THE 20TH INTERNATIONAL OPERATIONS & MAINTENANCE CONFERENCE IN THE ARAB COUNTRIES

BGI AS AN INTEGRATED APPROACH FOR CLIMATE CHANGE ADAPTATION IN SAUDI ARABIA

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Contents

Introduction

The use of the term “infrastructure” in BGI is a recognition that the natural processes associated with vegetation and hydrology contribute valuable and functional services to human societies. There has been growing awareness of the value of so-called “green” infrastructure (e.g., open space and tree canopy). Including “blue” in BGI is a natural extension of the green infrastructure concept, since green features depend on water and affect local hydrology. BGI integrates hydrological and ecological water treatment within designs, where green features are seamlessly integrated with blue features. In reintroducing natural processes within the built environment, BGI strengthens urban ecosystems, improves quality of life, and promotes sustainable water and stormwater management. BGI will be an integral part of future urban living as cities move towards climate change adaptation strategies. Climate change adaptation anticipates the adverse effects of climate change by taking appropriate action to prevent or minimize the damage it can cause or taking advantage of opportunities that may arise. Green Infrastructure is among the most widely applicable, economically viable and effective tools to combat the impacts of climate change and help people adapt to or mitigate the adverse effects of climate change.

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Introduction

Taken together as a comprehensive system, these components of BGI projects strengthen urban ecosystems by employing natural processes in man-made environments. They combine the demand for sustainable water and stormwater management with the demands of adaptive urban life and planning. BGI has shown promise in enhancing resiliency in urban environments. BGI complements and can also reduce the need for grey infrastructure. It also helps to offset some of the negative impacts of urbanization on local hydrology and can be especially effective in mitigating risks associated with climate change. Blue-green infrastructure has shown promise in enhancing resiliency in urban environments. BGI complements and can also reduce the need for grey infrastructure. It also helps to offset some of the negative impacts of urbanization on local hydrology and can be especially effective in mitigating risks associated with climate change.

Introduction

Blue-Green Infrastructure (BGI) offers a feasible and valuable solution for urban areas facing the challenges of climate change. It complements and, in some cases, replaces the need for grey infrastructure. BGI connects urban hydrological functions (blue infrastructure) with vegetation systems (green infrastructure) in urban landscape design. It provides overall socioeconomic benefits that are greater than the sum of its individual components. Taken together as a comprehensive system, these components of BGI projects strengthen urban ecosystems by employing natural processes in man-made environments. They combine the demand for sustainable water and stormwater management with the demands of adaptive urban life and planning.

Saudi Arabia has accelerated the pace of its climate action. The Kingdom will achieve the SGI target of placing 30% of its land and sea under protection by 2030, and plant over 600 million trees within the same timeframe, an increase of over 150 million trees from the initial goal to plant 450 million by 2030.

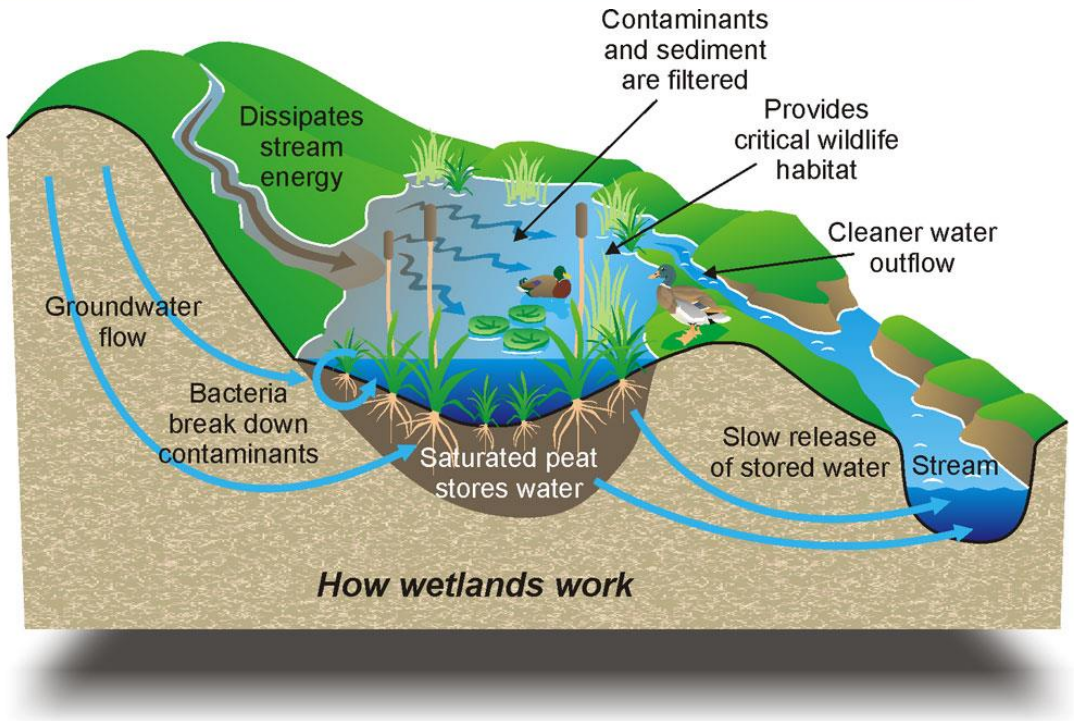
Introduction

Restoring floodplain forests is often cheaper in terms of maintenance costs than purely technical solutions such as building dams and floodplain reservoirs. Green Infrastructure thus can deliver the same level of flood prevention as purely technical solutions, often at lower cost, while being more resilient, and additionally deliver further benefits (as compared to single-purpose technical solutions). There are multiple benefits of climate change adaptation such as opportunities to strengthen the economy of the city and the port, improving the quality of life in neighborhoods and districts, increasing biodiversity in the city and fostering.

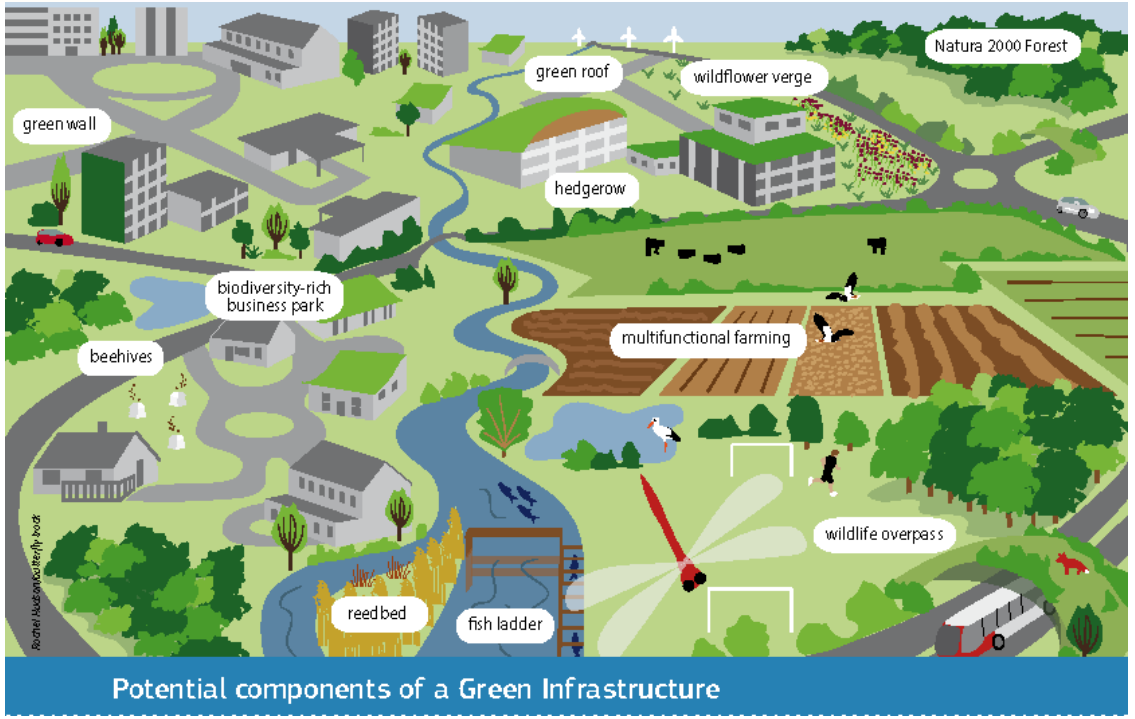
Green Infrastructure

Green infrastructure is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation. This network of green (land) and blue (water) spaces can improve environmental conditions and therefore citizens' health and quality of life. It also supports a green economy, creates job opportunities and enhances biodiversity. As the global trend of urbanization continues steadily, cities are increasingly an important facet of our future. Whether for the good or bad, principles of urban design can and will affect the quality of life for many people. This urbanization brings both advantages and challenges. While cities often enhance prosperity, quality of life, and even resource efficiency in the long-term, in the short-term growing cities face the joint challenges of constructing built infrastructure to meet the rising demand for urban services and for providing access to these resources in a sufficient and socially equitable manner.

