply	• Periodic flooding: **Salinisation** of coastal agricultural **land** [h] • Saltwater intrusion into aquifers: **Reduced freshwater availability** for irrigation [b] • **Alteration** of estuarine-dependent coastal **fisheries** [b]	• Direct **crop damage** from flooding [b] • Soil **erosion** [b] • **Yield decline** due to waterlogging [l] • Creation of conditions favouring **fungal infestations** in certain crops [l]	• Negative impact on **rain-fed agricultural production** [h] • **Yield decreases** [g] • Lack of **water availability for irrigation** [b] • Decreased streamflow **increases the salinity** of estuaries and wetlands and **decreases outflow of sediment and nutrients**, negatively affecting coastal fisheries [b] • **Decrease in recruitment** for river fishery species [d] • Increased **livestock mortality** [b]	• More favourable climate for **weed and insect pests**, reducing yields [d] • Snow and ice cover changes: **Reduced availability of irrigation water** in summer due to early snowmelt [a] • Wildfires: **Disruption of food production** [d] • Increase in vector- and waterborne diseases: **Agricultural productivity is reduced** by increased morbidity and mortality within the population [m] • More rapid **drying of soil** after rainfall or irrigation [h] • **Negative impact** on freshwater and diadromous **fisheries**, including local extinctions [d] • Direct negative **health impacts for livestock** and changes in ranges of diseases affecting it [d]

a Kundzewicz et al., 2007
b Bates, Kundzewicz, Wu & Palutikof (Eds.), 2008
c Wilbanks et al., 2007
d Nicholls et al., 2007
e Easterling et al., 2007
f Fischlin et al., 2007
g Confalonieri et al., 2007
h Svendsen & Künkel, 2008
i The New York City Department of Environmental Protection (NYCDEP), 2008
j Zwolsman et al., 2009
k Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), 2008
l Rosenzweig, Iglesias, Yang, Epstein & Chivian, 2001
m Audibert, 2010
n www.ewater.com.au

Annex 3: Adaptive capacity assessment

This table identifies four main determinants of adaptive capacity, and provides some points which should be considered when assessing adaptive capacity against these determinants. The following stages, which include the choice and assessment of indicators, are location-specific and are therefore not detailed here.

Determinant	Economy	Society	Governance	Ecosystems
Description	This category covers activities from all economic sectors (including agriculture, industry, services, R&D) that feed or are generated by a city. It covers the full range of systems, including energy, water, technology development, health services, etc.	The social determinant encompasses a range of factors, which include information (availability and access to), social capital (the connections within and between social networks and groups) and human capital (the sum of the knowledge, education and skills possessed by individuals within a society).	Governance relates to all levels of society, and describes the process by which a society makes decisions and who is involved in that decision-making process. Institutions are at the centre of governance.	Ecosystems are composed of plant and animal life as well as of the non-living environment in which they exist, but also of the interaction between these elements.
Why is this factor being considered?	There is, in principle, a positive correlation between higher income, efficient systems with built-in redundancy and access to technological solutions on one hand, and a higher adaptive capacity on the other.	Adaptation, as viewed in the context of this handbook, is a societal response to climate change. Planning and implementation of adaptation actions will require the application of society's knowledge and skills. These are therefore positively correlated with higher adaptive capacity. Moreover, connections between social networks allow for the spreading of this knowledge and information across society and also have an inherent value.	The principles of good governance (UNDP, 1997) are similar to those upon which successful strategic planning rely. Since strategic planning is the basis for the planning and implementation of successful adaptation, good governance is needed for adaptation.	Ecosystems mainly influence the sensitivity of a city, since they are both affected by and have the ability to absorb climate change impacts. This sensitivity will affect their ability to contribute to adaptive capacity. Healthy ecosystems enhance the adaptive capacity of economic and social systems, because ecosystems are an integral part of the functioning of other systems and because they can provide a wealth of coping solutions.
Key areas to consider to determine adaptive capacity *	• Economic diversity and development • Wealth distribution • Energy sustainability and independence • Industrial productivity • Technological state and operational soundness of systems • Balance of trade • Resource availability and resource use efficiency • …	• Quality of life • Education levels and professional skills • Level of engagement in civil society, collective action • Participation in social networks and groups • Links between social networks and groups • Awareness of risks • Preparedness for emergency situations • Demographic situation • …	• Participation in decision making • Consensus building between interest groups • Responsiveness of institutions to stakeholder needs • Effectiveness and efficiency of institutions • Accountability of decision makers • Transparency of processes through access to information • Equity of opportunities across societal groups • Temporal perspective of development • Enforcement of legal frameworks • …	• Ecosystems services: regulation, provision, supporting and cultural roles • Interactions and interdependencies of ecosystem services • Biodiversity • 'Buffer zones' to hazards • Historical record of role of ecosystems in response to hazards and anthropogenic exploitation • Health status and natural/anthropogenic pressures affecting ecosystems (stress/exploitation levels) • Existing policies affecting ecosystem services • …

