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INNOVATING IN URBAN GREEN AND BLUE INFRASTRUCTURE TO IMPROVE THE FOOD-WATER-ENERGY NEXUS

An Implementation Guide for Cities and Subnational Governments

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Foreword

Cities consume 75% of natural resources, and produce 50% of global waste, in addition to 60-80% of greenhouse gas emissions. However, as well as playing a significant role in contributing to emissions, cities can play a powerful role in contributing to solutions. It is the role of policymakers and communities to experiment with alternative solutions to problems. Cities are, after all, critical hotspots of innovation for transitioning to more sustainable systems.

I believe that this Nexus Implementation Guidebook for Cities is essential reading for anyone who has ever questioned how they can enhance the sustainability and liveability of their community. The guide is skillfully structured to appeal to a wide range of readers and assist them in taking appropriate action in finding answers that will work for their local context.

We can certainly learn a lot from researchers who produce knowledge and decision-makers who use knowledge. One of the unique aspects of this guide is that it adeptly blends the expertise of knowledge users and producers as it has been developed based on extensive research by scientists and practitioners, which adds great value to the readers' learning journey. I hope that this form of collaboration will become more prominent in the future as this guide certainly demonstrates the advantages of bringing both groups together.

With this in mind, I am sincerely of the opinion that this guide will facilitate groups and individuals in working together and learning from one another to initiate the implementation of innovative resource management practices.

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Acronyms and abbreviations

ACCCRN	The Asian Cities for Climate Change Resilience Network
ADP	African Development Bank
AUDA	The African Union Development Agency
AULNA	Urban agriculture Low space No space in Antananarivo
CBD	Conference on Biological Diversity
COP	Conference of the Parties
CRFS	City region food system
EbA	Ecosystem-based Adaptation
FAO	Food and Agriculture Organization
FWE	Food-Water-Energy
GBI	Green and Blue Infrastructure
ICPD	International Conference on Population and Development
IDB	Interamerican Development Bank
IFNA	Initiative for Food and Nutrition Security in Africa
IMF	International Monetary Fund
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IWMI	International Water Management Institute
KPI	Key performance indicators
LID	Low Impact Development
PPP	Public-private partnership
RUAF	Global Partnership on Sustainable Urban Agriculture and Food Systems
SDGs	Sustainable Development Goals
SUDS	Sustainable Urban Drainage System
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs, Population Division
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UN-HABITAT	United Nations Program for Human Settlements
WFP	World Food Program

Preface

"Food-Water-Energy Nexus" (FWEN) is a new framework to address old problems in cities: unsustainable use and scarcity of natural resources, inefficient and wasteful management and social inequalities. FWEN is based on "systems thinking" instead of "silos thinking" to help integrate different sectors and departments in managing resources to improve efficiency and quality in the use of food, water and energy. By identifying the connections between these elements and the sectors involved in their governance, this guide adopts an "urban metabolism" approach. It outlines an integrated management vision in providing environmental services to its inhabitants. By considering the synergies and trade-offs between these resources within a collaborative governance approach, the methodology presented here can help urban managers and policy makers on the pathway toward sustainable development. Deployment of Green and Blue Infrastructure (GBI) can improve the FWEN. The FWEN approach addresses several of the Sustainable Development Goals (SDGs) simultaneously, particularly SDG 11 (Sustainable Cities and Communities), and supports the implementation of the 2030 Sustainable Development Agenda (United Nations, 2015).

Environmental, social and economic crises are already exacerbated by the impacts of climate change and biodiversity loss (IPCC, 2021). The COVID-19 pandemic teaches us a hard lesson about how important it is for cities to develop resilience strategies, that include resource management and infrastructure, to adapt to these multiple impacts. Planning for a future with more frequent and intense extreme events must include nature-based solutions and support for cities to adequately respond to the challenges that lie ahead. Green and Blue infrastructure, along with integrated resource management approaches such as the FWEN, will be instrumental in securing a safe and healthy urban environment.

Systems Thinking

Systems Thinking means taking a 'joined-up' approach to natural resource management. It identifies interactions between different parts of a system (such as a city) and considers how different sectors influence each other. This approach shifts the focus from the parts themselves, to how the parts are organized as a collective. Changing the interactions between the parts can lead to change in the system as a whole, and this co-operation can make the system function better than the parts could achieve on their own. To learn more on systems thinking, visit: https://learningforsustainability.net/systems-thinking/

Silos Thinking

Silos thinking (or silos mentality) explains an approach to resource management that only focusses on sectoral approaches, whereby each sector has its own goals without considering how they influence, and are influenced by, other sectors. Silos can occur when certain parts of an organization are resistant to share information and resources with other parts of an organization. This can lead to a lack of cooperation, making organizations less effective at achieving their goals. Breaking down silos through cross-sector partnerships is explained at: https://www.un.org/ecosoc/sites/www.un.org.ecosoc/files/files/en/2016doc/partnership-forum-issue-note1.pdf

Urban metabolism

Urban metabolism is the circulation, exchange and transformation of resources through the city. It can refer to a range of natural resources, including food, water or energy. Cities today often function with linear metabolisms, where resources are extracted from places far away, are transported and consumed by residents, and then generate waste which is removed from the city. Making these urban metabolisms more circular is one of the ways in which cities are trying to become more sustainable. This can be done through better resource management and increased recycling. For more information visit: https://africa.iclei.org/unravelling-the-stories-of-our-cities-using-urban-metabolism-to-shape-thriving-african-cities/

About this guide

This step-by-step guide is a tool for public managers, leaders and concerned citizens committed to sustainable development. Its ultimate goal is to help you identify and/or adopt green and blue infrastructure (GBI) innovations to improve the FWEN in your community.

If you are reading this, you will be interested or already involved in improving your community's space and livability at some level. As you move along, you will realize others share your interest. You can begin by gathering a group committed to "getting the ball rolling". This group may include colleagues, teachers, students, researchers, local businesses, or community members looking for change to protect the environment, health, nutrition, mobility, or wellbeing in their community. At the end of each section, readers will be able to check their understanding of what they can achieve with the tools presented or suggested from other sources via links. The online format allows readers to easily share its contents and hopefully foster lively discussions among its users.

Sustainable development

Sustainable development is a concept that established the 3 dimensions for human development in the 21st century: environmental, economic and social. At its core, sustainable development is about protecting ecosystems and minimizing the impact of humans on the environment, whilst addressing social problems and improving livelihoods. The UN Brundtland report summarizes it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The Brundtland report can be found at https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf. For more information and how the concept evolved see The UN's 17 sustainable development goals can be found at: https://sdgs.un.org/goals and https://www.iisd.org/about-iisd/sustainable-development.

Green and Blue Infrastructure (GBI)

Green and blue infrastructures are natural and semi-natural landscape elements that form a network. This network of green (land) and blue (water) spaces can improve environmental conditions and provide benefits for city residents, such as improved health or spaces for recreation. Green and blue infrastructures also provide wider benefits, such as water management functions or air temperature regulation. These benefits collectively are called ecosystem services (ES). GBIs are also described or integrated in definitions such as "ecosystem-based adaptation (EbA)", "green spaces", "green/eco-engineering", and "natural capital" when applied to ES valuation. Definitions and images are available at https://www.epa.gov/green-infrastructure/green-infrastructure-design-and-implementation. For more guidance on blue-green infrastructures, visit: https://www.water.vic.gov.au/__data/assets/pdf_file/0029/89606/Green-

This guide results from the extensive research undertaken by the scientists and practitioners gathered in the 3-year IFWEN project –"**Understanding Innovative Initiatives for Governing Food, Water and Energy Nexus in Cities"** (https://jpi-urbaneurope.eu/project/ifwen/), supported by the Belmont Forum (http://www.belmontforum.org/) and JPI Urban Europe (https://jpi-urbaneurope.eu/) as part of the Sustainable Urbanization Global Initiative – SUGI (https://jpi-urbaneurope.eu/project/ifwen/). The project was led by a research consortium of six organizations: Getulio Vargas Foundation (FGV- Fundação Getúlio Vargas – Escola de Administração de Empresas FGV-EAESP), ICLEI – Local Governments for Sustainability, Yale University, Stockholm Resilience Center, Ming-Chuan University and The Nature of Cities (TNOC). Funders include the São Paulo Research Foundation (FAPESP), the German Federal Ministry of Education and Research (BMBF), the National Science Foundation (NSF), the Swedish Research Council (FORMAS), Ministry of Science and Technology of Taiwan (MOST) and START (start.org).

How to use this guide

The guide is divided into five sections describing the planning cycle steps and addressing the issues according to the type and scale of the intervention. In the Introduction, we lay out the principles and concepts, set the scene and justify. Sections 1 to 5 describe the steps towards implementation, including examples of urban GBI. We conclude with reflections on the way forward based on case studies of the IFWEN project.

At the end of each section, we allow readers to interact in a team and assess their progress by testing problems and solutions of experiences in their own city/ community. There are links to exercises, supplementary materials and videos.

IFWEN Project

The "Innovation in Food-Water-Energy Nexus in Cities" (IFWEN) project is a multi-disciplinary research collaboration with seven partner organizations, that aims to advance knowledge for improving the governance of the interactions between food, water and energy (FWE) in cities. It considered blue-green infrastructure initiatives in eight cities across the world, to learn lessons about how GBI can help in governing the FWEN.

IFWEN Participating cities, 2018-2021:

- Antananarivo, Madagascar (1,613,375 inhabitants)
- Dodoma, Tanzania (100,286 inhabitants)
- Florianópolis, Brazil (421,240 inhabitants)
- Gangtok, India (100,286 inhabitants)
- Johannesburg, South Africa (957,441 inhabitants)
- Lilongwe, Malawi (989,318 inhabitants)
- Nagpur, India (2,405,665 inhabitants)
- Sao Jose dos Campos, Brazil (533,000 inhabitants)
- Kunming, China (8,460.088 inhabitants)
- Chinese Taipei, Taiwan (2,592,878 inhabitants)

Expected learning outcomes

After reading this guide and completing the exercises at the end of each section, you will be able to: understand how to address social and environmental challenges through the nexus approach; identify your community's infrastructure problem(s) and search for innovative nature-based solutions such as green and blue infrastructure; understand what is needed to address the challenges; gather ideas to assemble a team, develop and implement a plan; and understand what is required to secure the success of the undertaking.

1. Getting started

Identify **what** needs to be changed and/or improved; verify the available and/or missing resources.

2. Visioning

Establishing a vision: **who** will be involved and **what** will be achieved.

3. Planning

Establishing **how** to get there.

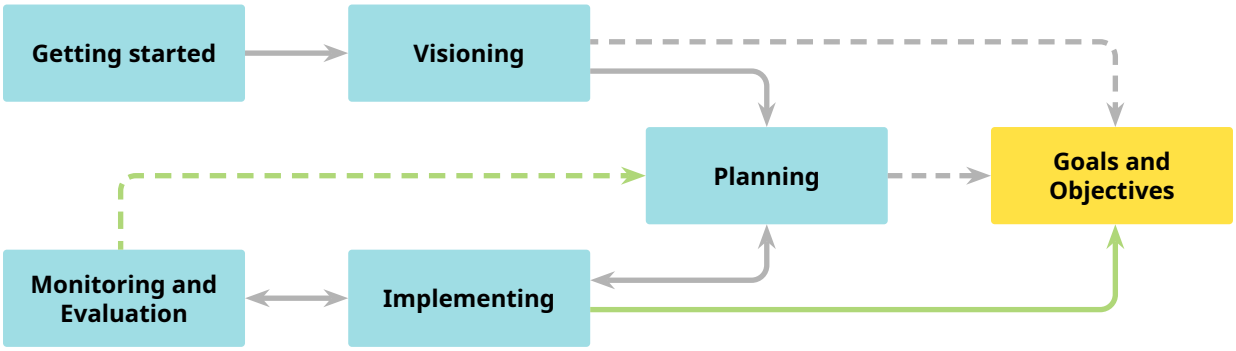
4. Implementing

Identifying the tools and approaches and setting the plan in motion.

5. Monitoring and Verification

Assessing results and adjusting strategies.

Reflections and the way forward



1. Getting started	2. Visioning	3. Planning	4. Implementing	5. Monitoring and Evaluation
Where are we?	*Where do we want to innovate?*	*How will we get there?*	*Getting there!*	*How is it working?*
Steering group	**Key collaborators**	**Core team and collaborators**	**Relevant departments and stakeholders**	**Monitoring team (in-house or third party)**
Frame issues and identify who is affected	Define what is to be achieved (outcomes)	Organize and coordinate collaborators	Coordinate implementation team (s)	Monitor continuously and evaluate periodically
Identify scope and scale of the issues	Identify potential solutions for the issue(s)	Establish a timeline	Manage collaborators and implementation team	Analyze and evaluate changing conditions
Define initial goals and expectations	Identify who can make it happen	Establish benchmark	Engage beneficiaries and motivate partners in activities	Identify data gaps
Identify challenges	Identify threats and opportunities	Define and assign tasks	Keep implementation team updated on progress	Analyze and evaluate performance (preferably by third party)
Map infrastructure	Identify challenges	Identify data sources and collect information	Assess, update and secure resources	Develop alternative strategies to correct or improve responses
Identify water, energy and food systems	Identify and engage key stakeholders and leadership	Establish the baseline	Strengthen team capabilities	Register activity progress and communicate results
Map connections, inefficiencies and potential synergies	Assess legal and institutional framework	Identify tools - available and required	Foster and strengthen community networks for implementation and monitoring	Assess and register impacts and unintended results
Identify innovative approaches to the problem	Identify resources - available and required	Procure planning tools internally and externally	Use social media and communication strategies to inform the public	Provide regular progress reports to the general public
Map stakeholders and collaborators		Determine risks and strategies to address them	Review results and mid-term goals	
		Define indicators to monitor and evaluate progress		

Figure 1. Planning and Implementation Guide Cycle.
Source: Authors´ own

This guide does not provide all the answers but should assist you in finding them. Our ambition goes as far as your enthusiasm, commitment and dedication, mobilized and applied to a case in point.

Note: To keep the guide as objective and easy to read as possible, it references external sources accessible through links in the main text and ***Appendix C*** for detailed information.

Introduction

Expected learning outcomes

After you finish reading this Introduction, you will have more tools to understand "the big picture", how global environmental concerns affect your community in terms of water, food and energy, and how your government, together with other organizations could respond to the impacts of urbanization, climate change and biodiversity loss. You will also be able to identify how urban green and blue infrastructure (GBI) could be used as innovative alternatives to complement or substitute existing conventional "grey" infrastructure as nature-based solutions (NbS). You will become familiar with key terms in the governance and management of natural resources, understand how they interact, and how urban GBI can improve your community's material flows of food, water, and energy (the FWE Nexus).

Nations have joined efforts to establish a sustainable development pathway for human societies, founded on negotiation processes that address social, environmental and economic issues, concerning all people and societies, through treaties and guidelines built on each other for decades. In the 21st Century, guidelines include the United Nations Climate Convention (UNFCCC), the Convention on Biological Diversity (CBD), the New Urban Agenda and the Sustainable Development Goals (SDGs) of Agenda 2030.

To guarantee a healthy planet that future generations can rely upon for their survival and wellbeing, we need to be more respectful and efficient in using our planet's natural resources. Food, water and energy demand is rising and is projected to continue exponentially. By 2050, our planet will have to feed an estimated 9.7 billion people, most of whom live in cities in Africa and Asia. Global energy and water consumption will rise by 50% and 55% respectively by 2050[1].

The way we are currently managing these resources is threatening cities' abilities to deliver sustainable access to goods and services. Cities must match the needs of the growing population and address environmental challenges. There needs to be a shift away from the "take-make-waste" model, in which intensive resource extraction fuels the production of single-use products and infrastructures, leading to increased volumes of waste and access disparities. The **food-water-energy nexus** offers pathways to shape urban metabolisms that are more circular and built on cross-sectoral synergies. It also provides opportunities to address inequalities and resource insecurities. For instance, studies show that enough food is available to feed the global population. However, distribution is unequal, and there is much waste.

However, the complexity and scale of global environmental change challenges cannot be tacked by national governments alone. Transformative change

Take-make-waste model

Also known as linear metabolism of cities, this model has been the conventional – and unsustainable - consumption and production model of western societies for centuries. As we move toward a global population of over 9 billion humans by 2050, the majority of whom live in cities, means this model is no longer an option. Sustainable cities and communities must function within a circular model, in which resource use is optimized, drastically reducing waste. Squandering Earth´s resources has long been unsustainable and as the global environmental crisis becomes unmanageable, societies can no longer afford to ignore Nature´s warnings.

Transformative Change

Transformative change means a fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values. The environmental problems faced globally, and climate change in particular, demand that societies strive for transformative change. The UN 2030 Agenda for transformative change: https://sustainabledevelopment.un.org/post2015/transformingourworld/publication

1 International Energy Outlook 2019, OECD Environmental Outlook to 2050

for a sustainable planet and fewer inequalities will require all levels of government to work together with civil society in addressing these challenges. Collaborative and multilevel governance is the key to this undertaking. In the past 20 years, scientists, policymakers, and practitioners have developed tools and strategies to support local efforts. The first step in the journey is to understand how natural resources are processed in and outside cities to meet human needs.

Problem statement and background

Most humans now live in cities[2]. The increasing urbanization trend is predicted to persist into the foreseeable future in many countries. We have become an "urban species", and cities are our "natural habitat", for better or for worse. While most of us are born and thrive in a predominantly artificial environment, we still depend on natural resources for our survival and wellbeing, both within and beyond our cities' boundaries. Resources such as water, energy, land and food are taken for granted in our complex urban metabolism, which is based on an unsustainable linear model. Given the threats from global environmental change caused by human activities, such as climate change, land degradation and biodiversity loss, however prevalent the built environment, cities must integrate into the natural world.

Civilization must align with Nature's circularity principles in which there is no waste while enhancing efficiency and effectiveness in using resources to meet human needs. To achieve this goal will require ingenuity, policies, plans, and strategies. One such approach is to implement innovative urban green and blue infrastructure (GBI), a Nature-based Solution (NbS) that can provide the means to strengthen this connection between people and nature, as has been demonstrated in several cities throughout the world. In this guide, we will refer to GBIs as NbS interchangeably. Additionally, larger-scale initiatives focusing on Ecosystem-based Adaptation (EbA) including GBI have also been addressed as strategies to tackle the impacts of climate change.

Multilevel Governance

Multilevel governance is the term given to the negotiated, non-hierarchical exchange between institutions at the local, municipal, regional, national and international scales. The last four decades have seen a re-organization in how resources are managed, and governance tends to be conducted collectively between public, private, and non-state actors such as NGOs. Multi-level governance has both 'vertical' and 'horizontal' dimensions. For more information visit: https://www.oecd.org/regional/multi-levelgovernance.htm

Land Degradation

Land degradation is the deterioration or loss of productivity in soils. It is a driver of food insecurity and is largely caused by unsustainable agricultural practices. Land degradation both contributes to, and is affected by, climate change. When land is degraded it has lower biological productivity, worse ecological integrity, and a loss of value to humans. It adversely affects livelihoods. An IPCC chapter on land degradation can be accessed at: https://www.ipcc.ch/site/assets/uploads/sites/4/2019/11/07_Chapter-4.pdf

Biodiversity Loss

Biodiversity loss refers to a decline in the number, variety, and variability of living organisms on earth. This includes diversity within species, between species, and between ecosystems. Biodiversity loss is a big problem facing human societies, with the scale of loss of nature producing severe effects for both environmental and human well-being. A full report on the state of biodiversity loss and ecosystem threats can be accessed here: https://www.ipbes.net/global-assessment

Nature-based solutions (NbS)

Nature-based solutions (NbS) are ways of addressing climate change and other socio-environmental problems by fostering nature, usually at larger scales. By putting effort into the sustainable management and use of natural assets, the benefits that nature provides can be harnessed. Nature-based solutions include conservation, restoration, and environmentally regenerative activities. The UNEP´s Fifth edition of the Adaptation Gap Report 2020 focuses on nature-based solutions, defined as "locally appropriate actions that address societal challenges, such as climate change, and provide human well-being and biodiversity benefits by protecting, sustainably managing and restoring natural or modified ecosystems." Find more on nature-based solutions at: https://www.unep.org/nature-based-solutions-climate

Ecosystem-based Adaptation (EbA)

Ecosystem-based Adaptation is officially defined by the Convention on Biological Diversity (CBD) as "the use of biodiversity and ecosystem services [...] to help people to adapt to the adverse effects of climate change' which may include 'sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits for local communities" (CBD, 2009).

2 By 2007, the world's population was 7.2 billion people, over 50 per cent living in urban settlements, reaching 55 per cent in 2018. The UN estimated that by 2050, over two-thirds of Humankind will be urbanized (UNDESA, 2019)

Principles and concepts

Innovation and urban Green and Blue Infrastructure

In many parts of the world, living in cities became synonymous with artificial lifestyles and distancing from Nature, particularly in the second half of the 20th century. While this has brought about many problems, such as land scarcity, unequal resource distribution and pollution, it has also established cities as places of opportunity, human interaction and creativity. Cities are also where innovation can flourish, improving the quality of life for their inhabitants. And while science and technology have advanced tremendously in the past 200 years, nature has been the best source of inspiration for innovative urban solutions.

Innovation

Innovation is the generation of new ideas, services, systems and processes. Innovation is important for sustainability as new ideas foster better solutions and improvements in existing systems. There have already been many technological innovations for sustainability, such as the development of renewable energy technologies. However, achieving sustainable development will also require many social innovations, where communities and institutions find new creative solutions to social and environmental challenges. A report on social innovation and the environment can be viewed here: https://ec.europa.eu/environment/integration/research/newsalert/pdf/IR10_en.pdf

Conventional or "grey" infrastructures often produce harmful side effects. Green and blue infrastructure can be healthier, cheaper and more effective in many situations. Table 1 illustrates that GBI solutions can offer more adequate responses to urban challenges.

Grey Infrastructure

Grey infrastructure is manmade infrastructure/ construction to address issues such as flooding, runoff, stormwater, as well as to provide water, wastewater treatment, transport, energy, etc., using manufactured materials, mostly concrete, hence the name.

Table 1. Urban Challenges and Infrastructure Solutions

Urban Challenges	Conventional or "grey" solution	Urban GBI solution	Ecosystem services (ES)	Benefits and goods
Food insecurity Lack of access to quality nutrition Obesity and other nutrition-related diseases	Centralized food distribution Chemical fertilizers Genetically modified food	Urban agriculture (UA) AU associated with organic agriculture Community gardens Edible gardens Green roofs Circular food systems with nutrients cycling	Provisioning	Clean Water Fuel (biomass, wood, pulp) Raw materials (fiber, fodder, fertilizer) Food (fish, game, vegetables, fruit) Medicinal plants
Heat island Stormwater runoff Flooding Soil erosion Water pollution Air pollution	Artificial air conditioning Piping and canals Dikes and contention walls Water and wastewater treatment plants Mechanical indoor filters Reservoirs	Street trees Parks and urban forests Bioswales Permeable pavement Wetlands Green roofs and vertical gardens Sponge cities Renaturing river margins and streams	Regulating	Air and water purification Climate control – cooling, shade Global climate emissions reductions Pollination Erosion control Flood and runoff control Waste treatment

Urban Challenges	Conventional or "grey" solution	Urban GBI solution	Ecosystem services (ES)	Benefits and goods
Urban violence and crime Psychological diseases Stress	Repression Medical treatment	Parks and urban forests Gardens	Cultural / Amenities	Recreation Spirituality Health and wellbeing
Pest proliferation Soil pollution Biodiversity loss Zoonotic diseases	Using pesticides Chemical remediation Medical treatment	Green spaces Green corridors and belts Parks and urban forests Renatured urban waterways	Supporting / habitat	Biodiversity conservation Soil protection Pollination and seed dispersal

Source: adapted from Almenar et al (2020).

Green and Blue Infrastructure: Connecting Nature and the urban environment

Urban Green and Blue Infrastructure (GBI) is a socio-environmental solution using natural elements interconnected in a multifunctional network of vegetation and water bodies in cities and surrounding areas. It integrates the built environment[3] and natural habitats, providing ecological or ecosystem services (Table 2), that support and enhance urban activities. At the same time, these interconnected systems – such as parks, green belts and corridors, street trees, lakes, streams, and wetlands – help protect biodiversity, and mitigate and adapt to the impacts of climate change, such as storms, flooding, and droughts. Urban GBIs range in scale from local to regional and can be implemented by individual citizens (private gardens), communities (urban agriculture), local governments (city parks and constructed wetlands), states and/or national governments (urban forests, conservation units), managed and implemented in a partnership or individually. GBIs are associated with the concept of ecosystem services (ES), defined by the UN as *"The direct and indirect benefits that humans derive from natural and managed ecosystems, such as provisioning (including food), cultural, regulatory and supporting services."* (UNEP / IWMI 2011:21). In 2013, the European Environmental Agency issued the first version of the Common International Classification of Ecosystem Services for Integrated Environmental and Economic Accounting to establish common standards for classifying and measuring ES.

Ecosystem services (ES)

Ecosystem services are the benefits that flow from nature to people. They are the supporting, provisioning, regulating, and cultural/spiritual services provided by ecological processes to individuals or society at large. Nature provides the underlying support system that allows all things on earth to survive, and provides services like drinking water, food, and timber. It regulates natural phenomena through processes of pollination, air temperature and climate regulation, and offers cultural services like wellbeing, spiritual comfort and recreation. CICES aims to classify the contributions that ecosystems make to human wellbeing, their most recent report can be found at: https://seea.un.org/sites/seea.un.org/files/lg23_cices_v5.1_final_revised_guidance_03-10-2017.pdf

GBI solutions are applied differently in developed and developing countries, also categorized as countries with medium and low income by the World Bank (Box 1). As a research topic, GBI also places a stronger emphasis on social justice and public health.

3 The "built environment" refers to the human-made surroundings that support human activities, including buildings, roads, lighting, infrastructure, and other elements resulting from human labour. Contemporary approaches also include institutional, economic and cultural aspects in defining the built environment (Opoku, 2016).

Box 1. Urban GBI in the Global South

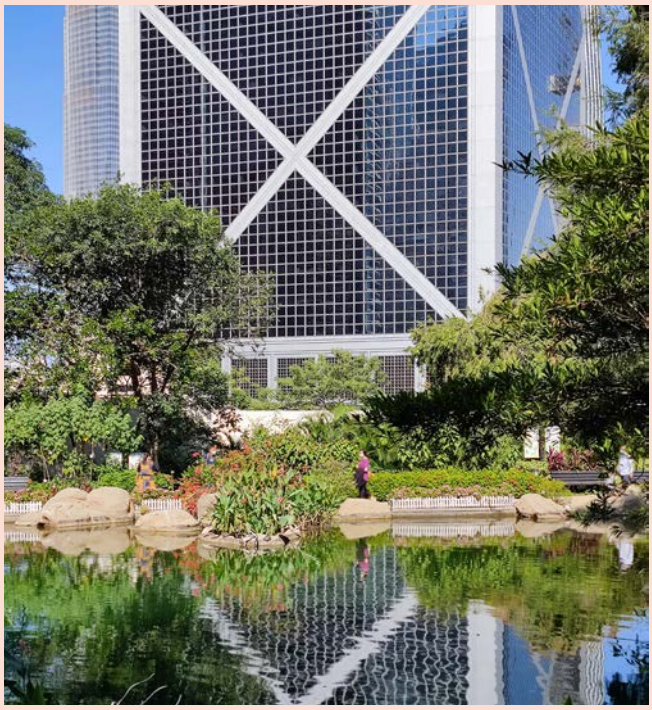
Although cities in developing countries, particularly the large ones, share socio-economic characteristics and vulnerabilities, urban GBI varies widely across the regions. Specific GBI typologies in a particular area relate to the cities' demographic and development aspects. In Africa, where food security is a significant issue, urban populations traditionally practice urban and peri-urban agriculture (including food gardens, vertical and roof farming), which addresses poverty alleviation and flood control. Some more developed cities, such as Cape Town, also invest in green areas to improve health and the local urban environment. With deep inequality issues, Latin-American towns have implemented the GBI approach, through green spaces and urban agriculture, focusing on both social and ecological concerns, for example, urban land use, food provision, sanitation and assessment of soil and water quality. Studies on urban GBI highlight the vulnerability and social problems in Latin America and the Caribbean (LAC). For a list of GBIs per region and country, cited in journals between 2015 and 2019, see ***Table C1*** in Appendix C.