Green Infrastructures

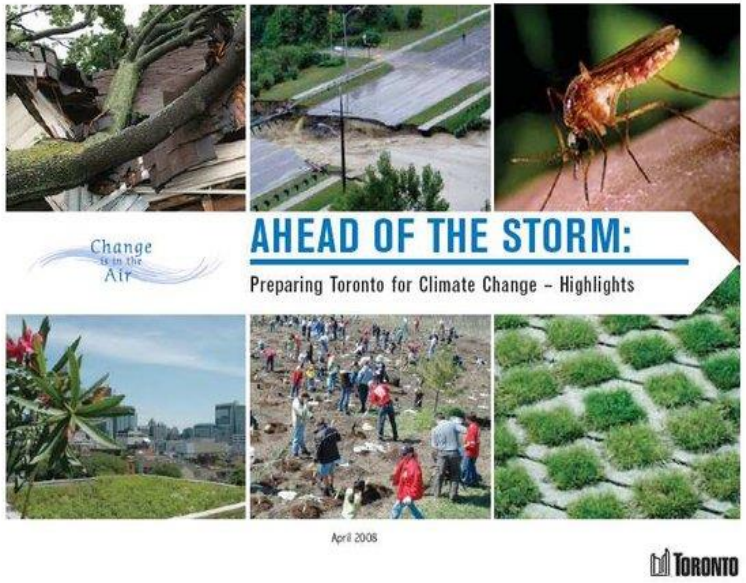


Source: European Environmental Agency



Source: European Environmental Agency

Green Infrastructures



Source: https://climatechange.lta.org

Green Infrastructures

Source: https://climateadaptationplatform.com

Source: https://sustainablymotivated.com/

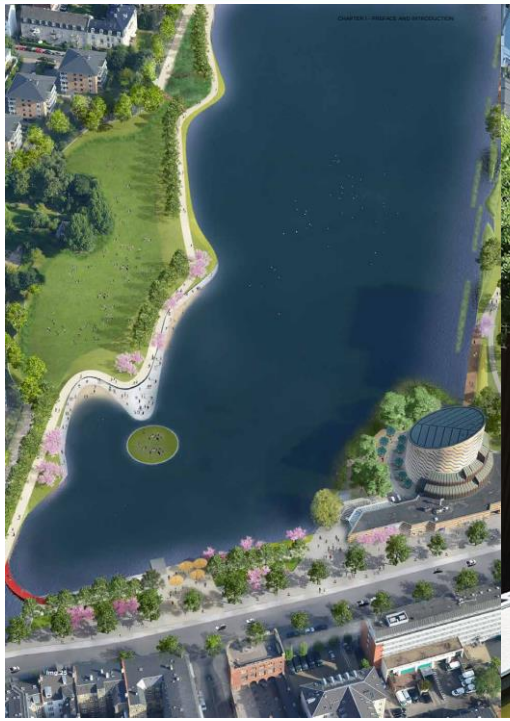
Blue Infrastructure

"Blue infrastructure" refers to urban infrastructure relating to water. Blue infrastructure is commonly associated with green infrastructure in urban environments and may be referred to as "blue-green infrastructure" when being viewed in combination. Rivers, streams, ponds, and lakes may exist as natural features within cities, or be added to an urban environment as an aspect of its design. Coastal urban developments may also utilize pre-existing features of the coastline specifically employed in their design. Harbors, quays, piers, and other extensions of the urban environment are also often added to capture benefits associated with the marine environment. Blue infrastructure can support unique aquatic biodiversity in urban areas, including aquatic insects, amphibians, and water birds. There may considerable co-benefits to the health and wellbeing of populations with access to blue spaces in the urban context. Accessible blue infrastructure in urban areas is also referred as to blue spaces. Urbanization is presenting us some of the most important challenges of our time.

Blue Infrastructure

However, is also represents one of the greatest opportunities and responsibilities to shape the sustainable and resilient cities of the future. When we specifically consider the urban challenges related to water, we see a multitude of issues that threaten the sustainable development of cities, such as pollution of groundwater and surface water, lack of clean drinking water, poor drainage infrastructure, groundwater extraction and flooding. Many of these water issues are interrelated and are part of the same urban water cycle: poor drainage systems may result in pollution of surface water, pollution of surface water may result in a lack of clean drinking water, a lack of clean drinking water may result in groundwater extraction, groundwater extraction may result in subsidence which increases the risk of flooding, etc. It is important to consider these issues in the context of the urban water cycle, which is critically different from the natural water cycle. Looking at these differences, it becomes immediately apparent that the way we design and build cities, with all its different pieces of infrastructure: houses, roads, parks, ports, roads, etc., has a huge impact on the water flow in and around the city.

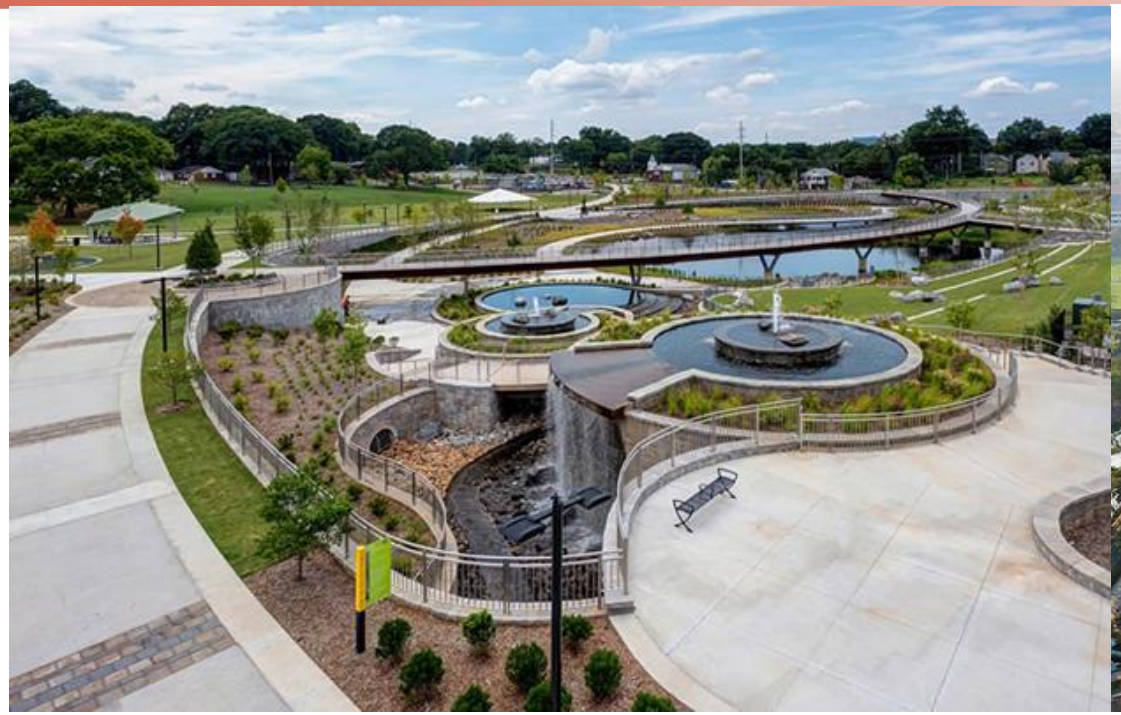
Blue Infrastructures



Source: https://ramboll.com

Source: https://icem.com.au

Blue Infrastructures



Source: https://dirt.asla.org

Blue Infrastructures

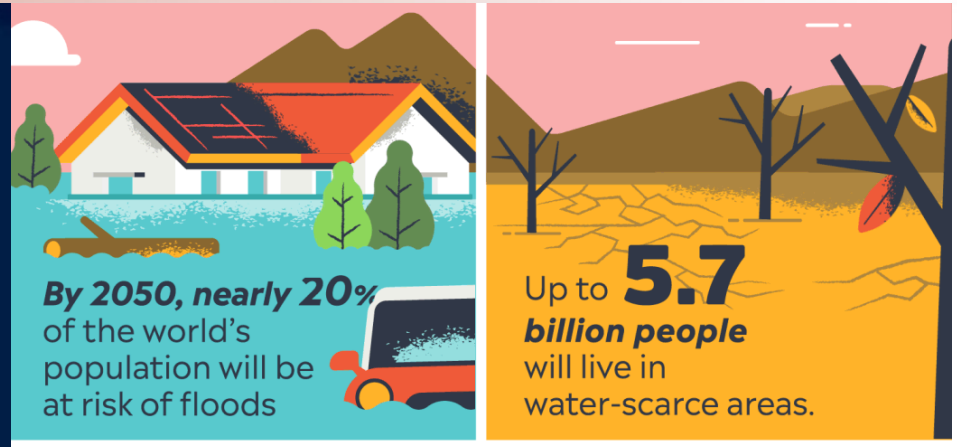
Source: https://www.governing.com/

Source: https://www.connectedtoindia.com/

Climate Change Adaptation

Urban green and blue infrastructure can mitigate climate change through carbon sinks, avoided emissions, and reduced energy use while offering multiple co-benefits (high confidence). Urban green and blue infrastructure, including urban forests and street trees, permeable surfaces, and green roofs offer potentials to mitigate climate change directly through storing carbon, and indirectly by inducing a cooling effect that reduces energy demand and reducing energy use for water treatment. Globally, urban trees store approximately 7.4 billion tones of carbon, and sequester approximately 2179 million tones of carbon annually, although carbon storage is highly dependent on biome. Among the 10 multiple co-benefits of green and blue infrastructure are reducing the urban heat island (UHI) effect and 11 heat stress, reducing stormwater runoff, improving air quality, and improving the mental and physical 12 health of urban dwellers. Many of these options also provide benefits to climate adaptation. BGI will be an integral part of future urban living as cities move towards climate change adaptation strategies.

Climate Change Adaptation



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Creating Next-Generation Infrastructure, World Bank

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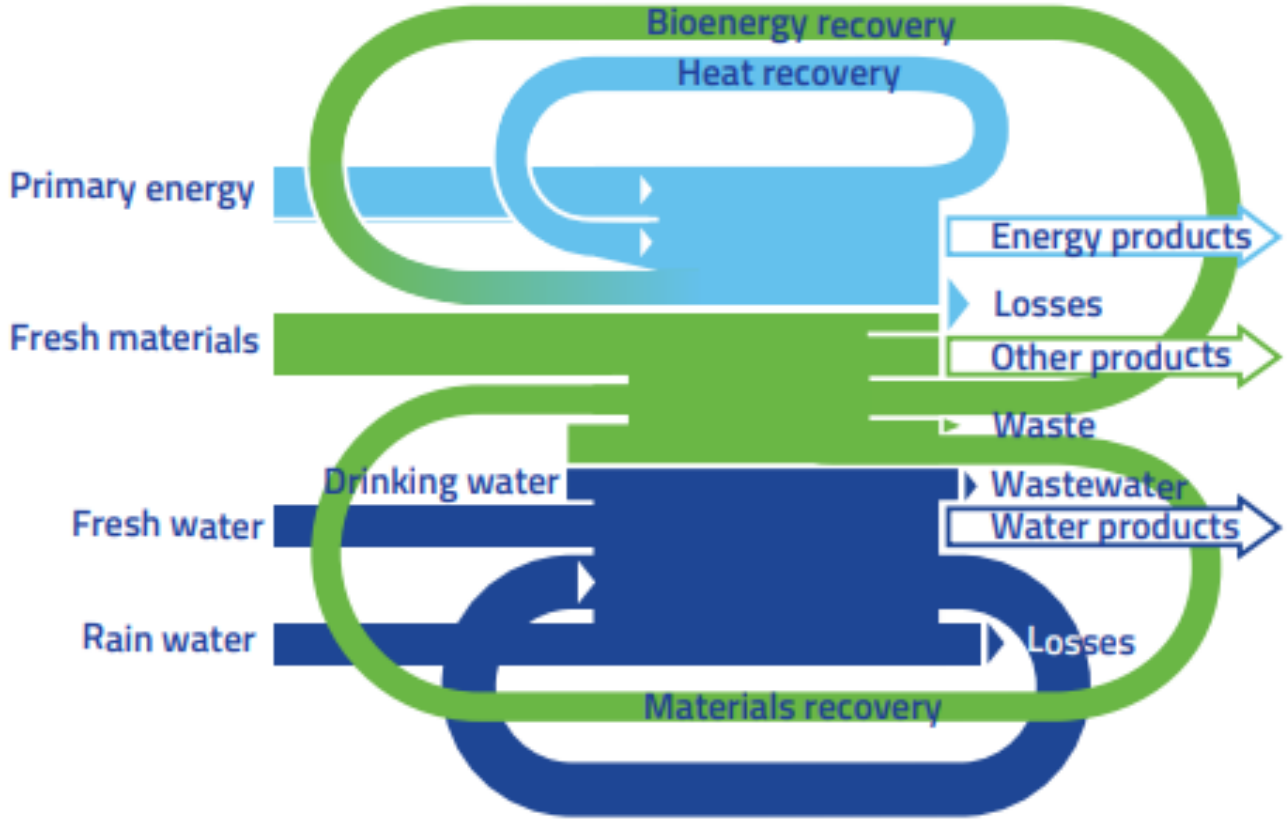
Climate Change Adaptation

