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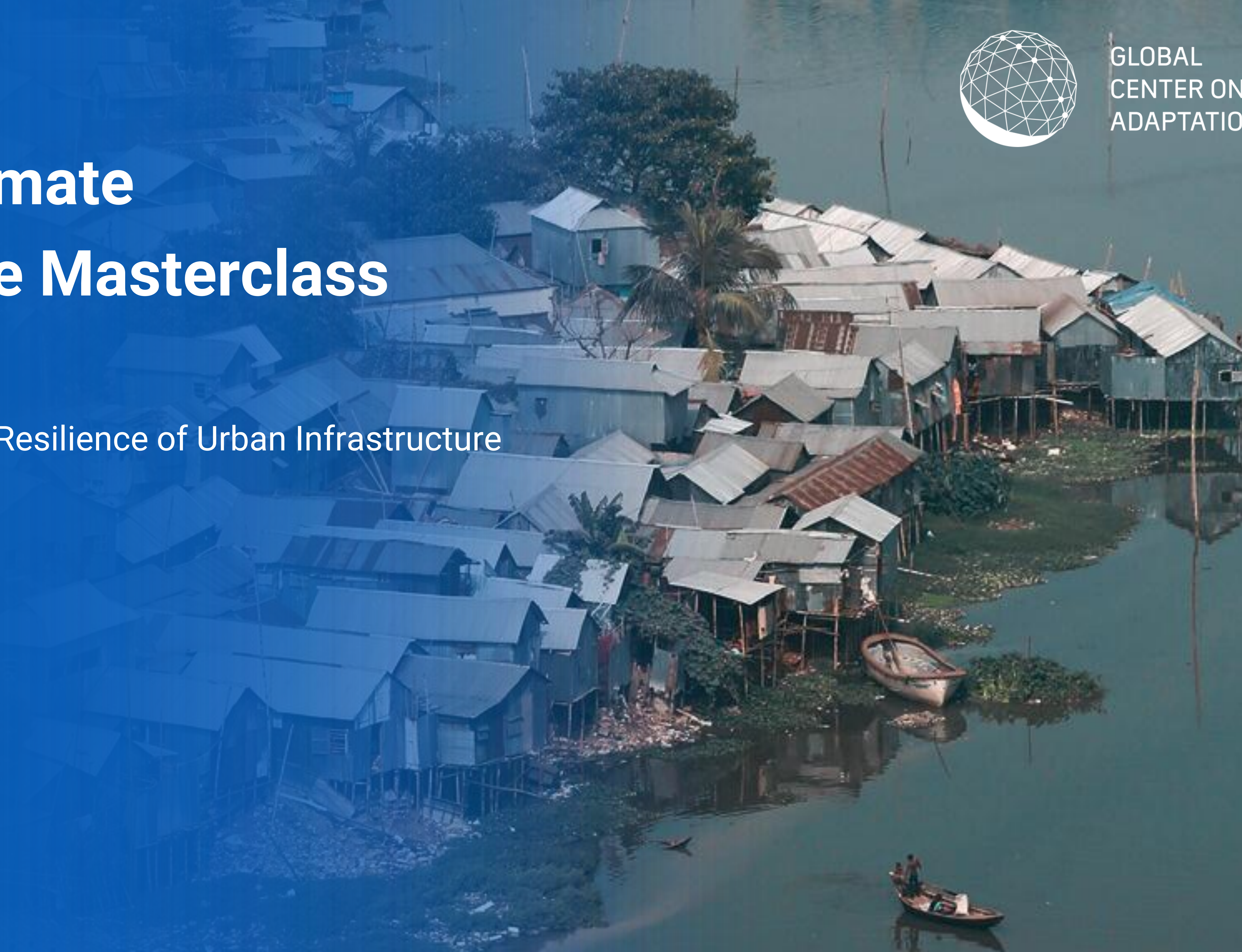
ADAPTATION

# Urban Climate Resilience Masterclass

## Module 4

Ensuring Climate Resilience of Urban Infrastructure



Korail slum, Dhaka; Photo by Ricci Coughlan, DFID

# UCRMC Course Overview

Welcome to the Urban Climate Resilience Masterclass! You are about to start **Module 4.**

**Module 1**

Introduction to Climate Change and Urban Resilience

**Module 2**

Understanding Climate Risks in Your City

**Module 3**

Locally Led Adaptation for Urban Resilience

**Module 4**

Ensuring Climate Resilience of Urban Infrastructure

**Module 5**

Step-by-Step Guidelines for Delivering Climate Resilient Infrastructure

**Module 6**

Financing Climate Resilient Urban Infrastructure

# Acknowledgements

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# Acknowledgements

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These contributions were instrumental in ensuring the relevance and quality of the UCRMC Modules.

# Agenda

01 **Why This Topic Matters**

02 **Learning Objectives**

03 **Concepts & Definitions**

04 **How Climate Change Impacts Urban Infrastructure**

05 **Climate Impacts on Infrastructure in Kenya**

06 **What Makes Urban Infrastructure Resilient?**

07 **Ways to Build Resilient Urban Infrastructure**

08 **Climate Resilient Infrastructure in Kenya**

09 **Interactive Exercise**

10 **Summary**

Korail slum, Dhaka; Photo by William Veerbeek, Flickr

# Housekeeping

### Listen

Listen carefully, follow along and make your own notes.

### Ask

Ask the trainers questions or clarifications at any time.

### Share

Your own experience is valuable and we encourage you to share it.

### Discuss

Share and discuss with others during exercises, breaks and reflections.

# 01 | Why This Topic Matters

Photo by Aleksandar Pasaric, Pexels

# Why This Topic Matters

Infrastructure is the backbone of urban systems. Infrastructure & services are vital for ensuring the necessities of life and promoting economic activity.

Climate change poses risks to urban infrastructure including loss, damage and service disruption, leading to cascading impacts across sectors.

City planners need to understand how to make sure that urban infrastructure and services are resilient to climate change so that they are not damaged and disrupted by climate hazards.

Investing in climate resilient infrastructure makes economic sense, reduces post-disaster expenditure, and ensures continuity of urban services during disasters, helping minimise losses.

This module introduces a range of approaches to building climate resilience of urban infrastructure, including structural measures, non-structural measures and Nature-based Solutions (NbS).

# 02 | Learning Objectives

Photo by Safari Consoler, Pexels

# Learning Objectives

## By the end of Module 4 participants will be able to:

Understand the cascading impacts of climate change on urban infrastructure.

Understand the various ways of building climate resilience in urban infrastructure, including through hard and soft infrastructure.

Be familiar with a systems approach to understanding complex issues at the nexus of urban planning and climate change and associated solutions.

Be familiar with Nature-based solutions (NbS) as an approach to deliver climate resilience in urban infrastructure.

Understand how to mainstream climate risk and resilience into infrastructure planning processes and instruments.

# 03 | Concepts & Definitions

Nairobi; Photo by Nina R, Wikimedia

# Concepts & Definitions

**Resilient Infrastructure**
Infrastructure systems and networks, and the services they provide, that can resist and absorb disaster impacts, maintain adequate levels of service continuity during crises, and swiftly recover so that future risks are reduced or prevented.

**Structural Measures / Grey Infrastructure**
Physical systems required for a city's operation; including roads, bridges, telecommunications, transportation networks, energy generation and distribution systems etc.

**Non-Structural Measures / Soft Infrastructure**
Human capital and institutions required to maintain a society and economy, including laws, rules, systems and the people, inputs and outputs involved in delivering services such as healthcare, financial institutions, law enforcement, and education.

**Ecosystem Services**
The benefits that nature provides to people. They include carbon storage and sequestration, biodiversity maintenance, food and water provision, recreation and tourism, opportunities for income etc.

**Ecosystem-based Adaptation (EbA)**
A nature-based solution that harnesses biodiversity and ecosystem services to reduce vulnerability and build resilience to climate change.

# Concepts & Definitions

**Nature-based Solutions (NbS)**
Actions that address societal and environmental challenges through the protection, sustainable management and restoration of ecosystems, benefiting both human well-being & biodiversity. NbS have the potential to enhance resilience to climate change and reduce the impact of disasters. NbS can include green, blue and blue-green infrastructures.

**Blue Infrastructure**
Characterized by natural and artificial water systems, including wetlands, ponds, lakes, streams rivers, riverbank and storm water provision.

**Green Infrastructure**
Characterized by well-functioning biophysical systems, mostly related to green spaces that support biodiversity and natural ecological processes, such as mangroves, coastal salt marshes, coral reefs, sea grasses, sand beaches, dunes, forests, street trees, grasslands.

**Blue-Green Infrastructure**
Nature-based (structural) infrastructure using the capacities of green space and water; includes green roofs for stormwater runoff management, coastal reforestation of mangroves.

# Review Exercise

## Test your knowledge, and challenge those around you:

- Choose one of the definitions.
- In 2 mins, draw a simple sketch of what you think this concept would look like in real life.
- Challenge someone else on your table to guess which of the definitions you have drawn.

Do you have any questions on the definitions or concepts?

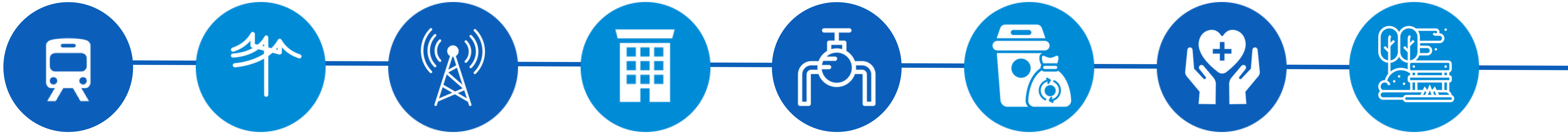
- Resilient Infrastructure
- Nature-based Solutions (NbS)
- Grey Infrastructure
- Green Infrastructure
- Soft Infrastructure
- Blue Infrastructure
- Ecosystem Services
- Blue-Green Infrastructure
- Ecosystem-based Adaptation (EbA)