* Indicators should then be defined for each key area identified by the city

Annex 4: Co-benefits of sustainable water management options

Options	Urban water management benefits	Selected quality of life benefits and co-benefits to other urban management sectors
Alternative supplies for non-potable demand	• Water supply: Reduces demand • Water supply: Reduces treatment and pumping costs	• Ecosystems: Less water needs to be abstracted from the environment • Urban economic activities: Increased water availability for other purposes • Agriculture and urban green areas: Provides a cheap source of irrigation water
Metering and tariffs	• Water supply: Reduces demand • Water supply: Reduces treatment and pumping costs	• Ecosystems: Less water needs to be abstracted from the environment • Quality of life (social equity): Variable tariffs ensure low-cost fulfilment of basic water needs for low-income groups
Behaviour change	• Water supply: Reduces demand • Water supply: Reduces treatment and pumping costs	• Ecosystems: Less water needs to be abstracted from the environment • Urban economic activities: Increased water availability for other purposes • Energy: Reduced energy consumption through the use of less hot water
Water efficiency measures	• Water supply: Reduces demand • Water supply: Reduces treatment and pumping costs	• Ecosystems: Less water needs to be abstracted from the environment • Energy: Reduced energy consumption through the use of less hot water • Urban economic activities: Increased water availability for other purposes
Leakage management	• Water supply: Reduces demand • Water supply: Reduces treatment and pumping costs	• Ecosystems: Less water needs to be abstracted from the environment • Quality of life (noise and disruption): Future repairs are avoided by pipe replacement • Quality of life (health): Reduces risks of contaminants entering pipes • Urban economic activities: Provides a more reliable supply of water
Aquifer Storage and Recovery	• Water supply: Increases storage capacity • Water supply: Protects water quality • Stormwater management: Runoff reduction • Wastewater treatment: Contaminant removal	• Quality of life (health): ASR provides natural protection from organic pollution and contaminated stormwater runoff • Ecosystems: Subsurface baseflows from ASR can be used to support natural ecosystems • Agriculture and urban green areas: Provides a cheap source of irrigation water
Urine diversion toilets	• Wastewater treatment: Reduces costs	• Agriculture and urban green areas: Provides a cheap fertiliser, and increases urban food security • Ecosystems: Reduction of the nutrient load from wastewater effluent
Soil Aquifer Treatment	• Stormwater management: Peak runoff reduction • Wastewater treatment: Reduces costs	• Agriculture and urban green areas: Provides a cheap source of irrigation water
Constructed wetlands	• Wastewater treatment: Reduces costs • Stormwater management: Reduces runoff • Water supply: Reduces potable water demand	• Quality of life (aesthetic enjoyment and amenity value): Increase in urban green space • Urban development: On-site treatment of greywater and stormwater • Ecosystems: Creation of urban ecosystems
Waste Stabilisation Ponds	• Wastewater treatment: Reduces costs • Water supply: Reduces demand for potable water	• Agriculture and urban green areas: Provides a cheap source of irrigation water • Quality of life (disposable income): Source of local income through harvesting of fish and plants
Biogas production from sludge	• Wastewater treatment: Reduces costs	• Agriculture: Provides a cheap fertiliser • Quality of life (increased disposable income): Reduces cooking and heating bills • Urban economic activities: Provides a cheap and renewable energy source
Sludge reuse	• Wastewater treatment: Reduces costs • Stormwater management: Improves soil moisture retention	• Ecosystems: Source of nutrients • Agriculture and urban green areas: Provides a cheap fertiliser and soil conditioner • Urban economic activities: Provides a cheap and renewable energy or fuel source
Greywater reuse	• Water supply: Reduces demand for potable water • Wastewater treatment: Reduces costs	• Ecosystems: Creation of urban ecosystems • Agriculture and urban green areas: Provides a cheap source of irrigation water • Quality of life (aesthetic enjoyment and amenity value): Increase in urban green space
Site planning	• Stormwater management: Reduced runoff • Wastewater treatment: Pollutants are contained at the source and nonpoint pollution is managed	• Ecosystems: Protection and enhancement of local habitats • Urban development: Development of land can be implemented cost-effectively • Quality of life (aesthetic enjoyment): Stormwater-sensitive landscaping emphasises aesthetic features
Porous paving, swales, etc…	• Stormwater management: Reduced runoff • Water supply: Recharge of underlying aquifers • Wastewater treatment: Pollutant removal	• Urban economic activities: Reduced flooding risk • Quality of life (aesthetic enjoyment and amenity value): Swales provide grassy areas
Rainwater harvesting	• Stormwater management: Reduced runoff • Water supply: Reduces demand for potable water	• Ecosystems: Less water needs to be abstracted from the environment • Urban economic activities: Provides a more reliable supply of water • Agriculture and urban green areas: Provides a cheap source of irrigation water • Quality of life (general): Reduces water bills and provides a more secure supply of water
Green roofs	• Stormwater management: Reduced runoff • Water supply: Can reduce demand for potable water • Wastewater treatment: Removal of airborne pollutants from runoff	• Ecosystems: Creation of urban ecosystems • Quality of life (health): Improves air quality and reduces the urban heat island effect • Quality of life (aesthetic enjoyment and amenity value): Increase in urban green space • Energy: Reduced energy consumption through the use of less heating and air conditioning
Detention ponds and basins	• Stormwater management: Reduced runoff • Wastewater treatment: Pollutant removal	• Quality of life (aesthetic enjoyment and amenity value): Increase in urban green space. Use as playgrounds or sports facilities possibly during dry weather • Urban economic activities: Encourages investment in urban areas that would otherwise be prone to flooding