Energy

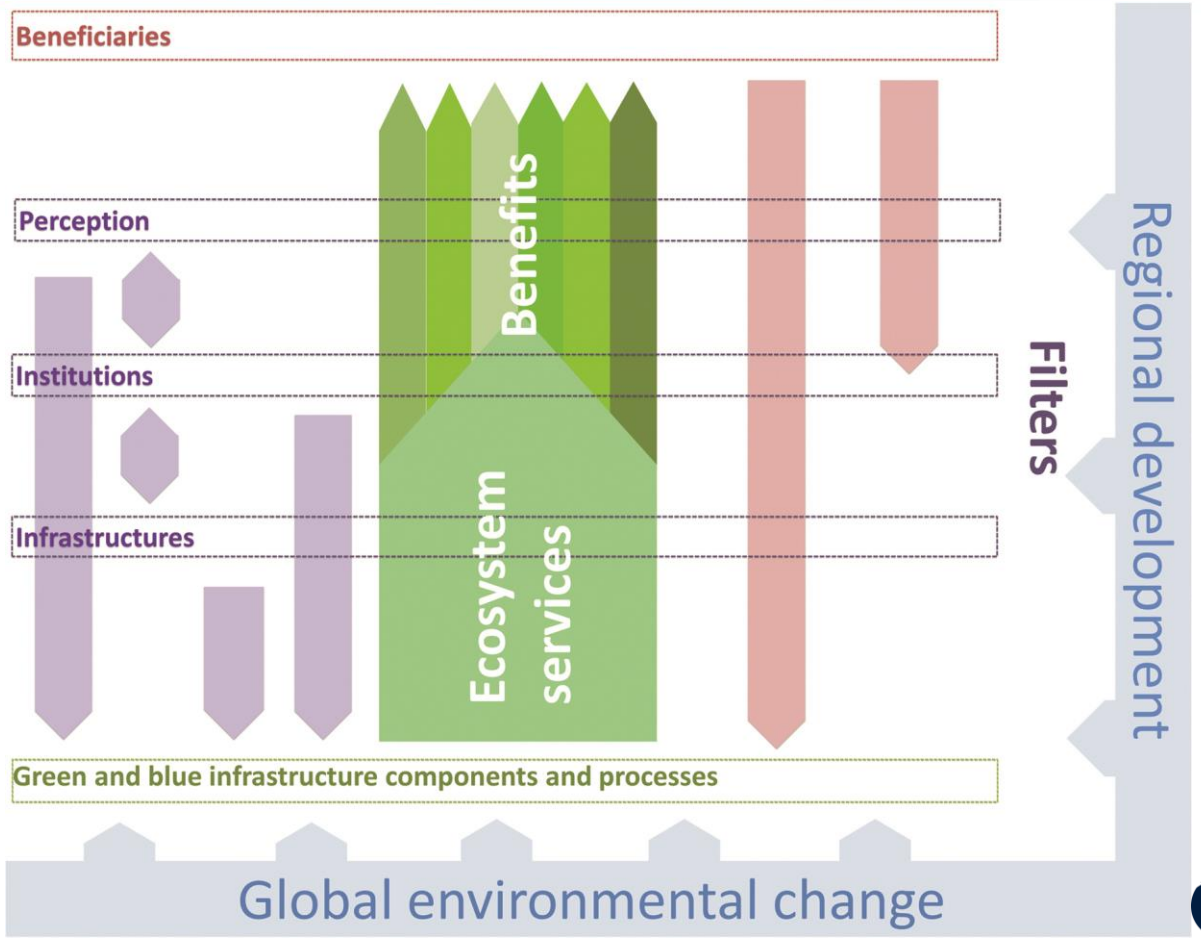
Organic materials

Water



Schematic of the Urban Metabolic flow, Climate KIC-Imperial College

Climate Change Adaptation



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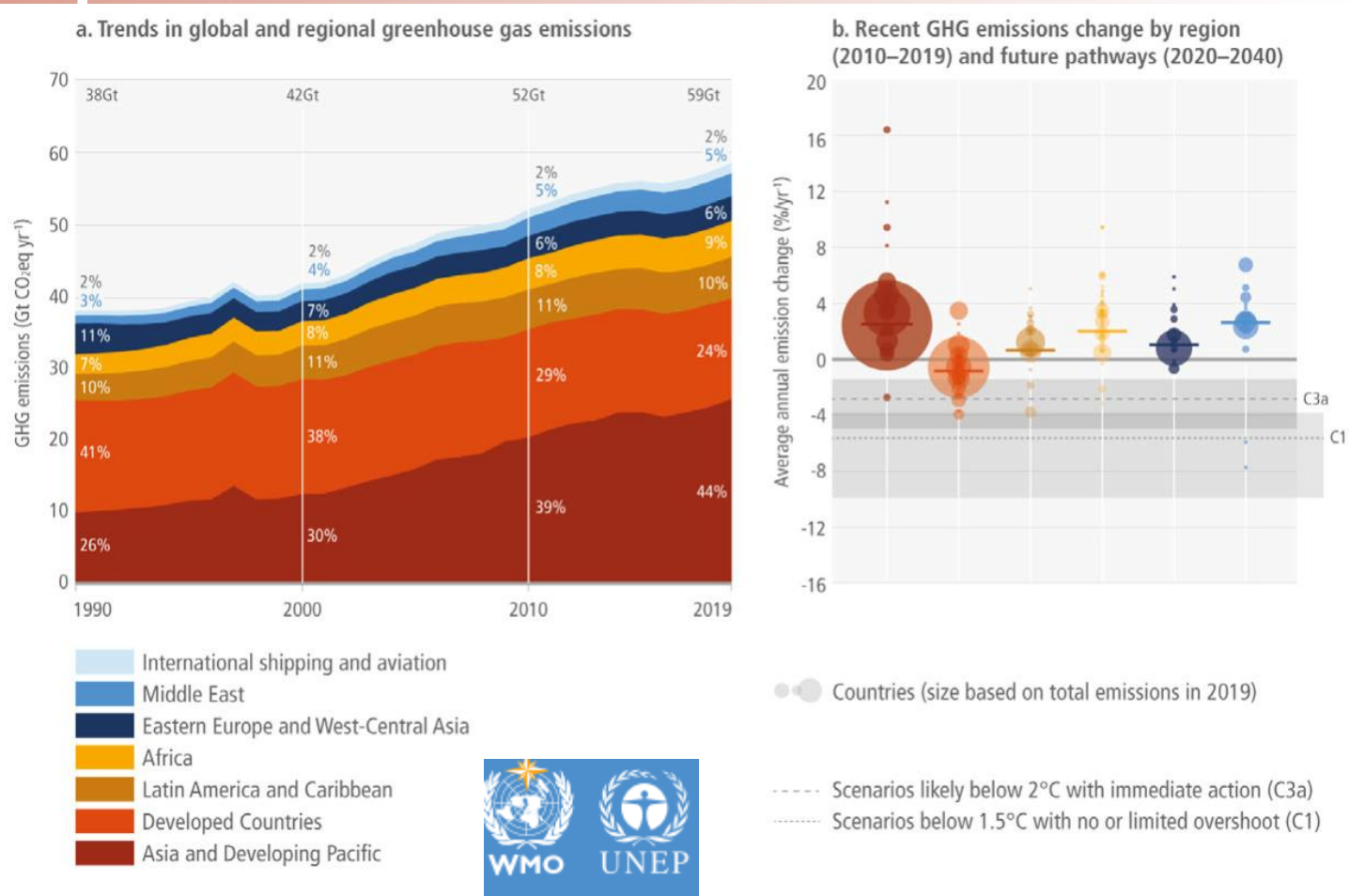
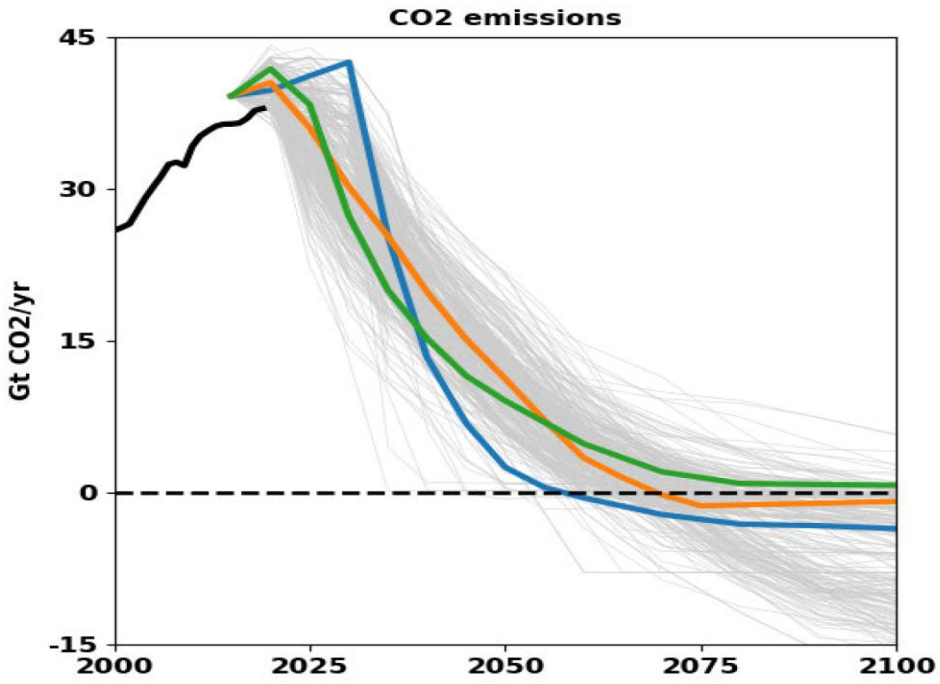
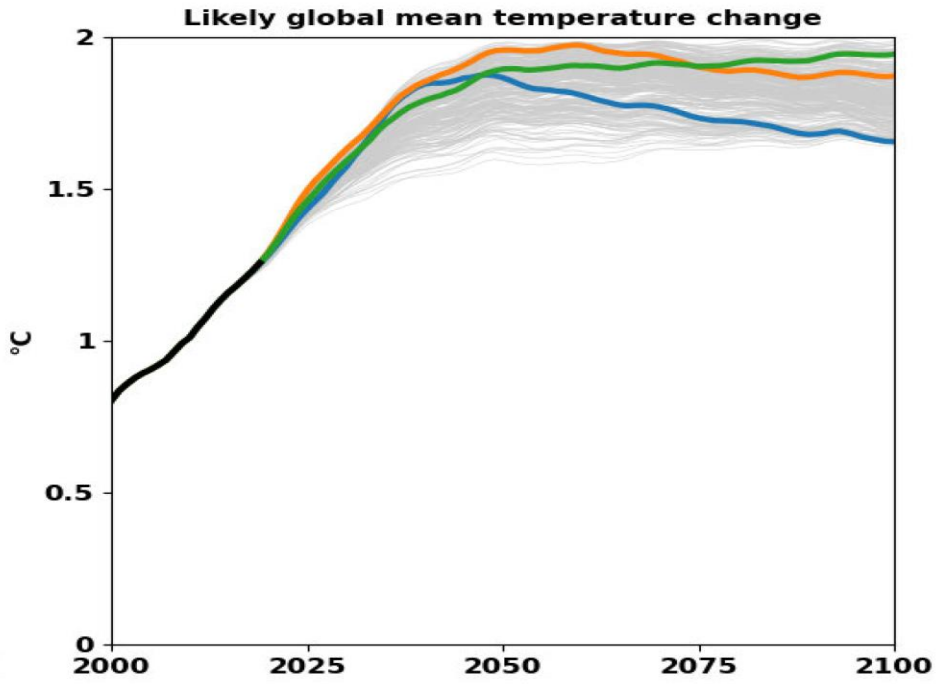
Climate Change Adaptation