# 04 | How Climate Change Impacts Urban Infrastructure

Kibera; Photo by Nina R, Flickr

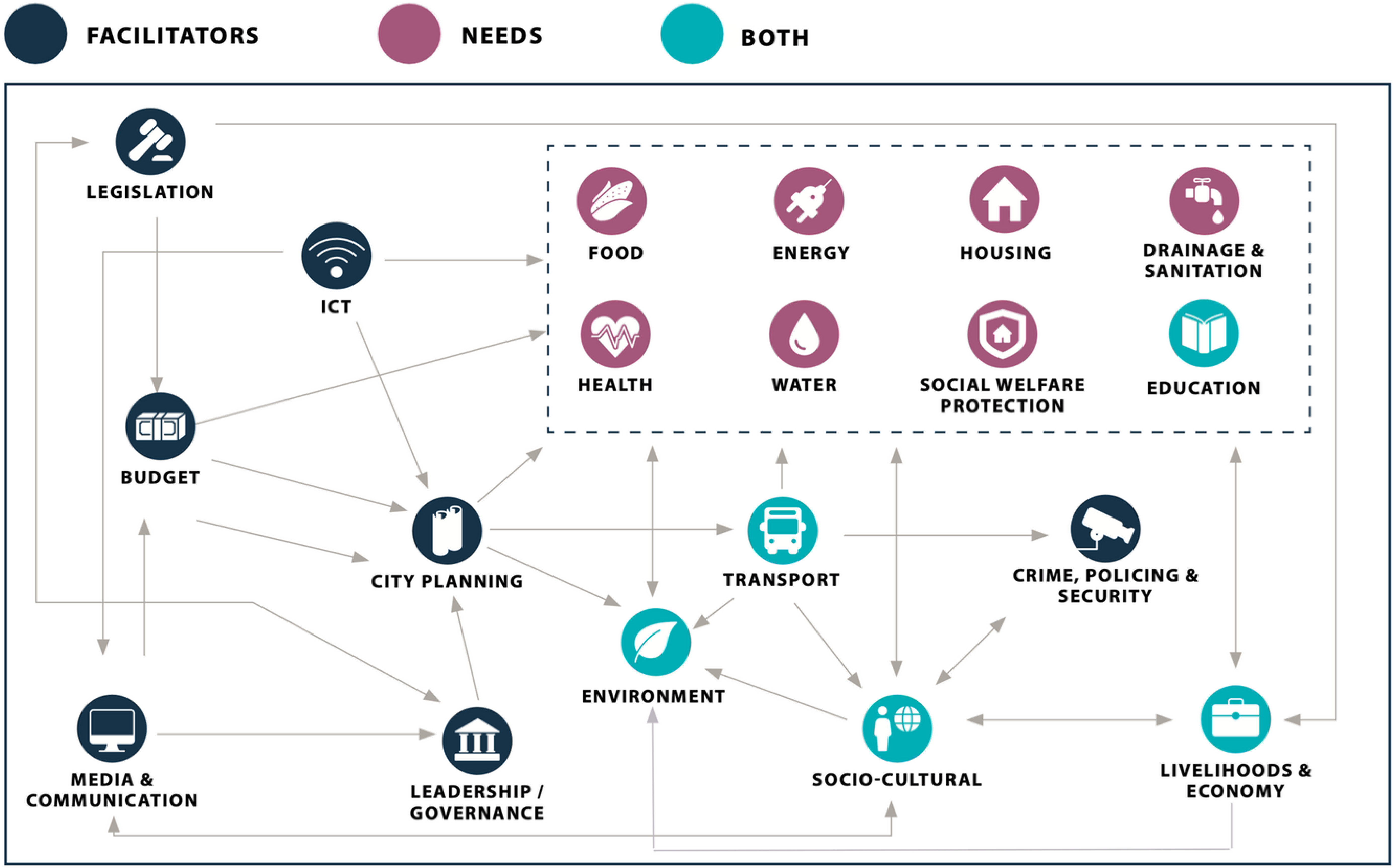
# Infrastructure is the backbone of a city's development

- Infrastructure systems consist of interconnected networks of assets that deliver vital services to support urban lives and economies.
- Physical assets form the building blocks of urban infrastructure upon which all urban services are built.
- Some critical infrastructure for cities include roads and transportation networks, energy systems, telecommunications networks, buildings and housing, water supply systems, sewage and waste management facilities, healthcare facilities, and public spaces.
- In addition to assets, infrastructure systems also include operational organizations and regulatory authorities responsible for governing service provision at various levels.



Transportation | Energy | Telecoms | Buildings | Water | Waste | Health & Sanitation | Public Spaces

# Infrastructure & services are critically interconnected



# Recap: Climate resilient infrastructure

Cities need to climate proof existing and future infrastructure & services so that they are resilient to climate change.

# How climate change impacts urban infrastructure

### Asset damage

Climate change can cause direct physical damage to infrastructure assets. Asset damage leads to additional costs and deterioration in the performance and value of the asset and the services it provides.

### Examples

Heatwaves lead to overheating of power generation equipment, causing failure.

### Service disruption

Climate change can cause disruptions in the provision of infrastructure services. This can cause additional costs to maintain the same level of service under different climatic conditions (e.g. larger reservoirs are needed to address more variable precipitation).

Flooded and washed-out roads, bridges, ports and railways cause disruption to public transport services and impact supply chains.

### Changing demand for infrastructure services

Climate change impacts the demand for infrastructure services, putting pressure on service providers.

Increased electricity demand for cooling due to increased temperatures, which can lead to power outages and grid overloads.

# How climate change impacts urban infrastructure

| | Heatwaves | Storms & Cyclones | Flooding | Sea-Level Rise |
|---|---|---|---|---|
| **Transportation** | • Overheating of road surfaces and rail tracks, leading to deformations and service disruptions.<br>• Thermal expansion causes vehicle engines and transit system components to overheat and malfunction. | • Damage to bridges, roads, and transit facilities from strong winds and flying debris.<br>• Disruptions in air and sea port operations due to high winds and severe weather. | • Waterlogged roads and transit systems leads to service disruptions, particularly in low-lying areas.<br>• Sediment and debris accumulation on transport routes, hinders movement. | • Coastal erosion damages roads and rail lines near shorelines.<br>• Submergence and saltwater corrosion of coastal transportation infrastructure |
| **Energy** | • Overheating of power generation equipment reduces efficiency and increases risk of outages.<br>• Increased electricity demand for cooling leads to power outages and grid overloads. | • High winds damage power lines and energy production facilities.<br>• Disruption of energy supply chains due to damage to substations, transmission towers and lines. | • Flooding disrupts power production and distribution, affecting substations and grid connections.<br>• Contamination of fuel supplies leading to generator and power station failures. | • Submergence of low-lying power plants and transformer stations due to rising sea levels.<br>• Accelerated corrosion and wear of energy infrastructure in coastal zones. |

# How climate change impacts urban infrastructure

| | Heatwaves | Storms & Cyclones | Flooding | Sea-Level Rise |
|---|---|---|---|---|
| **Telecoms** | • Additional burden to cool equipment in exchanges and base stations, resulting in increased failure rates and impacting service delivery.<br>• Increased burden on telecoms for emergency response exacerbates system loads. | • Structural damage to antennas and satellite dishes impairs communication services.<br>• Power outages during storms lead to loss of telecom services when backup systems fail. | • Water damage to underground cables and telecom equipment disrupts services.<br>• Inundation of key network nodes disrupts telecom services. | • Corrosion and functional degradation of telecom equipment in coastal areas due to saltwater exposure.<br>• Rising maintenance and repair costs for infrastructure exposed to marine environments. |
| **Buildings** | • Increased energy demand for air conditioning strains electrical systems, risking outages,<br>• Heat exacerbates deterioration of building materials, leading to faster degradation. | • Structural damage to buildings from wind, impacting roofs and windows.<br>• Frequent need for structural repairs and reinforcements in buildings in cyclone-prone areas, increasing costs. | • Flooding causes significant damage to lower floors and basements, necessitating costly repairs.<br>• Moisture and mold problems persist long after initial floodwaters recede. | • Soil erosion and instability lead to foundational issues in coastal buildings.<br>• Risk of higher insurance premiums and challenges in maintaining property values in coastal areas. |

# How climate change impacts urban infrastructure

| | Heatwaves | Storms & Cyclones | Flooding | Sea-Level Rise |
|---|---|---|---|---|
| **Water** | • Increased evaporation rates reduce water supplies, impacting availability.<br>• Higher water temperatures affect water quality, increasing treatment challenges. | • Damage to water infrastructure such as pipes and treatment plants during storms.<br>• Storm runoff contaminates water supply with pollutants and debris. | • Damage to water distribution systems, such as burst pipes leading to disrupted services.<br>• Flooding overwhelms water treatment facilities, leading to contamination of water supply. | • Loss of coastal water infrastructure and natural water buffers like wetlands.<br>• Saltwater intrusion compromises the quality of freshwater resources. |
| **Waste** | • Higher temperatures increase the risk of waste combustion and fires in disposal sites.<br>• Increased waste generation from disposables used during heatwaves, such as plastic water bottles and cooling products. | • Damage to waste management infrastructure like recycling centers and landfills.<br>• Storms disrupt collection and processing, leading to waste accumulation across communities. | • Disruption of waste collection routes due to flooded roads and damaged infrastructure.<br>• Floodwaters spread waste and hazardous materials, complicating cleanup efforts. | • Sea-level rise leads to inundation of landfills near coastlines, risking the release of contaminants into surrounding areas and water bodies. |

# How climate change impacts urban infrastructure

| | Heatwaves | Storms & Cyclones | Flooding | Sea-Level Rise |
|---|---|---|---|---|
| **Health & Sanitation** | • Heatwaves lead to a surge in heat-related illnesses, overloading healthcare facilities.<br>• Increased demand for emergency services and medical care during periods of extreme heat. | • Damage to healthcare infrastructure hampers emergency response.<br>• Disrupted access to healthcare services due to damaged transport routes and facilities. | • Flooding compromises sanitation systems, escalating the risk of waterborne diseases.<br>• Damage to health care facilities, for example due to water ingress. | • Sea-level rise leads to saltwater intrusion into freshwater systems, compromising water quality and sanitation facilities at coastal medical centers. |
| **Public Spaces** | • Extreme heat reduces the usability of outdoor spaces, affecting citizen health and decreasing community engagement. | • Damage to landscaping, trees, and recreational facilities reduces the availability of public spaces.<br>• Increased maintenance and restoration costs for public spaces after storm events | • Parks and public gardens become waterlogged, restricting recreation and community events.<br>• Long-term impacts on the ecological health of public spaces due to repeated flooding. | • Permanent inundation of low-lying public areas like parks and beaches, reducing available recreational space and altering the landscape.<br>• Erosion of coastal public spaces resulting in loss of land and damage to infrastructure. |