In some Asian countries, urban GBI includes parks, green areas, rooftop and vertical gardens that are widely used, particularly in high-density cities. These GBI serve to tackle the urban heat island effect and provide recreational areas. In 2014, China established a national program called "Sponge City" which was implemented in several urban areas to address flooding and water shortage.

Adopting GBI as a mitigation/adaptation strategy convergent with national guidelines or even linked to a global environmental agenda is still not frequent, and the focus is foremost socio-economic. Except for China, the main goal of urban GBI in developing countries is to function as a provider of ecosystem services. China's Sponge City concept takes a more holistic approach, addressing climate change and biodiversity loss.

Overall, the focus has been on local developmental concerns, addressing urban-rural interactions, land-use policies, food insecurity and poverty alleviation. Many of these issues are intertwined with problems arising from rapid urbanization, such as informal settlements, lack of access to primary natural resources and sanitation, and environmental degradation, aggravated by inadequate governance and insufficient financial resources and capacity.

Acknowledging the enormous cultural, historical, and environmental differences between cities in the developing world, shows that there is no "one-size fits all" solution to consolidate GBI strategies. Nevertheless, there are enormous opportunities to use GBI as an alternative approach, as some cases demonstrate, to improve urban ecosystem services. For instance, the city of Durban, South Africa, revitalized a waste landfill and reforested the area, helping to capture carbon and generate income for the local communities; Medellin, Colombia, successfully implemented a greenbelt development project with landscape and environmental benefits, despite controversies about its social justice implications, and the Sponge City Program in China reports some successful pilot initiatives to address stormwater management.



Source: Macedo et al., 2021

Table 2. Urban GBI in developing countries: differentiation according to natural element predominance

Vegetation	Water bodies
Green infrastructure (GI)	Blue infrastructure (BI)
Urban forest	Wetland
Green space	Lakes
(Urban/Community) garden	River
Street/Urban trees	Creek
Urban greening/Greenery	Stream
Green belt	Permeable pavement
Urban agriculture/Farming	Urban drainage
Peri-urban agriculture	Ponds
Sponge city	Mangrove
Green roofs	
Living/Green walls	
Green way or greenway	
Urban Park	

Source: Macedo et al. (2022) adapted from Bellezoni et al. (2021)

Urban GBIs can also interact with conventional infrastructure, sometimes complementing or even substituting them. Systems using GBI in combination with grey infrastructure are also categorized as hybrid infrastructures. GBI can be more efficient than conventional infrastructure by providing several ecosystem services simultaneously. An essential aspect of urban GBI in developing countries is addressing social and developmental challenges. Studies assessing the academic literature on GBIs in Africa, Asia, China and Latin America demonstrate the benefits of specific typologies that go beyond landscape or environmental benefits to address food insecurity and health. In China, for instance, low impact development (LID) strategies are applied to Sponge Cities, a unique integrated urban planning approach that highlights stormwater management. See here for more examples, detailed descriptions and photos.

Hybrid Infrastructure

Hybrid infrastructure is infrastructure with both 'grey' components, which are usually human-engineered and constructed from hard materials, and 'blue-green' components, which are natural spaces that provide ecosystem services.

Low Impact Development (LID)

Low Impact Development is a land development strategy for managing stormwater at the source with decentralised micro-scale control measures (Hansen et al., 2017).

Sponge City is a concept addresses stormwater management to respond to rapid urbanization and increasing impervious surfaces in cities. It originated in the US during the 1990´s, as low impact development (LID) measures, previously named Best Management Practices (BMPs). A Sponge City includes GBI strategies such as bioswales, rain gardens, ponds, green roofs, and permeable pavements. In late 2014, the Government of China launched a nationwide initiative called the Sponge City Program (SCP) to tackle flooding due to rainwater runoff in urban areas. The SCP establishes guidelines and goals for pilot cities that are constantly being reviewed, and expects that by 2030, 80 percent of urban areas have complied to the requirements. The SCP seeks to "[...] promote water responsive cities capable of eliminating water logging and preventing urban flooding, improving urban water quality, mitigating impacts on natural ecosystems and alleviating urban heat island impacts." (Ulku et al., 2018).

The Food-Water-Energy Nexus (FWEN): Managing natural resources in the urban environment

Cities are defined not only by territory and the built environment but as socio-technical systems that also draw on resources beyond their geopolitical boundaries. They are living systems, encompassing everyday activities such as work, play and travel. Although this has been known for a long time, acknowledging the importance of efficiently managing and distributing these resources became a global concern. The world must immediately address increasingly complex and interconnected risks arising from rapid urbanization and global climate change.

The Food-Water-Energy nexus (FWEN) is an integrated approach to addressing knowledge and resource flows in response to silo thinking, (the management of departments, people and resources in isolation). The FWE nexus aims to improve the use of and access to vital resources, reducing inefficiencies and waste by focusing on integrated approaches to management and governance. In 2011, the concept of FWE nexus was brought to the forefront of the sustainable development debate by the international community (Figure 2) to address the scarcity of these resources as the human population and its demand for natural resources grows (Hoff 2011). In cities, the flow of food, water and energy is facilitated by infrastructure and governed by public and private agents, coordinated within governance frameworks.

The FWEN approach contributes toward developing solutions that increase food, water and energy security, particularly in vulnerable communities. It fosters better food, water and energy security by improving access, management efficiency and reducing waste, contributing to achieve several SDGs in Agenda 2030, particularly SDG 11, on Sustainable Cities and Communities. Municipalities must be part of the solutions, as the governments closest to local populations. Despite not being in control of every aspect of the FWE nexus, municipal governments are better equipped to deal with local problems and can harness human capital to engage in urban environmental governance. Understanding and better managing the synergies and trade-offs, at the local level, between food, water, and energy resource consumption is vital for more sustainable cities.

Rapid Urbanization

Rapid urbanization explains the trend of human populations growing in cities. Cities are growing rapidly, and there is increasing pressure on the land and resources that supply cities. By 2050, it is expected that two thirds of the world population will live in urban areas, with associated pressures for infrastructure and services. World urbanization prospects can be viewed in a UN report at: https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf

Integrated Approach

An integrated approach involves managers beyond disciplinary, departmental and sectoral boundaries to address complex problems, make decisions and communicate efficiently. For a good, short description, see https://www.youtube.com/watch?v=oAdJWAJvevo

Scarcity

Scarcity (of Resources: Water, Energy and Food) is the point at which the aggregate impact of all users of a resource impinges on its supply or quality, to the extent that demand cannot be satisfied fully. Scarcity has complex drivers, it can occur due to a physical shortage of a resource, or due to the failure of institutions to adequately manage resources. Scarcity can be addressed by protecting natural assets such as soil and water resources, increasing supplies, decreasing demand, or changing allocation for a resource. Water scarcity is one of the most significant resource scarcities, and was the focus of the 2006 Human Development Report: http://hdr.undp.org/sites/default/files/reports/267/hdr06-complete.pdf

Governance

Governance can be generically defined as the task of running a government, or any other organization. The concept evolved to a broader approach, in which it refers to interactions between formal institutions and civil society actors, involving "power, authority and influence to enact policies and decisions concerning public life and social upliftment." Islam M.S. (2017) Governance and Development. In: Farazmand A. (eds) Global Encyclopedia of Public Administration, Public Policy, and Governance. Springer, Cham. https://doi.org/10.1007/978-3-319-31816-5_1990-1

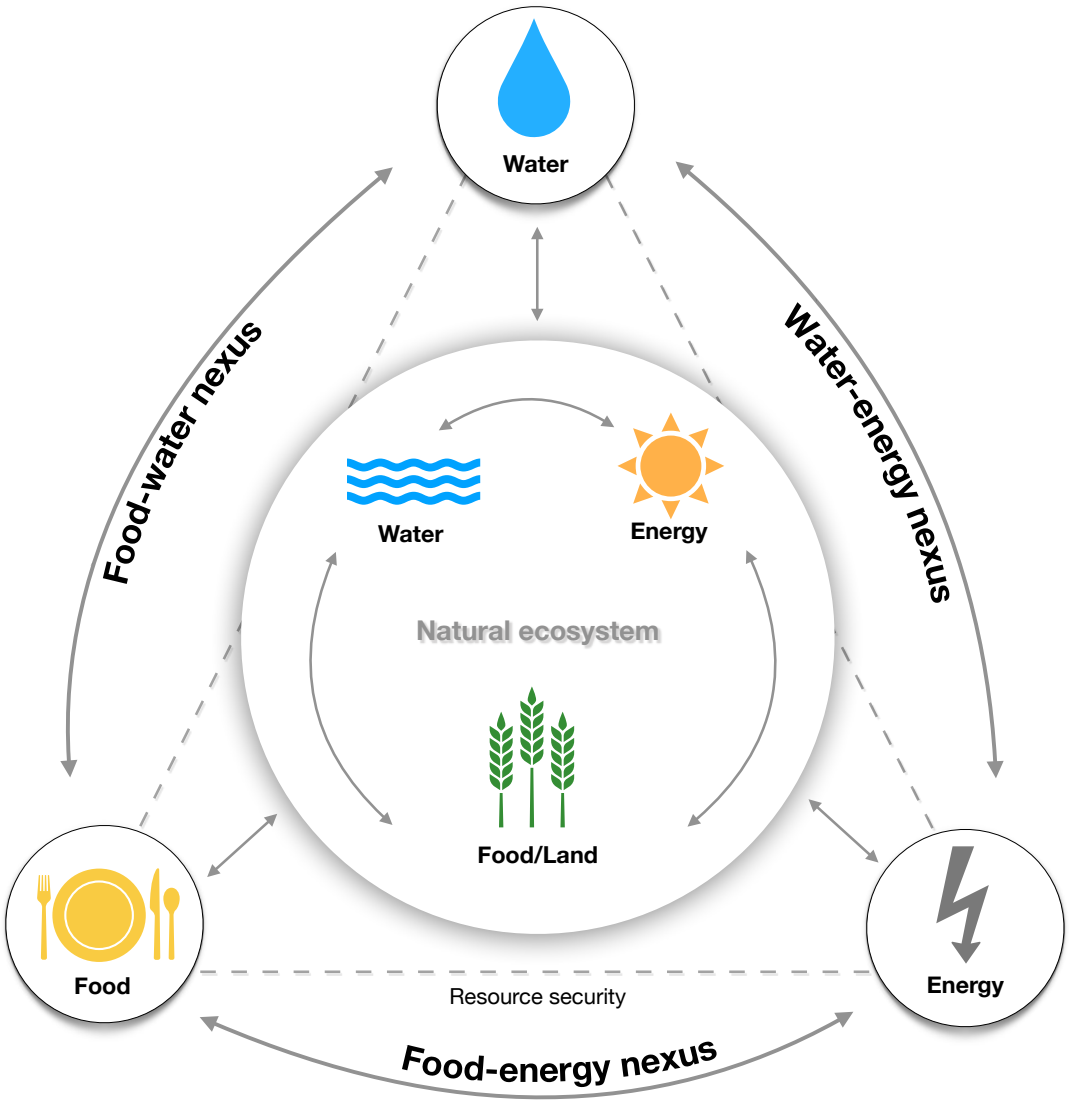


Figure 2. Water-energy-food nexus approach.
Source: Adapted from Hoff (2011), Bazilian (2011) and UN-ESCAP (2019)

Assessing what we have learned in this section
*To assess your understanding and progress, see **Table A1** and exercise sheets in **Appendix A**.*

1. Getting started

Where are we?

Expected learning outcomes

After reading this section, you will have a clear picture of your community's FWE linkages whether and how GBIs are used or involved in the FWE nexus. You will be able to identify the problems in the systems and the opportunities for innovative solutions.

This section is about understanding your city's metabolism: undertaking diagnosis and identifying the potential for innovations. Metabolism refers to "the exchange processes that produce the urban environment" (Broto, Allen & Rapoport, 2012., p. 851). Cities can be seen as socio-ecological systems made up of flows of resources (Kaika and Swyngedouw, 2006). The case of Gangtok, in India (Box 2) provides a good example of an integrated solution within an urban metabolism circular model that addresses food, water and energy. The case of food, water and energy (waste) in Gangtok, India (Box 2) illustrates this concept. This guide presents elements, actions, and information for you to collectively assess the problem and put in place solutions based on natural resources. You will be able to identify green and blue infrastructures (GBIs) to improve access to food, water and energy resources. You will learn that when combined with the urban and built environment, GBI will optimize resource use and management in your neighborhood, community or city. Asking the right questions is vital for getting the answers you need (Table 3).

Box 2. Urban Metabolism – Gangtok, India

Waste segregation at source is generally not practiced in Gangtok, making waste processing and recovery of recyclable material exceedingly tricky. This leads to an accumulation of unprocessed solid waste at the landfill site. Due to the site's sloping topography from northwest to southeast, residues leak into the Ranikhola River, polluting it. In Gangtok, the pollution of water bodies is exacerbated by constant waste dumping and flowing downstream to residential areas.

In 2018, the Gangtok Municipal Corporation piloted a bio-composting plant to close the food and waste loop. Since the implementation of the OWC, organic waste from the area is used for compost and no longer going to landfills, thus saving fuel costs and reducing the waste which enters jhoras. This reduces pressure on the city's solid waste system. Furthermore, the process is more sustainable; the generated compost is sold to the local farmers and used on surrounding farms.

The detailed case study is available at https://e-lib.iclei.org/publications/IFWEN_Gangtok_FINAL.pdf.

Table 3. Relationships between different types of green and blue infrastructure and food-water-energy topics, according to GBI-FWEN literature

	GBI typologies \ FWEN topics	Food				Water						Energy					
		Food safety	*Food supply*	*Food security*	*Nutritional quality*	*Water quality*	*Water demand, Supply & Savings*	*Stormwater runoff & Flood control*	*Wastewater reuse & Treatment*	*Groundwater quality & Quantity*	*Water management*	*Energy supply & Security*	*Energy efficiency*	*Energy savings*	*Climate change, Carbon footprint & Storage*	*Urban heat island*	*Thermal & Cooling effects*
Green Infrastructure	*Urban forest*		+ -	+		+	+ -	+	+		+	+		+	+	+	+
	Green spaces		+ -	+ -	+	+	+ -	+	+		+	+		+	+	+	+
	Urban/Community gardens		+ -	+	+	+		+								+	+
	Street/Urban trees					+ -	+ -	+ -	+	+ -	+	+		+	+	+	+
	Urban greening/Greenery											+	+	+	+	+	+
	Green belt																+
	Urban agriculture/Farming	+ -	+	+	+	+ -	+ -	+ -	+ -	+	+	+	+	+ -	+ -	+	
	Peri-urban agriculture/Forest											+			+		
	Nature-based solutions															+	+
	Sponge city					+		+	+		+				+		
	Green roofs		+	+	+	+ -	+	+	+		+		+	+	+	+	+
	Living/Green walls													+	+	+	+
	Green/Smart buildings												+	+	+		+
	Green infrastructure					+	+	+			+		+		+		-
Blue Infrastructure	*Water body*		+			-								+		+	+
	Constructed/Urban wetlands		+			+	+	+	+		+			+	-	+	+
	Lakes/Ponds	-	+	-		+	+	+	+					+			+
	Urban river	-	+	+		+ -	+	+			+	+				+	+ -
	Creek														+	+	+
	Coastal vegetation		+												+		
	Blue infrastructure																+
	Forested wetlands													+	+		
	Streams					+		+	+		+			+		+	+
	Rain gardens					+		+						+	+		+
	Detention/Stormwater ponds					+		+	+					+	+		+
	Permeable pavements					+	-	+									
	Bioswales					+		+									
	Urban drainage							+									

Note: Yellow cells refer to positive effects; red cells to negative effects; orange cells to positive and negative effects. Source: Authors. Adapted from Bellezoni et al. (2021)

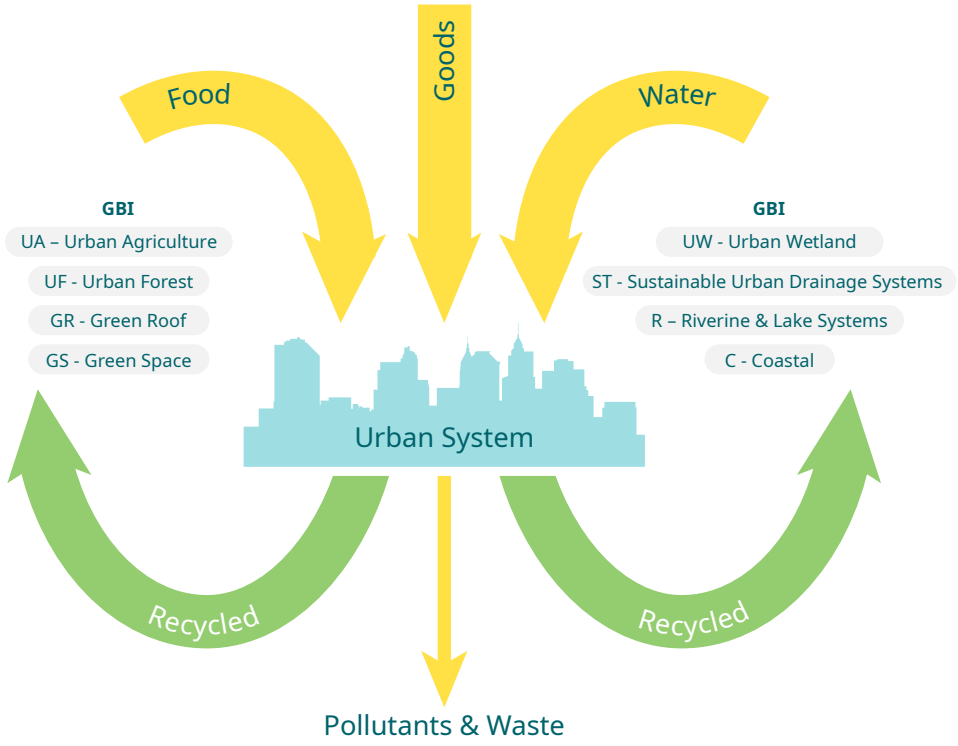


Figure 3. How Urban GBI can Improve City Metabolism – Including more forms of GBI into urban systems can reduce pollutants and waste and reclaim outputs as new inputs.
Source: Authors' own

Identifying issues and challenges

Every city has to deal with infrastructure problems and provide adequate services to its inhabitants. Municipal governments usually have the means to map critical areas or the need for improved infrastructure. However, they often prefer conventional solutions, which are well-known and considered more straightforward, and cheaper. This is not necessarily true, what needs to be highlighted instead is the search for more innovative and holistic approaches, which are the most sustainable in the medium to long term.

Assessment of FWE Systems

Food, water and energy are three fundamental systems for cities and are intrinsically connected in material terms. As urban populations grow, so do their needs; challenges for the municipal administration increase in scale and complexity, requiring coordinated and effective responses. However, a lack of connections that prevent positive synergies often results in inefficiencies due to various resources being governed and managed by different organizations. Nevertheless, there is space to use GBI to improve urban metabolism by creating synergies among different resources, such as the case of São José dos Campos, Brazil (see Box 3).

Box 3. Governing food, water and energy (FWE) nexus using Green and Blue Infrastructure (GBI) in São José dos Campos, Brazil

São José dos Campos (SJC) is located in the east of São Paulo State in Brazil and is the central municipality in the metropolitan region of Paraíba River Valley. Despite being one of the most populated cities in the state (around 730,000 inhabitants), SJC's population density is lower compared to other large urban centers in Brazil. The valley is situated between the cities of São Paulo and Rio de Janeiro and contributes considerably to the regional GDP. It is also a critical aeronautical and aerospace hub in Latin America, hosting important federal scientific research institutes, technology companies, universities, colleges, and training facilities to develop labor skills. These factors contribute to it being a center of innovation in the region.

Municipalities in Brazil have little leverage for directly governing food, water, and energy systems. Food is mainly produced outside the city and sold in street markets, grocery stores or supermarkets, mainly in the hands of the private sector. Water supply is a municipal concession but managed by state or private companies. In the case of SJC, water and sanitation are managed by SABESP, a mixed-economy company controlled by the State of Sao Paulo. Energy is regulated by the federal government, and municipalities are mainly consumers.

Despite the autonomy limitations, the city government has been innovative to incorporate some aspects of FWE in its planning mechanisms and municipal policies. The city has developed an energy inventory as part of its climate change mitigation efforts and worked on a macro drainage plan to prevent flooding. Highlights include a large, protected area called Banhado, by the Paraiba River. The municipality has also supported sustainable farming practices. It established a pilot project to pay for ecosystem services for small farmers to conserve riparian forests and protect water bodies. Many aspects of these FWE initiatives have been incorporated in the Master Plan revision and several municipal laws.

The ICLEI FWEN case study for São José dos Campos can be found at Source: https://e-lib.iclei.org/publications/IFWEN_Sao%20Jose_FINAL.pdf.

Image source: Shutterstock

Thus, the first step is to *map the supply and demand of FWE in your community or city* to identify problems and opportunities for innovation using GBI (see Table A2 in Appendix A). To improve the nexus governance of the system you are targeting, you must first define its scope. Guiding questions include:

- **Food system in your jurisdiction:** How is food produced and distributed? Which departments are involved? What kind of food is produced/made in the city, what is imported, what is exported and by whom?
- **Water system in your jurisdiction:** How is water produced, treated, and distributed in your community? What are the challenges, who is responsible, what is the cost, where are the sources? Define the scope of the water system you are assessing. Should it include only piped water? Commercial and industrial water?
- **Energy system in your jurisdiction:** How is energy produced and distributed? What are the challenges, who is responsible, what is the cost, and where are the sources, how is it metered? Define the scope of the energy system you are assessing. Will it be only electricity, or will it include other energy sources? Will it have informal supply and demand? What is the local potential for a decentralized energy supply?
- **Linkages between food, waste, water and energy:** How is food transported? What kind of fuel is used? How much and what type of energy is used to process food? How is it stored? What is the energy demand for storage or the cold chain? Where is waste sent to, what kind of treatment, if any? Is waste used as a material/energy source? Is it dumped in rivers? Mapping the three systems and finding out how they are connected and governed can help you identify potential innovations to fix problems and/or opportunities to improve the systems using GBI.

Cold chain

It is a set of rules and procedures that ensure the proper storage and distribution of goods that need temperature control and is interconnected with refrigeration equipment. See for example the case of vaccines at https://www.paho.org/en/immunization/cold-chain.

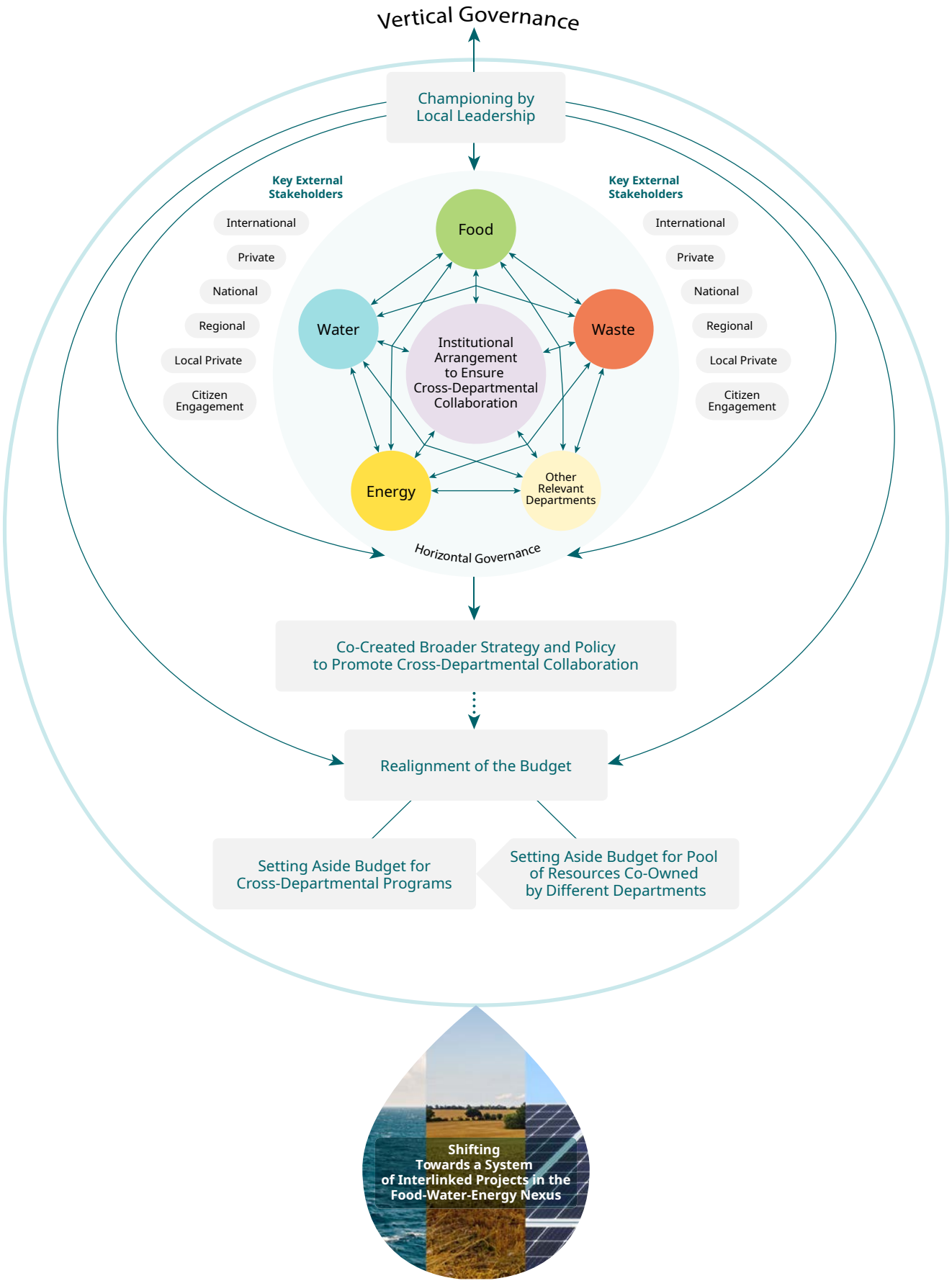


Figure 4. A Systems Thinking Approach to Governance.
Source: Authors' own

Identifying opportunities for innovation in GBI

You begin by identifying the need or opportunity for innovation to address spatial and socio-environmental problems: what could or needs to be changed or improved? Getting started depends on some basic assumptions, regardless of the capacity available in your local government or community:

1. You have identified a problem or an opportunity to use green and blue infrastructure (GBI) to improve the food-water-energy nexus (FWE) in your neighborhood/community/city.
2. You know who should be considered as beneficiaries of the solutions.
3. You will be able to assemble a core team, working or steering group (SG).
4. You know who must be engaged for political support and for raising the necessary resources.

Core team, working or steering group is a group of people that will decide on priorities and manage the general operations and activities involved in a project. They steer work that is undertaken by others and are strongest when they take an adaptive approach to monitoring and evaluation. This means that as the project develops, it is important to learn and change to improve the work being done. For guidance on setting up a steering group, visit: http://www.socialenterprisesolutions.co.uk/wp-content/uploads/2011/03/21_steering_group.pdf

The consultation with various stakeholders is fundamental to identifying those opportunities and getting social and political support for implementation later on. The City of Johannesburg in South Africa has convened a large group of internal and external stakeholders to map opportunities for better management of resources (see Box 4). Collaborative governance implies engaging civil society and government, starting with consultation. The case of Gangtok in India is also a good example (see Box 5).

Box 4. Assessment – Johannesburg, South Africa

Johannesburg certainly shows potential to align priorities for food, water and energy sustainability. Still, there does not seem to be a strategy that intertwines the sectors. Instead, each issue is addressed separately in planning, acknowledging the importance of other sectors.