Climate Change Adaptation





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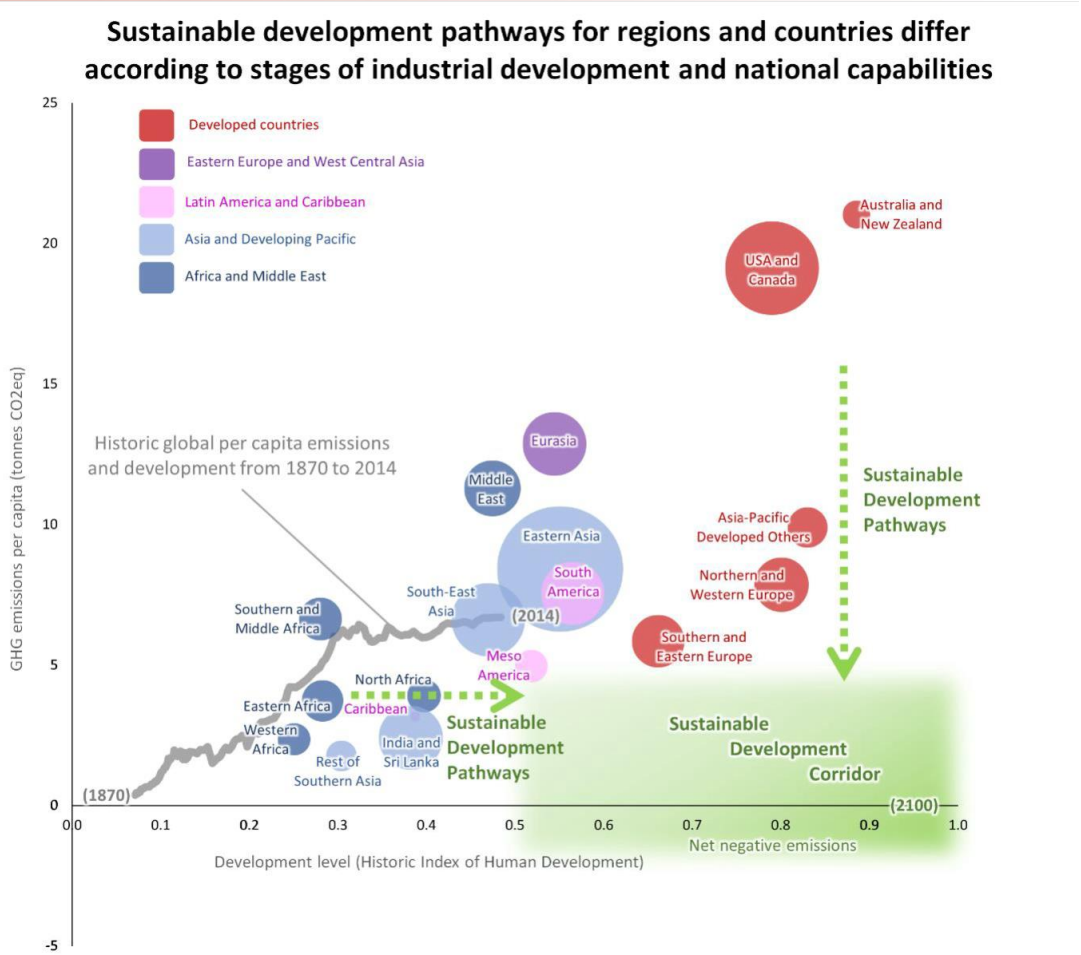
Climate Change Adaptation

The graph shows global average per capita GHG emissions (vertical axis) and relative "Historic Index of Human Development" (HIHD) levels (horizonal) have increased globally since the industrial revolution (grey line). The bubbles on the graph show regional per capita GHG emissions and human development levels in the year 2015, illustrating large disparities. Pathways towards fulfilling the Paris Agreement (and SDG 13) involve global average per capita GHG emissions below about 5 tCO_2e by 2030. Likewise, to fulfil SDGs 3, 4 and 8, HIHD levels (see footnote 7) need to be at least 0.5 or greater. This suggests a 'sustainable development zone' for year 2030 (in green); the in-figure text also suggests a sustainable development corridor, where countries limit per capita GHG emissions while improving levels of human development over time. The emphasis of pathways into the sustainable development zone differ (green arrows) but in each case transformations are needed in how human development is attained while limiting GHG emissions.

ACCEPTED SUBJECT

WMO UNEP



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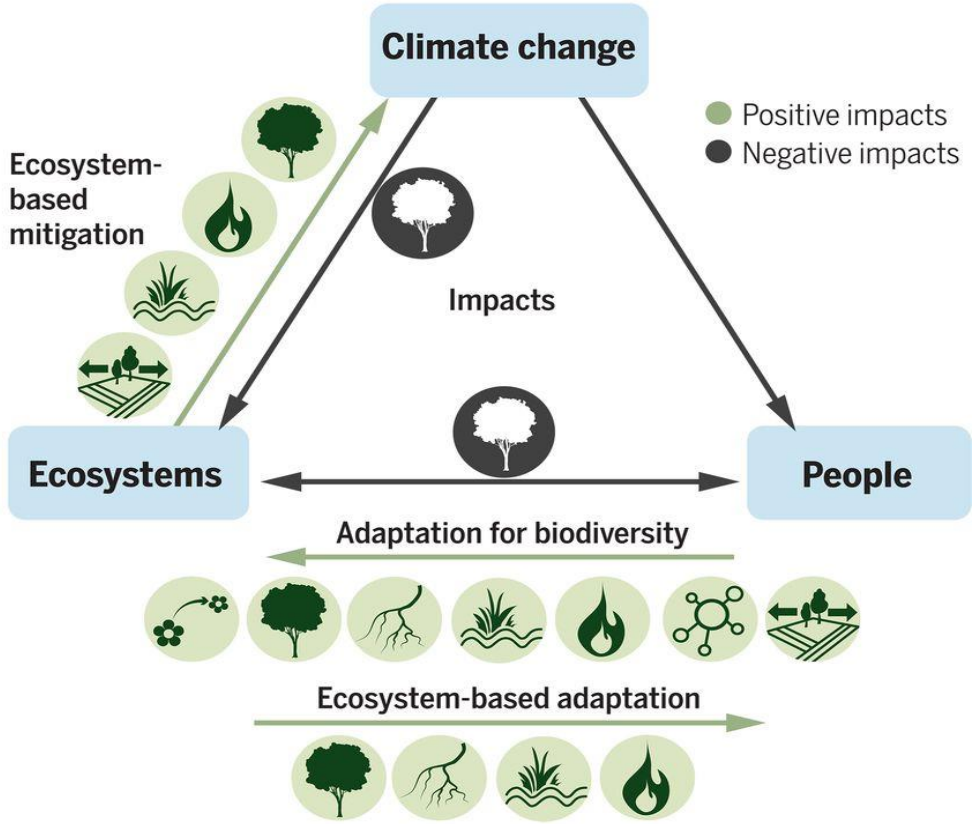
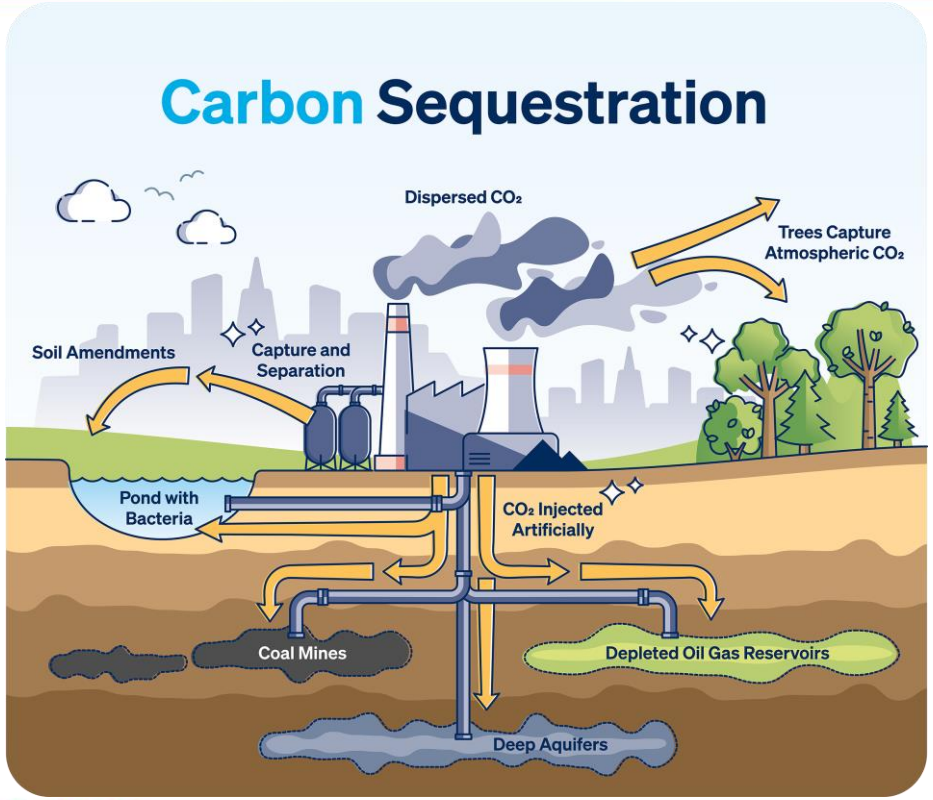
Climate Change Adaptation