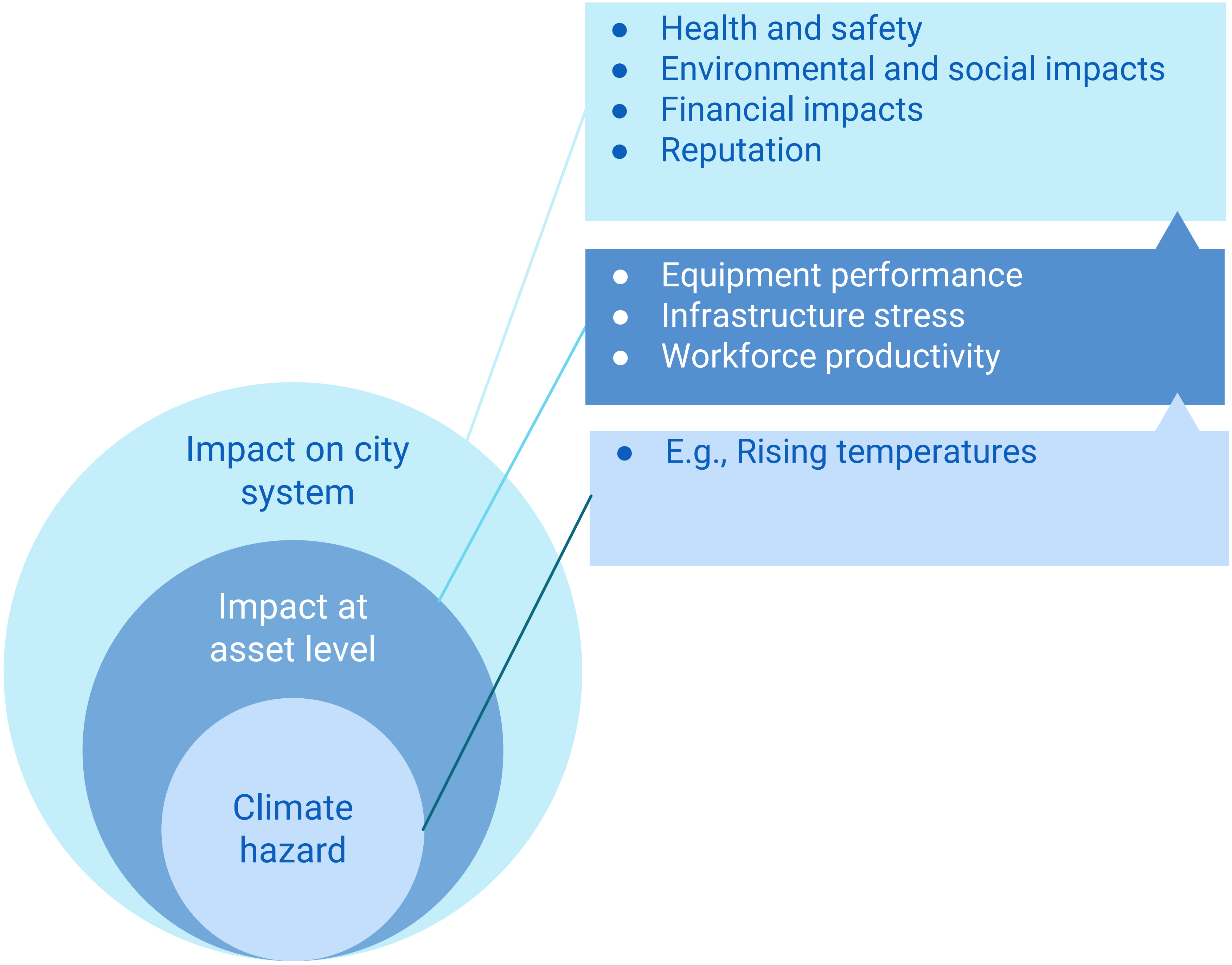
# Cascading Impacts of Climate Change

**Cascading impacts of climate change**

Infrastructure increasingly operates as an interdependent "system-of-systems", meaning infrastructure assets depend on each other for delivering urban services

However, this also means there is potential for cascading failures and systemic risks due to climate impacts

A single climate impact on one infrastructure asset or service in a city can cause a cascade of impacts across other assets & services, leading to more severe and pronounced negative consequences for a city.



# Cascading Impacts of Climate Change

**Case Study | Ghana Flooding**

Climate risks to Ghana's transport sector from floods and landslides, could cause USD $3.9 billion in damages by 2050, nearly triple the USD $1.3 billion invested in transport infrastructure in 2019.

The impact of flooding could severely damage roads and transportation infrastructure in Eastern, Central and Western districts in Ghana. This could lead to cascading impacts on healthcare systems. It could isolate over 80% of the population from accessing healthcare, which would disproportionately affect women who are frequent users of these services.

Building the climate resilience of infrastructure & services should be viewed in the context of the entire system, rather than focusing on a single asset or service.


UGC photo

# Climate Impacts on Vulnerable Groups

**People Living in Informal Settlements**

- Increased temperatures put pressure on an already-stressed water supply, which has a disproportionate effect on urban poor living in informal settlements. They have to pay high prices to buy water from informal vendors when it is not available.
- Heat-related illnesses, especially of children and the elderly, increase living costs as public health facilities have limited capacity to provide care at affordable cost.
- Insecure tenure of informal settlements restricts household access to electricity to cope with heat. They experience load-shedding more often and need to rely on services from informal vendors.

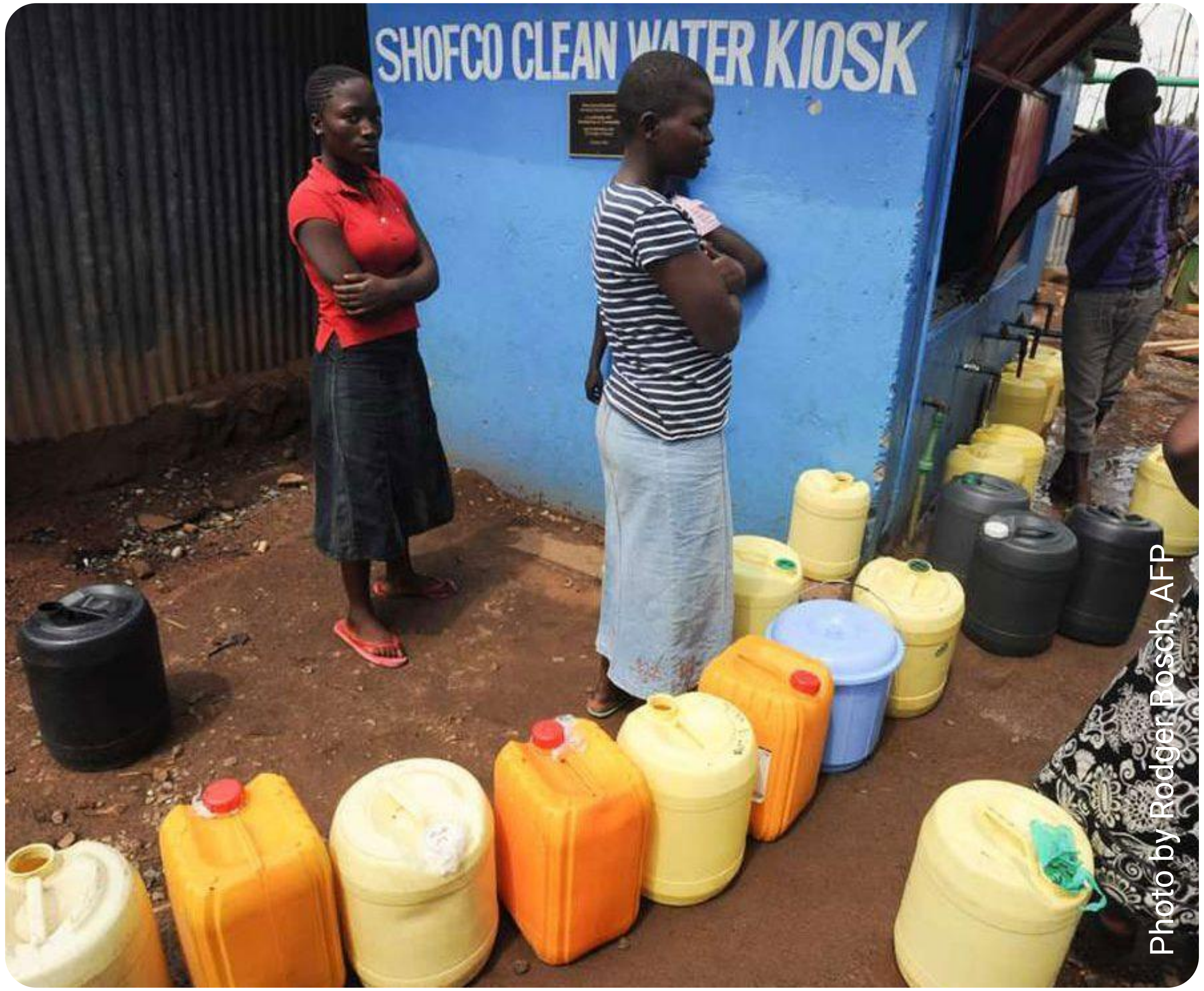



Photo by Rodger Bosch, AFP

# Climate Impacts on Vulnerable Groups

### Informal Settlement Riverine Communities

- Communities in informal settlements, are often located near rivers.
- Climate change has increased the risks they face owing to their location.
- Heavy rainfall and flooding due to extreme weather events have damaged or washed away houses in riverine communities and put lives at risk.
- Informal workers who run their businesses on the roadside and open spaces lose businesses during intense rainfall and waterlogging.

Nairobi; Photo by AP

# Climate Impacts on Vulnerable Groups

### Women and Girls

- Women and girls often suffer the impact of climate impacts on infrastructure.
- Increased drought can lead to water scarcity, which disproportionately puts burden on women who often spend significant time collecting water if they do not have access to piped water.
- Changing rainfall patterns leading to waterlogging and and flooding of roads make women’s and children's mobility difficult and unsafe. The cost of travelling for work increases when roads are flooded. Women, who often use public transport and walk to work, suffer most.

# 05 | Climate Impacts on Infrastructure in Kenya

Northern Kenya; Photo by Luis Tato, AFP

# Impacts of climate change on critical infrastructure

## Transportation

- **Increased flooding** has caused damage to roads, airports and railway infrastructure, which in turn has caused disruption of transport related services.

- **Sea level rise** has led to coastal flooding and erosion, affecting infrastructure such as ports and coastal roads.

# Impacts of climate change on critical infrastructure

### Energy Generation & Transmission

- More frequent and intense extreme weather events such as **storms, heavy rainfall, and strong winds** have damaged energy transmission lines, towers, and substations, leading to disruptions in electricity supply.

- **Extreme high temperatures** have increased evaporation from reservoirs, impacting hydropower generation e.g. in Kisumu, Nairobi and Arid and Semi Arid lands (ASALs) such as Wajir, Garissa

Imara Daima railway station, Nairobi;
Photo by David Gichuru, The Standard

# Impacts of climate change on critical infrastructure

### Telecom

- Extreme weather events such as **heavy rainfall, floods, cyclones and storms** often damage or disrupt telecom infrastructure, including landlines and mobile networks and fibre optic internet cables

Photo by Rodger Bosch, AFP

# Impacts of climate change on critical infrastructure

## Buildings

- **Extreme rainfall** has damaged buildings. The heavy rains that struck East Africa from March to May 2024 resulted in a new level of pressure on aging and unplanned buildings and basic infrastructure. Some buildings collapsed while others were completely ruined by heavy rains and flooding.