Source: Modules 3, 4 and 5 of the SWITCH Training Kit (ICLEI European Secretariat, 2011)

SWITCH – Managing Water for the City of the Future

www.switchurbanwater.eu

The SWITCH project has generated a wealth of information and guidance to help cities make the transition from their existing water management systems to the next generation of more sustainable and integrated solutions. Thirty-three partners from around the globe have been bringing people together in cities in Africa, Europe, South America and Asia to undertake research, test innovations and build capacity.

In addition to this handbook, a wide range of products has been published to accompany cities on their journey to sustainability. These include:

- SWITCH in the City: putting urban water management to the test brings together the experiences of twelve global cities with demand-led research, multi-stakeholder engagement and scaling up.
- City Water Balance, City Water Economics and City Water Drain provide decision-making software tools on technical, environmental and socio-economic options for water management.
- The SWITCH Transition Manual uses examples to communicate the key steps required to facilitate a SWITCH towards more sustainable urban water management.
- SWITCH Water Sensitive Urban Design and Sustainable Urban Drainage Manuals provide creative and artful ways to incorporate stormwater into urban planning along with best practice guidelines for stormwater management under extreme conditions.
- Water Demand Management in the City of the Future offers tools and instruments for practitioners.

www.switchurbanwater.eu

Now also available:

The SWITCH Training Kit

Integrated Urban Water Management in the City of the Future

Integration in urban water management is the key for getting water systems prepared for climate change and thus making them more sustainable in the long run. The SWITCH Training Kit has been developed to show how integration can be realised in practice.