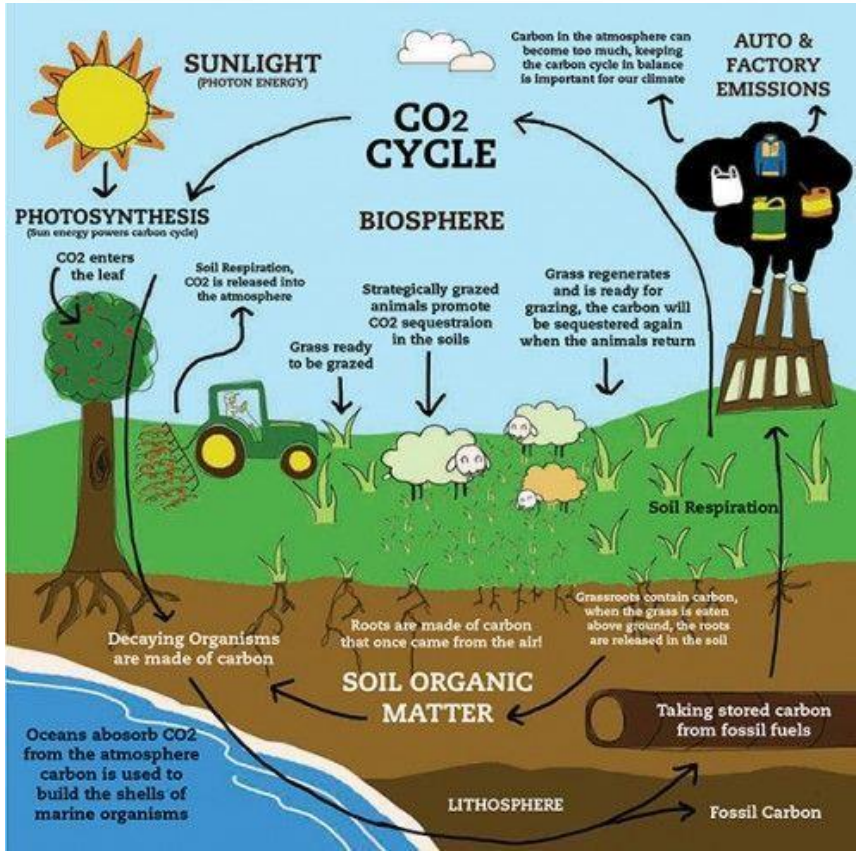
- Reafforestation
- Forest creation in unsuitable areas (negative)
- River restoration
- Wetland restoration
- Protection and expansion of natural/ seminatural areas
- Increased connectivity
- Species translocation
- Natural fire regime restoration



Source: https://www.science.org/

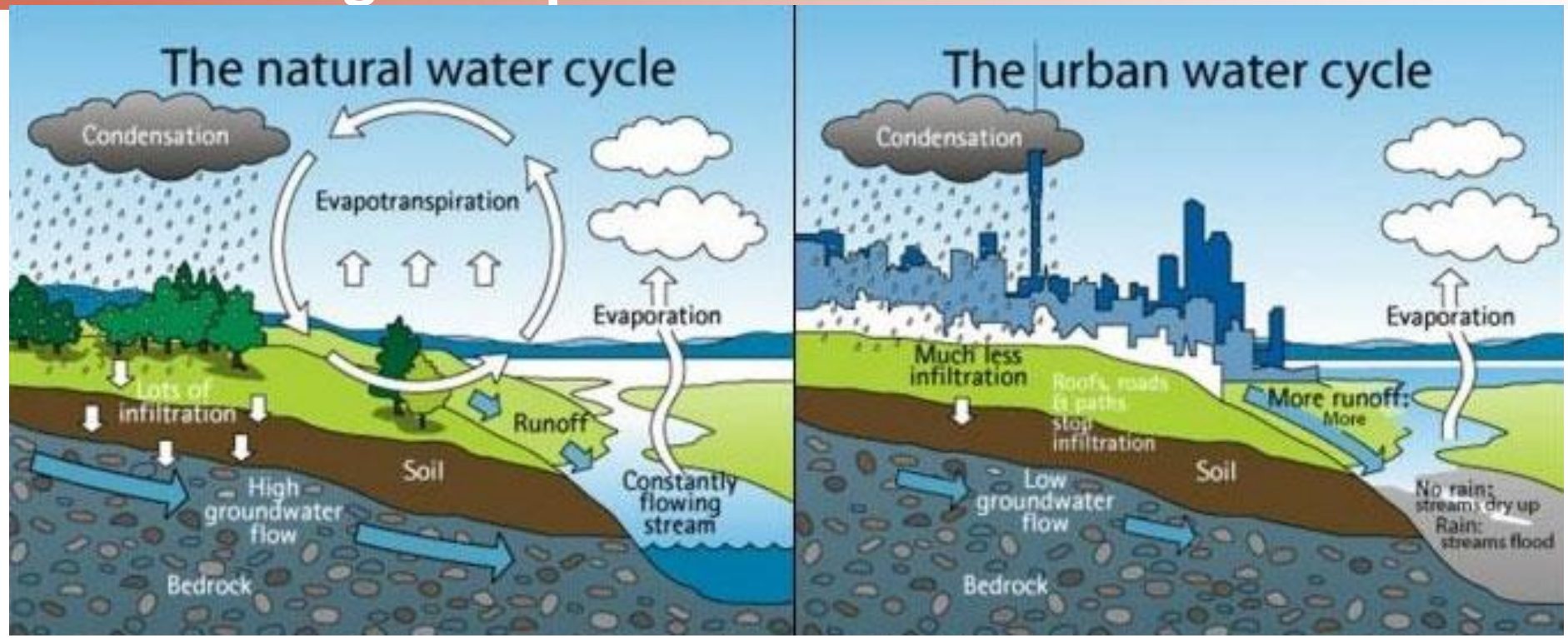
Climate Change Adaptation





Source: www.fibershed.com

Climate Change Adaptation

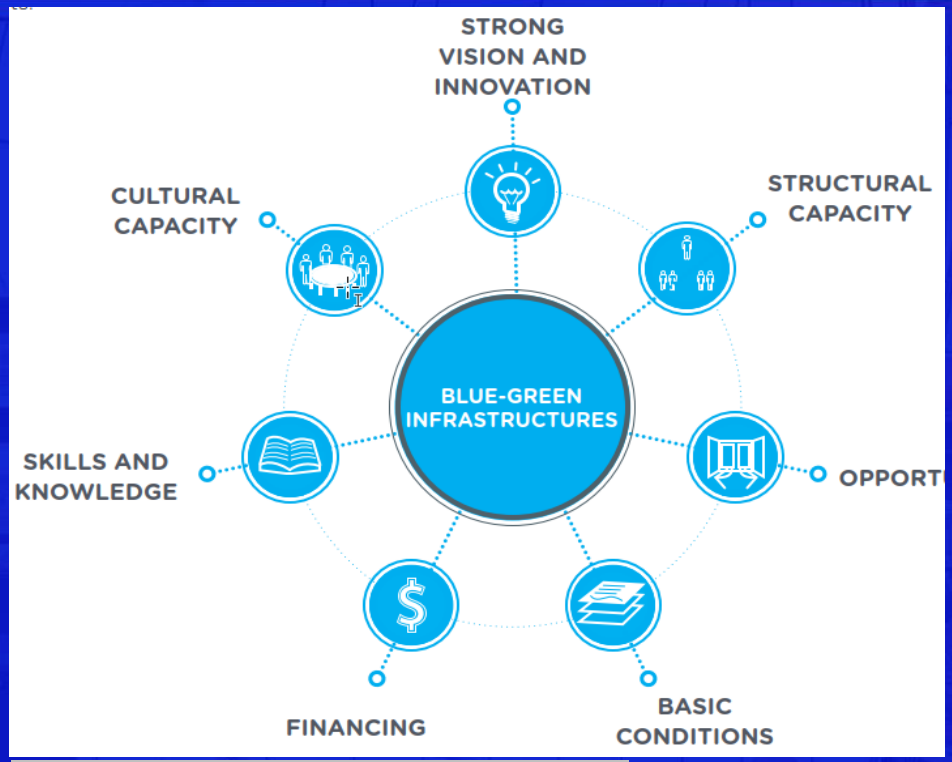


Source: Holland Water Challenge

Integrated BGI Approach

Source: https://ramboll.com

Integrated BGI Approach

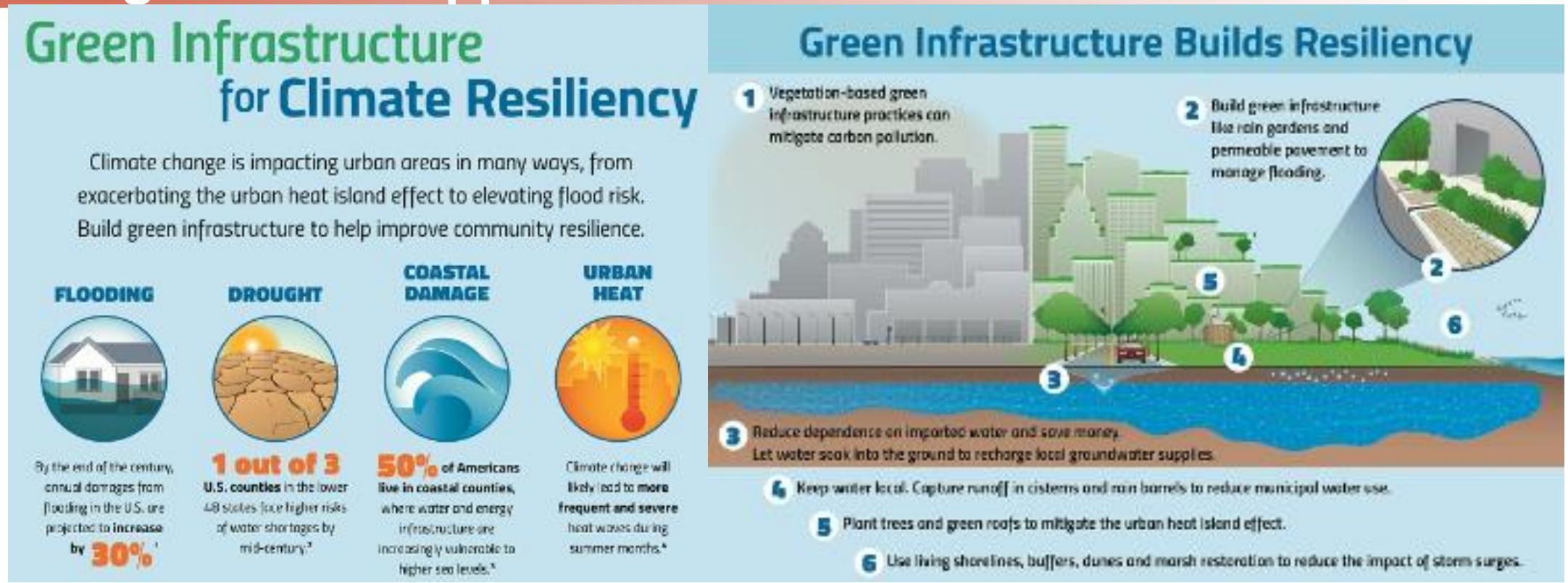


Source: Livable Cities Lab, Prof. Herbert Dreiseit

BGI overall socioeconomic benefits

- Blue-green infrastructure has shown promise in enhancing resiliency in urban environments
- BGI complements and can also reduce the need for grey infrastructure.
- It also helps to offset some of the negative impacts of urbanization on local hydrology and can be especially effective in mitigating risks associated with climate change.