- **Extreme rainfall** has also damaged other built infrastructure such as dams. The heavy rains that struck East Africa from March to May 2024 caused some dams to collapse, including the Old Kijabe Dam, resulting in massive damage and fatalities.

- The National Disaster Operations Centre considers 192 dams in Kenya to be at high-risk due to water levels being at, or over, capacity. This threatens downstream communities with flood damages.

Wall collapsed during heavy rains in Ruaka town, Kiambu; Photo by The Standard

# Impacts of climate change on critical infrastructure

## Water

- **Droughts** have led to reduced water availability and water scarcity, affecting water supply and sanitation systems.

- Water scarcity can also put strain on manufacturing & industry, small businesses, agriculture and other economic activities that relies on reliable water supply.

- Water stress puts a disproportionate impact on poor and marginalized groups who already tend to have lower access to reliable water sources.

Kenya; Photo by Hadynyah, Getty Images (licensed via Canva)

# Impacts of climate change on critical infrastructure

**Waste**

- With increasing waste volumes in Nairobi, there is also expected to be a rise in the emissions that not only pollute the environment but also pose a health risk to informal waste workers.

- The waste sector can contribute to **cascading climate impacts,** as poor waste collection can lead to urban pollution that clogs drainage infrastructure and increase urban flood risk.

# Impacts of climate change on critical infrastructure

## Health & Sanitation

- More frequent and severe **droughts and floods** lead to contaminated water sources. Combined with inadequate sanitation facilities, this poses significant risks to public health, spreading diarrheal diseases, cholera, and other water-related illnesses.
- **Flooding** has led to inundation of sanitation infrastructure e.g. overloading of sewer systems
- Higher temperatures contribute to **heat waves** and the urban heat island effect, increasing heat-related health risks such as heat stress e.g. in Mombasa, Kisumu and Nairobi.

Kibera; Photo by Vlad Karavaev, iStock

# Impacts of climate change on critical infrastructure

## Public Spaces

- Increasingly common **heatwaves** pose significant risks to public health, while also making public spaces uninhabitable.

- Other public spaces, especially those that are located along rivers now face the challenge of constant **flooding** and encroachment from communities living near the rivers.

Kenya; Photo by Byelikova Oksana, Getty Images (licensed via Canva)

# Experience Share

## Open Floor

→ Do you have any examples or stories of the impacts of climate change in your city?

→ Consider the infrastructure, communities, and environments that may have been affected.

→ Raise your hand if you have an example or story to share with the room.

Photo by Waterdotorg, Flickr

# 06 | What Makes Urban Infrastructure Resilient?

Photo by Tuu Sitthikorn, Canva

# Why it is important to make infrastructure resilient

Climate resilient infrastructure positively impacts the social and economic wellbeing of urban populations. By building resilience of infrastructure cities can ensure:

**Increased Reliability of Service Provision**

Ensures consistent access to essential services, even during climate-related extreme weather events including floods and heatwaves

**Increased Asset Life**

Prolongs the lifespan of infrastructure assets, maintaining their functionality and service provision capabilities over time

**Improved Efficiency of Service Provision**

Optimizes resource allocation and streamlines service delivery, leading to more effective and equitable delivery of essential services

# Why it is important to make infrastructure resilient

| | Increased Reliability of Service Provision | Increased Asset Life | Improved Efficiency of Service Provision |
|---|---|---|---|
| **Social** | • Enhanced public health and well-being, particularly in vulnerable communities during emergencies<br>• Reduced vulnerabilities of human life and livelihoods by providing continued access to vital services | • Preservation of public health and safety through preventing infrastructure failures and service interruptions<br>• Promotion of social stability and resilience by ensuring continued functionality of infrastructure assets | • More equitable access to essential services, reducing disparities in service delivery and promoting social inclusion<br>• Greater public satisfaction and trust in urban infrastructure systems through streamlined service provision processes |
| **Economic** | • Economic stability and resilience in urban areas, with businesses able to operate without interruption<br>• Attraction of investment and support for economic growth by providing a conducive environment for businesses to thrive | • Economic savings and efficiencies through reduced frequency of asset replacements and repairs<br>• Maximization of benefits derived from infrastructure development, supporting long-term economic sustainability | • Reduces financial burden on governments and taxpayers through cost-effective operation of infrastructure systems<br>• Fosters innovation and competitiveness by attracting investment and supporting economic growth in urban areas |

# What makes urban infrastructure climate resilient?

# What makes infrastructure climate resilient?

It is  planned, designed, built and operated in a way that anticipates, prepares for, and adapts to changing climate conditions.

It can withstand climate-related disruptions and continue to provide services such as power, water, and healthcare services even during crises.

It can recover rapidly from climate-related disruptions without rebuilding the vulnerabilities of the past.

It considers interdependencies and how changes in one infrastructure system may affect risk elsewhere e.g. an increase in paved surfaces for improved road networks may increase flood risk.

It supports inclusive social and economic resilience so that people are less vulnerable to climate hazards.

Dhaka; Photo by LepetitNicolas, Flickr

# Two approaches to climate resilient infrastructure

01

**Climate Proofing Infrastructure:** When building new infrastructure or upgrading existing infrastructure, ensure that the design of the asset can withstand current and future climate impacts

**Example:** Upgrade road networks in floodplains using climate resilient design standards and materials, so they can withstand more frequent flooding caused by climate change.

02

**Infrastructure that Addresses Underlying Vulnerabilities:** Make infrastructure investments to address peoples' underlying vulnerability so they are less severely affected by climate impacts

**Example:** Provide better access to reliable electricity, so that when extreme heatwaves occur, they are not as vulnerable to heat stress and can cool their homes effectively.

Dhaka; Photo by Bobulix, Flickr

# Design Principles for Climate Resilient Urban Infrastructure

01 | Systems Approach

02 | Adaptive Management

03 | Equity & Inclusion

Photo by Luis Tato, AFP

# 01 | Systems Approach

**A systems approach** is used to address the interdependencies across different infrastructure assets and services within a city. It considers how individual assets influence one another and how they interact with the overall system.

A systems approach identifies risks to the entire system, including cascading impacts. It also considers that resilience building interventions should increase resilience of the entire system, not just a single asset or sector.

**Example:** Road infrastructure is interconnected with water management infrastructure, for managing run-off water during rainfall. To increase the climate resilience of road networks, city planners must consider this interconnection. Making drainage systems more resilient will help ensure that roads can cope with future flooding events.

Khulna Dacope Koira, Bangladesh; Photo by Emdadul Islam Bitu, UNDP Bangladesh

# 01 | Systems Approach

**Case Study | Rosario, Argentina**

**Background**: Since 2001, Rosario, Argentina has demonstrated systems-level change by integrating agriculture into the city's environmental and land use policies, accompanied by social programs. This helps the city be resilient to flooding and heat events.

**Interconnected issues**: Food production, land use, social benefits. The city faced economic crisis, record-breaking rainfall and flooding, along with food insecurity, unemployment, displacement and poverty.

**Intervention**: Initially the city equipped citizens with the resources to grow produce on vacant land and sell it at local markets. After major floods in 2007, the city identified flood risk zones to convert into "vegetable garden parks" for urban agriculture.

**Benefits**: These land use changes limit urban sprawl, provide cooling, and absorb excess rainfall. This also provides other linked benefits including green jobs, composting and renewable energy.

Rosario, Photo by WRI

# 02 | Adaptive Management

**Adaptive management** is a strategy that helps handle the uncertainties linked to climate change over the lifetime of an infrastructure investment. Sources of uncertainty include climate model projections, especially at the local scale, and socioeconomic changes linked to urban growth.

This means **integrating flexibility from the start**, so that infrastructure plans can respond to changing circumstances and multiple possible climate scenarios across the life of the investment. This also reduces costs, avoiding locking in large up-front investments.

Requires **monitoring and evaluating performance** over the lifetime of the investment, which allows decisions to be made at later points in time, according to performance, updates to climate science and attitude to risk. Climate risk assessments (CRAs) are an important input to these decisions.

Khulna Dacope Koira, Bangladesh; Photo by Emdadul Islam Bitu, UNDP Bangladesh

# 02 | Adaptive Management

### Case Study | Thames Estuary 2100 Plan, UK

TE2100 Plan outlines how increasing flood risk in the Thames estuary will be managed up until 2100, adopting a flexible approach to manage uncertainty.

The Plan monitors ten change factors: sea level, peak surge level, peak river flows, flood defense condition, barrier operation, economic development, erosion and deposition, natural habitat, land use plans, attitude to risk.

If rapid change is detected in these factors (for example sea level rise), the plan will be adjusted and a new adaptation pathway followed

This could include allowing flood defense interventions to be brought forward in time, designing structures to allow for modifications, and securing land for new defenses.

Westminster Bridge in London, Photo by Tom Arthur, Flickr

# 03 | Equity & Inclusion

## Equitable & Inclusive Access to Services

Effective urban infrastructure planning must ensure accessible, reliable and quality services for all. By 2050, urban areas are expecting an influx of 2.5 billion people, mainly in Asia and Africa. By the same year, up to 85% of urban poor neighborhoods are projected to be at risk of flooding, compared to about 60% of the broader urban landscape.

Disparities in access to climate resilient urban infrastructure, especially among the urban poor lacking basic services, compounds their existing vulnerabilities.

Social factors like gender and age result in differential vulnerabilities from poor access to services, even within vulnerable groups.

For example, in urban poor settlements, women bear the brunt of climate-related water scarcity as they fetch water for households. Reliable piped water infrastructure at the household level can help relieve this burden and contribute to women’s well-being.

Kallyanpur slum, Dhaka; Photo by Kibae, UN Photo

# 03 | Equity & Inclusion

## Equitable & Inclusive Decision-Making

Prioritizing equitable access involves engaging women and marginalized communities not only as end beneficiaries but also as active participants in shaping urban infrastructure development.