As part of an exercise to identify the drivers of environmental challenges, the City of Joburg (CoJ) convened stakeholders from municipal departments and entities for a workshop to articulate and prioritize these specific challenges. Participants identified sixty-five challenges that were merged where necessary into 49 particular issues and grouped under 16 themes. Participants then voted for the three most pressing issues to improve environmental and social sustainability. (What was the result; what is the point for this case to be included in this section?) Perhaps it needs to provide more detail... it is not clear that this box links to the “mapping, etc. [...]” sentence above. Firstly, this was useful to note how many issues were articulated per theme and where the city officers believed action would be most effective.

It should be noted that the votes identified points of intervention with widespread co-benefits and not the importance of the theme to the City. For example, the theme “Inequality” received no direct votes and is an ever-present priority for the City. However, it is embedded in other specific themes, such as Informal Settlements, Food Insecurity, Waste Management, and Infrastructure Planning.

During the identification process (item 1 above), it is also crucial to recognize and support existing initiatives to up-scale them to have a more significant impact and, if possible, improve the practice. Those niches of innovation can be disseminated and provide an essential source of knowledge for other similar initiatives. For example, the city of Chinese Taipei identified the potential for existing local urban agricultural (UA) endeavors to provide vegetables and reinforce community ties, before enacting the Taipei Garden City policy to support the spread of this GBI to other parts of the city (Box 20). Similarly, Florianópolis in Brazil scaled up a local composting initiative in a community to over 100 other points in the city. It also innovated to connect composting with local gardens and be part of a health policy initiative to promote good nutrition habits (Box 6).

Assessing what we have learned in this section

*To assess your understanding and progress, see **Table A2** and exercise sheets in **Appendix A**.*

2. Visioning

Where do we want to innovate?

Expected learning outcomes

After reading this section, you will know how to search for and identify GBI innovations to address FWE challenges in your community.

This is the part where we explore "the big picture" and search for "out of the box" solutions. Creativity, co-creation, and collaborative action start here. We must see beyond barriers and seek to identify potential innovative solutions, engage stakeholders (including citizens) and harness support. Identifying challenges and collaborators can be the first step toward understanding how to improve FWEN governance and the role of local governments and citizens.

What is the potential for innovation?

Understanding the FWE systems can reveal innovative alternatives motivated by two main drivers:

- **Threat.** There is a (potential) major problem in one of the systems. The quality or quantity of FWE is problematic in the present or possibly in the future. An innovative initiative to the nexus approach using GBI can solve a pressing issue.
- **Opportunity.** There are always opportunities to improve the FWE nexus using GBI. It can save resources or improve one or more components of the system. Innovations can be found locally or through external sources of knowledge and finance. Many options can provide ideas for innovation or funding (see ICLEI's Climate Finance Decision Making Tree for guidance at https://iclei.org/en/publication/climate-finance-decision-making-tree).

Mapping the threats and opportunities for innovating in GBI can help identify the innovation that best fits the city's needs. If there is a threat, you will need to search for an innovation that could tackle this threat through internal or external sources. Suppose the motivation is the existence of an opportunity, in that case, you need to assess this innovation's potential positive and negative impacts.

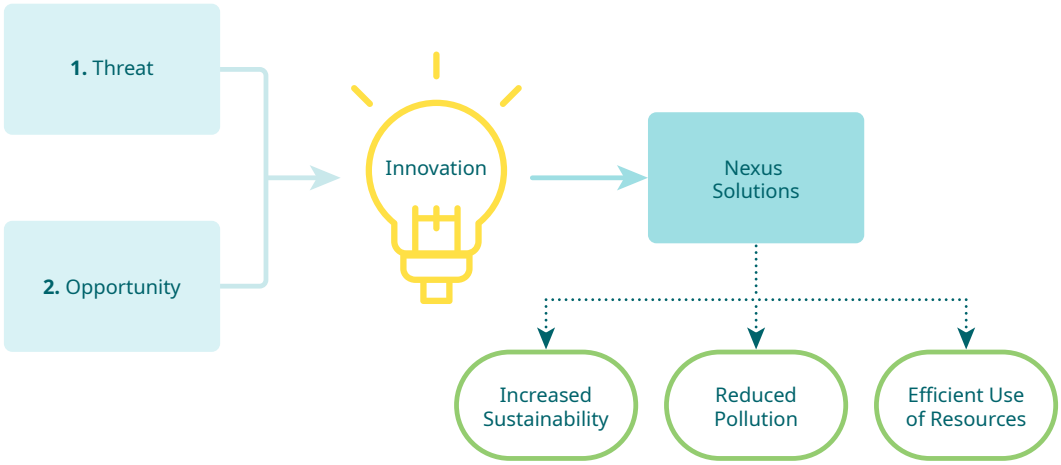


Figure 5. The Drivers of Innovation.
Source: Authors' own

Box 5. Towards building resilience: How governments learn and innovate through collaborative governance in Gangtok, India

Gangtok (India) has drastically altered its landscape by converting cultivated areas, forests, and wetlands into urban land. The decimation of Gangtok's natural resources poses risks for the city's sustainability, while affecting its resilience to environmental and climatic issues such as rainfall variability and landslides. In 2014, a partnership between ICLEI South Asia, the Asian Cities for Climate Change Resilience Network (ACCCRN) and the Rockefeller Foundation aimed to develop a resilience strategy for Gangtok. Together, ICLEI and ACCCRN developed the ICLEI ACCCRN Process (IAP), a toolkit to enable local governments to assess their climate risks in the context of urbanization, poverty and vulnerability and formulate resilience strategies. The goal of the IAP process was to enable Gangtok Municipal Corporation's (GMC) climate team to undertake a project to demonstrate tangible improvements in the city to state and national governments. Gangtok's climate team identified critical vulnerabilities (i.e., increased temperatures and short duration heavy rainfall). Its IAP report recommended improving waste management, so GMC submitted a proposal to the ACCCRN small grants fund. The Rockefeller Foundation provided the resources for constructing an organic waste composter. The IAP was centered mainly around a Shared Learning Dialogue (SLD) process. The SLD tool facilitates multi-dimensional information sharing and enables stakeholders from diverse backgrounds to engage in a two-way knowledge transfer. The SLD sessions were facilitated by ICLEI and the International Institute for Environmental Development (IIED) with key stakeholders in the city, including the city's Mayor, NGOs, universities, and various governmental departments. This enabled the IAP to gain insight from many individuals to identify the city's main environmental problems and the most vulnerable groups and ultimately feed into the city resilience strategy. The SLD process is multi-directional, enabling the stakeholder group to feed into the initiative and gain knowledge from the other stakeholders, allowing the project to maintain public engagement.

Source: https://e-lib.iclei.org/publications/IFWEN_Gangtok_FINAL.pdf.

Identify Challenges

After you have mapped your city's opportunities and threats, the next step is to identify challenges to realizing the innovation:

- **Identify the key internal and external stakeholders for the innovation.** Many innovative initiatives require the collaboration of different actors to bring new resources to the system. Who are the main actors that govern the systems, and under what rules? How would they have to change to make the innovation a reality? Rules might also have to change.
- **Assess legal and institutional framework.** Formal and informal rules, or institutions, influence how the FWE systems work, how they are connected, and how GBI improves the nexus between them. What rules and regulations, formal and informal, affect the FWE systems? Some of those rules would have to change to allow innovation to occur.
- **Identify resources, including financial and human, both available and required.** Once you identify key stakeholders, the rules under which they operate, and what kind of change is needed, you must assess the resources that will enable changes. Investment and finance can also be innovative. They can bring new resources and improve efficiency in the use of resources. However, many investments can carry risks. Therefore, resource assessments should include finding out where they will come from and the challenges to obtaining finance, political support, and knowledge.

Assessing what we have learned in this section
*To assess your understanding and progress, see **TablesA3** and **A4** and exercise sheets in **Appendix A**.*

3. Planning

Deciding how to get there.

Expected learning outcomes

After reading this section, you will be able to design the action plan for NbS and urban GBI innovation(s) and enable your community to map FWE issues. You will be able to identify the challenges using the tools available in your context and/or will know where to find additional resources.

It is now time to establish the roadmap. Note that the process is not entirely linear, and many tools and procedures can be applied in different project planning and implementation stages.

Notwithstanding the importance of each and every step of the process, **planning** is key to the success of your endeavor. Once you are comfortable with the concepts and definitions and how they apply to your case/problem, you can plan to innovate using GBI to improve the FWE nexus.

Box 6. Bottom-up action inspiring municipality urban agriculture legislation in Florianópolis, Brazil

Florianópolis is one of the pioneer cities in Brazil to have a legal framework for agroecological production of food and medicinal plants, aimed at fostering nutritional security and improved health. The Cultiva Floripa Program was established by a municipal Decree in 2017 and amended in 2018, 2020 and 2021. It aims to promote urban agriculture, the sustainable use of natural resources, rainwater harvesting, recycling, composting and solar energy production. The program is managed by municipal departments, the Municipal Environment Foundation (FLORAM) and the Capital Improvement Authority (COMCAP). Activities include managing organic waste through composting and vermicomposting, producing seedlings and seeds, and certification of organic production. The PMAU involved organizing community actions such as cleaning up, composting, and implementing community gardens. Civil society engagement included working groups and associations partnering with NGOs to provide training and capacity building. The initiative, inspired and supported by social movements, resulted in the creation of networks such as SEMEAR to secure the continuity of the program. There are currently 112 community gardens mapped by the city in Municipal School Units, Health Centers and neighborhoods. Vacant public lots were used as community gardens and composting facilities, thus avoiding waste dumping and contamination. The program is implemented through a management group composed of the Municipal Environment Foundation (FLORAM), Superintendence of Fisheries, Mariculture and Agriculture, Capital Improvement Authority (COMCAP), Municipal Secretariats of Health, Education, Infrastructure, Urban Planning and Development, and other direct and indirect administration bodies of the municipality. The Decree also established a Forum including several institutions and representatives of civil society, acting as an advisory body and coordinated by the Management group.

Source: https://e-lib.iclei.org/publications/IFWEN_Florianopolis_FINAL.pdf

Now that you have framed the problem, you need to gather people to be involved in the process. The quality of your plan will depend on engaging motivated people who can devote time to the task ahead. The collaborative governance (CG) approach addresses people and how they interact. This approach should be adopted during planning. Depending on the context, CG will help to engage stakeholders, foster new ideas, and harness support and resources for innovating. In Lilongwe, the capital of Malawi, we find an interesting example of collaborative governance that had to deal with several complex issues (Box 7). However, this is not always possible in the early stages, so we explore the concept in ***section 4. Implementing***.

Box 7. Collaborative Governance – Lilongwe, Malawi

The quality of rivers in Lilongwe is compromised by a lack of adequate waste collection and management which means much of the city's potable waste contaminates the rivers. Most waste entering the river system is organic, and the inorganic waste is mainly related to food packaging and distribution.

The UNA Rivers project (UNA Rivers) in Lilongwe is a pilot project which sought to protect and improve the quality of Lilongwe's rivers by preventing waste from entering the river systems. The project aimed to initiate a composting process, diverting food loss and food waste from the Lizulu and Tsoka market (located upstream on the banks of the Lilongwe River). Food waste was directed to a composting site, and the resulting compost could then be sold to generate income. The project also undertook local river clean-ups to directly remove litter and waste from the market's river.

Complex governance relationships in the market needed to be understood. This represented a shared arrangement in which all of the vendors ensured that everyone made money in the market.

Source: https://e-lib.iclei.org/publications/IFWEN_Lilongwe_FINAL.pdf

A clear idea about what is needed and achievable will drive the planning process. Check whether your organization has planning initiatives, a methodology, or procedures to build the roadmap. If not, there are many planning tools available on the internet. We provide a simplified logic model (Figure 6) with one GBI example if you need some inspiration. Primary activities in this step require the following:

- **Set up a core team (working or steering group - SG)**. Identify, select and engage the people who will be involved, those who will lead and what each person will be responsible for. Everyone's responsibility must be clearly discussed and communicated. Participants must be able to follow up and be empowered by leadership and the team. The team members need to be interested in food, water, energy and GBI.
- **Identify data sources and gather information.** Having quantitative data to establish a baseline and then measure progress along the way will make it easier to control results and review the course of action. If not, you can start with simple measurements and qualitative reports.
- **Establish a benchmark.** Finding best practices is a good start for goal setting and following up. It helps you learn from your peers' successes and avoid mistakes. A closer look at these cases can help you understand if they apply to your situation.
- **Map all the planning processes** in your neighborhood, city or region to identify synergies between the existing operations and FWEN improvement.
- **Identify enabling legal and institutional frameworks.** All institutions and governments have rules and regulations to guide public policies and measures. Start by listing and understanding what municipal legislation and institutions provide a framework for your actions and goals. To mention a few: decrees, laws and master plans; environmental, housing, and works departments; foundations and agencies.
- **Establish baseline(s), milestones and goals.** It is essential to know where you are and where you want to go before deciding how to get there.
- **Establish a timeframe.** Set tentative deadlines for each phase that can be reviewed as you move along.
- **Assess threats and risks.** What could threaten your initiative? What are the risks involved in pursuing your goals? There will be many, foreseeable or not. Organizing them on a table will help you to move forward.

- **Develop complementary plans and strategies, and design scenarios.** If needed, depending on the complexity of the problem and solutions, you can apply the same tools and methods to develop these plans.
- **Develop contingency plans and alternative pathways.** By now, you have an idea of what might happen along the way, and you will be able to assess alternative routes using the same tools and models.

Note that these activities may not happen in this exact order. They will depend on the team assembled to develop the plan and available resources.

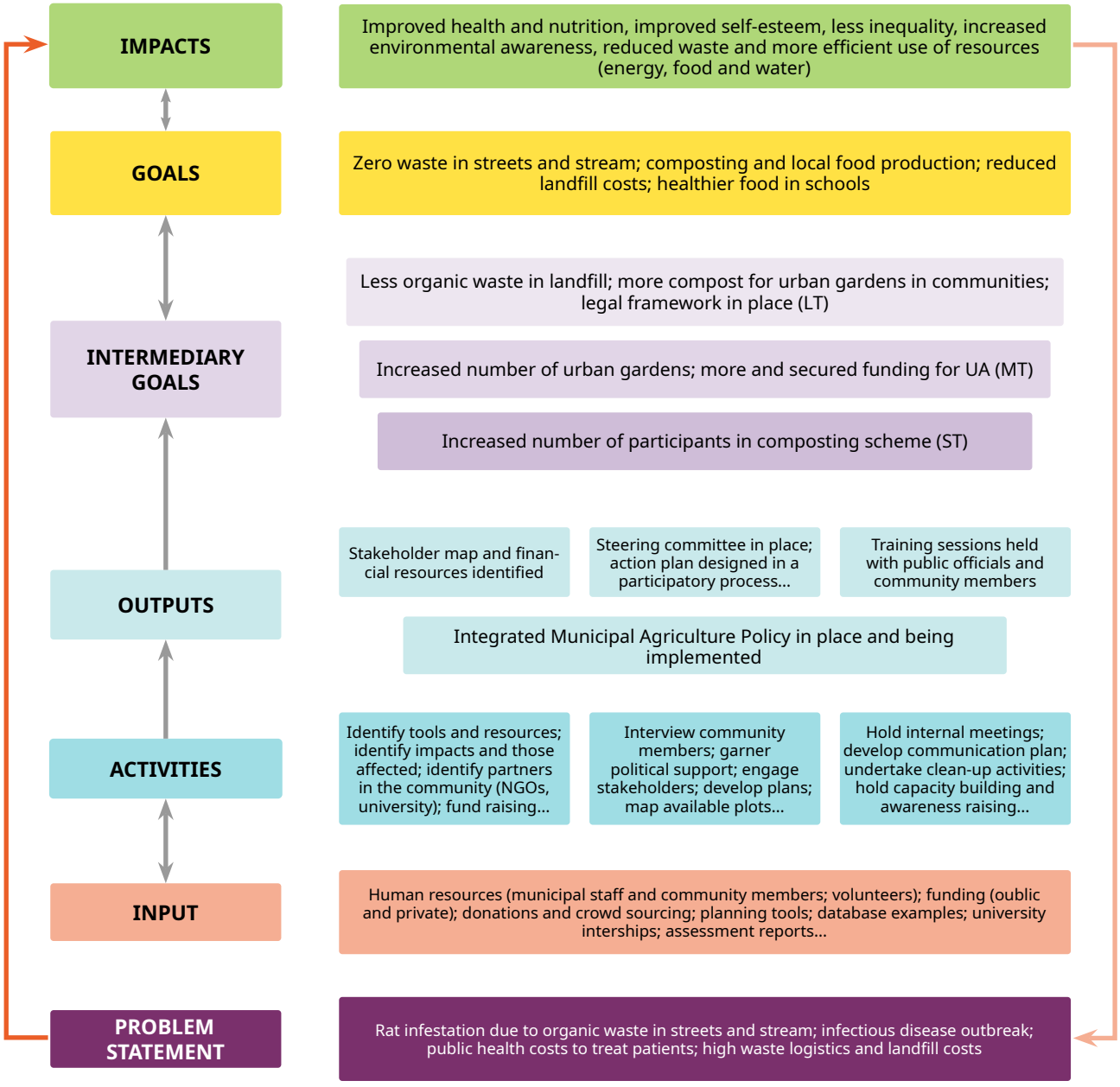


Figure 6. Logic model example – Municipal Urban Agriculture Policy.
Source: Authors' own

There is a wide range of planning tools for larger-scale projects. Suppose your community or city will be involved or affected by infrastructure projects not necessarily under municipal jurisdiction. In that case, we mention some of them below. This information should help you participate in informed decision-making processes, such as public hearings and consultations.

Spatial planning

Spatial planning refers to "the methods used [...] to influence the future distribution of activities in space" (EC, 1997; EU, 2018). In fact, cities have to deal with urban space constraints, which often leads to uneven environmental justice. A landscape approach is essential in promoting greater equal access to GBI, as the entire system needs to be considered. Developers should assess GBI at different spatial and temporal scales, collaborating, when necessary, at the transboundary level (across city borders) to assess synergies and trade-offs at the landscape scale.

Spatial Planning

Spatial analysis through remote sensing is frequently used to provide information, using Geographic Information System (GIS) for land use planning at different scales. In cities, for instance, remote sensing is used to inform land-use planning and analyze the impact of urban growth on the environment or prevent sprawl into hazard-prone areas (Sudmeier-Rieux et al., 2019). Similarly, it can identify environmentally sensitive areas to protect the environment, regulate development activities and promote sustainable land use planning (Leman, Ramli, & Khirotdin, 2016).

Geographic Information System (GIS)

Geographic information system (GIS) is a computer system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data related to positions on the Earth's surface. It is thus a way of linking databases with maps, to display information, perform spatial analyses or develop and apply spatial models.

Spatial urban planning tools

Maps are the spatial representation of information that can support the analysis of data on the urban territory and its systems, such as land use and occupation, demographics, environmental and health features, water bodies, vegetation, etc. Mapping tools (e.g., geographical information system - GIS) are thus a way of linking databases with maps to display information, perform spatial analyses or develop and apply spatial models.

Overall, a spatial approach requires a broad assessment of current land uses, limitations and opportunities for development. This necessitates the collection and analysis of a substantial amount of information, including, but not limited to:

- Biophysical information
- Infrastructure, including critical green infrastructure
- Population
- Land use
- Hazards and risks
- Land ownership, land tenure
- Legal context
- Ecological and economic zoning (EEZ).

Ecological and economic zoning (EEZ)

An instrument for the sustainable development and conservation of the resources in Amazonia.

GBI planning should consider these processes at various spatial scales. Start with the largest scale in which they play a role or have influence. Ideally, planning a conventional engineering structure would take the same approach. However, while these large-scale considerations optimize functionality and avoid unforeseen effects for engineering structures, they are indispensable for the success of GBI.

Goals of spatial planning for GBI (Sudmeier-Rieux et al., 2019):

- Organize land uses and the basis for subsequent urban planning or land use planning in rural/semi-rural areas (which is then more detailed).
- Promote sustainable development (social, environmental, economic).
- Develop access to information and knowledge.
- Enhance and protect natural resources and cultural heritage.

Find a balance among multiple demands and competing interests. Reduce the impacts of hazardous events by restricting development in hazard-prone areas; accommodate and plan land-use according to risk levels; implement zoning and coding; design infrastructures for hazard reduction.

Box 8. Spatial Planning Tool – Sao Jose dos Campos (SJC), Brazil

Aiming to achieve access equity to geographic data, the Sao Jose dos Campos City Hall has launched the Geosanja Portal in 2019 in order to organize and provide a large part of the municipality's geographic databse in a single platform, which facilitates the activities of the City Hall technicians and provides access to the population in general. This portal enables the download and consultation of urban planning maps, such as the Intergrated Development Master Plan and Zoning. By using Open Source tools which eliminate costs with property license for the use of the system and provide flexibility in customization and development of applications in the tool itself, GeoSanja is available to the entire population via the website of the Municipality of Sao Jose dos Campos. The Arboriza Sao Jose Program (which enables the preventive analysis of trees, digital registration and inventory), is the city's most recent and relevant program in arboreal heritage management and quality of urban life and was also incorporated in the Geosanja Portal. Through QR Code tags, the population can identify the trees, which generates knowledge and engagement in the importance of urvan forestry as green infrastructure. Information about other services is also available on the platform, such as wifi connection points, bus stops, electric car refuelling stations, elevated crossings, bike lanes, open markets, in addition to other information about complementary legislation, administrative boundaries and the traffic system. The Observa is another high-tech project, which was developed by the company Visiona for monitoring, inspection, and environmental control using satellite images and remote sensing. It is an indispensible tool in combating environmental degradation. In another partnership with the company, the Sao Jose dos Campos City Hall will validate the images from the first Brazilian nano-satellite called V-CUB. In this way, Sao Jose dos Campos has been consolidating geoprocessing and geographic information tools to improve territorial planning and tackle social and environmental injustices, while also supporting the development of other sectoral public policies.

Source: https://e-lib.iclei.org/publications/IFWEN_Sao%20Jose_FINAL.pdf.

Integrating ecological engineering into the planning phase of your project can be useful to address GBI alternatives. Infrastructure for sustainability includes technological improvements such as solar panels and biodigesters, as implemented in the Ecovillage in Dodoma, Tanzania (Box 9).

Ecological Engineering

Ecological Engineering is the design of ecosystems for the mutual benefit of humans and nature. Ecological engineers design, monitor and restore eco-systems, and design systems that reconnect or re-integrate human society with its natural environment. It's underlying principles are the conservation of nature and of non-renewable energy sources, the application of self-design, and a reliance on system approaches.

Box 9. Ecological Engineering – Dodoma, Tanzania

Dodoma relies on the National grid energy mix, which is split roughly in thirds generated by hydropower, oil and natural gas. Only approximately 18% of Tanzanians have access to electricity, and household energy is still highly dependent on biomass from wood and charcoal. However, besides local environmental degradation in vulnerable areas where trees are scarce, carbon emissions in Tanzania are high due to long-distance charcoal transport.

The entry point for nexus innovation in Dodoma was climate-safe and productive agriculture. Solar panels were installed to power water pumps and electricity in the village. The panels were installed as part of broader climate awareness initiatives to track how climate change is affecting the area. In addition, biogas digesters and energy-efficient cooking stoves were provided to further change the energy mix and reduce reliance on wood and charcoal, which have caused deforestation. The financial investment was critical to this project. It allowed holistic implementation through proven technologies while also developing soft skills to ensure the system could be maintained.

Source: https://e-lib.iclei.org/publications/IFWEN_Dodoma_FINAL.pdf.

Risk Assessment

Assessing risk is another critical step of the planning process. Undertaking a risk assessment can help you foresee and avoid events that place the project at risk. In our case, the risk is related to food, water, and energy vulnerability. The information required depends on the complexity involved in the project. It is always important to conduct a baseline assessment for future monitoring of the implementation process and results (see ***section 5. Monitoring and Evaluation***). Basic steps to evaluate hazards, exposure, and vulnerability include:

- Identifying the problem area or activity
- Identifying risks, occurrence, intensity, and impacts
- Mapping responses (existing, required, and potential)

This information will allow the development of mitigation strategies and contingency plans. Try searching Google by typing keywords, such as "risk assessment template", for instance. You will find many sites with free downloadable options, including tutorials on building your own template on YouTube.

Environmental Impact Assessment and Strategic Environmental Assessment

Environmental impact assessment (EIA) is the process to evaluate the impacts of public and private projects on the environment. It is one of the components of multi-criteria analysis, often regulated at the national or subnational level to understand the impacts of an intervention. EIA is used to decide the course of an intervention, including non-implementation, and anticipate mitigatory actions. Planners should ensure that the EIA meets local, regional, and national regulatory requirements. It has the

primary purpose to inform decision-makers, stakeholders, and the general public of the environmental implications of a proposal as the basis for consultation and debate. Many interventions that impact GBI can be mapped in an EIA process. EIA can also act as an instrument to provide GBI solutions to existing infrastructure proposals. See ***Table C5*** in Appendix C for the steps involved in an EIA with related activities and application examples.

Strategic Environmental Assessment (SEA)

Strategic Environmental Assessment (SEA) is defined as: "a systematic process for evaluating the environmental consequences of proposed policy, plan or program initiatives to ensure they are fully included and appropriately addressed at the earliest stage of decision-making on a par with economic and social considerations" (European Commission, 2019a). The steps involved in SEA are similar to EIA, except that they evaluate a policy, plan or program rather than a project. They are more comprehensive in scope, so we specifically refer to NbS rather than GBI.

The main functions of **Strategic Environmental Assessment (SEA)** concerning NbS may include (OECD, 2010):

- Assessing the vulnerability of different ecosystems, habitats, land uses and livelihoods to given types of natural disasters and preparing spatial plans and maps to show vulnerability zones.
- Helping to quantify the rates and magnitude of environmental changes that are taking place from various causes (e.g., human-induced or natural processes) and interpreting the effects of these changes on NbS.
- Assessing how development goals may be threatened or optimized by particular types of NbS.
- Mainstreaming specific "green measures" in public-private partnerships prepared at international, national and regional levels.
- Identifying ways of mainstreaming NbS at various scales in the urban environment.

Ecosystems are highly dependent on the more extensive enabling environmental processes. Often, ecosystems cannot be sustained by managing individual sites in isolation. The integrity and health of ecosystems at landscape scales determine the potential of NbS to limit flood risk, for example. If evaluated on small spatial scales, the impact of NbS on water systems may seem trivial. In contrast, on larger scales, the presence and integrity of ecosystems may make an enormous difference in the overall impact of flood events.

In addition to evaluating effects and feasibility on the environmental system, each infrastructure solution should be rooted in the local socio-economic and institutional context. NbS for flood risk are less commonly used than traditional measures, therefore it can be challenging to implement within the local socio-economic and institutional context. Ecosystems behave differently depending on the location, requiring locally specific knowledge of ecosystem parameters. This requires ecologists and engineers to jointly develop specific local ecological engineering solutions. Thus, NbS have to be designed for each particular context, based on sound knowledge of how changes in water flow, sedimentation, infrastructure, vegetation, land use and climate change influence the ability of ecosystems to support society's demands. They are not a panacea and cannot always replace grey infrastructure. Often, they achieve their most significant impact when they act as hybrids to complement and enhance grey infrastructure.

Systems analysis and multi-criteria analysis

A systems analysis seeks to evaluate interactions between and within the natural environment and socio-economic sub-systems. The multi-criteria analysis presents an initial opportunity to compare a range of solutions and eliminate those that do not appear feasible. Criteria defined by the developers could include:

- Costs: capital investment costs (CAPEX) and operation and maintenance costs (OPEX or O&M)
- Resilience benefits and avoided costs
- Ecosystem services or co-benefits (e.g., environmental, social, economic)
- Risks, synergies, and trade-offs

- Maturity timeline (e.g., how long will it take for the NbS to reach maturity and provide resilience benefits? This is a vital key performance indicator since NbS tend to capitalize their benefits on longer-term horizons)
- The lifespan of the NbS and the broader project.