Integrated BGI Approach



Source: https://www.epa.gov/

Integrated BGI Approach

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European Commission

european greenbelt

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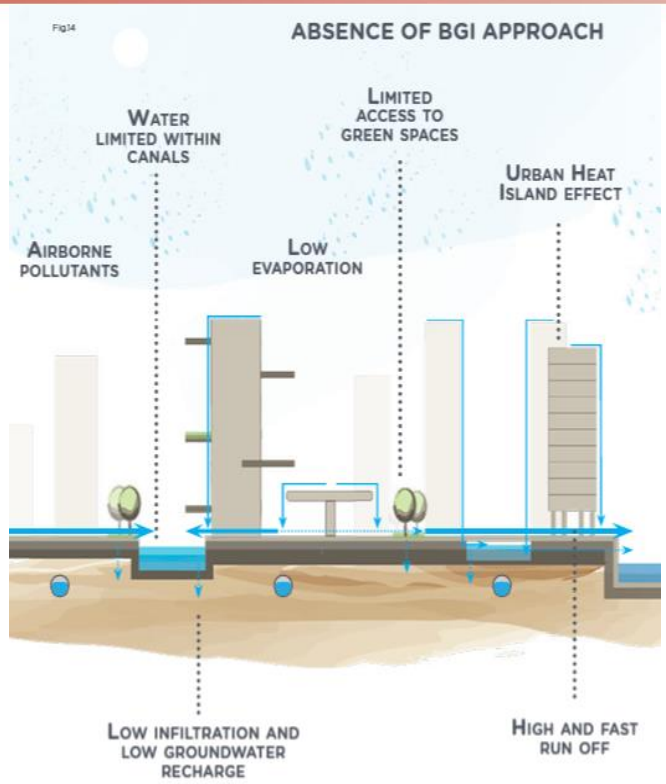
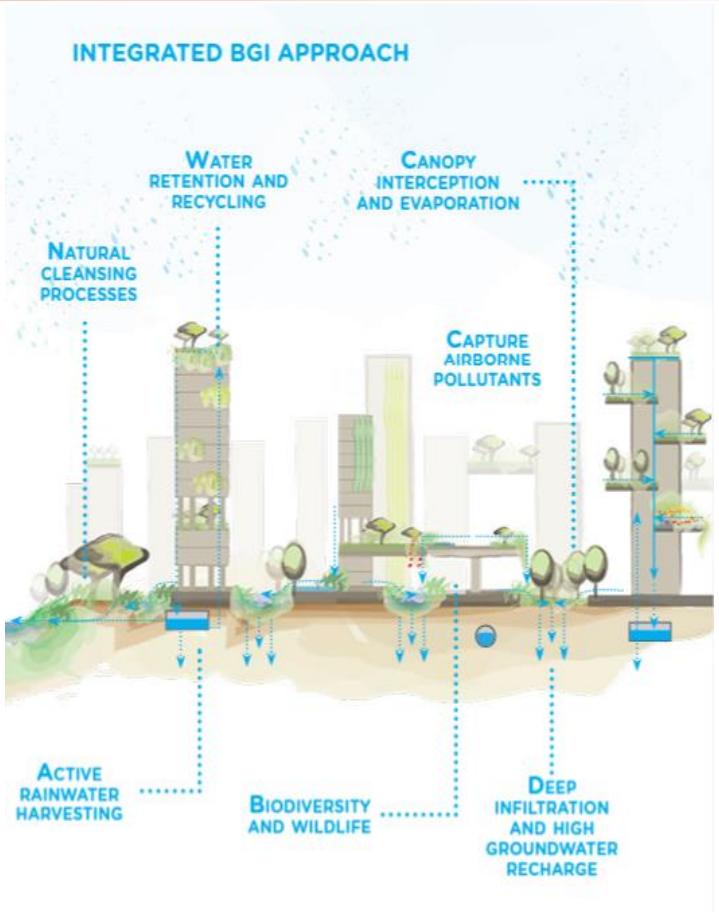
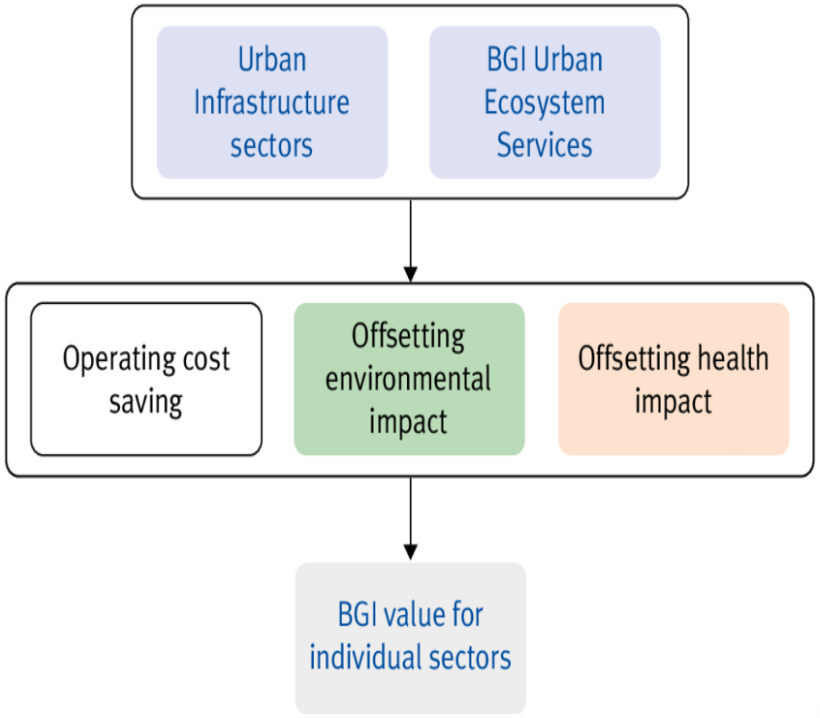
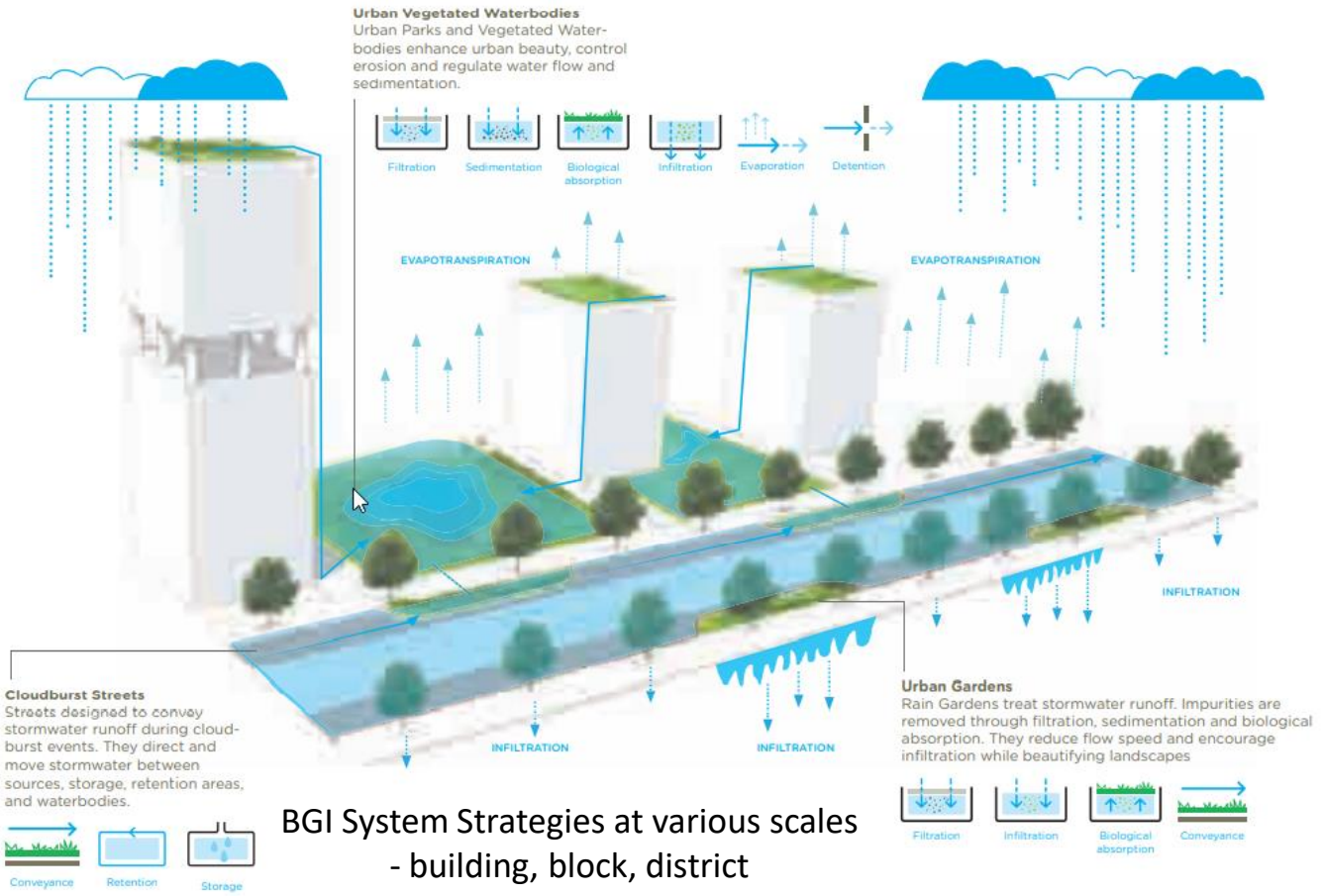
Integrated BGI Approach