Community-based development processes are pivotal in integrating diverse perspectives, especially from vulnerable communities. This is crucial for fostering holistic resilience-building by ensuring equitable distribution in urban service delivery

For urban service planners and providers, adopting inclusive and participatory methods for climate risk assessments and infrastructure planning offers a starting point for engagement that integrates unique needs of diverse groups

Madogo, Tana River County, Kenya; Photo by IOM

# 03 | Equity & Inclusion

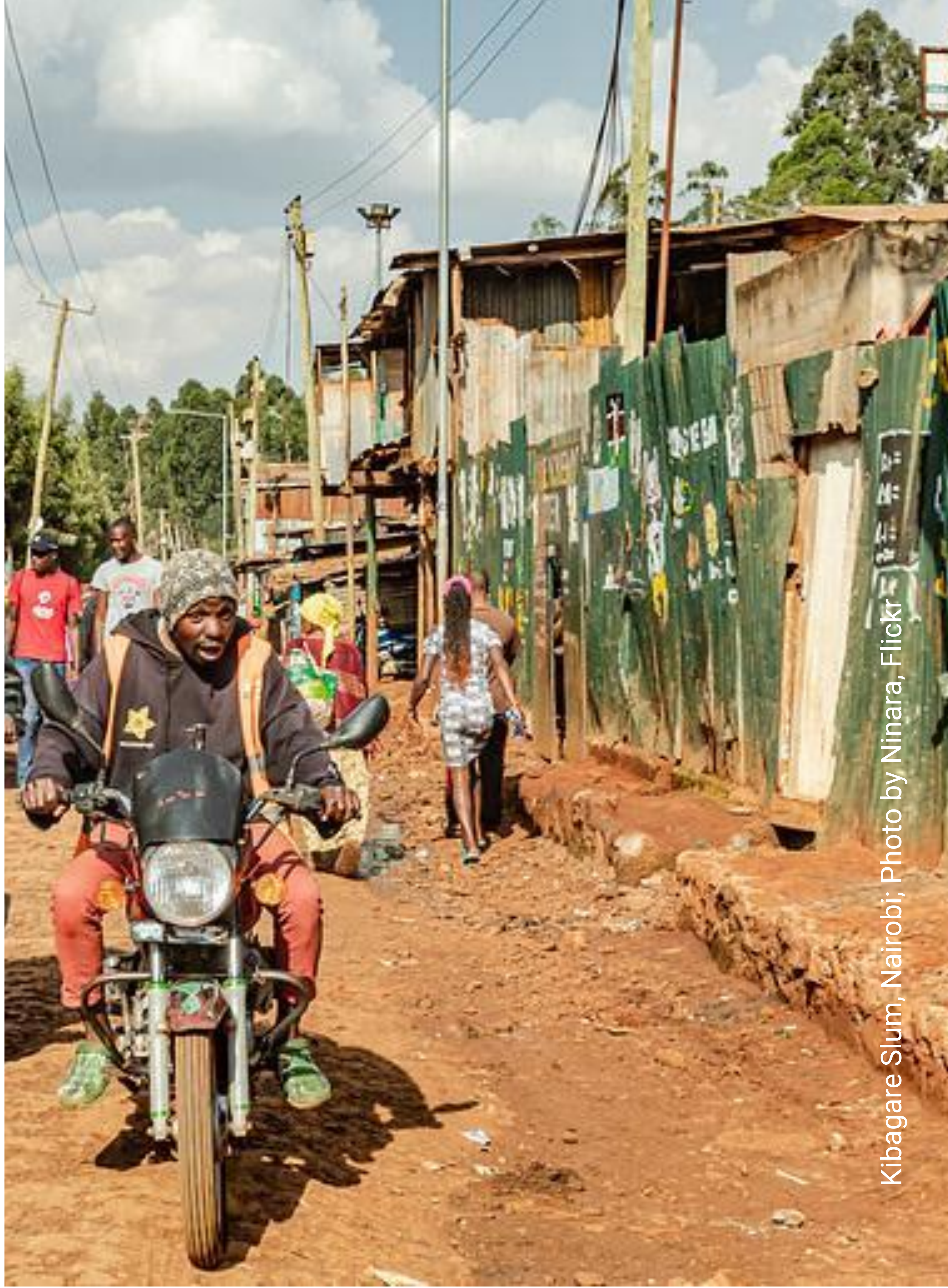
**Case Study | Kibera, Kenya**

**Where is Kibera:** In the centre of Nairobi, one of the world's largest informal settlements, home to over 300,000 people

**Problem**: Poor drainage and sanitation infrastructure and unsafe housing make residents of Kibera vulnerable to extreme flooding.

**Intervention**: Developed a network of community-designed and managed public spaces where flood protection combines green and grey infrastructure with core services. 5,000 residents were involved in the design.

**Impact**: Improved service access and flood protection for over 125,000 residents, particularly benefiting women and youth. This included: 11 new climate resilient spaces, 520m of flood protection installed, and 840m of drainage infrastructure installed.



Kibagare Slum, Nairobi; Photo by Ninara, Flickr

# Questions

## Open Floor

Does anyone have any questions about what makes climate resilient infrastructure?

Photo by Brian Inganga, AP

# 07 | Ways to Build Resilient Urban Infrastructure

Photo by Daniel Irungu, EPA-EFE

# Three ways to build resilient urban infrastructure


01 | Structural Measures


02 | Non-Structural Measures


03 | Nature-based Solutions

# 01 | Structural Measures

**Structural measures** are physical constructions and assets that are built to reduce or avoid the impacts of climate hazards.

They are also known as 'hard' or 'grey' infrastructure, since they are often made of concrete or other long-lasting materials.

Examples of structural measures include:

- Building a sea wall or using permeable paved surfaces to reduce run-off during heavy rainfall
- Retrofitting existing infrastructure e.g. raising the height of a bridge to protect against sea level rise

Photo by Edmundo_Cruz, Getty Images (licensed via Canva)

# 01 | Structural Measures

**Case Study | Da Nang, Vietnam**

**Problem**: Poor people live in inadequately built houses, at high risk to storm-related damage. As a result, many face financial stress and struggle to recover from crises.

**Intervention**: Da Nang implemented a project that provided 300 loans to low-income households in 8 disaster-prone wards. Loans were administered via Da Nang's Women's Union and supply technical assistance to construct disaster-resilient houses, made from brick, cement and steel (structural measure).

**Impact**: As of 2022, support was provided to 4,100 low-income households in the central coastal areas. All homes survived the multiple storms and significant flooding that hit Vietnam in 2020. They protected lives and means of subsistence and, in many communities, further protected adjacent neighbours.

Vietnam; Photo by Nhac Nguyen, AFP

# 01 | Structural Measures

**Case Study | Malindi, Kenya**

The Vasco da Gama pillar is a historic landmark in Malindi which attracts thousands of domestic and foreign tourists.

**Problem**: Coastal erosion and sea level rise weakens the physical fabric of the site and structural integrity of the monument

**Intervention**: Construction of sea wall to curb further erosion and protect the historic site from collapsing (structural measure)

**Impact**: Protecting a historic monument against climate-related impacts, preserving an economically important tourist site

Malindi; Photo by Kelvin Karani, The Standard

# 02 | Non-Structural Measures

**Non-structural measures** are 'soft' measures that reduce climate risks. They focus on improving institutional, organizational and human capacity to respond to climate change.

These non-physical measures include policies, plans, capacity building, investment in data collection and technology, awareness raising, monitoring and evaluation (M&E), etc.

Examples of non-structural measures include:

- Establishing inclusive early warning systems that collect data on climate risks.
- Building capacity of urban actors to ensure basic understanding of climate information and implications on key urban sectors
- Developing policies & building codes to reduce climate risks and promote resilience of urban infrastructure.


Photo by GCA

# 02 | Non-Structural Measures

## Case Study | Punjab, Pakistan

**Problem:** Punjab province in Pakistan, predominantly in a floodplain, is vulnerable to flooding as well as periods of drought and water scarcity; this negatively impacts economic development and leads to loss of lives.

**Intervention**: The government of Punjab passed an order that every publicly funded project with a budget of over 1 billion Pakistani rupees undergo a risk screening and resilience mainstreaming protocol. They adopted an online risk screening tool, designed to fit within the province's existing project development cycle, to help departments (initially energy, irrigation, and agriculture) identify and integrate climate risk into project design (non-structural measure)

**Impact:** Building government capacity and institutional architecture for embedding resilience within projects and programmes


Pakistan; Photo by AP

# Combined Structural & Non-Structural Measures

Cities can **combine structural and non-structural measures** for more holistic resilience solutions.

Building resilience of infrastructure has conventionally focused on structural or ‘hard’ measures (e.g. engineering practices). However, deploying non-structural or ‘soft’ measures is equally important – urban actors need appropriate information, capacity and enabling policy environment to take action.

In many cases, the two types of measures are integrated into a resilience intervention. Examples of combined measures could include:

- Physical flood protection measures such as dams and flood defenses, combined with hydrological catchment modelling.

- Water distribution infrastructure and community water management committees that monitor groundwater availability and quality.

Demonstration of the use of a Tromino, a passive seismic tool used for stratigraphy and bedrock mapping, to local water officials, Kenya; Photo by USGS

# Combined Structural & Non-Structural Measures

**Case Study | Gorakhpur, India**

**Problem:** Gorakhpur (population 670,000 and growing quickly) faces frequent **flooding**, **seasonal waterlogging**, and related **health and mobility challenges**. Poor communities are most affected.

**Intervention**: Gorakhpur has established a ward-level committee to ensure ongoing provision and maintenance of municipal services. They have made investments in storm water drainage, hand pumps, and better toilets (structural measures). They have also established community-level monitoring of solid waste and better maintenance of drainage channels (non-structural measure) to minimize flood risks.

**Impact:** Almost 6000 people have benefited from new drains in Mehewa Ward. September 2012 saw record rainfall when 423mm fell in one month, yet Mehewa ward did not experience waterlogging.

Gorakhpur; Photo by Dainik Bhaskar

# Combined Structural & Non-Structural Measures

**Case Study | Semarang, Indonesia**

**Problem:** Semarang is at risk from sea level rise and river inundation, with the expected number of households in flood-prone areas to increase to 50% by 2050.

**Intervention:** The city government implemented a Flood Early Warning System (FEWS) project between 2012 and 2014. It included flood shelters (structural measure) and evacuation plans to alert vulnerable communities. This was accompanied by disaster risk management training to educate communities in flood-prone areas to be more prepared (non-structural measure).

**Impact:** Vulnerable communities residing in coastal areas were more capable to respond to emergencies and minimize risk, injury, and casualties. Local government agencies benefited by understanding where infrastructure capacity should be strengthened to minimize the impact of flood on major water infrastructure.

Tawang train station, Semarang; Photo by Aji Styawan, WSJ

# 03 | Nature-based Solutions

**Nature-based solutions** (NbS) is an umbrella term referring to "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."