Performance Indicators

Ideally, planners should define the key performance indicators (KPI) at this stage, before starting the implementation process. These could be a combination of qualitative and quantitative indicators and should include co-benefits (e.g., reduce the number of flood days to no more than 5 per year). Reference or baseline scenarios should also be determined (e.g., 20 flood days per year). A set of indicators should be developed to monitor implementation, effectiveness, and performance. It is crucial to select a relevant set of indicators and incorporate them into Monitoring and Evaluation plans. Additionally, developing custom targets and indicators according to countries' needs allows reporting on both losses of GBI and progress made on GBI solutions. There is a broad range of indicators to monitor and assess green projects. You will find ***Table C2*** in Appendix C with a sample of key monitoring and evaluation performance indicators, using different green initiatives as examples. We also address M&E in Section 5 in more detail.

Performance indicators

Performance indicators are a way of measuring the progress or success of a project. It is helpful for indicators to be 'SMART', Specific, Measurable, Achievable, Relevant, and Time-based. Whilst quantitative measures are often seen as the best way to measure your activities and outputs, qualitative measures such as the experiences of local communities can also provide information for project evaluation.

To start thinking about how performance can be measured at the local government level, visit: https://icma.org/sites/default/files/Getting%20Started%20Performance%20Management%20for%20LG.pdf

Ecosystem service valuation. Expressing ecosystem service values in monetary units provides guidance in understanding user preferences and current generations' relative value on ecosystem services. These values help to make decisions about allocating resources between competing uses. The Economics of Ecosystems and Biodiversity (TEEB) valuation database can help estimate ecosystem services' monetary values before an impact (van der Ploeg and de Groot, 2010). Other project viability indicators include:

- **Net present value (NPV):** Sum of the current value of all cash-flows associated with a project. It considers the time value of money; thus, it is strongly influenced by discount rates. Positive NPV means that the project is viable.
- **Internal rate of return (IRR):** The discount rate at NPV equals zero. Liable to give multiple rates of return, especially for projects with significant expenditure at both the beginning and end of their economic life. However, IRR is unsuitable for ranking projects with significantly different outlays.
- **Payback period (PB):** Time required to recover the initial cash outlay in the project. It favors projects that generate substantial cash inflows in the earlier years (and discriminates against projects that bring significant benefits later).
- **Benefit to cost ratio (BCR):** BCR rule is liable to give incorrect rankings if projects differ in size. BCR is sensitive to how costs have been defined in setting out cash flows.
- **Annual capital charge/equivalent annual cost (ACC):** Yearly cost of the initial outlay and operating costs associated with an investment. ACC helps select between alternatives that provide similar services but have different expense patterns used in public price regulation. These alternatives often have unequal project durations.
- **Life cycle cost (LCC):** total cost of the project's entire life/duration.

Economic and Financial Tools

Policy assessments

A policy assessment seeks to inform decision-makers by predicting and evaluating the potential impacts of policy options. It is the latest extension of the assessment concept, namely from the project and/or program level to the policy level. Therefore, governments and public institutions must evaluate the effectiveness of public policies. They must assess their impact on social welfare to determine how to improve their interventions and identify the areas in which they have been more effective.

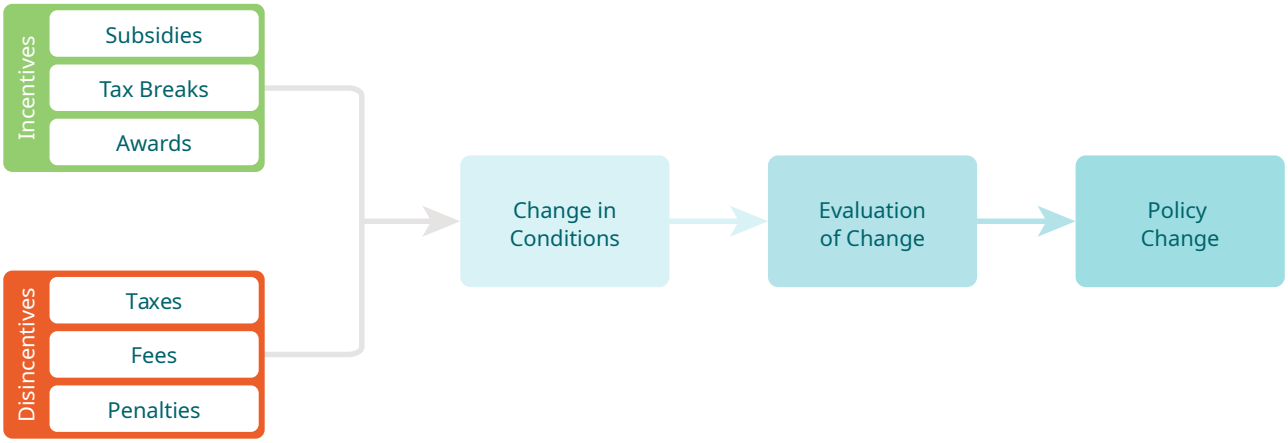


Figure 7. How Policy Assessments Lead to Policy Change.
Source: Authors' own

Reform of incentives and subsidies

Incentives and subsidies systems (see Box 10) often emerge as requiring substantial upfront cost (high installation costs) for NbS investors and, depending on the solution, they might also have significant maintenance costs. On the other hand, policymakers place NbS on the agenda as a solution to consider in urban planning and design. There is a mismatch between the economic/social/environmental value of green infrastructure and their financial analysis. The quantified benefits of these solutions may not compensate for the high implementation costs, discouraging parties to invest. Aligning expectations of both public and private agents regarding NbS development is carried out through incentives, that have distinctive natures and configurations. This can promote and facilitate green infrastructure adoption by private investors (see more in Liberalesso et al., 2020).

Creating the right conditions for investment in the green economy requires a combination of capacity building, information sharing, dissemination of exemplary policy practice, social assistance, skill development, general education, and awareness to ensure that green measures are well designed, implemented, and enforced. Thus, defining and understanding the business case and revenue stream are essential first steps to building support and securing finance for NbS projects. Nonetheless, you must remember that these projects do not benefit from the decades of precedent that underpin traditional infrastructure investment and investors and lenders are often inexperienced with financing GBI projects.

Project developers need to ensure that new trade deals and 'perverse' subsidies (such as for palm oil plantations on peatland) do not undermine the progress of GBI.

Box 10. Innovation and public expenditures

Examples of public expenditure measures that promote innovation concerning NbS and GBIs:

- Subsidies for parts of the research and development (R&D) chain, from basic research in universities to applied research in labs and industry, often on a cost-sharing basis
- Writing or improving public procurement norms to include sustainability criteria.
- Support for the demonstration of projects with costs that are too high to attract private investors.
- Creating a clear demand for technology in the marketplace, such that the private sector has a strong incentive to drive the innovation process.
- Creation of common infrastructure required for greening economic activities, such as smart grids oraffordable access to broadband internet connections.
- Targeted support to key green industries.

Source: IDB, 2020.

Positive Incentive Measures – tax breaks, subsidies, awards

Incentives can motivate residents, the private sector, NGOs, and communities to protect, manage, or expand NbS projects. Examples of such incentives of government investments include (Source: Knuth, 2005; UNEP 2016):

- Fast-tracking of permits for development.
- Tax exemptions or refunds/waivers for private landowners to reward NbS or existing environmental protection initiatives.
- Provision of grants and loans for NbS projects on private lands when funding is available.
- Foregoing government revenue - by reducing or removing fees.
- Tax incentives and rebates: E.g., on property tax, import taxes and duties, sales tax etc., for purchasing green technologies or services.
- Municipal budget allocation: For instance, allocating a portion of tax proceeds from real estate taxes to green space management. The city of Florianópolis used policies as a tool for urban agriculture and waste management implementation (see Box 11). The cost of tree planting can also be included in municipal bonds for specific improvement projects, like street repairs.
- Accelerated depreciation: Allows an investor to depreciate the value of eligible fixed assets at a higher rate, reducing the investor's taxable income. This is often used to encourage renewable energy generation.
- Loan support: Favorable lending conditions (such as loan guarantees or less stringent repayment conditions) or low-cost financing (such as subsidized interest rates or soft loans).
- Legislative support to favored industries: E.g., providing legal incentive to develop renewable technologies or NbS.
- Green public procurement: Goods and services purchased and commissioned by governments and state-owned enterprises usually represent a large proportion of total public spending. Government demand for green goods and services can induce sustainable production and provide businesses with a high-volume and long-term buyer.

Note that these policies all use scarce fiscal resources. Green industrial policy should be designed so that government investments are targeted at helping new industries mature, be closely monitored, and adhere to a strict time-limit.

Box 11. Municipal Budget Allocation – Florianopolis, Brazil

The Cultiva Floripa Program, established in Florianopolis in June 2017 by Decree and updated in 2020, aims to promote urban agroecological practices. The project aims to enhance the co-benefits of these practices, such as repurposing land use within the urban context. It also fosters maintaining clean and litter-free urban areas while promoting community participation and engagement.

COMCAP and CEPAGRO provided technical guidance to members of the community volunteering to separate organic waste. Volunteers were taught to separate waste correctly for composting at the project's facilities. The training helped maintain the composting facilities and the gardens, now open to the public.

The policy enabled the city to allocate some of its budget to invest in urban agriculture in the various departments involved. The initiative allowed the city to reuse organic waste by composting the material and repurposing it for organic urban gardens. The city has achieved greater independence for food production in several neighborhoods, greater autonomy for waste management and less waste taken to landfills.

Source: https://e-lib.iclei.org/publications/IFWEN_Florianopolis_FINAL.pdf.

Disincentive measures – taxes, fees, and penalties

Supporting a green economic transition will require that governments address existing market failures such as entirely lacking markets; for instance, many ecosystem services and markets fail to account for economic activities actual costs and benefits. Unsustainable economic activity often enjoys a price advantage when negative externalities exist. When the production or consumption of goods and services has negative spill-over effects, the cost is not fully reflected in market prices. An externality means that the market price of an unsustainable good or service is lower than its actual social costs, with the difference borne primarily by people other than the buyer and seller. In addition to the problem of fundamental fairness, this is an issue because, for markets to efficiently allocate resources, prices need to accurately reflect the total social costs of economic activity.

Market-based instruments can help create a more level playing field between green activities and their unsustainable alternatives. Some of these policies can also increase public revenue, which could make a vital contribution to financing a green economy.

Pricing techniques can be used to internalize costs known as externalities using a corrective tax, charge, or levy, sometimes referred to as full-cost pricing. Such taxes can provide clear incentives to reduce emissions, use natural resources more efficiently, and stimulate innovation. In China, Kunming City came up with an efficient system to guarantee local government engagement in cleaning up their water before discharging it in Dian Lake (see Box 12), based on the polluter pays principle, combining incentive and disincentive mechanisms.

Environmentally related taxes can be broken down into two categories:

- Polluter pays – charging producers or consumers responsible for creating a pollutant.
- User pays – charging for the extraction or use of natural resou.

The revenue raised from environmental taxes can be used to:

- Mitigate the damage caused by unsustainable production and consumption.
- Promote green economic activity.
- Contribute to other priority spending areas.

The overall tax burden can be kept unchanged by lowering negative incentive taxes simultaneously with the introduction of environment-related taxes (for example, replacing subsidies for fossil fuels with support for renewable energy). This can help make green taxes politically more acceptable and may also result in a double or even triple dividend – a reduction in pollution and an increase in efficiency and employment.

Importantly, subsidizing unsustainable activities can come at a cost to providing critical public services. Subsidies can also encourage poor environmental and resource management. Artificially lowering the price of goods through subsidization encourages inefficiency, waste and overuse, leading to the premature scarcity of valuable finite resources or the degradation of renewable resources and ecosystems. Subsidies reduce the profitability of green investments. When subsidization makes unsustainable activity artificially cheap or low risk, it biases the market against investment in green alternatives. The difficulty of reforming subsidies is practical and political. A strategy for subsidy reform should include the following:

- Design complementary measures, such as short-term restructuring aid for industries, support and retraining for workers and welfare transfers for the poor.
- Wide stakeholder consultation.
- A strong communication strategy to reassure affected groups that they will be supported.
- Ongoing monitoring and review are essential to determine subsidy reform's effectiveness and unintended consequences. Also, to determine whether mitigation policies – especially financial support – reach their intended beneficiaries and achieve their objective.

Box 12. Payment System for Cleaning the Dian Lake in Kunming, China

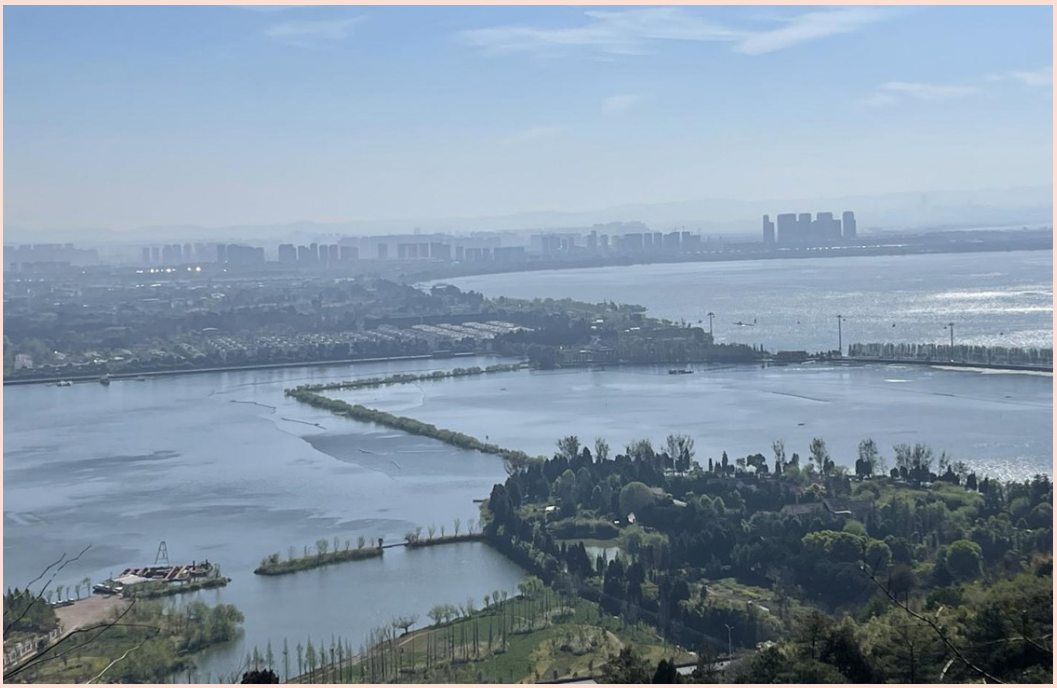
Kunming City, the capital of the Yunnan Province in China, is a subnational government formed by several districts, and is facing increasing water challenges in recent decades. The city is close to Dian Lake, the largest freshwater lake in Yunnan Province. However, the lake has been severely polluted by agriculture and Kunming City's rapid development due to historical reasons. Thus, an initiative to control the pollution of Dian Lake was started that could promote the protection of water resources in Dian Lake. The policy resulted from a 2012 decision of the 18th National Congress of the Communist Party of China, aimed to strengthen the establishment of an ecological civilization. It also complied with the General Office of the State Council of the People's Republic of China's requirement for improving environmental protection compensation mechanisms.

Kunming City established an ecological compensation mechanism including water quality assessment criteria for the rivers that flow into Dian Lake. The initiative is based on the polluter pays principle: "the one who pollutes the Dian Lake is supposed to be responsible for the pollution treatment progress and pay for it".

At the same time, its districts, local Ecology and Environment Bureau and other related departments were supposed to monitor and improve the rivers' water quality by adopting the established measures. District governments were responsible for budgeting the ecological compensation provisioned from the special provincial award funds. At every year-end, there would be an evaluation of the water quality in each municipal or district area. The districts by the rivers that failed to effectively control water pollution had to pay their compensation money to Kunming City.

Conversely, local governments meeting the requirements were awarded a prize. Kunming city refunded their investment and an additional percentage to recognize their efforts and encourage them to clean the water.

During the implementation period of this initiative, local governments were able to fund a series of actions to address the water pollution of Dian Lake. Initiatives included monitoring stations along the rivers, the 107 km sewer interception and treatment system around the lake, a water-saving project, cleaning initiatives of the 29 rivers and their 90 tributaries, pollution control initiatives in agriculture, and the implementation of ecological restoration projects as afforestation and building wetlands.



Authors and photo: Yihui Chen, Xiaoyu Zhang and Tianyu Li, Yunnan Academy of Ecology & Environmental Sciences, China.

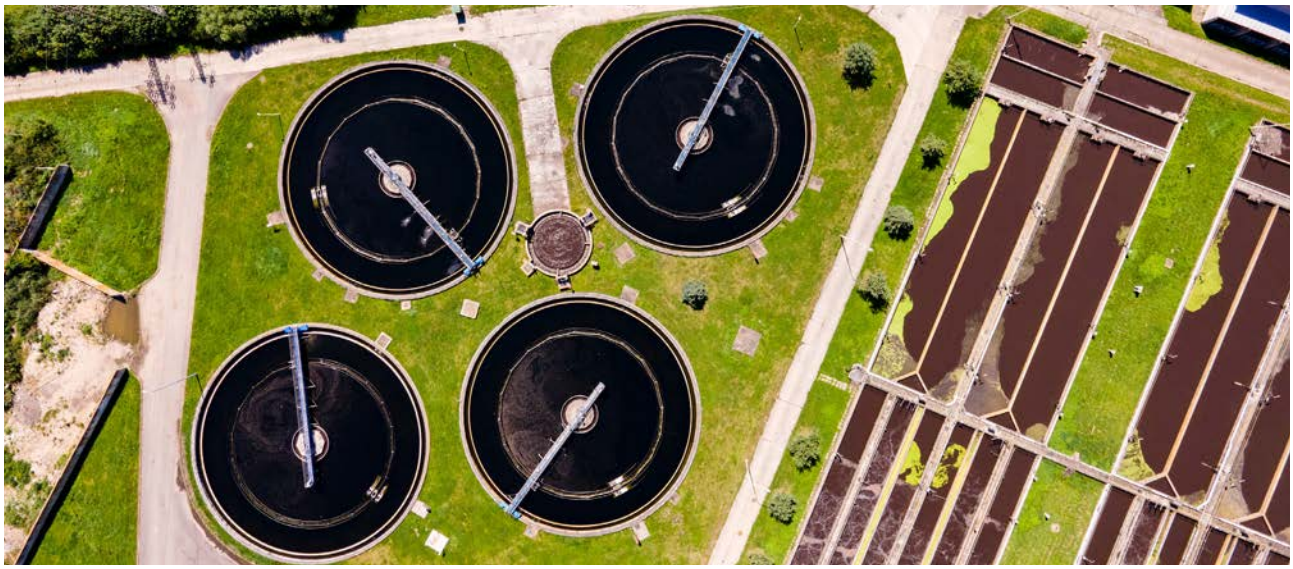
Public-private partnerships

A public-private partnership (PPP) is a cooperative arrangement between two or more public and private sectors, typically long-term. In other words, it involves government(s) and business(es) that work together to complete a project and/or to provide services to the population. Although these arrangements have been well-known for some time, the way governments are setting up PPPs to address the FWE nexus has been innovative in different developing countries and show promise to leverage the nexus, at different scales such as in Nagpur, India and Antananarivo, Madagascar. Nagpur municipal government managed to establish a participatory process that supported a multilevel PPP (see Box 13), to address water pollution and energy in a city with almost 3 million inhabitants in 2022. In Antananarivo, on the other hand, a PPP to improve sanitation (see Box 14), involving a British sanitation company, local government and communities and 300 waste pickers since 2012 has provided an innovative wastewater treatment system that produces liquid fertilizer to support urban agriculture while improving sanitation.

Both public-private and intergovernmental partners can pool resources for a common goal. Private donations, sponsorships, and endowments may also provide supplemental resources (Salbitano et al., 2016). However, the PPP's success will depend on the context of the projects since ecosystems are particular to their local area. An NbS that works well in one location and on a specific scale may not work well in another ecosystem and scale. Guidelines on NbS implementation need to be adapted locally to fit the context. This requires working in multi-disciplinary teams that include ecologists, engineers, economists, and planners.

PPPs can be a tool to provide more quality infrastructure services to more people. When well designed and implemented in a balanced regulatory environment, PPPs can improve efficiency and sustainability of public services, such as, provision of energy, transport, telecommunications, water, healthcare, and education. PPPs can also allow for better risk allocation between public and private entities. These arrangements are typically found in transport infrastructures such as highways, airports, railroads, bridges, and tunnels. Examples of municipal and environmental infrastructure include water supply and wastewater facilities.

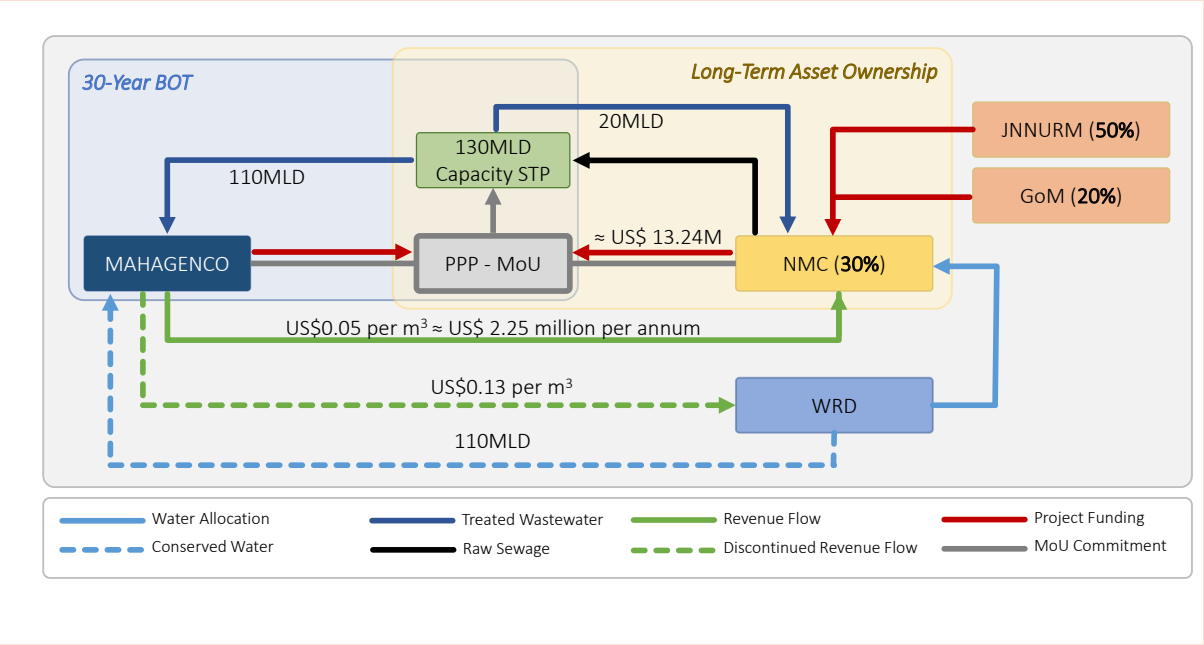
A list of available tools for planning and implementation of GBIs, NbS and EbA can be found in ***Table C3*** and ***Table C4***, in Appendix C.



Box 13. Public-Private Partnership (PPP) – Nagpur, India

In Nagpur, rapid urban growth has led to a greater demand for energy. In addition, there is an urgent need to mitigate the severity of urban water stress by creating innovative alternatives to freshwater in power plants. The discharge of sewage from the city had resulted in contamination of agricultural lands beyond the city. Legal actions pursued against Nagpur Municipal Corporation (NMC) compelled it to improve and expand its sewage treatment capacity, but the construction of a new Sewage Treatment Plant (STP) was out of reach for the finances of NMC. However, this limited funding stimulated created avenues to generate revenue from its sewage treatment output.

A 130 MLD, sewage treatment plant was commissioned in July 2016 to tackle the issue of water availability. One of the critical reasons for the project's success was a PPP between the NMC, the wastewater treatment plant owner, and the MahaGenCo enterprise, responsible for its operation and maintenance for 30 years. From 2015 to 2016, they worked in a Build-Operate-Transfer (BOT) public-private partnership model. The collaborative effort resulted in the NMC negotiating for additional freshwater to meet its increasing demand and securing the STP as a long-term asset. NMC also had funds from the Government of Maharashtra (GoM) and the Government of India (GoI, the national government) through the Jawaharlal Nehru National Urban Renewal Mission (JNNURM). The STP resulted financially viable, and part of the revenues are shared between MAHAGENCO and NMC (see the PPP scheme below).



PPP for the sewage treatment plant wastewater reuse initiative in Nagpur

Note: BOT: Build, Operate and Transfer; MLD: Million liters per day; JNNURM: Jawaharlal Nehru National Urban Renewal Mission; GoM: Government of Maharashtra; MAHAGENCO: Also known as Maharashtra State Power Generation Company Limited (MSPGCL); PPP MoU: Public-Private Partnership, Memorandum of Understanding; NMC: Nagpur Municipal Corporation; WRD: Water Resources Department.

Source: Rodrigo Bellezoni, Ayoola Paul Adeogun and Marc Picavet, 2022

For a detailed case study see https://e-lib.iclei.org/publications/IFWEN_Nagpur_FINAL.pdf

Box 14. Partnership between the private sector, local government and communities for urban agriculture and sanitation in Antananarivo, Madagascar

Loowatt is a private company headquartered in London and has been working in the sanitation sector in Antananarivo since 2012. The company's work addresses the liquid sanitation issue in the city and consists of installing mobile toilets in households that pay a monthly fee on reliable sanitation services. Currently, the company collects waste weekly (Segretain, 2021); patented technology 'provides a hygienic, waterless toilet, with a liner that wraps human waste and pulls it into a container' (Loowatt, 2020).

Loowatt partnered with the AULNA (Urban agriculture Low space No space in Antananarivo) program, providing liquid fertilizer from the toilet service system to regenerate household agricultural plot substrates (Segretain, 2021). In this case, the entry point within the nexus is water, and the GBI is represented by urban agriculture.

The primary collaboration between Loowatt and the local government was through SAMVA (Autonomous Society for the Maintenance of Antananarivo). SAMVA provides formal sanitation services (including wastewater treatment and household waste collection) to the commune of Antananarivo. The company signed a 15-year convention with SAMVA, which let them access a network of local wastewater treatment plants (biodigesters) owned and managed by SAMVA (Segretain, 2021). Loowatt also provided training to employees at SAMVA.

There was a strong engagement between Loowatt and the local communities through the RF2s and the informal waste collection sector (Segretain, 2021). The RF2s are composed of users and neighborhood representatives providing daily water and sanitation management (AfD, 2020). The RF2s provided local knowledge and worked closely with Loowatt and citizens to install the eco-toilets; Loowatt used the data gathered from RF2 representatives to better understand the neighborhoods and their needs.

The informal waste collection sector is significant in Antananarivo, with over 300 informal pickers working in one landfill - the Andranalitra dumpsite. There are many more across the city (Climate and Clean Air Coalition, no date) whose livelihoods depend on recovering materials from landfills. Loowatt hired the informal workers to help them collect waste from their eco-toilets; they were offered a job, trained, and kept in the company.

Author: Ioana Gabriela Simion. Source: 'The benefits of working in partnership with utility and service providers'

Assessing what we have learned in this section
*To assess your understanding and progress, see **Table A5** and exercise sheets in **Appendix A**.*

4. Implementing

Getting there!

Expected learning outcomes

After reading this section, you will have more tools that will enable you to implement the action plan and help your community to assess FWE issues. Using the available tools, you will address your own problems and search for additional resources.

In this section, you will learn how to identify the tools and approaches available in your organization to support activities established in the roadmap. You will also find information about some popular tools available free of charge on the internet that could be applied in your case.