Module 1:	Strategic planning – Preparing for the future
Module 2:	Stakeholders – Involving all the players
Module 3/4/5:	Water supply / stormwater / wastewater – Exploring the options
Module 6:	Decision support tools – Choosing a sustainable path
Target group:	Water managers, urban planners and engineers from local governments and water, wastewater and drainage utilities.
Use:	For training workshops, but also for individual reading.
Accessibility:	Freely available at *www.switchtraining.eu*

Interested in building the capacity of your city or organisation's water professionals for adaptation? Please contact ICLEI to arrange for a tailor-made training offer to be realised in collaboration with technical experts from the global SWITCH consortium (*water@iclei.org*).

www.switchtraining.eu

ICLEI European Secretariat – *www.iclei-europe.org*

ICLEI is an association of over 1,200 local governments that represents the interests of local authorities within the United Nations and at international policy forums. It is committed to supporting cities, towns and urban regions in their efforts to develop adaptation strategies and action plans, and to guide them through a systematic process of implementation and management. ICLEI is involved in creating and advancing tools that support local governments in assessing their vulnerability and developing their adaptation and resilience strategies. The association considers itself as an interface between various levels of government – from the European Union to the local level and vice versa, as well as between research, policy and practice. The ICLEI European Secretariat takes part in the following projects related to climate change adaptation:

- CHAMP, a project which aims to train and support local and sub-regional authorities in implementing an integrated management system for climate change mitigation and adaptation, and to promote the method and the model Europe-wide (*www.localmanagement.eu*).

- AsianCitiesAdapt brings together science and policy in order to identify the local impacts of climate change and to develop concrete local adaptation strategies in four Indian cities as well as four cities in the Philippines (*www.asian-cities-adapt.org*).

IWA – *www.iwahq.org*

The International Water Association is a global reference point for water professionals, spanning the continuum between research and practice and covering all facets of the water cycle. Through its network of members and experts in research, practice, regulation, industry, consulting and manufacturing, IWA is in a better position than any other organisation to help water professionals create innovative, pragmatic and sustainable solutions to challenging global needs.

Get involved with the IWA Climate Change and Adaptation Specialist Group 1) to identify climate-related impacts and risks in water utility operations and water resources management, 2) to increase awareness of climate change impacts on water utility operations and water management, 3) to stimulate adaptive actions in utility operations and water management, with the aim to enhance climate robustness, and 4) to connect the different communities involved (water utilities, water management, and climate change research): *http://www.iwahq.org/Home/Networks/Specialist_groups/List_of_groups/Climate_Change_and_Adaptation/*

Join 2,000 like-minded water, climate and energy professionals from across the globe at the IWA World Congress on Water, Climate and Energy in Dublin, Ireland in May 2012 to exchange ideas, explore the state of the art and debate the key issues underlying the science and practice of these inextricably linked natural, utility and infrastructural issues of our time: *http://iwa-wcedublin.org/* Keep up to date or submit an article on climate adaptation through the IWA Journal of Water and Climate Change: *http://www.iwaponline.com/jwc/*

UNESCO-IHE – *www.unesco-ihe.org*

The mission of the UNESCO-IHE Institute for Water Education is to contribute to the education and training of professionals and to build the capacity of sector organisations and knowledge centres in the fields of water, the environment and infrastructure, in developing countries and countries in transition. In view of the urgency to meet the challenges of climate change adaptation and the increasing demand for capacity, relevant experiences world-wide are constantly being integrated into UNESCO-IHE's educational programmes.

UNESCO-IHE offers a wide range of short courses. In the field of climate change the on-line course 'IWRM as a tool for adaptation to climate change' is offered annually (starting date: early September). From 4 to 22 July 2011, the newly developed course 'IWRM as a tool for adaptation to climate change: decision making under uncertainty and conflicting interests' will be offered for the first time at UNESCO-IHE's premises in Delft, the Netherlands. More information about these courses can be found on the website: *www.unesco-ihe.org*.

This handbook was produced as part of the SWITCH project which aimed to achieve more sustainable urban water management in the "City of the Future". A consortium of 33 partner organisations from 15 countries worked on innovative scientific, technological and socio-economic solutions with the aim of encouraging widespread uptake around the world.

www.adaptationhandbook.org

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