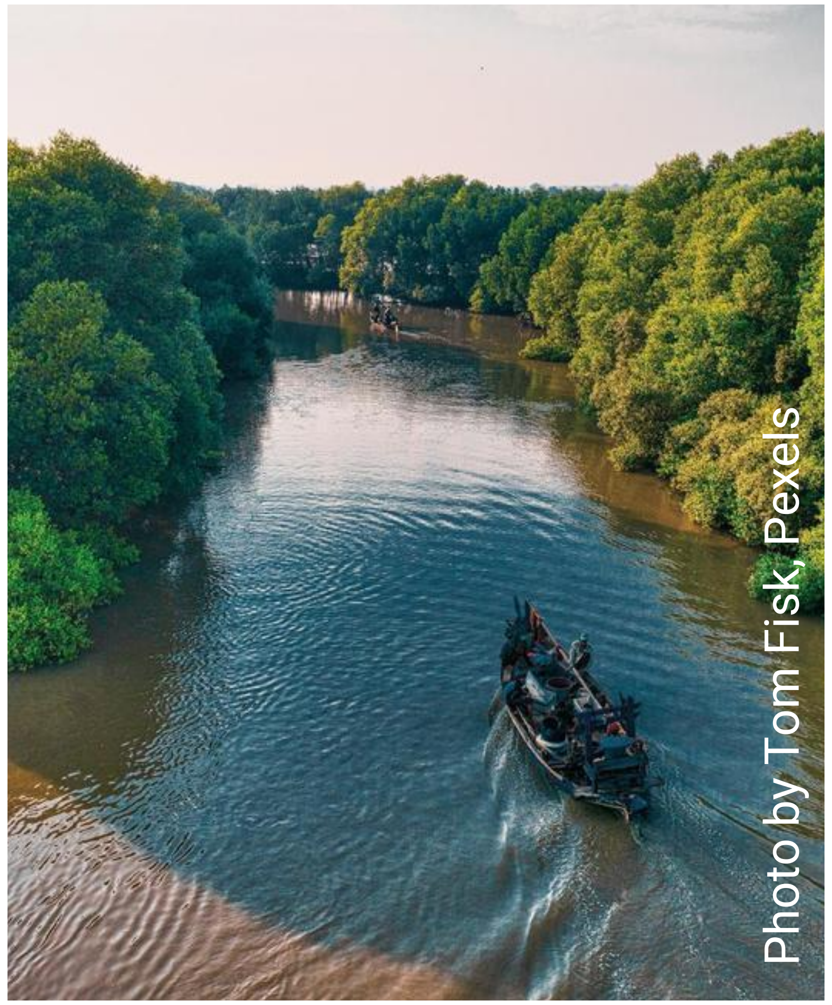
NbS use the benefits of natural processes to support resilience. This can include natural flood defenses, urban cooling, access to water, and many more services that provide benefits to people living in cities .

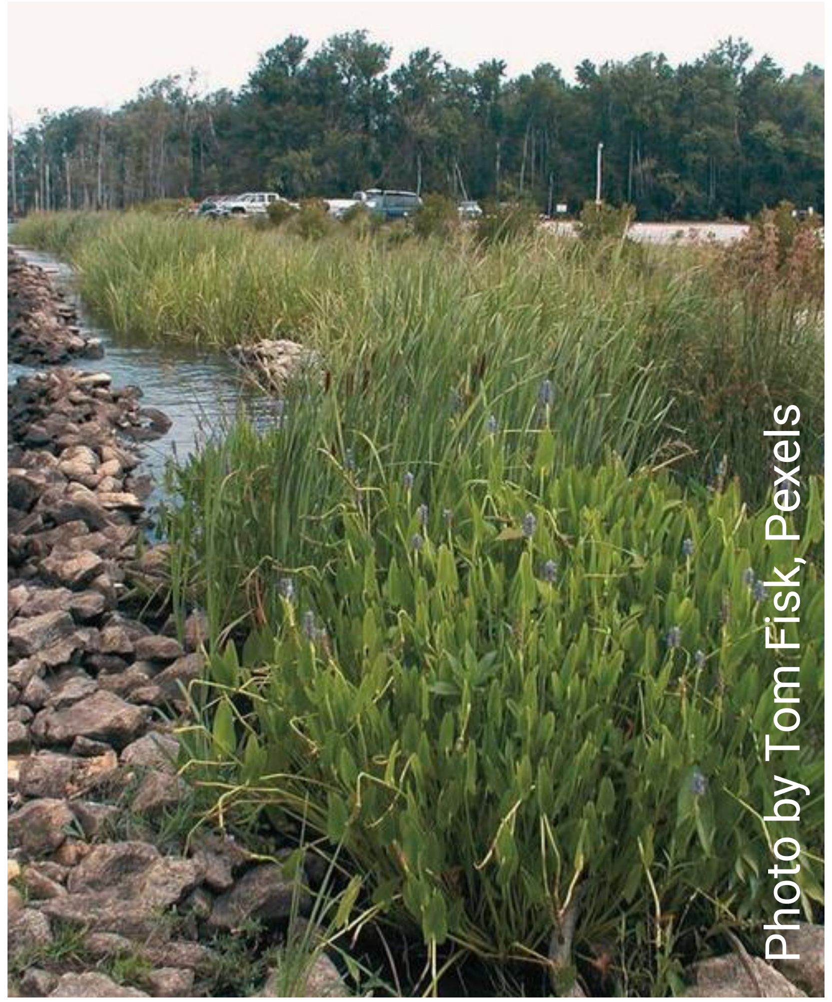
NbS approaches that integrate natural ecosystem processes into infrastructure planning offer an effective alternative or addition to traditional built/grey infrastructure

Nature-based solutions are often more cost-effective than grey infrastructure. Recent estimates suggest that the average cost of implementing NbS for infrastructure is half of their traditional grey infrastructure counterparts

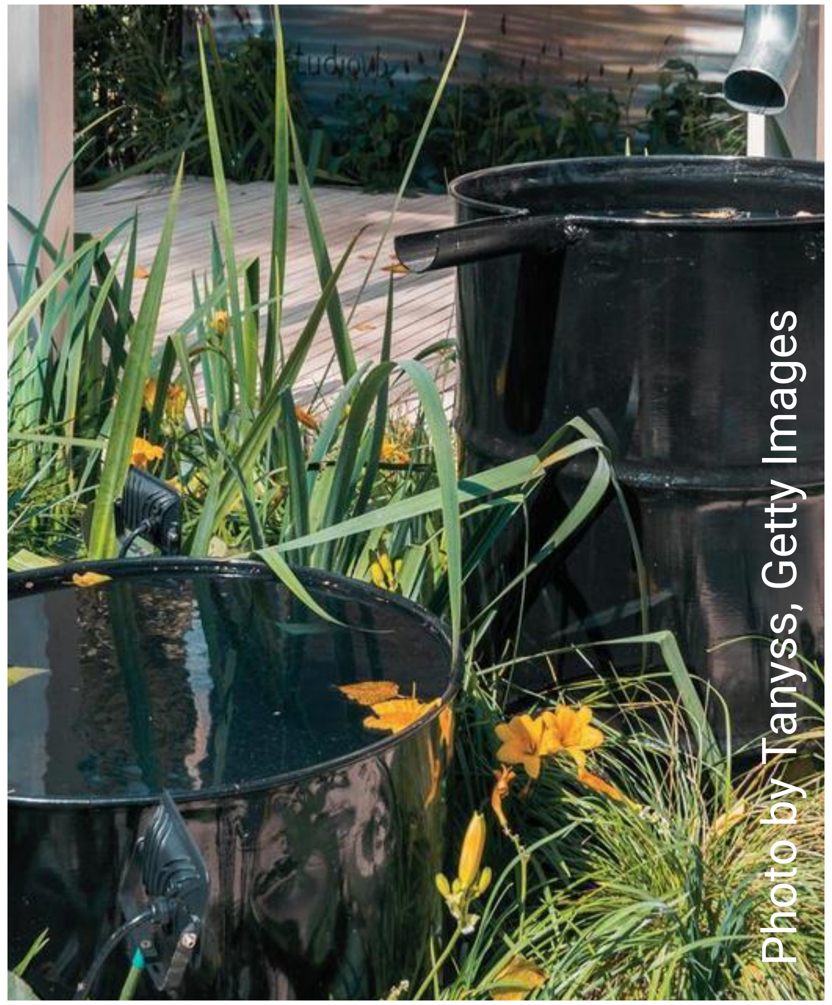

Photo by Jomphong, Getty Images (licensed via Canva)

# 03 | Nature-based Solutions








**Natural**

Restoration and conservation of natural habitats, with active management

**Semi-cultivated**

Living shorelines
Constructed wetlands
Hybrid reefs
Riparian buffers

**Cultivated**

Bioswales
Rooftop gardens
Urban forests
Green alleys

**Engineered**

Permeable pavements
Rainwater harvesting
Groundwater recharge wells

# 03 | Nature-based Solutions

Nature-based solutions are important because they can reduce some of the negative impacts of grey infrastructure in cities:

The expansion of built-up areas and impermeable surfaces, often at the cost of green and blue (water-based) spaces, heightens the risks associated with climate change including heatwaves and floods.

Urban areas can be 10-15°C hotter than their rural counterparts. Concrete surfaces like roofs and pavements absorb more heat and are resistant to cooling, contributing to the urban heat island effect.

Urban expansion in reclaimed blue spaces, such as degraded lakes and wetlands, disrupts natural drainage patterns, leading to higher instances of urban flooding during heavy rainfall.

NbS approaches that integrate natural ecosystem processes into infrastructure planning offer an effective alternative or addition to traditional built/grey infrastructure.


Photo by Radu Bercan, Canva

# 03 | Nature-based Solutions

Nature-based solutions can complement, substitute for, or protect traditional grey infrastructure to enhance the resilience of urban service delivery to climate change.

**Complement**: Restoring watersheds, which serve as ecological infrastructure supplying water to reservoirs, plays a vital role in regulating hydrological processes and maintaining water quality.

**Substitute**: Using deep-rooted vegetation for slope stabilization offers a cost-effective alternative to building concrete retaining walls, and is estimated to save up to 90% in implementation costs.

**Safeguard**: Afforesting mangrove forests could protect shorelines from erosion, thus safeguarding nearby roads, buildings, and utilities from wave damage during storms and sea surges.

ICBAAR Project Bangladesh, Photo by UNDP Bangladesh

# 03 | Nature-based Solutions

## Benefits of Nature-based Solutions

### They provide a range of climate adaptation and mitigation benefits

- Temperature regulation
- Improved air quality
- Flood risk reduction
- Stormwater regulation
- Water security
- Biodiversity and regeneration
- Carbon sequestration

### They additionally offer multiple social benefits

- Tourism and recreation
- Stimulate local economies
- Contribute to public health
- Spaces for interaction
- Contribute to mental health
- Eco-cultural heritage
- Climate education

# 03 | Nature-based Solutions

**Case Study | Dhaka, Bangladesh**

Dhaka's rapid urbanization has led to the destruction of wetlands, causing poor drainage and water stagnation, leading to frequent flooding.

Waterlogging is also a problem due to poor drainage, impacting transportation, telecoms, water supply and electricity.

The Hatirjheel basin was restored over 6 years with the aims of: retaining stormwater, transforming a wastewater canal into a freshwater lake, connecting 2 major roads.