As in previous phases, implementation requires collaboration between planners and managers of public and private land and reliable and committed funding to warrant continuity. Various institutional arrangements, governance structures, and processes enable and support your work. However, the functions and/or staff involved may be different. Your goals identified in previous stages should be reviewed from the outset and throughout the implementation process. Any changes in context, information or project assumptions should be monitored throughout implementation, goals reviewed and adapted as appropriate with the help of indicators (Box 15). This information should be fed back into the loop for course adjustments whenever necessary.

Box 15. GBI-FWEN indicators

Providing detailed guidance on developing indicators is beyond the scope of this publication. Many indicator frameworks and initiatives exist or are being designed to support cities with monitoring their progress on sustainability efforts. Some examples: City Prosperity Initiative developed by UN-Habitat; Guidance Note: Data for Implementation and Monitoring of the 2030 Agenda for Sustainable Development and Mainstreaming the 2030 Agenda for Sustainable Development – Reference Guide for UN Country Teams; Inter-agency Expert Group on Sustainable Development Goal Indicators (see more, box iii.6 in UNESCAP).

Regardless of its application, some qualities of good indicators are listed below:

- **Relevant:** The indicator should measure a critical aspect of an objective or output
- **Objective:** The indicator should be measurable, based on facts as opposed to feelings or impressions: measuring the same
- **Available:** Indicators should be based on data that are readily available or on data that can be collected with realistic additional effort as part of the project implementation
- **Realistic:** It should not be difficult or costly to collect the information
- **Specific:** The measured changes should be attributable to the project, and they should be expressed in precise terms (quantitatively and qualitatively)
- **Timebound:** There should be a clearly defined time frame to expect and measure changes.

There is growing scientific and empirical evidence showing that NbS, such as green and blue infrastructure, work cost-effectively. However, decisions on what and where to implement them are always context and site-specific. The approach to design and implementation of GBI will vary significantly in scope and scale. See some examples of well-known GBIs in Appendix B and here.

However, the process from design to implementation should be progressively iterated. Participants must consider the results from stakeholder engagement, regulatory requirements, and financial targets and ensure that the project meets its key performance indicators - KPIs (See ***Table C2*** for an extensive list of KPI, and the RUAF´s City Region Food Systems Program for a framework here). We present below a wide range of resources to support this process. Since the scale and scope of the project and local capacity and resources may vary widely, you should be able to adapt the recommendations below to your needs. We list several tools and approaches for more significant or more complex interventions, but certain principles apply to any scale, such as the concern about costs and indicators.

Tools and governance approaches: how to make it happen

Capabilities and Learning

Project developers do not need to be experts in designing and implementing NbS such as GBI. But they must understand the problem, the resources available and/or required, and assemble the right team. This will allow developers to have access to new market niches, competitively respond to tenders, and tap into new sources of finance for projects. Collaborators can either be professionals in the market, students, colleagues, or civil servants from other departments. Suppose there is no one available with the necessary skills. In that case, the steering group can request leadership to train team members to absorb new information and practices. Antananarivo provides examples on how to build capacity to implement small-scale projects with significant impact in urban and rural communities (see Box 16). The human resources department in your organization might be able to help you find the right person for the job.

Box 16. The Learning Process – Antananarivo, Madagascar

Antananarivo suffers from 49.3% chronic malnutrition, which is slightly higher than the national average of 47%. Lack of access to health services is a major challenge that affects people's food and nutritional situation. Underlying poverty is exacerbated by the lack of access to drinking water besides frequent flooding. Only 15% of the population of Madagascar have access to electricity. Antananarivo has several projects to improve resource access and efficiency. One of the main pillars for innovation resulting from these initiatives is the learning process based on participatory methodologies that build trust and strengthen communities. A clear understanding of what had worked in similar contexts and adapting the solutions to local realities has allowed developing the most effective strategy. This has helped gain time through experience capitalization and boost local motivation by enabling decision-makers to envision potential opportunities. The participatory approach aims to play a critical role in the implementation phase. Each small-scale intervention will be decided in plenary sessions with the main actors involved to keep a shared vision throughout the whole process.

For a detailed account of the initiatives in Antananarivo, see https://e-lib.iclei.org/publications/IFWEN_Antananarivo_FINAL.pdf.

Other initiatives combine technology and governance strategies to address resource scarcity, coupling modelling tools with participatory approaches, as the FUSE methodology applied in Jordan and India (see Box 17). With international funding, Stanford University developed a living lab project that resulted in improving the FWEN in Amman and Pune (see a video on the FUSE project here https://www.youtube.com/watch?v=MIN0Zy6aWjM).

Box 17. FWEN governance approaches and tools: Food Water Energy for Urban Sustainable Environments

Novel policies and governance forms are needed to address competition for scarce resources in stressed urban Food-Water-Energy systems. FUSE adopts an innovative living lab approach in which stakeholders: 1) produce solutions for future urban-FWE challenges, 2) engage in participatory model building, and 3) examine the merits of proposed solutions. Innovative system models quantify connections and feedbacks among users, producers, distribution mechanisms, and resources. Such a coupled human-biophysical-engineering urban-FWEs framework and policy analysis tool has never been developed before. The FUSE approach is being applied to Amman, Jordan and Pune, India: growing urban regions with intermittent freshwater supplies and significant competition with agriculture for water and energy.

Source: FUSE project (https://fuse.stanford.edu/ - Stanford University)

Similarly, the SUNEX-IMFA modelling framework helps in preparing policy guidelines to address the FEW nexus. Although a more sophisticated approach, it is implemented within MS Excel, setting up modules for supply - and demand- sub-models (see Box 18).

Box 18. Formulating sustainable urban FWE strategy by optimizing the synergies between food, water and energy systems

SUNEX provides an integrated modelling framework of advanced tools to model and assess the Food-Water-Energy (FWE) systems' demand and supply sides, capture their interdependencies and maximize synergies through a nexus view that endorses efficient solutions for energy, water and food supply for urban regions. The approach has been applied in four case study cities with different socio-economic and climate characteristics, different consumption patterns and different local and remote FWE resource shares. A monitoring and control sensor network has been tested to improve water and energy savings for local food production. The results feed into FWE-supply guidelines ensuring replication to support the transition towards higher urban resilience.

FWEN tools should be based on scientific and technical information perceived as credible and legitimate. They should be interactive, offer a broad range of impacts and alternative policy solutions, and allow participants to explore the effects and options without help. Decision support tools can facilitate early and ongoing stakeholder participation to increase the likelihood of commitment to FWE initiatives.

SUNEX project (http://sunex-project.eu/wp/ - AIT Austrian Institute of Technology)
**For additional examples of nexus tools and methods, visit UN ESCAP (2019), annex II*

Many online courses, tutorials, tool kits, methodologies, and best practices inspire and support actions. Other municipalities, networks, NGOs and foundations are a few potential sources. Knowing your own municipal, state, or national governments' resources is also essential. You might be surprised to find that knowledge is within reach in your own country or jurisdiction (Figure 8). Check other levels of government for available funding and capacity building opportunities. Professional associations and universities are also knowledge sources and can be found almost anywhere. Local knowledge is another fundamental source of information in many communities. Stakeholder meetings can help you find volunteers and citizens with traditional knowledge relevant to nature-based solutions.

Municipalities are single administrative divisions that have powers of self-government as granted by national or regional laws.

Networks are collections of independent entities that share knowledge or communications to further their goals, and often share interdependencies with each other.

Professional associations represent the interests of a particular industry and seek to further the interests of individuals engaged in those professions. They can assist individuals and organizations with networking, learning and research.

Local Knowledge is knowledge that has developed over time in a given community or social group and is specific to a local area. It is based on experience, and often has a long history. It is often embedded in community practices and cultural traditions and is also referred to as traditional knowledge or indigenous knowledge. This form of knowledge is under threat and should be given recognition and voice where possible.

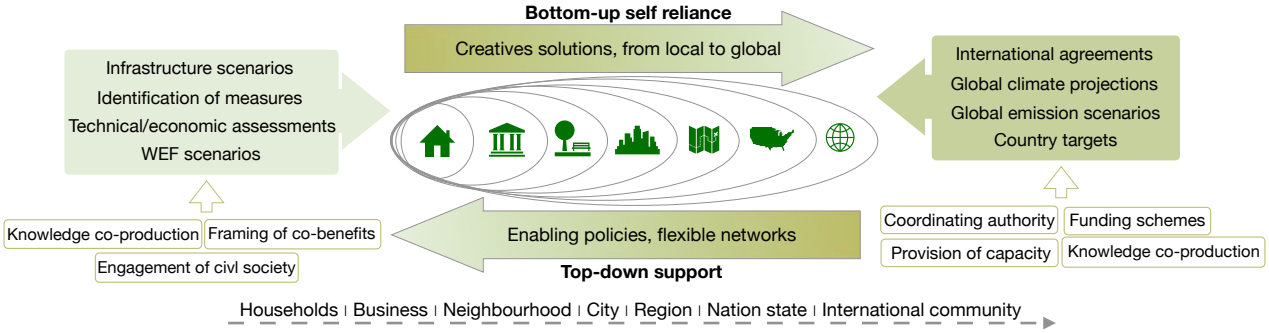


Figure 8. Integration of bottom-up and top-down perspectives
Source: Bellezoni et al., 2022, adapted from Suzuki et al., 2010; Homsy et al., 2019.

Collaborative governance

Complex urban problems require solutions that cannot be dealt with by one person or sector. Getting people together is essential to tackle multifaceted issues and conflicts in deciding trade-offs and synergies. In public administration, collaborative governance (CG) is increasingly used to address collective action in response to sector-specific governance issues, such as natural resource management and non-state actors' involvement in consensus-oriented decision-making processes and public-private partnerships. Such interactions are often challenging in developing countries, and not necessarily formalized. Sometimes,

Bottom-up actions are those that begin at the most local level: the city or its particular neighborhoods and buildings.

Top-down support increases the capacity of cities to solve their own problems by providing them with policies, targets, financial mechanisms, etc.

Public-private partnerships are cooperative arrangements between two or more public and private actors and is often a long-term contract between a government entity and a private party. The aim of public-private partnerships is often to develop an asset or public service, and there are many different types of PPP contracts, with varying degrees of private-sector involvement.

To access a reference guide on public-private partnerships, visit: https://pppknowledgelab.org/guide/sections/83-what-is-the-ppp-reference-guide

formal-informal collaborations must be faced and can lead to positive outcomes, as in the case of Lilongwe, Malawi, despite many challenges (see Box 19). This case contrasts with an example from Chinese Taipei, Taiwan where urban agriculture and community gardens were promoted with multiple benefits to the participating neighborhoods (Box 20). Nevertheless, both models involved participatory and collaborative arrangements in cities.

CG builds on face-to-face interactions between stakeholders. Its success depends on leadership, trust-building, shared understanding and responsibility, and commitment (Ansell and Gash, 2007). An example of a collective planning process for GBI implementation is the Participatory Resilience Assessment tool, developed under the ENABLE project (Enabling Green and Blue Infrastructure Potential in Complex Social-Ecological Regions: A System Approach for Assessing Local Solutions). The tool helps deepen stakeholders' understanding of how green and blue infrastructure works within its broader urban context. It is helpful to decide priorities on a qualitative rather than a quantitative basis, and knowledge, capacity and cooperation are built through identifying strategies rather than before or alongside it.

Box 19. Lilongwe, Malawi: Formal-Informal Collaboration

In cities of developing countries, many informal organizational structures are working with FWEN, such as waste recycling and urban agriculture initiatives. Collaboration between the formal and informal sectors poses a key challenge for successfully implementing innovative FWEN initiatives. This was particularly apparent in ICLEI's River restoration project in Lizulu Market, Lilongwe's largest informal marketplace in the UNA Rivers initiative. 22 volunteers were trained in composting, producing around 15 tonnes of compost, and workshops assisted 5,000 more on the benefits of sustainable waste management. A key aim for ICLEI was to educate the local government on the benefits of working with informality. Yet, during the initiative's early stages, Lilongwe City Council wished to formalize the site as part of a broader project to reclaim land outside official planning documentation.

Given the informal nature of much FWE provision in Lilongwe, any initiative seeking to innovate within these sectors must engage with informality. As opposed to eradicating informality to accommodate and implement expensive infrastructure projects, it is more cost-effective for governments to work within these systems. Such arrangements can be better incorporated into existing networks benefiting from the existing organizational capacity. The initiative set out to achieve this, but it was challenged by Lizulu's complex informal governance system.

Balancing informal and formal structures of governance was a demanding task in Lizulu. In contrast to the common perception of informal governance as disorganized, each market section has its own representative on a broader market committee. The project team liaised with the Urban Vendors Association to discuss the informal market´s issues and promote collaboration between volunteers and market vendors. Composting profits were partly redirected toward the market committee to ensure the future sustainability of the initiative.

An initial look may assume informality implies unsophistication. As Lizulu demonstrates, informal governance structures are complex and involve intricate relationships not dissimilar from 'traditional' conceptions of governance structures. The case demonstrates that informality must be considered when working in cities in developing countries. Even where there is social buy-in, a project can only achieve its objectives if the formal structures of governments learn to collaborate with informal arrangements and incorporate them. Considering these embedded contextualities throughout and before the project starts could help mitigate challenging issues relating to informality.

For further detail, see https://e-lib.iclei.org/publications/IFWEN_Lilongwe_FINAL.pdf
Author: Andrew Hughes

The scale of intervention also determines the most efficient scope of governance. Sometimes, communities can self-govern and compensate for the lack of resources (e.g., human capital, knowledge, finance) in developing countries. Communities have local knowledge and are often stewards of the environment, as demonstrated by the Florianópolis and the Johannesburg cases (see Boxes 11 and 21).

Box 20. Collaborative Governance – Chinese Taipei, Taiwan

Taiwan Province of China developed rapidly in the second half of the twentieth century, food consumption habits have significantly changed, and diets now contain less fruit and vegetables on average.

Taipei Garden City (TGC) 's goal of sustainable citizenship promotes innovative forms of integrative management, emphasizing citizen participation and reflecting the policy's grassroots origins. TGC began as a social movement in 2014 when various urban gardeners came together at a government-sponsored art installation. The activity allowed citizens to transform an empty lot into temporary, informal garden sites and this had several benefits. The additional green space offers many ecosystem services beyond food provision, such as water retention and floodwater control. Some participants formed the Farming Urbanism Network (FUN) and developed a strong network of support and funding using social media. They created an online knowledge-sharing platform and used crowdfunding to generate income. With this, the FUN was able to pressure political candidates into promoting urban agriculture and expanding green infrastructure, eventually spawning the Taipei Garden City policy. The movement's leaders have remained central figures and were invited by the city to help design the policy framework. Three acting members sit on the advisory board that dictates the policy's direction.

Furthermore, the organization continues to pressure the policy as a citizen watchdog group. FUN leaders organize annual reviews of the policy's progress in workshops, gathering government and civil society members who analyze and make recommendations. Collaborative decision-making and community relations development are principal goals of the policy. The FUN's role in the scheme is just one example of this. In addition, enhanced cooperation between different government agencies is another crucial benefit of the Garden City project.

See https://e-lib.iclei.org/publications/IFWEN_Taipei_FINAL.pdf for a more detailed description of the initiative.

Finally, in financing and implementation, the private sector can help scale up GBI for risk reduction, climate change adaptation and others, such as waste management and sanitation (see, for example, Boxes 10, 11, 12 and 13). For assessing GBI´s benefits more easily, without needing full scale economic inputs, CIRIA has developed a free tool with guidance, B£ST (Benefits Estimation Tool – valuing the benefits of GBI). On B£ST, monetary value allows comparing GBI and gray infrastructure solutions based on trade-offs and co-benefits.

Overall, the project's characteristics and context will define stakeholder engagement, and project developers should be able to identify the required capacity, to accordingly engage with:

- Public administration: decision-makers and staff from different levels of government.
- Community: landowners, representative groups, community members, NGOs, civil society groups and local businesses.
- Experts: scientists, academics, technical consultants.
- Broader project team.
- Project beneficiaries.

The list can go on, so carefully considering the participants will be vital to the initiative's progress and success.

Box 21. Partnerships for School Greening in Johannesburg, South Africa

At the city scale, district education departments can provide a fundamental partnership for helping GBI projects to work on the ground. In 2013, the Environment and Infrastructure Services Department in the City of Johannesburg launched a project to support urban agriculture and environmental education in 41 of the city's schools. Food gardens were set up for school feeding in areas of the city that experience food insecurity. The gardens helped add healthy foods to the students' diets and fulfil their nutritional needs. Besides the food gardens, some schools received an outdoor classroom with landscaping and trees, besides alternative technology provisions such as a biogas digester, rainwater harvesting tanks, a solar water heater and waste recycling. These provisions offered educators and learners new forms of engagement with the outdoor environment in their school and created co-benefits such as skills development and work opportunities.

In some schools, the children formed eco-clubs. They participated in food growing competitions with other schools in the region, which brought opportunities to win prize money and grow more food at their school. The project also trained unemployed young adults from the local areas to understand how to install and operate the equipment provided. This offered the participants skills training and a period of employment, allowing the local community to sustain the project after it had been set up. By incorporating skills and employment opportunities into the project, the EISD fulfilled a social need whilst preparing for maintaining the project, which was a pivotal contributor to the project's success. The young adults were trained by CityParks, who maintain the city's green spaces and work in close partnership with the EISD department at the city. The EISD department was able to pull together resources for their blue-green infrastructure initiative by implementing strategic alliances. Their partnerships included the district education departments implementing a GBI project in schools. The Expanded Public Works Program (EPWP) added national funds to support the project, and CityParks provided environmental knowledge and experience. When setting up your GBI project, it is helpful to consider how resources, tools and expertise can be leveraged through cooperation with other organizations within reach.

Partnership building like this can improve the project's scale and impact and help create the highest possible social benefit. Demonstrating the social benefits of the GBI initiative can translate into incentives for partners to collaborate and promote the initiative's sustainability after it has been implemented. Urban agriculture creates positive social outcomes for community development, such as increased food resilience, skills and knowledge in growing and planting, and better social connection. The School Greening project in Johannesburg demonstrated that working co-operatively with other organizations is key to realizing and maximizing the co-benefits.

Author: Naomi Chatfield-Smith

Regulatory tools

Legal and institutional frameworks shape land use and occupation interventions, resources management, and consumption. Regulations, norms, policies, programs, and plans are standard in any organized society; they will, however, vary widely from place to place in all levels of government. They can enable your project and provide support for your actions. Meanwhile, outdated or ineffective legislation can be a barrier to innovation.

Effective regulation can provide strong support for meeting cities' socio-environmental and economic goals. Ineffective regulation, conversely, will hinder recovery, inhibit growth, undermine efforts to address complex issues such as climate change and reinforce citizens' skepticism of government. If a regulatory policy supports economic and social renewal, its core institutions and processes need to be further developed. This includes:

- Strengthening evidence-based impact assessments to support policy coherence.
- Institutional capacities to identify and drive reform priorities.
- Paying more attention to the voice of users, who need to be part of the regulatory development process (OECD, 2010).

Promulgating eco-friendly regulation also leads to achieving sustainability goals. Today, agencies are introducing eco-friendly practices across a broad spectrum of rules. Project developers should demonstrate the legal compliance of the NbS and secure appropriate permits. For example, constructed wetlands must show that they can treat water according to existing and anticipated future regulatory standards. Water quality will likely have to comply with the same standards for conventional wastewater treatment facilities.

Securing permits can be time-consuming and require extensive coordination with multiple departments. The process should begin during the initial stages (often translated into investment or high transaction costs). NbS schemes are likely to require the cooperation of officials to secure permits because they may be seen as beyond code, a potential opportunity for rent-seeking, kickbacks, or corruption. To reduce the likelihood of bribery, interactions between all stakeholders throughout the project lifecycle should be open, transparent, and documented. All stakeholders should be aware of this.

Economic Valuation

Valuing Nature is more than appreciating the products of Nature. We do not have enough econometrics for the economic tagging of urban GBI. Often this valuation is undertaken in a private context; thus, not available for a broader audience.

The inability to clearly identify the revenue streams generated by nature-based solutions and incorporate them into the overall project's financial structure is a significant barrier to creating bankable, sustainable infrastructure projects. Not all GBI will generate revenue streams, but its multifunctionality characteristics may potentially reduce disaster risks and address societal issues, whereas gray infrastructure cannot. Thus, NbS such as GBI can help gain access to funding by reducing project risks, possibly being more attractive to investors (see Boxes 11, 12 and 13).

Financing institutions lack protocols to incentivize NbS and design participative tenders, while companies lack the commitment to integrate NbS in their core business, posing yet another challenge to GBI implementation. Increasing investor confidence in predicted program outcomes will require that GBI programs address key sources of uncertainty. They must either close information gaps or design robust programs prepared to perform well even in the face of uncertainty.

The International Institute for Sustainable Development (IISD) developed the sustainable asset valuation tool (SAVi) that provides policymakers and investors with a comprehensive analysis of how much their infrastructure projects and portfolios will cost throughout their life cycles, taking into account risks that are overlooked in traditional methodologies. SAVi combines robust science, systems thinking and financial valuation. Its three features—simulation, valuation and customization—are inherently interlinked. It values the cost of risks and externalities and the dangers that can emerge from externalities over a project's life cycle. In short, this tool allows estimating different economic benefits for different scenarios.

Alternatively, the City Benefits Tool developed under the Food Initiative Project includes economic, health, and environmental benefits per unit of change generated through solutions based on circular economy principles. Once a city has identified a target circular economy for food scenarios to work towards, potential benefits can be estimated using this tool. Wherever possible, locally-relevant benefit factors should be used to carry out benefit calculations. Once you develop a model, it is easy to create and relatively easy to use this tool. You can quickly adapt it to different contexts by changing the language, currency and quantitative estimates of benefits.

These analyses require that all ecosystem benefits be converted into monetary terms. There are essential methodological considerations that differ from traditional project development. Notably, the economic analysis should be compared against a reference scenario (e.g., business-as-usual). They should include reliable estimates for design and construction costs (CAPEX), OPEX, opportunity costs, transaction costs, among others. As project developers tend to be less experienced in NbS, the transaction costs are likely to be higher (for more details, see IDB, 2020 and the Natural Capital Protocol).

Sensitivity analysis (SA) is critical for understanding potential scenarios that could hinder the estimated benefits of a given NbS project. In the face of uncertainty regarding the performance of a particular variable (e.g., cost or benefit), project developers should undertake a sensitivity analysis. Applying SA will allow understanding how the cost-benefit analysis outcomes may vary by altering the costs and benefits.

The list below includes some potential valuation methods for NbS benefits and co-benefits:

- **Willingness-to-pay** is defined as the amount of money that can be taken away from a person's income at a higher level of environmental quality to keep his utility constant. It is, therefore, the theoretically correct measure of the welfare change—and hence the benefits—associated with changes in environmental quality.
- **Contingent valuation** (CVM) (hypothetical market) is a well-established technique used to assign a monetary value to non-market goods and services, such as environmental resources. CVM is a survey-based technique in that it asks individuals to report their willingness to pay for a specified improvement in environmental quality.
- **Travel cost method** (TCM): Used for calculating economic values of environmental goods. Unlike CVM, it can only estimate the use-value of an environmental good or service. TCM is mainly applied in determining the monetary values of recreation sites, such as national parks. For example, TCM can estimate part of the economic benefits of coral reefs, beaches or wetlands stemming from recreational activities.
- **Hedonic pricing** (related market): Relies on market transactions for differentiated goods to estimate the economic benefits or costs associated with environmental quality. It uses the value of a surrogate good or service to measure the implicit price of a non-market good. For example, house prices can provide a value of particular environmental attributes.

- **Dose-response:** Estimates the externality (impact) cost using extensive modelling and actual analysis of what dose of pollution eventually will cause how much of a response. Example: Coal power plants. If people breathe sulfur (dose), how much money will it cost their health treatment? Dose-response analysis depends on people's values.

Outreach strategies

Planners should continuously inform and consult the key stakeholders and ensure their ownership and involvement (see boxes 5, 18 and 21). In your communications, be sensitive to both short-term and expected long-term impacts and consider the gains for communities and the environment. Monitor impacts of the construction and rehabilitation work to local stakeholders. Flexibly adjust project implementation where required based on changing stakeholder needs and emerging information.

Information and communications technologies

Humans have always been creative about communicating. In this guide we have seen examples of how communities can use friendly IT and social media to engage in collaboration, as in Chinese Taipei and Johannesburg (see Box 20). You can also explore other forms of communication. In Lilongwe (Box 22), the UNA project used photovoice, in which vendors and market visitors were given cameras and asked to express their stories of the river, and to document the progress of the project as it evolved. For a detailed account of this multifaceted experience, see: https://e-lib.iclei.org/publications/IFWEN_Lilongwe_FINAL.pdf.

We live in a fast-paced time, a digital era that is changing the way people interact and learn. For instance, during the pandemic (2020-2022), remote communications received a boost, as it became the best – and often only – available means for people to communicate, work and attend classes. Although some cities and communities do not have access to high tech systems or databases, virtually everyone on Earth has access to a cellular phone and social media. You can find any information if you have access to the internet and search engines, such as Google, Bing and others. It would be impossible to keep up with innovations since something new becomes available every day! You can find links and references to updated and consolidated applications (apps), online tools, guides, and publications on some of the websites listed in this publication.

Assessing what we have learned in this section
*To assess your understanding and progress, see exercise sheets in **Appendix A**.*

5. Monitoring and Evaluation

How is it working/progressing?

Expected learning outcomes

This publication was designed to assist managers in acting on the ground, guided by the vision and focused on the goals, ensuring that the process is on track. Periodical verification allows the administration to assess progress and update the plan to adjust to changing circumstances. The frequency will depend on the scale and complexity of the initiative.

Monitoring is vital to provide evidence of progress and performance and build internal knowledge (and capacity) on the merits and implementation of the initiative. Monitoring and Evaluation (M&E) as a practice is an essential component of adaptive project management; based on the monitoring results, the project can be modified if needed to improve performance. It is also necessary to identify changing conditions when adaptation measures must be implemented (see Figure 6. Logic model example – Municipal Urban Agriculture Policy). You can find further methods and tools for designing M&E plans in guidebooks by GIZ, UNEP and FEBA (2020) and a report by Borus et al. (2014).

Regular project M&E should take place to ensure that:

- Implementation: the project is implemented according to the design.
- Effectiveness: the project is operating effectively (once implemented).
- Performance: the project is delivering the intended results, and if not, can it be adjusted to achieve the intended effects (Huthoff et al., 2018). This is critical to building the evidence base.

Monitoring activities during and after implementation is needed to guarantee effectiveness and grow an evidence base. They are also required to record lessons learned for future use. Carefully monitor the development of the ecosystem in the area of implementation and the larger landscape (see Boxes 4, 9, 16 and 17). The use of maps is essential for spatial data representation and the city of São José dos Campos, in Brazil applied spatial tools that helped define the alluvial plane for conservation (see Box 8). GIS technology can be beneficial to produce maps indicating the best location for GBI giving a good understanding of the water flow paths, measuring the infiltration capacity in the soil, preventing problem with stormwater and so on (see the Klima 2050 tool). Infographics, dashboards, videos and factsheets may also be used to present data attractively to a broader public and to policymakers. Refer to the monitoring system to assess how the components of the project have been implemented (see Box 15).

As the benefits of Nature-based solutions (NbS) such as GBIs can be realized over many decades, it is vital to understand the regulatory environment. This will allow the project to adapt to forthcoming policies before negatively impacting the solution. The sustainability of an NbS depends on community willingness and commitment. It is crucial to involve all social groups in the community by explaining the project and its benefits. Stakeholder engagement and consultation are essential for a successful M&E plan (see Boxes 5, 6, 13 and 14). They are used to collect further information on the critical project data gaps and priority issues from different stakeholders and to continue to engage stakeholders in preparing additional policy support and planning processes (FAO, 2022).

Practical guidance should be provided on the use and protection of vital ecosystems. It is essential to ensure that project representatives listen to the community. To enable scaling-up and improvement of global best practices, publish evaluations and share insights with other implementing organizations. Investigate possibilities for scaling up successful approaches in other areas. While the documentation of lessons should be done throughout the project, other nature-based projects need to capture and report these lessons in a way that is more broadly accessible. These tools might not be available, but simple and creative solutions can work both to monitor and support learning processes, such as the use of photovoice in Lilongwe (see Box 22).