Integrated BGI Approach





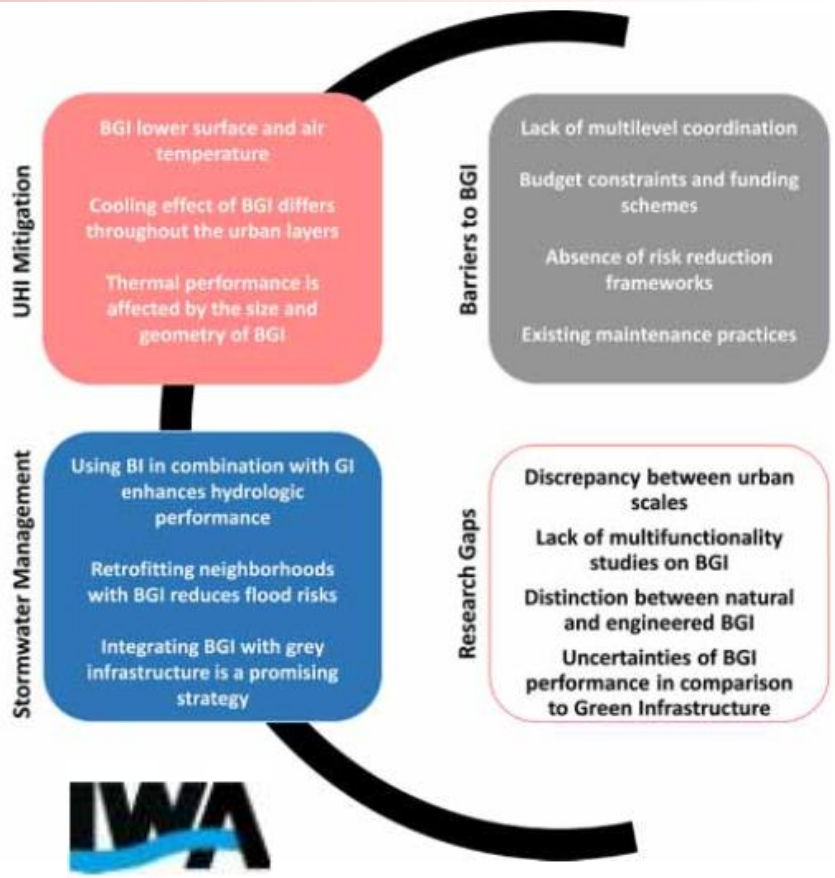
BGI System Strategies at various scales - building, block, district

Integrated BGI Approach

BGI System Sustainable Urban System

Integrated BGI Approach

- Findings on blue-green infrastructure (BGI) are reviewed considering urban heat island (UHI) mitigation and stormwater management.
- BGI effectiveness to UHI mitigation is influenced by geographic and climatic conditions.
- BGI can better manage stormwater than green infrastructure.
- Barriers to BGI implementation include lack of multilevel coordination, budget constraints and absence of risk reduction frameworks

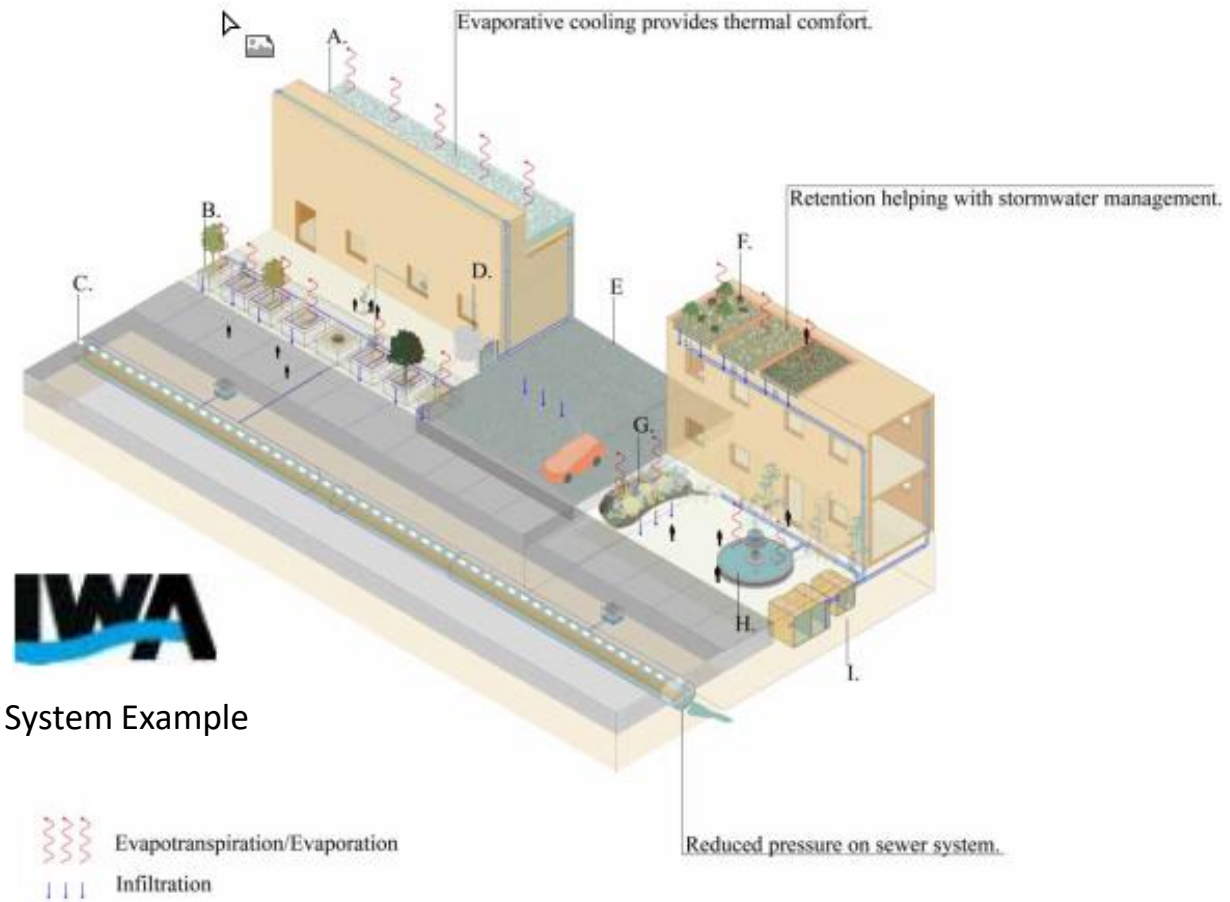


Integrated BGI Approach

Holistic Design: Grey, Green and Blue Infrastructure

A. Blue Roof
B. Tree Planting
C. Sewer Connections
D. Rain Barrel
E. Permeable Paving

F. Green Roof (Intensive; Semi Intensive; Extensive)
G. Rain Garden
H. Fountains
I. Underground Detention



BGI System Example

Integrated BGI Approach

Green-Blue Infrastructure Planning

Landscape Planning	Water Planning
Open Space Strategy	Sustainable Water Use Plan
Urban Forest Strategy	Integrated Water Management Strategy
Biodiversity Strategy	Flood Studies
Environmental Strategy	Stormwater Management Plan

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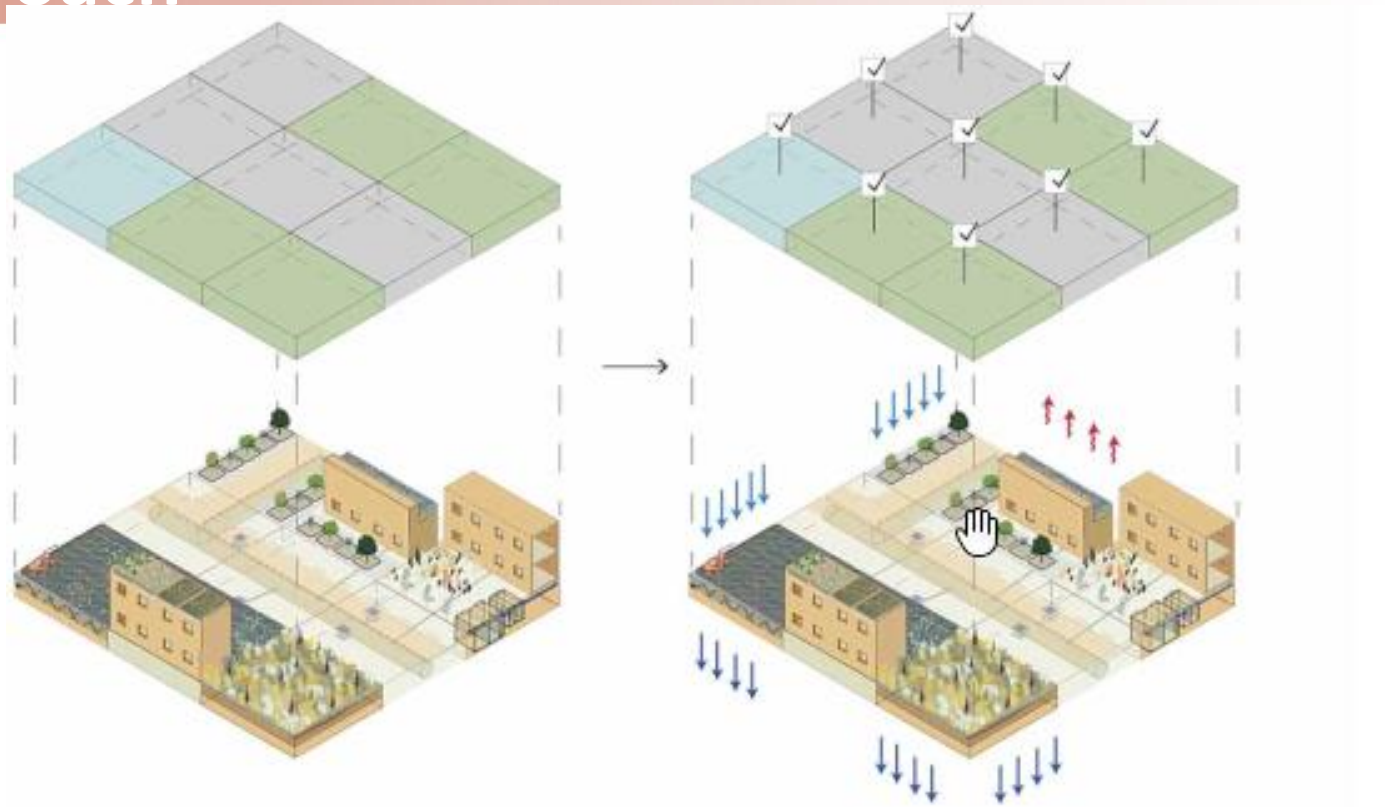

3. Optimization of layouts using green-grey layouts and evaluation costs

4. Final evaluation of the optimized design

Simulation-optimization of blue-green-grey infrastructure (Developed based on the study of Bakhshipour *et al.* 2019).

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Integrated BGI Approach

Green-blue infrastructure element		Description
Green roofs		Green roofs are building roofs which have be partially or completely covered in vegetation which is planted into a growing medium sitting above a waterproof membrane. Harvested rainwater can be used for irrigation.
Green walls		Green walls are a vertical garden on the side of a building which comprises vegetation planted within a growing medium which is attached to the wall. Rainwater or greywater from the building can be used to support plant health.
Street trees		Trees planted in growing medium underneath sidewalks which can be designed to be passively irrigated from stormwater runoff from pavements and roads. These can also be designed to enhance stormwater pollutant removal with the inclusion of special filter media. Permeable paving can also be used to channel stormwater into underground soil areas to support trees.
Gardens		Gardens comprise vegetation planted into a growing media (soils). Stormwater can be directed into gardens to provide passive irrigation, or an active irrigation system can be provided, fed by alternative water sources.
Raingardens		Raingardens are garden beds which are designed to capture, detain and treat stormwater runoff as it filters through the underlying filter media before it is discharged at the base of the system either into the surrounding soils or into the local stormwater network.
Swales		Swales are shallow, vegetated open channels that convey and treat stormwater. The vegetation can vary from mown turf to sedges.
Parks		Parks are public open space areas which provide the local community with a range of recreational activities. These could be irrigated using an alternative water supply or designed to provide stormwater detention and infiltration.