The initiative has reduced flood risk, enhanced city-wide connectivity and revitalized the cityscape through a grey-green approach to infrastructure

# 08 | Climate Resilient Infrastructure in Kenya

Nairobi; Photo by Ste, Flickr

# Climate Resilient Urban Infrastructure Needs

| Climate impact | Infrastructure type |
|---|---|
| Flooding | • Flood defense infrastructure e.g. flood walls/sea walls.<br>• Climate resilient land use planning. |
| Flooding causing transport disruptions | • Climate proof transport infrastructure e.g. climate streets with rainwater infiltration<br>• Environmental management eg. increased vegetative land cover to improve drainage<br>• Improve maintenance contracting and early warning systems. |
| Flooding causing damage to wastewater infrastructure | • Sustainable storm water drainage e.g. high-volume drainage channels, bioswales/vegetated swales.<br>• Climate proof sanitation systems including sewers. |

Nairobi; Photo by Tony Karumba, AFP

# Climate Resilient Urban Infrastructure Needs

| Climate impact | Infrastructure type |
|---|---|
| Increased temperatures leading to heatwaves | • Green infrastructure e.g. green parks, urban forests, green roofs, green bus stops.<br>• Shifts in building design, e.g. external shading, buildings with natural ventilation. |
| Changing rainfall patterns leading to reduced security of water supply | • Water harvesting systems e.g. water pans, dams.<br>• Climate proof water supply systems to avoid leakage and loss.<br>• Improved piping and distribution of water. |
| Changing rainfall patterns leading to food scarcity, water scarcity | • Drought resilient infrastructure e.g. irrigation systems, water pans, dams etc. |

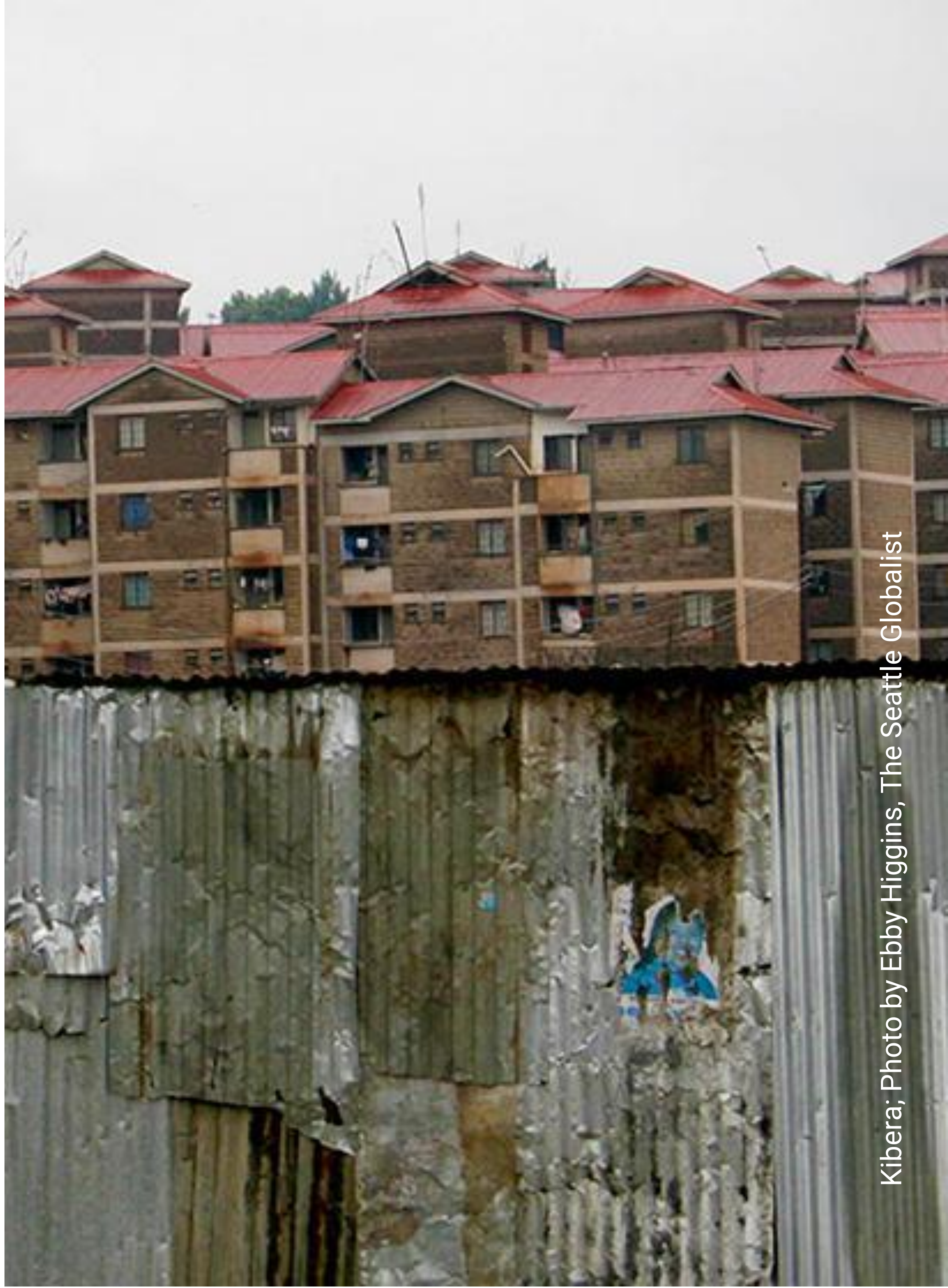
Homa Bay Town; Photo by Robert Omollo, The Star

# Guidelines for Resilient Infrastructure in Kenya

**National Adaptation Plan 2015-2030** recommends several climate resilient infrastructure needs. These include: climate resilient spatial planning; conducting CRAs; climate proofing infrastructure; constructing green buildings; developing resilient energy systems; expanding the use of renewable energy; and forest, landscape and ecosystem rehabilitation for climate resilience and biodiversity conservation

**National Urban Development Policy** recommends better quality, climate-resilient housing, green urban landscape development, and incorporating climate resilience into urban infrastructure design (section 6.4)

**County Integrated Development Plans (CIDPs)** of many counties recommend the integration of climate change adaptation and resilience strategies in development and spatial planning at county, city, municipal levels e.g. Vihiga, Lamu, Kiambu CIDPs.



Kibera; Photo by Ebby Higgins, The Seattle Globalist

# Guidelines for NbS in Kenya

Nature-based solutions (NbS) in Kenya are gaining traction as the country seeks sustainable strategies to address climate and environmental challenges while promoting socio-economic development. Here are some national policies which emphasize NbS:

**National Climate Change Action Plan:** emphasizes the importance of ecosystem-based approaches for climate adaptation and mitigation such as reforestation, sustainable land management, and ecosystem restoration.

**National Biodiversity Strategy and Action Plan:** calls for the integration of NbS into land use planning, natural resource management and sustainable development initiatives, and encourages community participation and partnerships for NbS.

**National Wetlands Strategy:** emphasizes using NbS to enhance ecosystem resilience, mitigate climate change impacts, and support biodiversity. The strategy advocates integrating NbS into national policies, land-use planning, and community practices. It also highlights the need for ongoing research and monitoring to evaluate and adapt NbS interventions.

# Types of NbS Suitable for Kenya

**Urban greening solutions:** develop and rehabilitate urban green parks, urban forests, open spaces, green rooves, etc. These can help to address flooding and heatwaves.

**River restoration** of degraded river ecosystems (e.g. the Nairobi river regeneration efforts). These can address flooding, heatwaves and disease outbreaks.

**Mangrove conservation and restoration** along the Indian ocean in Kenya's coastline. These can help address flooding, sea level rise, biodiversity loss and temperature increases.

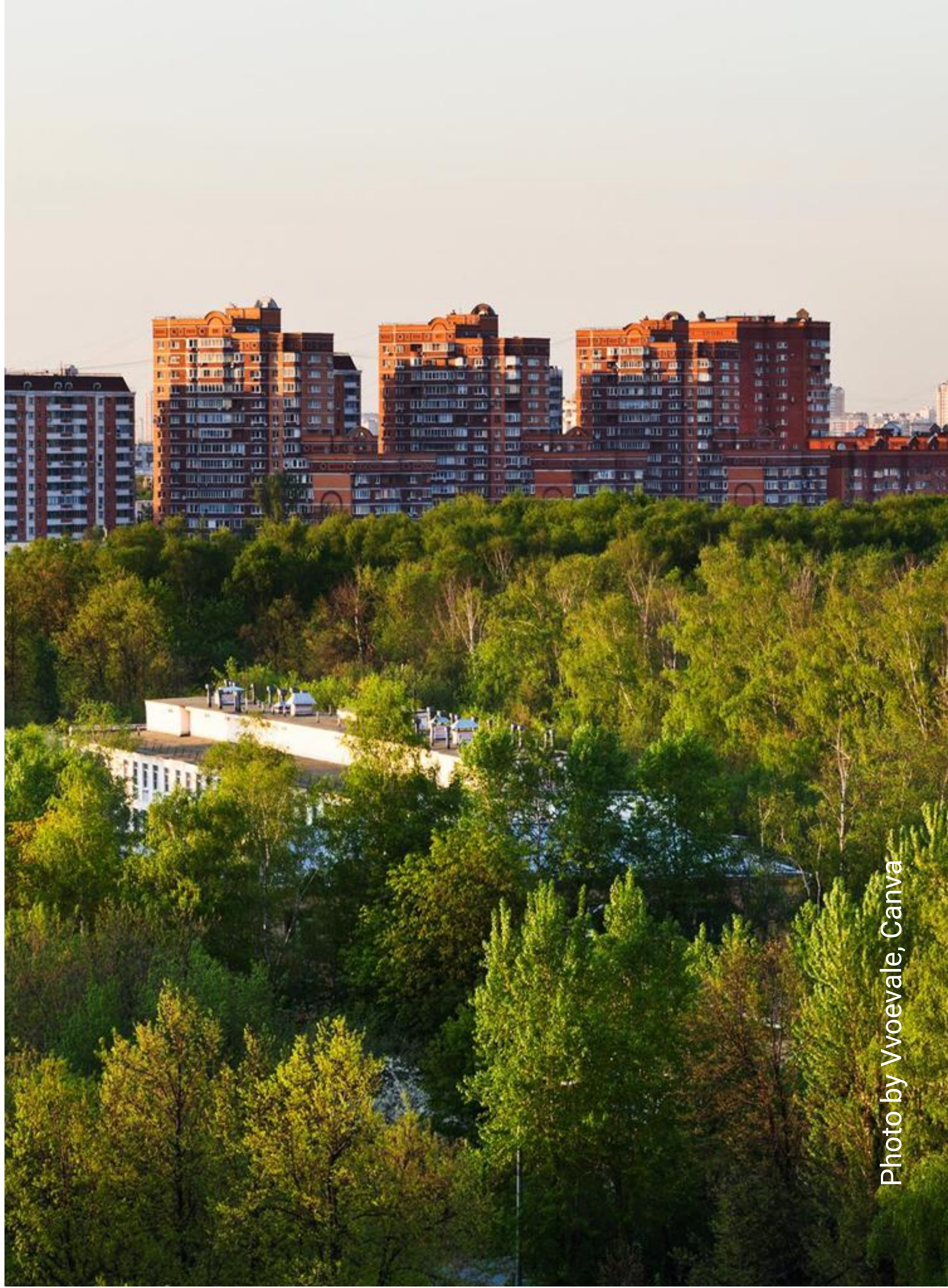


Photo by Vvoevale, Canva

# 09 | Interactive Exercise

Photo by Dbldy, Getty Images (licensed via Canva)

# Decisions for the Decade

- Investing in infrastructure for the future is full of uncertainty
- Let’s play a game to discuss the level of uncertainty in which we must operate.
- Are you ready?