Changes may occur in political, institutional, economic, social and environmental circumstances, and managers must adapt to cope with a dynamic context. A robust plan includes the capacity to positively respond to change. As in the early stages of planning, responsibilities must be clearly assigned and roles defined, including each department involved. Therefore, following up on implementation at every step is crucial to the initiative's success. Continuous monitoring and periodical evaluation are essential to reach the results as planned. Otherwise, you will have another plan in a pile. Preconditions for effective M&E include establishing performance indicators, preferably – but not exclusively – quantitative.

Box 22. Cleaning up the River, Lilongwe, Malawi

The bustling Lizulu and Tsoka informal markets in Lilongwe (Malawi) mainly sell vegetables. Around 70% of the waste produced is organic. A Malawian civil society organization, Our World International (OWI), piloted a project to turn the waste into compost. A group of women makes compost from the waste, sold to local farmers. The composting project was a success. In 2017, SwedBio's partner ICLEI Africa contracted OWI to implement and oversee a waste management project. The initiative is part of a larger plan to restore the Lilongwe River. It comes under the regional Urban Natural Assets for Africa: Rivers for Life (UNA Rivers) collaborative project funded by Sida (Swedish International Development Cooperation Agency) through SwedBio and led by ICLEI Africa. The Lilongwe River runs through the city, is its primary water source, and supports numerous communities downstream. However, market activities along the riverbanks have been identified as key sources of pollution. These markets are vital community spaces embedded in the urban framework of the city. Based on the importance of the livelihoods and economic opportunities they provide, the Lilongwe City Council selected them as pilot sites for part of an urban revitalization project (UNA Rivers). UNA Rivers was implemented by ICLEI Africa and worked to get nature-based solutions into land-use planning and local government decision-making processes relating to urban river systems. As part of the project, eight volunteers spent six weeks clearing organic waste from various locations in the markets. They volunteered to take photographs (in a process called photovoice) each week to document their experience collecting waste and turning it into compost. Their photos and stories revealed a high level of engagement and commitment to participating in a project that aims to improve their city's river. UNA Rivers helped to revitalize the river through improving coordination and community-based activities. The project's goal is to build sustainability and resilience at the local level, enhancing human wellbeing and alleviating poverty.

Complete case study available at https://e-lib.iclei.org/publications/IFWEN_Lilongwe_FINAL.pdf

Simply put, a monitoring and evaluation process is an integrated mechanism for continuous evaluation of specific measures, schemes or programs. It aims to assess the initiative's impact, track progress towards objectives and goals and adjust the course. Besides mapping and analyzing, a complete process includes reporting. It can be undertaken by the city, community or a third party, depending on the initiative's level of complexity. A successful M&E depends on good data and indicators, transparency, traceability, accountability and an effective communication strategy. Such M&E planning can be guided by a set of key questions that aim to ensure an integrated and comprehensive perspective on different components and sustainability dimensions of the initiative, for instance:

- What are we monitoring?
- Who are the users?
- What is the scale of the initiative?
- What is the governance system?
- What activities are being carried out?
- Who is responsible?
- What are the data gaps?

Key questions help identify apparent data gaps. Based on these data gaps and identified policy priorities, critical areas for more in-depth assessment can be defined. Ideally, this should be followed by new or additional data collection and research for each project. This assessment may also involve the re-interpretation of secondary data based on further questions. An example of in-depth evaluation is the CRFS[4]. indicator framework designed by RUAF and FAO. The indicator framework connects policy priorities to outcomes that cities may want to see in the future and defines possible indicators for each outcome, including, but not limited to:

1. Assess the current status and performance of a GBI initiative based on a set of performance indicators, following a whole-systems approach.
2. Identify priority areas for action with clearly defined outcomes and ways of measuring change.
3. Help with planning strategy and action to achieve the desired outcomes.
4. Establish baselines and monitor changes resulting from (future) policy and program implementation.

The indicators provided can also be used to establish a baseline to measure targets and impacts of strategies included in a policy strategy or action plan. Data collection and analysis on selected CRFS indicators can be done by applying a variety of methods, including:

- Qualitative and quantitative data collection using household, government and business surveys[5].
- Further stakeholder and expert consultations[6] (focus group discussions, interviews, etc.).
- Quantitative resources flow mapping[7].

Monitoring activities may include data collection, compilation, risk assessment, surveys and interviews. Well-designed data displays will be crucial to share results of the assessment phase and prepare for policy and strategy designs. Finally, it is essential to consider the presentation and visualization of data collected through the in-depth assessment and how these findings are communicated with policymakers. For this purpose, it is helpful to rely on a communications or data visualization expert. For project tools, examples and valuable insights from cities on displaying data and communication, please check the CRFS framework, where a complete set of projects outcomes is available.

Assessing what we have learned in this section

*To assess your understanding and progress, see **Table A6** and exercise sheets in **Appendix A**.*

4 City Region Food Systems Programme. For more details, visit: https://www.fao.org/in-action/food-for-cities-programme/overview/crfs/en/

5 For examples on sampling guidelines and questionnaire surveys for primary data collection, visit: https://www.fao.org/in-action/food-for-cities-programme/toolkit/crfs-assessment/indicator-framework/surveys/en/

6 For examples on stakeholders consultations (e.g. Focus group discussions, key informant interviews, stakeholder engagement) visit: https://www.fao.org/in-action/food-for-cities-programme/toolkit/crfs-assessment/indicator-framework/stakeholder-consultation/en/

7 For calculating indicators of urban/regional food production and consumption based on Life Cycle Analysis, refer to: https://ruaf.org/document/guideline-3-calculating-climate-change-related-indicators-of-urban-regional-food-production-and-consumption/

Reflections and the way forward

The process of innovation involves risks and uncertainties about the results. Still, it is necessary to advance new ideas in a given context. The niches of innovation might inspire others to face their challenges innovatively, generating a process that can transform a city or a group of cities. Ideas are disseminated at a fast pace in this information era. However, there is no silver bullet. Innovation in urban systems needs to be developed over time. Through a learning process of acquiring knowledge from external and internal sources and translating it into one´s context, public officials can innovate, disseminating this new knowledge in one´s practice and sharing experiences with others (Figure 9). Breakthrough innovations, such as the case of Gangtok (see Box 2), required a large number of resources and a complex net of external actors, from financing to knowledge brokers, to develop the idea and implement the initiative (Box 2). Nevertheless, you do not always need to start from scratch or learn from other cities or countries. There are many innovative initiatives in your city, and they are an opportunity to learn. The cases of Chinese Taipei (Box 20), Antananarivo (Box 16) and Florianópolis (Box 6) are examples of how to expand existing initiatives to a larger scale.

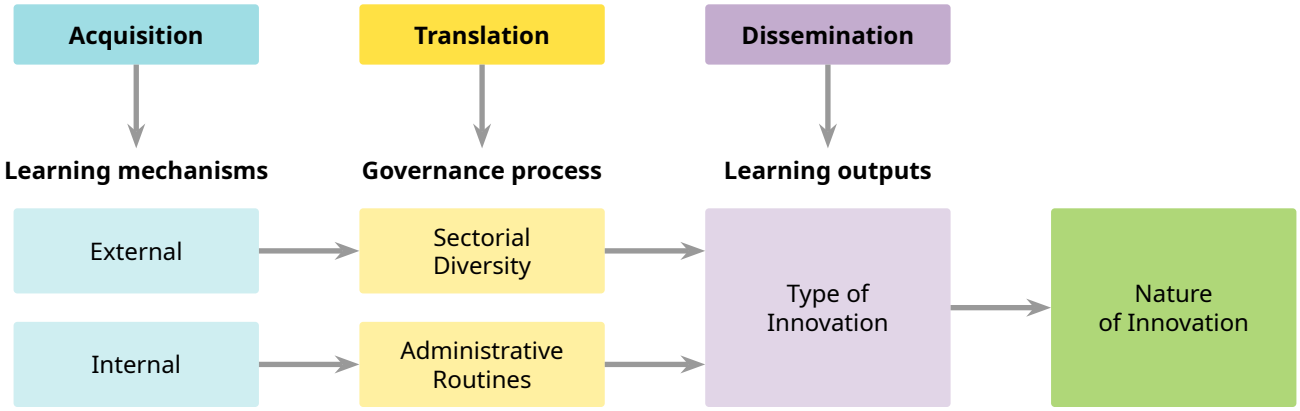


Figure 9. The role of learning mechanisms in a collective learning process
Source: Zambrano-Gutiérrez and Puppim de Oliveira, 2022

Innovation in FWEN is a long-term investment in engagement with different processes and stakeholders to better integrate food, water and energy systems in urban governance. Urban GBI is a promising alternative route to approach FWEN in cities, with many good examples worldwide from which to learn. This guide provides some ideas about the basic steps to develop innovations in GBI to improve FWEN. GBI and FWEN integration in the infrastructure portfolio of your city or neighborhood might be just a tiny component. Still, it might be an innovative approach in your sector or context, which may be spread to other places. Your experiences could be significant in promoting new practices elsewhere. Thus, let us innovate to create a better world for the next generations in our cities.

Since we started the research that underpins this guide in late 2018, scholarship and empirical knowledge on the FWE nexus has increased tremendously. Green and Blue Infrastructure and other nature-based solutions are also regarded as desirable and positive alternatives to conventional gray infrastructure in cities. The 2020 COVID-19 pandemic is putting our civilization and cities to the test. Resiliency and adaptation are vital concepts for city planning and management, and are increasingly recognized by practitioners. Given the speed at which environmental change is taking place and affecting the lives of millions of human settlements, there is no time to waste. The sooner we update, consolidate and apply this knowledge, the stronger our cities will become, guiding our societies to a more sustainable future. **We invite you to join us!**

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Appendix A

Working tables and exercise sheets per section

Introduction

Global to local – your context

List and briefly describe the key environmental issues affecting your community in different scales (**global, regional, local**), such as:

- Unplanned urbanization / urban sprawl
- Increasing urbanized population and loss of agricultural land
- Drought and soil erosion
- Water scarcity
- Extreme events and flooding
- Biodiversity loss and deforestation
- Depletion of fisheries
- Sea level rise and coastal erosion
- Air and water pollution
- Other...

*Choose **one** you think should be addressed in this exercise to describe in more detail below.*

Table A1 – Identifying your urban challenges and infrastructure solutions

Urban Challenges	Conventional or "grey" solution	Urban GBI solution	Ecosystem services (ES)	Benefits and goods

Green and Blue Infrastructure, grey infrastructure, hybrid solutions

Identify at least one innovative GBI solution that can be adopted instead of the conventional one in your case, if any (see examples in Appendix C.)

Green and Blue Infrastructure for FWEN

Describe who are the actors involved in implementing these solutions, and who are the beneficiaries. Identify the potential partners, human and financial resources (available and required), and whose political support will be needed.

Actors (e.g., municipal staff, university, NGOs, community members, etc)

Beneficiaries

Partners

Available funding sources

Potential funding sources

1. Getting Started

Where are we?

Assessing your city´s resources: mapping supply and demand of food, water and energy. Define the scope of the targeted resource(s); identify responsibilities, supply and demand and the linkages.
How is food produced and distributed? How is urban solid waste collected and treated?
How is water produced, treated and distributed?
How is wastewater collected and treated?
How is energy produced and distributed?
What kind of infrastructure is used for each resource and their interconnections?
Identify the responsible departments for each case, including jurisdictional level.

What are the main urban challenges related to food, water and energy in your community?
Resources:
Capabilities:
Legal framework:
Operational:
Governance:
Other:

Table A2. FWE Opportunities Assessment Table

Development of table with a summarized assessment of the FWE systems and opportunities for improving nexus. Can also use one table for each resource.

Resource	Food	Water	Energy
Scope			
Total Production (amount)			
Total Consumption (amount)			
Imports			
Exports			
Main actors in the supply			
Main actors in the demand			
Nexus with other components			
Problems			
City´s Leverage			
Opportunities for GBI innovation			

2. Visioning

Where do we want to innovate?

This is when you can actively search for inspiration, to find a solution that will better solve your problem. Search for innovative examples in cities and communities with similar challenges. This exercise is best and more effective with a participatory approach. Tables A3 and A4 aim to provide a framework to organize information that will help you answer the questions below.

Guiding questions

What do you expect as the best result from an intervention to address your particular problem?

Identify what kind of change or transformation you expect as an outcome.

What are the challenges to reach this outcome?

Identify the enabling environment elements:

Compare solutions and benefits (use table A3)

Who are the people / stakeholders that can help you to address these challenges?

Municipal staff / departments:

Community members/ volunteers / beneficiaries:

Professionals, experts, businesses, universities:

Legal and institutional framework (legislation, formal and informal institutions):

Potential funding opportunities:

Available and potential finance mechanisms:

Other ideas:

Other ideas:

Table A3. Examples of urban challenges and solutions – select your case

Urban Challenges	Conventional or "grey" solution	Urban GBI solution	Ecosystem services (ES)	Benefits and goods
Food insecurity	Centralized food distribution	Urban agriculture (UA)	Provisioning	Food (fish, game, vegetables, fruit, medicinal plants
			Regulating	
			Cultural/ spiritual	
			Supporting (habitat)	

Source: Adapted by the authors from MA, 2005 and TEEB, 2010

Table A4. Innovation Potential

This table identified the potential innovations and challenges for their realization.

Opportunities and threats in the FEW	Innov 1	Innov 2	Innov 3
Innovation description			
Key stakeholders			
Rules that need to be changed			
Resource gaps (finance)			
Resource gap (knowledge)			
Resource gap (political support)			
Filling gap – finance			
Filling gap – knowledge			
Filling gap – resources			

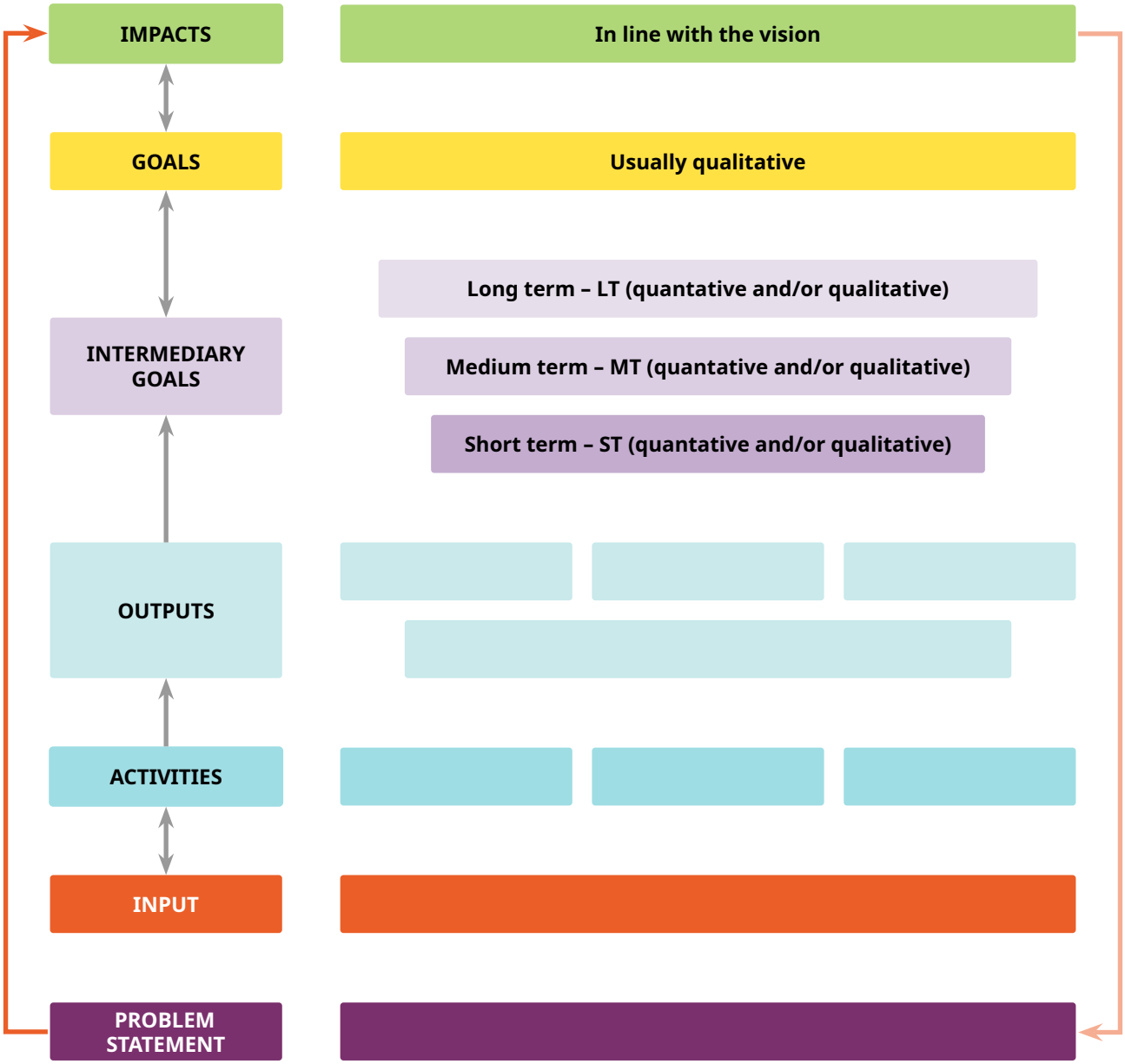
3. Planning

Deciding how to get there.

Table A5. Risk Assessment Form

Project Name:
Prepared By:
Date:

Problem Area or Activity	Risks Identified	Description	Probability of Occurrence	Impact Intensity	Existing Measures	Mitigation Strategy	Additional Measures	Contingency Plan



4. Implementing

Getting there!

This step is the most challenging in the process, since it probably involves many other departments, people and resources not necessarily within the power of managers to mobilize. Identifying who must be involved, what are the human and financial resources available for each phase of the project and overseeing their completion determines how successful implementation is. Besides what you have already achieved in the previous steps, it is important to know, for instance, the risks, strengths, weaknesses, opportunities and threats in the project. List below what you can identify and what are the tools available to help you.

Draw and fill in a SWOT analysis chart for your project	
Strengths	**Weaknesses**
Opportunities	**Threats**

List key barriers

Identify main risks

Identify departments / experts that must be involved

List tools available in your community (Apps, equipment, publications, etc.)

5. Monitoring and Evaluation

Deciding how to get there.

Based on the logic model you developed earlier, fill in as many cells as possible in the table below

Table A6. Simplified model for M&E based on results-oriented logic framework

Indicator	Definition	Baseline	Target	Data Source	Frequency	Assump-tions/risks	Responsible	Reporting
Goal								
Outcomes								
Outputs								
Activities								

List the tools you could use to help you in M&E and the parties involved in assisting you.

List the platforms available for communicating the initiative´s progress and results to the general public.

Appendix B

Hyperlinks, resources and tools available online free of charge

These resources are available online and can be downloaded free of charge. We add a brief explanation to facilitate identifying what can be best for your needs. The list is by no means exhaustive, and the links should be checked occasionally as they might change. These sources are valid in 2021.

- Examples of free GIS software: Quantum GIS (QGIS), available for download at: https://www.qgis.org/pt_BR and gvSIG, available for download at: http://www.gvsig.com/en
- World Health Organization WHO: https://www.who.int/topics/geographic_information_systems/en/ and https://www.who.int/heli/tools/maps/en/
- TEEB´s Estimation of Monetary Values of Ecosystem Services: presents the monetary values of ecosystem services (https://www.es-partnership.org/wp-content/uploads/2016/06/TEEB-D0-App-C.pdf); specifically for wetlands https://www.ramsar.org/sites/default/files/documents/library/teeb_waterwetlands_report_2013.pdf.
- TEEB database: a searchable database of 1,310 estimates of monetary values of ecosystem services. https://www.es-partnership.org/wp-content/uploads/2016/06/ESVD-TEEB-database.xls.
- IIED, IUCN, UNEP-WCMC and GIZ EbA Tools Navigator: features information on more than 230 EbA tools, methodologies and guidance documents; from planning, assessments and implementation to monitoring and mainstreaming https://www.iied.org/help-pilot-navigator-tools-for-ecosystem-based-adaptation.
- EcoShape's Building with Nature Platform (https://www.ecoshape.org/en/) and Building with Nature design guidelines (https://www.ecoshape.org/en/design-guidelines/) contain knowledge on 'building with nature' and guide users in choosing and implementing the best building with nature solution for their challenge.
- Green-Gray Assessment: How to assess the Costs and Benefits of Green Infrastructure for Water Supply Systems Working Paper (Gray, et al., 2019). World Resources Institute: provides a method to value the costs and benefits of integrating green or natural infrastructure into water supply systems www.wri.org/publication/green-gray-assessment
- The Mersey Forest Green Infrastructure Valuation toolkit: provides an open-source toolkit to value GI https://www.merseyforest.org.uk/services/gi-val/
- EHA Connect: provides a repository of tools and guidelines for crisis response and recovery https://ehaconnect.org/
- Guidelines for Rapid Environmental Assessment in Disasters: a tool to identify, define and prioritize potential environmental impacts in disaster situations. https://reliefweb.int/report/world/guidelines-rapid-environmental-impact-assessment-disasters-version-5-2018
- Examples of blue-green infrastructure – sketches, guidelines, detailed descriptions and photos. https://www.ice.org.uk/news-and-insight/the-civil-engineer/july-2021/theory-and-practice-of-blue-green-infrastructure
- CIRIA - Construction Industry Research and Information Association: https://www.ciria.org/CIRIA/Home/CIRIA/default.aspx?hkey=b9b32704-f151-4cb8-83fc-c9da82a10893
- Best – Benefits Estimation Tool – valuing the benefits of GBI. https://www.susdrain.org/resources/best.html
- City Benefits Tool, developed under the Food Initiative Project to estimate circular economy benefits: https://emf.thirdlight.com/link/q66t3zeu84cy-uyzd3g/@/preview/1?o
- Policy outreach and buy-in – FAO Food for cities programme toolkit: https://www.fao.org/in-action/food-for-cities-programme/toolkit/policy-support-and-planning/policy-outreach-and-buy-in/en/

- Klima 2050 tool - https://www.sintef.no/en/latest-news/2019/new-tool-shows-best-location-for-blue-green-infrastructure/
- FAO – Food for cities programme toolkit CRFS assessment on data display and communication. https://www.fao.org/in-action/food-for-cities-programme/toolkit/crfs-assessment/data-display-and-communication/en/
- United Nations, Sustainable Development Goals. https://www.un.org/sustainabledevelopment/

Specific urban risk indicators:

- UNDRR's Making Cities Resilient (MCR) Disaster Resilience Scorecard for Cities provides indicators on "safeguard natural buffers to enhance the protective functions offered by natural ecosystems". https://www.unisdr.org/campaign/resilientcities/toolkit/article/disaster-resilience-scorecard-for-cities
- Urban Disaster Risk Index developed by Carreño (2006) assesses disaster risk considering a city's physical exposure and the socioeconomic fragility and coping capacities of the population and institutions. It helps identify risk-prone localities and their specific social, institutional, and organizational vulnerabilities (Dickson et al., 2012; Khazai et al., 2015).
- Risk Management Index assesses a city´s risk management performance and its effectiveness based on predefined qualitative targets (Khazai et al., 2015), which should also include ecosystem-based approaches (PEDRR, 2016).
- Disaster Resilience Index (DRI) serves as monitoring and evaluation tool for benchmarking and measuring progress (or lack of progress) on the mainstreaming of risk reduction approaches in a city's development policies and processes (Khazai et al., 2015).
- Climate Adapt – Sharing adaptation knowledge for a climate-resilient Europe. Clearing house by the European Union at https://climate-adapt.eea.europa.eu/

Monitoring and Evaluation

- Monitoring and Evaluation for EbA guidebook at https://climate-adapt.eea.europa.eu/metadata/guidances/guidebook-for-monitoring-and-evaluating-ecosystem-based-adaptation-interventions
- The UN Food and Agriculture Organization - FAO has developed a series of tools to assist cities, including indicators.
- FAO - https://www.fao.org/in-action/food-for-cities-programme/toolkit/crfs-assessment/indicator-framework/en/
- FAO - https://www.fao.org/in-action/food-for-cities-programme/toolkit/crfs-assessment/indicator-framework/surveys/en/
- FAO - https://www.fao.org/in-action/food-for-cities-programme/toolkit/crfs-assessment/indicator-framework/stakeholder-consultation/en/
- FAO - https://www.fao.org/in-action/food-for-cities-programme/toolkit/crfs-assessment/data-display-and-communication/en/
- GIZ, UNEP-WCMC and FEBA (2020) Guidebook for Monitoring and Evaluating Ecosystem-based Adaptation interventions . Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Bonn, Germany: https://www.adaptationcommunity.net/download/ME-Guidebook_EbA.pdfT
- The RUAF Global Partnership on Sustainable Urban Agriculture and Food Systems is a consortium of expert institutions and individuals that includes cities, research institutes and NGOs, with a recognized track record in urban and peri-urban agriculture and urban food system solutions. The partnership is a platform for learning and knowledge brokering between science, policy and practice. https://ruaf.org

- https://ruaf.org/document/guideline-3-calculating-climate-change-related-indicators-of-urban-regional-food-production-and-consumption/
- IFWEN project website – www.ifwen.org
- Urban Heat Island Effect – Publications. https://www.sciencedirect.com/topics/engineering/urban-heat-island-effect and https://www.urbanheatislands.com/
- Un- Habitat - https://unhabitat.org/about-us

Suggested readings: Articles, guides and handbooks on GBI and FWE

- Bours, D., McGinn, C. and Pringle, P. 2013. Monitoring & evaluation for climate change adaptation: A synthesis of tools, frameworks and approaches. Evaluation Review 1. SEA Change CoP, Phnom Penh and UKCIP, Oxford Available at: https://www.ukcip.org.uk/wp-content/PDFs/SEA-Change-UKCIP-MandE-review-2nd-edition.pdf
- Bours, D., McGinn, C. and Pringle, P. 2014. Design, monitoring, and evaluation in a changing climate: Lessons learned from agriculture and food security programme evaluations in Asia: Available at https://www.ukcip.org.uk/wp-content/PDFs/UKCIP-SeaChange-MandE-ER1-griculture.pdf
- Civic, K. and Siuta, M. (2014) Green Infrastructure – Training manual for trainers. ECNC, Tilburg, the Netherlands and CEEweb for Biodiversity, Budapest, Hungary. Copyright © 2014 ECNC and CEEweb
- Clearing house - United States Environmental Protection Agency (EPA) – list of resources and examples on Green Infrastructure (GI), including publications and webcast materials. https://www.epa.gov/green-infrastructure/performance-green-infrastructure and modelling tools at https://www.epa.gov/green-infrastructure/green-infrastructure-modeling-tools
- ENABLE project – Participatory Resilience Assessment Tool: https://www.ecologic.eu/14554
- Handbook on green infrastructure developed for European cities. Danzinger, F., Drius, M., Fuchs, S., Wrbka, T., Marrs, C. (Ed., 2020). Manual of Green Infrastructure Functionality Assessment – Decision Support Tool. Interreg Central Europe Project MaGICLandscapes. Output O.T2.1, Vienna. Available for download free of charge at https://www.interreg-central.eu/Content.Node/MaGICLandscapes-Manual-of-GI-Functionality-Assessment.pdf
- Hansen, R., Rall, E., Chapman, E., Rolf, W., Pauleit, S. (eds., 2017). Urban Green Infrastructure Planning: A Guide for Practitioners. GREEN SURGE. Retrieved from http://greensurge.eu/working-packages/wp5/
- https://clinics.law.harvard.edu/environment/files/2019/09/certifications-green-infrastructure-professionals.pdf available at https://clinics.law.harvard.edu/environment/files/2019/09/certifications-green-infrastructure-professionals.pdf
- Ulku, M., Sui Xinxin, Michael van der Lans, Thomas Dillon Peynado, Jiechen Zheng and Camille Fong. 2018. ErQi Sponge City Final Report of the multidisciplinary project, by TU Delft University in collaboration with Arcadis for Wuhan, in China. Report available at https://d1rkab7tlqy5f1.cloudfront.net/Websections/Infrastructures%20and%20Mobility/Student%20projecten/Sponge%20City%20China/SCP_Final_report_nov2018.pdf
- Down to Earth blog - Reflections on COVID19., cities and urbans spaces in India. https://www.downtoearth.org.in/blog/urbanisation/covid-19-and-green-open-spaces-what-is-going-to-be-our-new-normal--71501
- https://wwfafrica.awsassets.panda.org/downloads/green_infrastructure_in_african_cities.pdf?31761/The-case-for-investment-in-green-infrastructure-in-African-cities
- ICLEI - Local Governments for Sustainability, 2020. Climate finance decision-making tree. Bonn, Germany. Available from https://e-lib.iclei.org//publications/GPSC/Finance%20tree_EN_final.pdf