Integrated BGI Approach

Green-blue infrastructure element		Description
Sports grounds		Sports grounds are large open space areas which support active recreational activities. These could be irrigated using an alternative water supply or designed to provide stormwater detention and infiltration.
Urban agriculture		Urban agriculture is the local production of food products. This can include community gardens which are open to the public, or commercially viable small-scale urban farms. Suitable alternative water sources can be harnessed for irrigation.
Green corridors		Green corridors are linear green spaces that can provide a range of connectivity services including natural habitat and recreational pathways. These areas are typically located along waterways or other easements.
Ponds and lakes		Ponds and lakes are open water bodies which are designed to permanently hold water. They can be fed by a stormwater supply or a recycled water supply. Vegetation can be included around the edge or in shallow sections.
Wetlands		Wetlands are heavily vegetated water bodies. These systems can either be natural features in the landscape or can be constructed to treat stormwater. They can appear as natural systems or integrated as hard edged features in urban areas.
Waterways		Waterways are channels that capture and convey flows from catchments. They include streams, creeks and rivers and can be natural or modified systems (e.g. rock edged or even concrete lined)
Forests		Forests are large areas of dense plantings of trees, shrubs and ground covers. They can be remnant, regrowth or newly created urban forests. Forests play an important part in the water cycle, creating pervious area to absorb stormwater.

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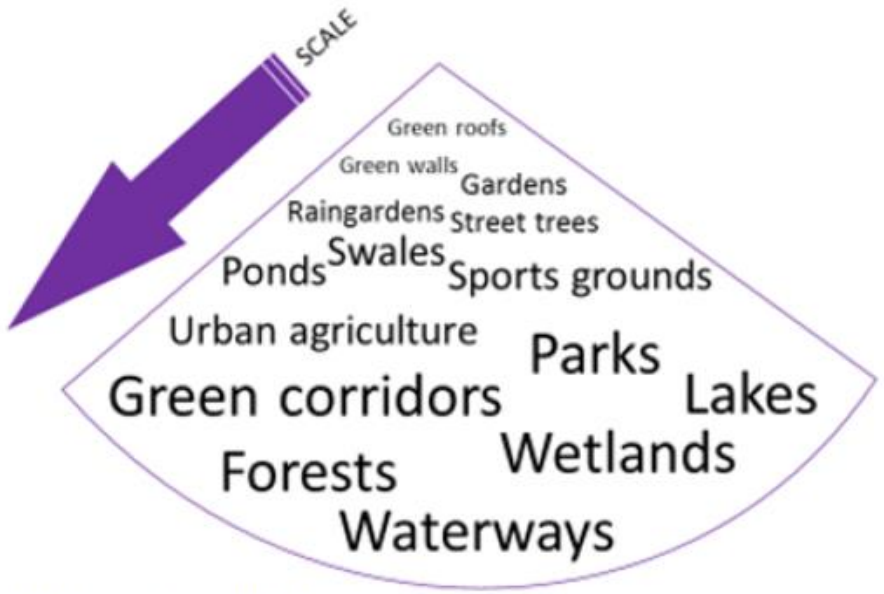
Integrated BGI Approach



Green-blue infrastructure elements applicability to scale

Interlinked green-blue infrastructure systems across scale

Saudi Arabia Climate Action Initiatives

The Saudi Green Initiative was launched by the crown prince with the motto, “climate action, energy security and economic prosperity must be treated equally.”

Since the launch of the SGI, Saudi Arabia has planted 18 million trees within the Kingdom and of those 13 million are mangroves.

The second edition of the SGI was organized in November on the sidelines of the UN climate change summit COP27 in Sharm El-Sheikh, Egypt.

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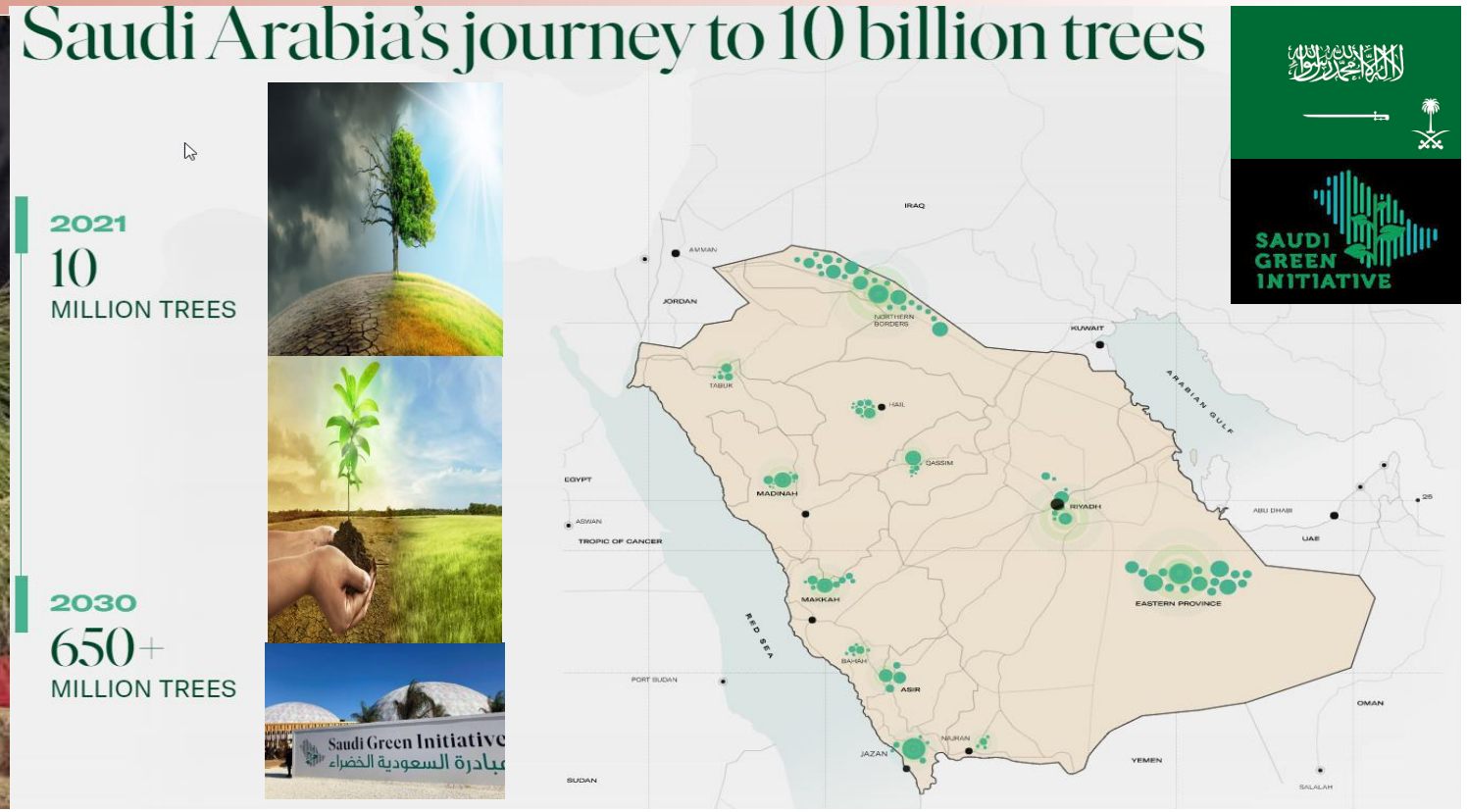
Saudi Arabia Climate Action Initiatives

Since the launch of Vision 2030, Saudi Arabia has made tremendous progress in addressing its unique environmental challenges, but there is much more to be done. The Saudi Green Initiative oversees Saudi Arabia's work to combat climate change, facilitating whole-of-society, and public and private sector collaboration to rapidly scale-up climate action. The Saudi Green Initiative works on increasing Saudi Arabia's reliance on clean energy, offsetting emissions, and protecting the environment, in line with Vision 2030. It aims to improve quality of life and protect future generations. Saudi Green Initiative (SGI) under which the Kingdom plans to plant more than 600 million trees, protect 30 percent of the country's land and sea from climate change and build the world's green hydrogen plant. Combined with a net-zero plan - where the kingdom will rapidly expand already significant investments in renewable energy - Saudi Arabia will work to restore, conserve and sustainably manage one billion hectares of land by 2040

Saudi Arabia Climate Action Initiatives

The Saudi Green Initiative aims to plant 10 billion trees - like rehabilitating 200 million hectares of degraded land. The goal also represents 4% of the global drive to reverse land degradation and 1% of the global effort to plant a trillion trees. As part of the plan, 30% of the kingdom (600,000 square kilometers) will be protected areas, and efforts will be made to protect coastal environments. The Green Middle East Initiative has a similar plan for the region. Saudi Arabia will work with countries to plant 50 billion trees across the Middle East. Over the past year, Saudi Arabia has accelerated the pace of its climate action. The Kingdom will achieve the SGI target of placing 30% of its land and sea under protection by 2030, and plant over 600 million trees within the same timeframe, an increase of over 150 million trees from the initial goal to plant 450 million by 2030.

Saudi Arabia Climate Action Initiatives



Saudi Arabia Climate Action Initiatives

Green Infrastructure in Riyadh City

Saudi Arabia Climate Action Initiatives

BGI in Riyadh City

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Saudi Arabia Climate Action Initiatives

BGI in Riyadh City

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Conclusion

1. Faced with climate change and environmental degradation many cities are turning to Blue-Green Infrastructure (BGI) solutions to enhance climate resilience as well as restore the health of ecosystems. BGI is a strategically planned network of natural and semi-natural areas, ranging in size from rain gardens right up to green streets, that are designed and managed to deliver a wide range of environmental, economic, and social benefits including improved water quality. A key aspect of BGI is its multifunctionality, specifically, its ability to perform several functions and provide several benefits within the same spatial area.

Conclusion

2. This means BGI harnesses the interrelationships between vegetation and the water cycle to improve living conditions in the city. In turn, this enhances both sustainable development and water- and greenery-related ecosystem services. There are multiple benefits of BGI including improved water quality, reduced potential for flooding, reduced infrastructure costs, and increased space for communities and wildlife. BGI not only enhances the resilience of cities to climate change but provides multiple economic, social, and environmental benefits. A variety of fiscal and non-fiscal tools can be used to enhance the uptake of BGI on public and private land, including incentives for on-site reuse of stormwater and the educating of the public on the benefits of BGI.

Conclusion

3. The Saudi Green Initiative oversees Saudi Arabia's work to combat climate change, facilitating whole-of-society, and public and private sector collaboration to rapidly scale-up climate action. The Saudi Green Initiative works on increasing Saudi Arabia's reliance on clean energy, offsetting emissions, and protecting the environment, in line with Vision 2030. Increasing vegetation cover and helping combat desertification through carefully planned afforestation initiatives across the kingdom of Saudi Arabia. Saudi Arabia's capital is transforming in an attempt to reduce the effects of climate change.

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