Source: Red Cross/Red Crescent

# Decisions for the Decade

Umbrella Flood Protection

Thumbs Up Development

Bucket Drought Protection

# Practice Run

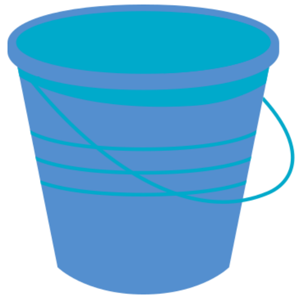
Umbrella Flood Protection

Thumbs Up Development

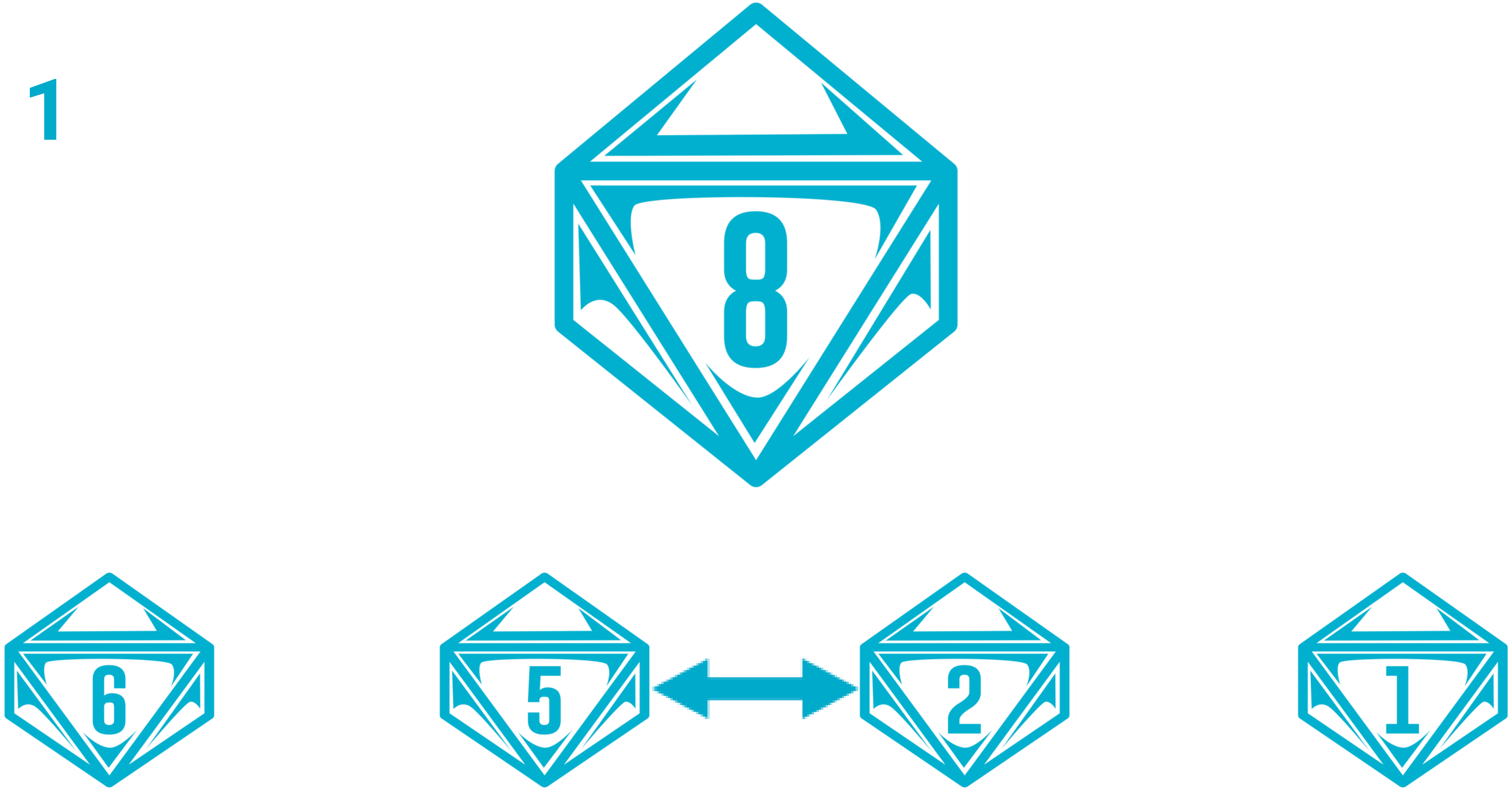
Bucket Drought Protection

# Decisions for the Decade

Strategy: Where should we invest?

| | | | |
|---|---|---|---|
|  Umbrella Flood Protection | | | |
|  Thumbs Up Development | | | |
|  Bucket Drought Protection | | | |

# Decade 1

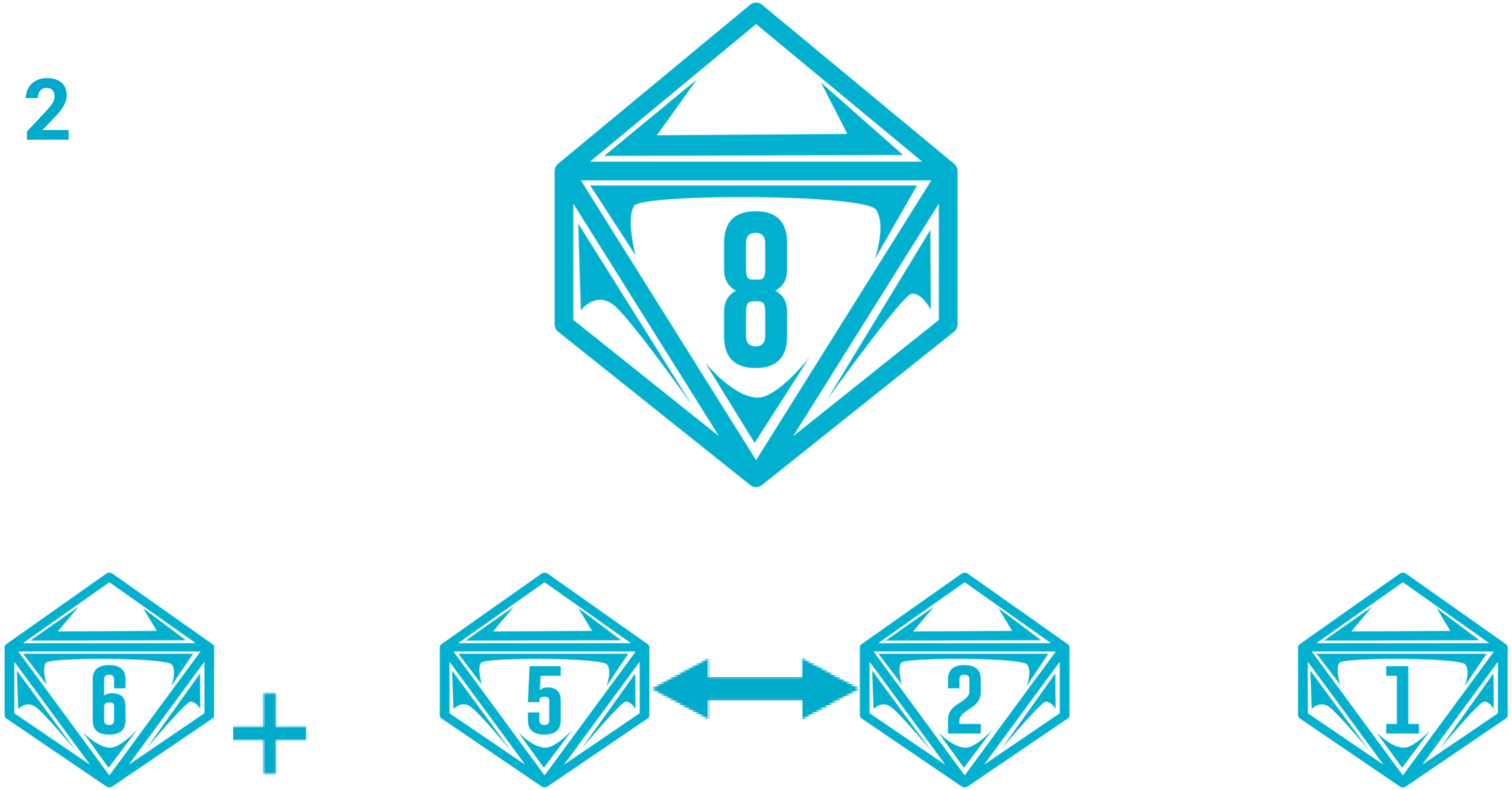



Too much flood disaster

Just right
It’s okay for development

Too little drought disaster

# Decade 2




Too much flood disaster

Just right
It’s okay for development

Too little drought disaster

# Decade 3

CONE OF UNCERTAINTY

Too much flood disaster

Just right
It’s okay for development

Too little drought disaster

# Discussion

Did your team make good decisions?

What is a good decision?

How did the decision making change over time as the risk levels changed?

Were you too cautious or too ambitious?

What other strategy could you have deployed?

# 10 | Summary

Photo by Seqoya, Getty Images (licensed via Canva)

# Summary & Next Steps

Congratulations on completing Module 4: Ensuring Climate Resilience of Urban Infrastructure!

**Module 1**

Introduction to Climate Change and Urban Resilience

**Module 2**

Understanding Climate Risks in Your City

**Module 3**

Locally Led Adaptation for Urban Resilience

**Module 4**

Ensuring Climate Resilience of Urban Infrastructure

**Module 5**

Step-by-Step Guidelines for Delivering Climate Resilient Infrastructure

**Module 6**

Financing Climate Resilient Urban Infrastructure

The next module in the UCRMC is **Module 5: Step-by-Step Guidelines for Delivering Climate Resilient Infrastructure.**

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