- Inter-American Development Bank – IDB. Thomas L. Crisman and Raúl Muñoz Castillo Authors. 2019. The role of green infrastructure in water, energy and food security in Latin America and the Caribbean: experiences, opportunities and challenges. Water and Sanitation Discussion Paper no. IDB-DP-00693. Available at https://publications.iadb.org/publications/english/document/The_Role_of_Green_Infrastructure_in_Water_Energy_and_Food_Security_in_Latin_America_and_the_Caribbean_Experiences_Opportunities_and_Challenges_en.pdf
- PBS Learning media – Curated free, standards-aligned videos, interactives, and lessons plans - https://www.pbslearningmedia.org/resource/history-geologic-eons/history-geologic-eons/
- Rutgers New Jersey Agricultural Experiment Station – educational programs on water management in the US. http://www.water.rutgers.edu http://www.water.rutgers.edu/Projects/Projects.htm. National Green Infrastructure Program http://www.water.rutgers.edu/Recent_Presentations/NGICP_Final_Review_Class.pdf
- Webinar on GI in Africa. Available at https://www.theafricaceoforum.com/en/webinars/africanizing-green-infrastructure-projects/
- Zhang K, Deletic A, Dotto CBS, Allen R, Bach PM (2020) Modelling a 'business case' for blue-green infrastructure: lessons from the Water Sensitive Cities Toolkit. Blue-Green Syst 2:383–403. https://doi.org/10.2166/bgs.2020.018
- Green Infrastructure Foundation - webinar and courses https://greeninfrastructurefoundation.org/training

Appendix C

Supplementary information per section

Preface

Systems Thinking means taking a 'joined-up' approach to natural resource management. It identifies interactions between different parts of a system (such as a city) and considers how different sectors influence each other. This approach shifts the focus from the parts themselves, to how the parts are organized as a collective. Changing the interactions between the parts can lead to change in the system as a whole, and this co-operation can make the system function better than the parts could achieve on their own. To learn more on systems thinking, visit: https://learningforsustainability.net/systems-thinking/

Silos thinking (or silos mentality) explains an approach to resource management that only focusses on sectoral approaches, whereby each sector has its own goals without considering how they influence, and are influenced by, other sectors. Silos can occur when certain parts of an organization are resistant to share information and resources with other parts of an organization. This can lead to a lack of cooperation, making organizations less effective at achieving their goals. Breaking down silos through cross-sector partnerships is explained at: https://www.un.org/ecosoc/sites/www.un.org.ecosoc/files/files/en/2016doc/partnership-forum-issue-note1.pdf

Urban metabolism is the circulation, exchange and transformation of resources through the city. It can refer to a range of natural resources, including food, water or energy. Cities today often function with linear metabolisms, where resources are extracted from places far away, are transported and consumed by residents, and then generate waste which is removed from the city. Making these urban metabolisms more circular is one of the ways in which cities are trying to become more sustainable. This can be done through better resource management and increased recycling. For more information visit: https://africa.iclei.org/unravelling-the-stories-of-our-cities-using-urban-metabolism-to-shape-thriving-african-cities/ and https://www.thenatureofcities.com/2018/07/24/urban-metabolism-real-world-model-visualizing-co-creating-healthy-cities/

Sustainable development is a concept that established the 3 dimensions for human development in the 21st century: environmental, economic and social. At its core, sustainable development is about protecting ecosystems and minimizing the impact of humans on the environment, whilst addressing social problems and improving livelihoods. The UN Brundtland report summarizes it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The Brundtland report can be found at: https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf. For more information and how the concept evolved see The UN's 17 sustainable development goals can be found at: https://sdgs.un.org/goals and https://www.iisd.org/about-iisd/sustainable-development.

About this Guide

Green and blue infrastructures (GBIs) are natural and semi-natural landscape elements that form a network. This network of green (land) and blue (water) spaces can improve environmental conditions and provide benefits for city residents, such as improved health or spaces for recreation. Green and blue infrastructures also provide wider benefits, such as water management functions or air temperature regulation. These benefits collectively are called ecosystem services (ES). GBIs are also described or integrated in definitions such as "ecosystem-based adaptation (EbA)", "green spaces", "green/eco-engineering", and "natural capital" when applied to ES valuation. Definitions and images are available at https://www.epa.gov/green-infrastructure/green-infrastructure-design-and-implementation. For more guidance on blue-green infrastructures, visit: https://www.water.vic.gov.au/__data/assets/pdf_file/0029/89606/Green-blue-Infrastructure-Guidelines-Feb17.pdf

Urban Green and Blue Infrastructure can be defined as an interconnected network of natural and semi-natural (urban) areas, including vegetation and water elements, as well as other environmental features, integrated with the built environment, strategically planned, designed, and managed at multiple scales, to sustain a balanced nature-human relationship and provide multiple functions to benefit human population, as well as biodiversity conservation (Macedo et al. 2021). The EPA website has some interesting examples. Although they apply to the US, many can be adapted to your environment. See: https://www.epa.gov/green-infrastructure/what-green-infrastructure

How to Use This Guide

The IFWEN Project

The "Innovation in Food-Water-Energy Nexus in Cities" (IFWEN) project is a multi-disciplinary research collaboration with seven partner organizations, that aims to advance knowledge for improving the governance of the interactions between food, water and energy (FWE) in cities. It considered blue-green infrastructure initiatives in eight cities across the world, to learn lessons about how GBI can help in governing the FWEN

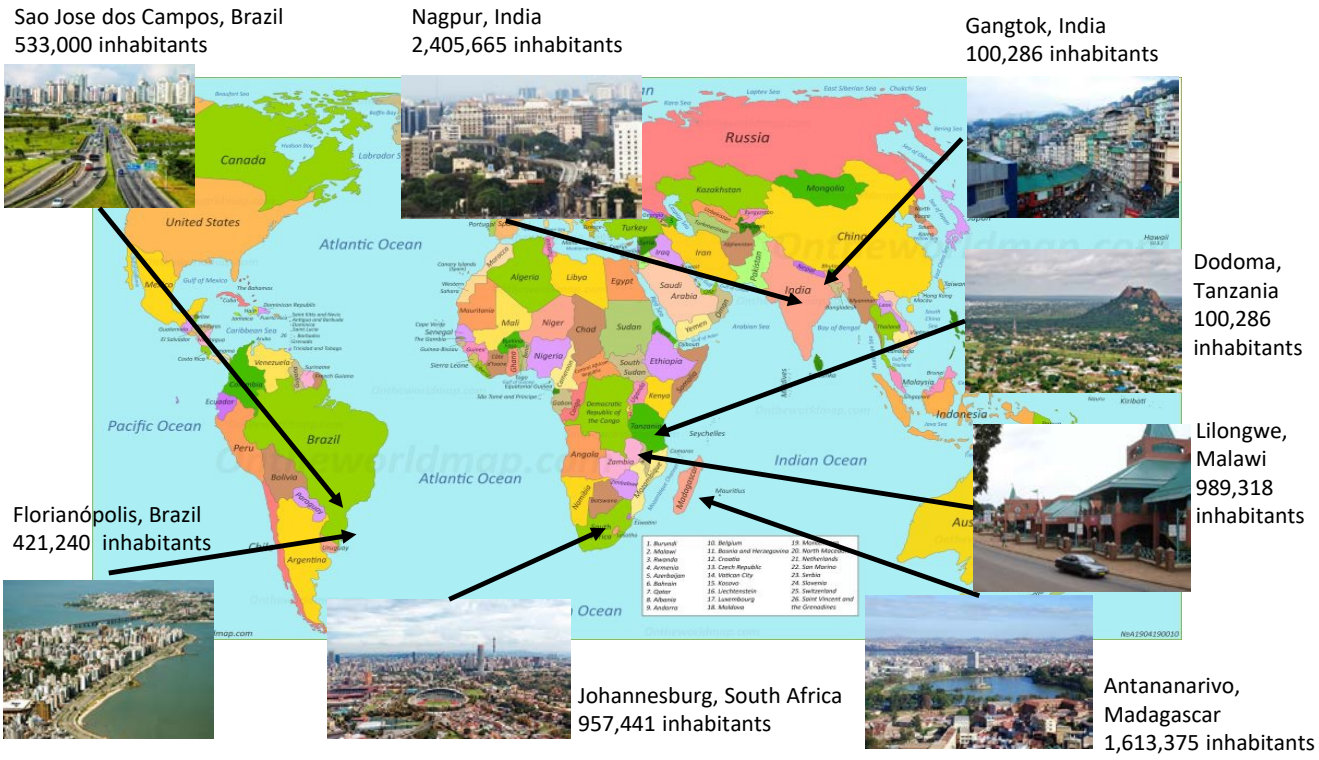


Figure C1. IFWEN Participating cities, 2018-2021

Introduction

Global Environmental Change

Our planet's fragility was revealed to the world when NASA released its full image of earth as seen from deep space in the 1970s. Since then, nations have undertaken joint efforts to establish a sustainable development pathway for human societies. In 1992, leaders of 178 countries gathered in the United Nations Conference on Environment and Development – UNCED 92, adopted Agenda 21, an action plan for the 21st century, along with other landmark agreements to protect life on Earth. Since then, the international community participating in the UN negotiation processes has addressed social, environmental and economic issues concerning all people and societies through treaties and guidelines built on each other for decades. One of the most pressing ecological challenges to be addressed by Humanity is global climate change, induced by increasing concentrations of greenhouse gases in the atmosphere since the Industrial Revolution. In the past 200 years, human activities based on burning fossil fuels have changed the climate system on a planetary scale. Together with biodiversity loss and demographic shifts, climate change is impacting human societies and life on the entire planet. The poor are the most vulnerable to the negative consequences of these global changes.

Figure C2. Composite image of earthrise from the moon captured by Apollo 17 mission in 1972. Source: NASA/Goddard/Arizona State University, 1972

The term **Anthropocene** was proposed by meteorologist Paul Crutzen in 2000, to distinguish this epoch from the Holocene, a period of relative climate stability. It defines Earth's most recent geologic time period or epoch (Anthropocene) as being human-influenced, or anthropogenic, based on overwhelming global evidence that atmospheric, geologic, hydrologic, biospheric and other earth system processes are now altered by humans. For more information see https://www.anthropocene.info/. Source: https://editors.eol.org/eoearth/wiki/Anthropocene.

"Planetary boundaries" is a concept based on the limits of the planet as a unique closed system. Systematized by scientists to describe "[...] the boundaries of the "planetary playing field" for humanity if we want to be sure of avoiding major human-induced environmental change on a global scale." (Rockstrom et al. 2009).

Earth system processes are classified as:

- Climate change
- Ocean acidification
- Stratospheric ozone depletion
- Atmospheric aerosol loading
- Global freshwater use
- Biogeochemical flows: interference with Phosphorous and Nitrogen cycles
- Land-system change
- Rate of biodiversity loss
- Chemical pollution

Available at: https://www.ecologyandsociety.org/vol14/iss2/art32/

Ecosystems are the lifeblood of the planet. An ecosystem is a community of living organisms and their physical environment, interacting as a system. When the nutrient cycles and energy flows in ecosystems are disrupted or changed, other parts of the ecosystem are affected due to the connections between parts. Humans are causing too much damage to ecosystems, many face collapse and need to be preserved or restored. Information on the threats to ecosystems and what drives them can be found at: https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/

UNCED 92 is a shortened term for the UN Conference on Environment and Development, that was held in Rio de Janeiro in 1992, also known as Rio 92 or the Earth Summit. It aimed to help governments rethink economic development and to address problems of pollution and natural resource depletion. Twenty-seven principles

were adopted in the 'Rio Declaration', as well as an international consensus called 'Agenda 21' to pursue a more sustainable development in the 21st Century. Other treaties that shaped international policies since then include the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), and the Forest Principles. Links to these documents can be found at: https://www.un.org/en/events/pastevents/UNCED_1992.shtml

UN Environment and Development Selected Landmarks

1972. First UN Conference on the Human Environment in Stockholm. The United Nations Environment Program (UNEP) is established.

1987. The World Commission on Environment and Development delivers the Brundtland Report to the UN General Assembly, consolidating the concept of Sustainable Development.

1989. First climate conference in Toronto, Canada. City adopts emissions reduction targets.

1992. United Nations Conference on Environment and Development in Rio de Janeiro, Brazil (UNCED 92 or Rio-92). Founding documents: Rio Declaration, Agenda 21, Framework Convention on Climate Change, Convention on Biodiversity, Forest Principles. Summaries of these documents are available at http://www.ciesin.org/datasets/unced/unced.html

1993. Convention on Biological Diversity (CBD) enters into force.

1994. United Nations Framework Convention on Climate Change (UNFCCC) enters into force.

1996. The United Nations Conference on Human Settlements is held in Istanbul.

2000. The United Nations Millennium Summit agrees to a set of time-bound and measurable goals for combating poverty, hunger, disease, illiteracy, environmental degradation, and discrimination against women; the Millennium Development Goals are to be achieved by 2015.

2002. The World Summit on Sustainable Development is held in Johannesburg, marking the 10-year anniversary of the United Nations Conference on Environment and Development.

2005. The Kyoto Protocol enters into force, legally binding developed country parties to goals for greenhouse gas emission reductions and establishing the Clean Development Mechanism for developing countries.

2005. The Millennium Ecosystem Assessment is released providing scientific information on the consequences of ecosystem change for human wellbeing.

2008. Member States launch the UN-REDD program. It has since spurred 14 national initiatives to combat deforestation, forest degradation and climate change.

2010. At COP 10, in Nagoya, Japan, the CBD establishes the Aichi Targets 2011-2020 to reduce habitat degradation and biodiversity loss.

2011. World population reaches 7 billion, of which over 50 percent in urban areas. See the UNs urban population reports in https://population.un.org/wup/

2011. Bonn Nexus Conference 2011. https://www.water-energy-food.org/events/conference-the-water-energy-and-food-security-nexus-bonn2011-nexus-conference

2012. UNEP Member States launch the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) to provide policymakers with reliable, independent and credible information on the status of biodiversity in response to concerns about the lack of policy-relevant information to tackle threats.

2015. The United Nations Sustainable Development Summit establishes Agenda 2030, a new global agenda on sustainable development, leading to the adoption of 17 Sustainable Development Goals, focusing on environment, including life below water, life on land, climate action, clean water and sanitation, and affordable and clean energy.

2015. At the United Nations Climate Change Conference in Paris, 195 countries adopt the first universal and legally binding global climate treaty landmark climate agreement.

2016. Paris Agreement enters into force.

2018. IPCC Cities Conference, Edmonton, Canada. Focus on integrating science and practice in cities socioenvironmental issues. See full report https://unhabitat.org/sites/default/files/2021/03/Cities%20IPCC%20Proceedings%20FINAL%20for%20Email-S.pdf

Sources: https://sdgs.un.org/2030agenda; https://www.unep.org/news-and-stories/story/environmental-moments-un75-timeline; https://www.adb.org/sites/default/files/publication/29664/world-sustainable-development-timeline.pdf

Intergovernmental Platform on Biodiversity and Ecosystem Services

https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf

https://www.cbd.int/history/

Sustainable Development Goals (SDGs), as defined by the UN, "are a universal call to action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere. The 17 Goals were adopted by all UN Member States in 2015, as part of the 2030 Agenda for Sustainable Development which set out a 15-year plan to achieve the Goals.

Fossil fuels. The modern era was built on development based on burning fossil fuels, mainly coal, oil and natural gas. They are not a renewable energy source, like the sun or the wind. Fossil fuel- dependent societies are vulnerable, as was demonstrated by the two oil crises in the 70's, which led to major global shifts in fuel production/ consumption. While they had negative economic impacts worldwide, the oil crises also spurred innovation, for example, developing biodiesel and ethanol from sugarcane in Brazil to use as vehicle fuel. See more in https://www.smithsonianmag.com/smart-news/1970s-gas-shortages-changed-america-180977726/, https://www.britannica.com/event/Arab-oil-embargo and https://energyhistory.yale.edu/module/oil-shocks-1970s

Take-make-waste model. Also known as linear metabolism of cities, this model has been the conventional – and unsustainable - consumption and production model of western societies for centuries. As we move toward a global population of over 9 billion humans by 2050, the majority of whom live in cities, means this model is no longer an option.

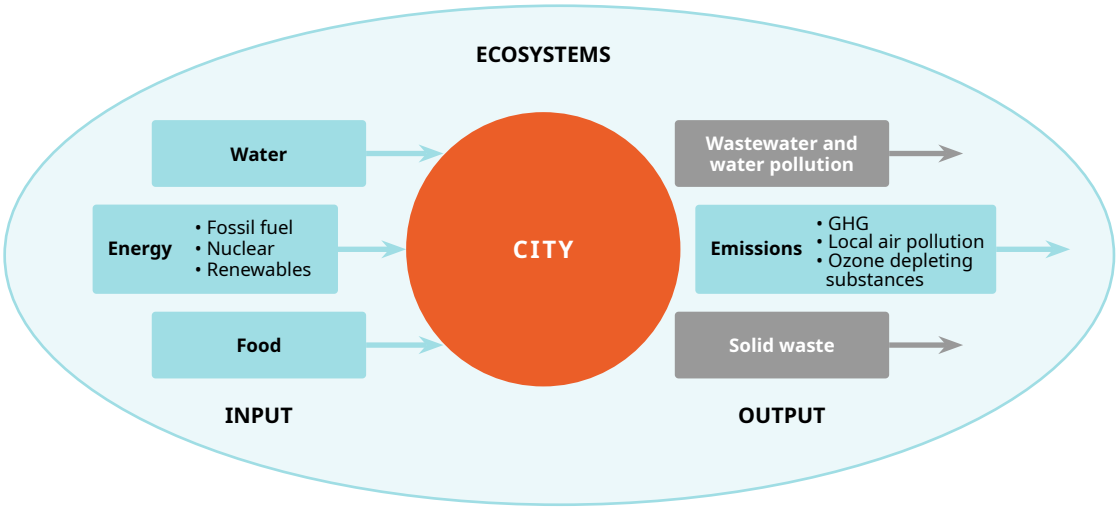


Figure C3. Urban Metabolism linear model

Sustainable cities and communities must function within a circular model, in which resource use is optimized, drastically reducing waste. Squandering Earth´s resources has long been unsustainable and as the global environmental crisis becomes unmanageable, societies can no longer afford to ignore Nature´s warnings.

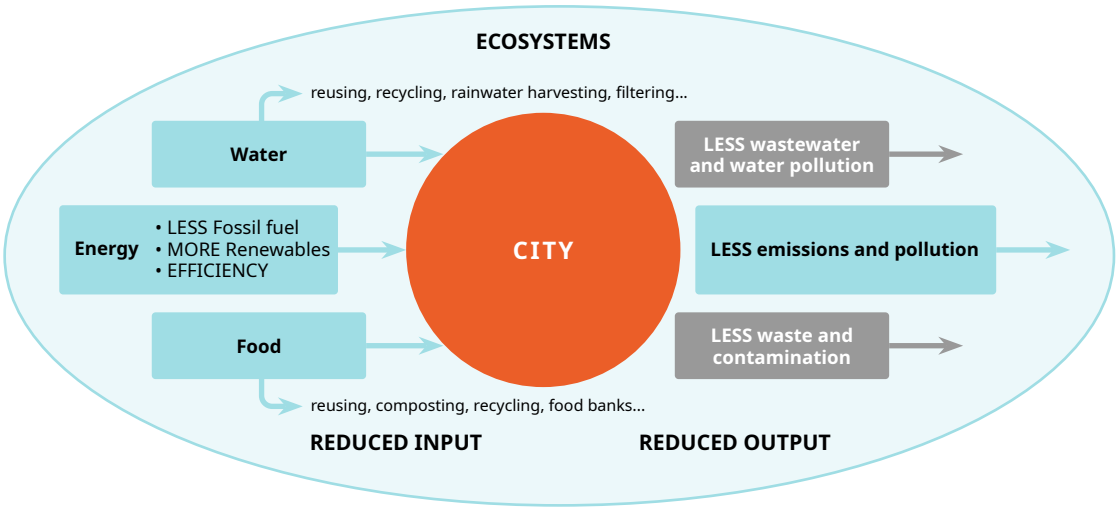


Figure C4. Urban metabolism circular model

Transformative Change means a fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values. The environmental problems faced globally, and climate change in particular, demand that societies strive for transformative change. The UN 2030 Agenda for transformative change: https://sustainabledevelopment.un.org/post2015/transformingourworld/publication

Multilevel Governance is the term given to the negotiated, non-hierarchical exchange between institutions at the local, municipal, regional, national and international scales. The last four decades have seen a re-organization in how resources are managed, and governance tends to be conducted collectively between public, private, and non-state actors such as NGOs. Multilevel governance has both 'vertical' and 'horizontal' dimensions. For more information visit: https://www.oecd.org/regional/multi-levelgovernance.htm

Problem Statement and Background

Climate Change is arguably the most challenging problem for Humanity and Earth in the 21st century. The burning of fossil fuels like coal, oil and natural gas has changed the composition of the atmosphere by increasing levels of greenhouse gases, especially carbon dioxide. This is the main cause of global warming, which interferes with the planet´s climate system, causing multiple effects, such as sea level rise, and increased frequency of droughts, floods and heatwaves. Climate change threatens water resources, food systems, and human wellbeing. Cities are highly vulnerable to climate change, because of high levels of both infrastructure and people. The IPCC regularly produces reports on climate change, which can be found at: https://www.ipcc.ch/reports/

Land Degradation is the deterioration or loss of productivity in soils. It is a driver of food insecurity and is largely caused by unsustainable agricultural practices. Land degradation both contributes to, and is affected by, climate change. When land is degraded it has lower biological productivity, worse ecological integrity, and a loss of value to humans. It adversely affects livelihoods. An IPCC chapter on land degradation can be accessed at: https://www.ipcc.ch/site/assets/uploads/sites/4/2019/11/07_Chapter-4.pdf

Biodiversity Loss refers to a decline in the number, variety, and variability of living organisms on earth. This includes diversity within species, between species, and between ecosystems. Biodiversity loss is a big problem facing human societies, with the scale of loss of nature producing severe effects for both environmental and human wellbeing. A full report on the state of biodiversity loss and ecosystem threats can be accessed here: https://www.ipbes.net/global-assessment

Nature in cities must be equitably shared between all inhabitants and sustainably managed for Humanity to reach a balanced relationship with the planet. More and more strategies, tools and resources to reduce our impact on Earth are available for world leaders to endeavor a shift from the current path of degradation toward a low impact, green and prosperous future. Nonetheless, efforts so far have not been enough. Accelerating this process and responding to the urgent call for action will require political will, a better understanding of the intricate mechanisms involved in the relationship between human societies and natural systems, and a concerted effort between people from all walks of life and nations. The connection between the built and the natural environments should become more harmonious, complementary and symbiotic.

Nature-based solutions (NbS) are ways of addressing climate change and other socio-environmental problems by fostering nature, usually at larger scales. By putting effort into the sustainable management and use of natural assets, the benefits that nature provides can be harnessed. Nature-based solutions include conservation, restoration, and environmentally regenerative activities. The UNEP´s Fifth edition of the Adaptation Gap Report 2020 focuses on nature-based solutions, defined as "locally appropriate actions that address societal challenges, such as climate change, and provide human wellbeing and biodiversity benefits by protecting, sustainably managing and restoring natural or modified ecosystems." Find more on nature-based solutions at: https://www.unep.org/nature-based-solutions-climate

Ecosystem-based Adaptation (EbA) is officially defined by the Convention on Biological Diversity (CBD) as "the use of biodiversity and ecosystem services [...] to help people to adapt to the adverse effects of climate change' which may include 'sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits for local communities" (CBD, 2009).

Principles and Concepts

Innovation is the generation of new ideas, services, systems and processes. Innovation is important for sustainability as new ideas foster better solutions and improvements in existing systems. There have already been many technological innovations for sustainability, such as the development of renewable energy technologies. However, achieving sustainable development will also require many social innovations, where communities and institutions find new creative solutions to social and environmental challenges. A report on social innovation and the environment can be viewed here: https://ec.europa.eu/environment/integration/research/newsalert/pdf/IR10_en.pdf

Ecosystem services (ES) are the benefits that flow from nature to people. They are the supporting, provisioning, regulating, and cultural/spiritual services provided by ecological processes to individuals or society at large. Nature provides the underlying support system that allows all things on earth to survive, and provides services like drinking water, food, and timber. It regulates natural phenomena through processes of pollination, air temperature and climate regulation, and offers cultural services like wellbeing, spiritual comfort and recreation. CICES aims to classify the contributions that ecosystems make to human wellbeing, their most recent report can be found at: https://seea.un.org/sites/seea.un.org/files/lg23_cices_v5.1_final_revised_guidance_03-10-2017.pdf

Sponge City is a concept addresses stormwater management to respond to rapid urbanization and increasing impervious surfaces in cities. It originated in the US during the 1990´s, as **low impact development (LID)** measures, previously named Best Management Practices (BMPs). A Sponge City includes GBI strategies such as bioswales, rain gardens, ponds, green roofs, and permeable pavements. In late 2014, the Government of China launched a nationwide initiative called the Sponge City Program (SCP) to tackle flooding due to rainwater runoff in urban areas. The SCP establishes guidelines and goals for pilot cities that are constantly being reviewed, and expects that by 2030, 80 percent of urban areas have complied to the requirements. The SCP seeks to "[...] promote water responsive cities capable of eliminating water logging and preventing urban flooding, improving urban water quality, mitigating impacts on natural ecosystems and alleviating urban heat island impacts." (Ulku et al., 2018).

Table C1. GBI Typologies per region in the Global South

GBI typologies	Africa % of total	Asia % of total	China % of total	LAC % of total	GBI type % of total
Green space	3,01%	7,23%	11,75%	3,01%	25%
Green infrastructure (GI)	3,01%	2,11%	3,92%	2,41%	11%
Urban agriculture (or farming)	4,82%	1,20%	1,51%	2,71%	10%
(Urban) park	0,60%	0,30%	5,42%	1,81%	8%
Wetland (urban or constructed)	0,90%	0,90%	3,01%	0,60%	5%
Urban greening (or greenery)	0,90%	2,71%	1,51%	0,30%	5%
(Urban or Community) Garden	0,60%	1,51%	0,60%	1,81%	5%
Green roof	0,00%	1,20%	0,90%	1,81%	4%
Sponge city	0,00%	0,00%	3,61%	0,00%	4%
Pond	0,90%	1,51%	0,90%	0,00%	3%
River (urban)	0,00%	0,00%	2,11%	0,90%	3%

GBI typologies	Africa % of total	Asia % of total	China % of total	LAC % of total	GBI type % of total
Urban forest	1,20%	0,60%	0,90%	0,30%	3%
Lake	0,30%	1,51%	0,90%	0,30%	3%
(Street or urban) tree	0,30%	0,60%	0,90%	0,90%	3%
Urban drainage (system)	0,60%	0,30%	0,30%	1,20%	2%
greenway or green way	0,30%	0,30%	0,60%	0,00%	1%
Green belt	0,00%	0,60%	0,30%	0,00%	1%
(Living or green) wall	0,00%	0,60%	0,00%	0,30%	1%
Permeable pavement	0,00%	0,00%	0,60%	0,00%	1%
Stream	0,00%	0,30%	0,30%	0,00%	1%
Creek	0,00%	0,00%	0,30%	0,00%	0%
Mangrove	0,00%	0,00%	0,00%	0,30%	0%
Blue infrastructure (BI)	0,00%	0,00%	0,00%	0,00%	0%
Total GBI type mentions / region	**17,47%**	**23,49%**	**40,36%**	**18,67%**	**100%**

Source: Adapted from Macedo et al. 2021

Note: Sample of 232 abstracts, total of 332 mentions of GBI types. Some abstracts refer to multiple GBI types, thus the number of mentions is larger than the number of abstracts in the sample.

Rapid Urbanization explains the trend of human populations growing in cities. Cities are growing rapidly, and there is increasing pressure on the land and resources that supply cities. By 2050, it is expected that two thirds of the world population will live in urban areas, with associated pressures for infrastructure and services. World urbanization prospects can be viewed in a UN report at: https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf

Scarcity (of Resources): Water, Energy and Food) is the point at which the aggregate impact of all users of a resource impinges on its supply or quality, to the extent that demand cannot be satisfied fully. Scarcity has complex drivers, it can occur due to a physical shortage of a resource, or due to the failure of institutions to adequately manage resources. Scarcity can be addressed by protecting natural assets such as soil and water resources, increasing supplies, decreasing demand, or changing allocation for a resource. Water scarcity is one of the most significant resource scarcities, and was the focus of the 2006 Human Development Report: http://hdr.undp.org/sites/default/files/reports/267/hdr06-complete.pdf

Governance can be generically defined as the task of running a government, or any other organization. The concept evolved to a broader approach, in which it refers to interactions between formal institutions and civil society actors, involving "power, authority and influence to enact policies and decisions concerning public life and social upliftment." Islam M.S. (2017) Governance and Development. In: Farazmand A. (eds) Global Encyclopedia of Public Administration, Public Policy, and Governance. Springer, Cham. https://doi.org/10.1007/978-3-319-31816-5_1990-1

An **integrated approach** involves managers beyond disciplinary, departmental and sectoral boundaries to address complex problems, make decisions and communicate efficiently. For a good, short description, see https://youtube.com/watch?v=oAdJWAJvevo

1. Getting started

Cold chain is a set of rules and procedures that ensure the proper storage and distribution of goods that need temperature control and is interconnected with refrigeration equipment. See for example the case of vaccines at: https://www.paho.org/en/immunization/cold-chain.

Grey infrastructure is an engineering solution mostly using concrete, hence the use of color to describe it.

2. Visioning

ICLEI's **Climate Finance Decision Making Tree**. Guidance on searching for finance for GBI and the nexus in cities. Available at: Finance tree_EN_final.pdf (iclei.org)

3. Planning

Core team, working or steering group is a group of people that will decide on priorities and manage the general operations and activities involved in a project. They steer work that is undertaken by others and are strongest when they take an adaptive approach to monitoring and evaluation. This means that as the project develops, it is important to learn and change to improve the work being done. For guidance on setting up a steering group, visit: http://www.socialenterprisesolutions.co.uk/wp-content/uploads/2011/03/21_steering_group.pdf

Spatial planning refers to "the methods used [...] to influence the future distribution of activities in space" (EC, 1997; EU, 2018). In fact, cities have to deal with urban space constraints, which often leads to uneven environmental justice. A landscape approach is essential in promoting greater equal access to GBI, as the entire system needs to be considered. Developers should assess GBI at different spatial and temporal scales, collaborating, when necessary, at the transboundary level (across city borders) to assess synergies and trade-offs at the landscape scale.

Key Performance Indicators (KPIs)

Table C2. Monitoring and evaluation sample performance indicators (or Key Performance Indicators, KPI)

Performance Indicator	Examples
Avoided cost	• The restored coral reef reduces the need for sand replenishment by X percent equaling X amount saved in annual sand replenishment costs; • The green roof reduces energy costs by $X amount per month
Revenue generation	• The reforestation initiative stabilizes water supply by x volume per year, generating x amount of revenue, relative to prior years.
Risk reduction	• The oyster reef dissipates storm surge and reduces in-land flood risk by x% • During periods of torrential rainfall, the forest reduces the number of homes affected by landslides
Regulatory Compliance	• The intervention operates according to code
Co-benefit production	• Supporting local livelihoods: the NbS generates x employment opportunities associated with tourism; • Supports biodiversity: the mangrove provides nesting sites to x number of migratory bird species; • Climate change mitigation: the forest sequesters approximately x amount of CO_2 per year

Source: Authors adaptation of IDB (2020).

Table C3. ICLEI and Partners – Planning and Implementation Tools for GBI and FWEN

Tool name	Sector(s) Thematic area(s)	ICLEI Planning and implementation tools Summary and URL	How can this tool be useful for IFWEN?
Local Biodiversity Strategy and Action Plan (LBSAP) Guidelines	Biodiversity	The Local Biodiversity Strategy and Action Plan (LBSAP) Guidelines guides local governments in detailing a broad strategy, as well as specific actions to protect and enhance local biodiversity. Available at: https://cbc.iclei.org/tools/ A good example of simple step-by-step guidelines is the urban forestry guide "Trees in the Townscape: A Guide for Decision Makers" (http://www.tdag.org.uk/trees-in-the-townscape.html).	Similar guidelines could be developed for cities to set up a comprehensive FWEN Management Plan or a GBI Management Plan with a focus on FWE. This could take the form of a small leaflet with a similar structure (Background, Getting started...).
The Nature of Mainstreaming: A local integrated planning toolkit for biodiversity and ecosystem services	Biodiversity	This toolkit helps local governments plan for biodiversity and ecosystem services (BES) more effectively by using the Integrated Planning process. Combining knowledge from research and practice, it discusses three common barriers to integrated planning for BES and six tips to overcome them. It contains case stories from the field and templates to ease application of the tips. The aim is to provide ideas for incrementally mainstreaming your approach to BES planning. Available at: https://cbc.iclei.org/wp-content/uploads/2017/09/Mainstreaming-toolkit-1GA.pdf	The quizzes and tips contained in this document can be ways to make guidelines more engaging for decision-makers. For instance, there is a quiz that can easily be filled in by readers to assess how integrated the planning process is within their department or organization.
RAMSES Transition Handbook and Training Package	Climate change adaptation and resilience	The Transition Handbook embeds the key RAMSES findings in a process management cycle, using widely known methodologies such as the Urban Adaptation Support Tool (http://climate-adapt.eea.europa.eu/knowledge/tools/urban-ast), the official support tool of the Covenant of Mayors for Climate and Energy. It synthesizes the project results in a practical step-by-step fashion, presenting resources for cities to strengthen their knowledge of climate adaptation planning. The Training Package complements the Transition Handbook by taking stock of existing toolkits to support adaptation management in cities and offers worksheets and exercises that cities can use to progress towards their adaptation goals. Available at: https://iclei-europe.org/publications-tools/?c=search&uid=7sG50gFj	The website for this project has a page called "Toolbox" that compiles all the tools developed during the project, including the Handbook and the Audio-visual guidance, a collection of videos (https://ramses-cities.eu/toolbox).
ICLEI ACCCRN PROCESS Building Urban Climate Change Resilience: A Toolkit for Local Governments	Climate change adaptation and resilience	The ICLEI ACCCRN Process (IAP) has been developed by ICLEI-Local Governments for Sustainability's South Asia and Oceania offices through involvement with the Rockefeller Foundation supported Asian Cities Climate Change Resilient Network (ACCCRN) program. It enables local governments to assess their climate risks in the context of urbanization, poverty and vulnerability and formulate corresponding resilience strategies. The IAP toolkit draws on the experience from the ten core ACCCRN cities (see www.acccrn.org) and supplements this with learning, models, approaches and best practices of existing ICLEI approaches. The toolkit was tested in three Indian cities - Shimla, Bhubaneswar and Mysore - and subsequently used in a range of cities in Indonesia, Bangladesh, the Philippines and India. With a strong city focus, this toolkit targets city governments and their role in catalyzing community building. It provides a streamlined process that is simple yet rigorous, and which can be implemented by the cities themselves, with only minimal need for external support. It enables local governments to assess their climate risks, formulate and implement corresponding resilience strategies. The vision is to build resilience to climate change across all urban systems and groups, in particular the poorest and most marginalized.	This toolkit is a reference for IFWEN that would accompany cities through the process of formulating a strategy for FWEN/GBI with minimal external support. It was devised for cities in developing countries, notably Indian cities, that do not necessarily have a lot of data already available. The focus on community building is also useful.

Tool name	Sector(s) Thematic area(s)	ICLEI Planning and implementation tools Summary and URL	How can this tool be useful for IFWEN?
City Biodiversity Index	Biodiversity	The City Biodiversity Index – or the Singapore Index – is developed and maintained by the Singapore National Parks Department with support from ICLEI, the CBD and others. It is the only biodiversity index designed specifically for monitoring and evaluating biodiversity in cities, and the first self-assessment tool to help local governments benchmark their biodiversity efforts. It comprises a) the "Profile of the City", which provides background information on the city; and b) the 23 indicators that measure native biodiversity, ecosystem services provided by biodiversity, and governance and management of biodiversity based on guidelines and methodology provided in the User's Manual. Cities that have applied the Singapore Index have found that: a) the process facilitates capacity-building in biodiversity conservation, b) the indicators also function as biodiversity conservation guidelines, and c) quantitative scoring could assist in setting priorities for conservation actions and budget allocation.	This is a self-assessment tool that can be adapted to IFWEN and used to gather data, evaluate and monitor policies, build capacity regarding GBI and FWEN and set priorities. The indicators can be modified to include existing GBI, services provided by GBI in terms of FWE, and governance and management.
CitiesWithNature	Biodiversity	CitiesWithNature is a unique initiative that recognises and enhances the value of nature in and around cities across the world. It provides a shared platform for cities and their partners to engage and connect, working with shared commitments towards a more sustainable urban world. Available at: https://citieswithnature.org	This platform allows cities to access resources and knowledge provided by experts and by other cities, and share their own plans and results. It is based on the multiple services provided by nature, so GBI can be included and connections can also be made with the FWEN.
CITYFOOD tools	Food systems	Food Governance Barometer: this tool was developed to support a self-assessment of strong and weak points in local food governance. The barometer builds on the actions defined in the Milan Urban Food Policy Pact framework under the work-stream 'Food Governance'. The barometer can be developed by local policy makers and other stakeholders and helps define areas for improvement. Cities can score their performance for each of the six actions using a "traffic light" coloring scheme (from green to red). Results can be compared for different years.	This is a simple visual tool that can be a first step in strengthening the governance of FWEN and the indicators can be adapted. Current indicators address (a) cross-department coordination and alignment of policies, (b) stakeholder participation, (c) local initiatives and civil society movements, (d) capacities and resources for policy making, (e) information systems and data, and (f) disaster risk reduction.
		CRFS Scan Guiding Framework: The CRFS data framework provides a set of research questions and data types that can be looked at when implementing a CRFS Scan. The data involved in the food system, categories of information that can be collected, and questions that can be asked in view of an interview or survey. The data framework can be used by the local CRFS project team to guide researchers, by (i) selecting areas of investigation and sources of information (ii) identifying the key actors to interview for each area, and/or (iii) identifying the questions to be asked to collect specific data. It gives an extensive overview of relevant data for each of these areas that may help respond to the key questions that help characterize the CRFS. Its aim is not to collect information on all indicators listed. It rather provides guidance on what data to possibly look for, where to find that data and the type of surveys that could be used to collect information through interviews with key stakeholders to help fill data gaps.	These types of guidelines can bring to the attention of policy-makers categories and sources of information that were not previously considered and can be useful in contexts where data are not readily available.

Table C4. Other Selected Planning and Implementation Tools for GBI, FWEN and EbA

Tool name - Project/developer	Sectors(s) Thematic area(s)	Type of tool	Description and URL	How can this tool be useful for IFWEN?
URBAL methodology **URBAL**	Food systems	Methodology (including workshops)	The URBAL methodology aims to help disentangle the goals and strategies that lead an innovation to sustainability, not necessarily to measure its impact. That is they chose to work with impact pathway mapping. While the identification of impacts can give clues about the effects and implications of a program, project or other initiative, it cannot answer the question of how and why an impact has occurred. Impact pathway analysis can. URBAL is building, testing and refining a tool that can help various actors identify the potential and risks for different sustainability dimensions for urban food system innovations. Building from assumptions of participatory engagement, they focus on policy makers and practitioners, to build a cognitive map or logical frame that makes explicit the impact of innovations on sustainability, i.e. to identify the actual changes produced by the innovation on sustainability, the ways they are induced by the activities performed by the innovation, and the ways they interrelate, from short-term changes (outputs) to medium-term (outcomes) and to long-term changes (usually referred to as impacts). The chosen approach will therefore assess not only the intended and unintended impacts on all sustainability dimensions, but also the pathways that led to these changes. Available at https://www.urbalfood.org/methodology/	• Focus on impacts of innovations on sustainability and why these impacts occur. • Focus on policy-makers. • Multiple dimensions considered.
INSOURCE modeling framework **INSOURCE**	FWEN	Modeling framework, visualization tool	The major goal of this project is to develop a shared urban data and modeling framework to help cities analyze and characterize FWE systems and nexus interrelationships. Shaped by urban stakeholder requirements, this framework will utilize a common urban 3D data model applicable to regions and cities in Europe and the United States. The INSOURCE modeling framework seeks to: (a) simulate impacts of land use, climate change and decentralization of FWE supply infrastructure in cities with different densities and under multiple constraints in order to ensure adequate energy, water and food distribution and storage capacity; (b) configure alternative urban and regional scenarios toward integrated carbon neutral and sustainable infrastructure, based upon decentralized and increasingly autonomous FWE supply; and (c) analyze scalability and transferability of prototype solutions to other cities. The main objective of INSOURCE is to develop tools and apply them to case studies in order to quantitatively assess the predicted impact of changes in urban land use due to population, climate change, the energy transition and the challenges of providing a truly resilient infrastructure. The project combines urban big data with emerging urban modeling tools in order to assess urban transformation strategies. The main result will be a shared urban data and modeling framework, integrating 3D visualization tools for stakeholders. Available at https://sites.google.com/nyit.edu/insource-fwe/home	• Analysis of impacts of urban transformation strategies (potentially GBI interventions) on FWE supply. • However, this is applied to cities in Europe and the United States which often have more data and more capacity than cities in developing countries.

Tool name - Project/developer	Sectors(s) Thematic area(s)	Type of tool	Description and URL	How can this tool be useful for IFWEN?
SUNEX policy guidelines **SUNEX**	FWEN	Modeling framework, policy guidelines	SUNEX offers an integrated approach to support the decision-making process in formulating inclusive urban FWE–strategy. The applied nexus-approach relies on real data, stakeholder's dialogue and consistent development scenarios to address and understand the complex interlinkage between the three systems and maximize their synergies. SUNEX will provide a modelling framework to assess the Food-Water-Energy System addressing the demand and the supply side. The objective is to develop efficient solutions for energy, water and food supply for urban regions. SUNEX will be demonstrated in 4 case study city regions reflecting different consumption patterns and resource uses – Berlin, Bristol, Doha and Vienna – and will finally provide policy guidelines for different physical and climatic framework conditions and consumption patterns. Available at http://sunex-project.eu/wp/	• Similar goals as IFWEN. • Policy guidelines adapted to the context.
City Benefits Tool Food Initiative **Ellen MacArthur Foundation**	Circular economy	Spreadsheet	The Benefits table includes economic, health, and environmental benefits per unit of change generated through solutions based on circular economy principles. Once a city has identified target circular economy for food scenarios to work towards, potential benefits can be estimated using this tool. Wherever possible, locally relevant benefit factors should be used to carry out benefit calculations. All values in the Benefits table represent the annual benefits that could be achieved by implementing circular economy solutions, compared to linear methods. Available at https://www.ellenmarcarthurfoundation.org/our-work/activities/food	• This type of tool is easy to create once a model has been developed and relatively easy to use. • Can be easily adapted to different contexts by changing the language, currency and quantitative estimates of benefits.
Participatory Resilience Assessment **ENABLE**	GBI	Collective planning process (including workshops)	A participatory resilience assessment helps deepen stakeholders' understanding of how the green and blue infrastructure works within its broader urban context. This shared understanding is built gradually through a series of workshops and is used as the starting point for identifying ways to secure a continued provision of benefits. The assessment develops a multiple evidence base (Tengö et al. 2014) for resilience-building actions, including available knowledge about ongoing and future changes, the character and values of local green and blue infrastructure and different options for maintaining and enhancing those values. The outcome is a set of identified strategies and actions for navigating changes and moving the system towards the stakeholders' joint target vision. Available at http://projectenable.eu/participatory-resilience-assessment-tool-building-resilience-urban-green-blue-infrastructure/	• Priorities are decided on a qualitative rather than quantitative basis. • Knowledge, capacity and cooperation are built through the process of identifying strategies rather than before or alongside it.

Tool name - Project/developer	Sectors(s) Thematic area(s)	Type of tool	Description and URL	How can this tool be useful for IFWEN?
Water Sensitive Cities Index **Cooperative Research Center for Water Sensitive Cities**	Water	Workshop, web-based platform	The WSC Index is a tool designed to benchmark a city's current performance against seven goals of a water sensitive city. These goals include both biophysical and socio-institutional goals, which organized 34 corresponding indicators. Each of the 34 indicators are scored on a 1-5 rating scale in a collaborative workshop process. The data is then entered into a web-based platform that can filter the results according to what is most useful for the user. Available at https://watersensitivecities.org.au/solutions/wsc-index	• Scores are decided collectively. This can reduce bias and can allow the tool to function even in the absence of robust and numerous data. The accuracy of the process depends on the honesty and desire to improve the participants, as well as their knowledge about the city or specific sector.
Behavioral Assessment Tool (BBAT), Community Level Survey (BCLS) and Environmental Assessment Tool (BEAT) **BlueHealth**	Blue spaces	Surveys, visualization tool	BlueHealth Behavioural Assessment Tool (BBAT): The BBAT is designed to help with the systematic observation of a site's use. It captures who is doing what and where and allows researchers to make comparisons between different groups and activities. BBAT outputs can be visualised in geographic heat maps, providing a visual way to assess and discuss results. BlueHealth Community Level Survey (BCLS): BCLS captures information by interviewing the population near to a site. Its questions gather a range of social and wellbeing data and ask people about their water-related visits in the last 4 weeks. Data collection is performed close to intervention sites but also further afield, to capture the reasons why some people don't visit an area. BlueHealth Environmental Assessment Tool (BEAT): The BEAT aims to help planners evaluate the social, physical and ecological characteristics of a space. Formed by fusing several existing assessment tools, it can be used to capture the makeup of an environment before starting a design project, or as a way of evaluating opinions about a space from the people who visit it. Available at https://bluehealth2020.eu/news/bluehealth-tools/	• Data collected by interviewing the population near a site of interest. Information gathered through popular knowledge and observation. This can be applied in contexts where data production is not automated or systematic.
Tool that indicates the best location for blue-green infrastructure **Klima 2050**	GBI	Visualization tool	Klima 2050 together with the Drenssten project have developed a tool based on GIS (Geographic Information System) that indicates the best location for blue-green infrastructure. The tool gives a good understanding of where the water is and where it runs, available area and altitude differences in the terrain. With all this acknowledged we can find the best location for the blue-green infrastructure. The tool should be utilized early in the project. Then roads, buildings, car parks etc. can be located where they do not interfere with the water's natural paths or destroy the sites suitable for blue-green infrastructure. Available at https://www.sintef.no/en/latest-news/new-tool-shows-best-location-for-blue-green-infrastructure/	• Can be integrated with existing GIS-based tools. • Perhaps only useful for large-scale projects or to mainstream GBI.

Tool name - Project/developer	Sectors(s) Thematic area(s)	Type of tool	Description and URL	How can this tool be useful for IFWEN?
WEF Nexus Tool 2.0 **Qatar Environment and Energy Research Institute**	FWEN	Modeling framework, computer tool	The WEF Nexus Tool 2.0 serves as a common platform that brings together scientific know-how and policy input in an effort to identify current and anticipated bottlenecks in resource allocation trends, while highlighting possible trade-offs and opportunities to overcome resource stress challenges. The tool is scenario-based and attempts to explicitly quantify the interconnections between the three resources, while capturing the effects of population growth, changing economies and policies, climate change and other stresses. It provides the user with the ability to create scenarios for a given country by defining the following inputs: • Food portfolio: identifying local food production levels versus imports, and technologies in agricultural production. • Energy portfolio: identifying sources of energy for water, and energy for agricultural production. Even though the water-energy-food framework is generic, scenarios created by the tool are site specific and defined by the local characteristics of the area of study. These may include local yields of food products, water and energy availability requirements, available technologies and land requirements. The characteristics are defined by the user and allow for the creation of country-specific profiles. The WEF Nexus Tool 2.0 © enables users to visualize and compare the resource requirements of their scenarios and calculate the "sustainability index" of each scenario. Available at: https://www.water-energy-food.org/resources/resources-detail/water-energy-food-nexus-tool-2-0/	• Focus on reducing trade-offs between FWE • Based on different scenarios in a specific context. Can be adapted to scenarios with GBI and without GBI.
B£ST (Benefits Estimation Tool) **CIRIA**	GBI	Computer tool (spreadsheet?)	CIRIA has developed a free tool and guidance, B£ST (Benefits Estimation Tool - valuing the benefits of blue-green infrastructure) for use on PCs. It makes assessing the benefits of blue-green infrastructure easier, without the need for full scale economic inputs. B£ST was first produced and released in 2015 and it has been updated in 2019. B£ST is used to assess and monetise many of the financial, social and environmental benefits of blue-green infrastructure. The results enable users to understand and quantify the wider value of SUDS and natural flood management measures. This can support investment decisions and can help to identify stakeholders and find potential funding routes. Available at: https://www.susdrain.org/resources/best.html	• Monetary value allows to compare GBI with grey infrastructure solutions based on FWE trade-offs and co-benefits.

4. Implementation

Table C5. Steps in an environmental impact assessment (EIA)

Steps	Description	Activities	Application
Information regarding the project	Provide an overview of: • the location, site, design, size, etc.; • the physical characteristics of project (including any demolition or land use requirements); • the characteristics of the operational phase of the project; • any residues, emissions, or waste expected during either the construction or the operational phase.	Collect information of the project	
The baseline scenario	Define the baseline scenario by providing: • a description of the current state of the environment in the EIA report; and • an outline of what is likely to happen to the environment should the project not be implemented, known as 'do-nothing' scenario.	Have experts collect and assess the following data (or use proxy indicators where data is difficult to find): • Physical: topography, geology, soil types and quality, surface, ground and coastal water quality, pollution levels, • Meteorological conditions, climate trends, etc.; • Biological: ecosystems (both terrestrial and aquatic), specific flora and fauna, habitats, protected areas, agricultural land quality, etc. • Socio-economic: demography, infrastructure facilities, economic activities (e.g. fisheries), recreational users of the area, etc.; • Cultural: location and state of archaeological, historical, religious sites, etc. • Make a risk assessment. • Write up a detailed and comprehensive baseline assessment to allow for an understanding of the extent of environmental impacts if the project goes ahead and in case of the 'do-nothing' scenario.	
Environmental factors	Identify and assess the direct and indirect effects of the project on population and health, on biodiversity, on land, soil, water, air and climate, on climate change, on natural resources, on risk of major accidents, and on material assets, cultural heritage and landscapes.	• Collect information regarding the effects of the project and integrate these considerations into the EIA. • For the integration, consult guidance material provided in the useful links.	In Germany, the Environmental Impact Assessment Act (2001) envisages the description and assessment of a project on human beings, animals and plants; on soil, water, air, climate and landscape; and incorporates the assessment associated to natural hazards.

Steps	Description	Activities	Application
Effects on the environment	Impact analysis to identify, predict and evaluate the significance of the project´s effects and consequences for the environment.	• Select clear criteria for the significance of the project effect on the environment, taking both the characteristics of an impact and the values associated with the environmental issues affected into account. • Determine its significance, considering cumulative effects over spatial and temporal scales. • Define significance thresholds and criteria for the assessment through a collaborative approach, involving all of the interested parties in the process of data collection and analysis. • Prepare EIA/risk assessment report.	India's guidelines for EIA of river valley projects, for instance, require analyzing impacts on forests and wildlife, on water logging potential, on upstream and downstream aquatic ecosystems and fisheries, as well as water-related diseases, climatic changes, risk and displacement.
Assessment of alternatives	Provide a description of the reasonable alternatives studied and an indication of the main reasons for selecting the chosen option with regards to environmental impacts.	• Identify alternatives that can accomplish the objectives of the project and are feasible in terms of technical, economic, political and other relevant criteria. • Assess alternatives by comparing the environmental effect of all alternatives. • Consult both with partners and the public to identify and assess alternatives.	In Botswana's EIA guidelines, the section on "consideration of project alternatives" incorporates the following information: • sources of water; waste disposal; housing sites; land use options after rehabilitation; alternatives to river diversions.
Mitigation and compensation measures	Based on identified adverse effects on the environment, envisage measures to avoid, prevent, reduce or, if possible, offset these impacts.	• Identify measures to avoid, prevent, reduce or offset adverse environmental effects of the project, promoting a long-term approach and giving priority to avoiding impacts (remediation and compensation should only be considered as a last resort).	In the case of a septage treatment facility project in the Philippines, based on an impact analysis showing adverse environmental impacts during the construction period, environmentally sound engineering and construction practices were used to prevent or minimize impacts.
Monitoring	Monitoring of adverse effects on the environment and/or measures taken to mitigate them to ensure the project construction and operation does not exceed projected impacts.	• Define monitoring measures. • Systematically monitor ex-post impact of adverse significant effects on the environment and hazard-related features to check if forecasted impacts are developing as predicted. • If impacts should not correspond to the forecasted ones, take steps to rectify. • Make monitoring results available to the competent authority and to the public.	The monitoring stage of EIA in the Philippines assesses performance of the proponent against the environmental compliance commitment (the certificate received upon project approval) to ensure actual impacts of the project are adequately prevented or mitigated..

Source: UNDRR (2020), based on ProVention, 2007; OECD, 2010; Gupta and Nair, 2013; European Union, 2017)

The main functions of Strategic Environmental Assessment (SEA) concerning NbS may include (OECD, 2010):

- Assessing the vulnerability of different ecosystems, habitats, land uses and livelihoods to given types of natural disasters and preparing spatial plans and maps to show vulnerability zones.
- Helping to quantify the rates and magnitude of environmental changes that are taking place from various causes (e.g., human-induced or natural processes) and interpreting the effects of these changes on NbS.
- Assessing how development goals may be threatened or optimized by particular types of NbS.
- Mainstreaming specific "green measures" in public-private partnerships prepared at international, national and regional levels.
- Identifying ways of mainstreaming NbS at various scales in the urban environment.

Ecosystems are highly dependent on the more extensive enabling environmental processes. Often, ecosystems cannot be sustained by managing individual sites in isolation. The integrity and health of ecosystems at landscape scales determine the potential of NbS to limit flood risk, for example. If evaluated on small spatial scales, the impact of NbS on water systems may seem trivial. In contrast, on larger scales, the presence and integrity of ecosystems may make an enormous difference in the overall impact of flood events.

Local Knowledge is knowledge that has developed over time in a given community or social group and is specific to a local area. It is based on experience, and often has a long history. It is often embedded in community practices and cultural traditions and is also referred to as traditional knowledge or indigenous knowledge. This form of knowledge is under threat and should be given recognition and voice where possible. To read about the role local knowledge can play in achieving the world's most pressing problems, visit: http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/ILK_ex_publication_E.pdf

Public-private partnerships are cooperative arrangements between two or more public and private actors and is often a long-term contract between a government entity and a private party. The aim of public-private partnerships is often to develop an asset or public service, and there are many different types of PPP contracts, with varying degrees of private-sector involvement. To access a reference guide on public-private partnerships, visit: https://pppknowledgelab.org/guide/sections/83-what-is-the-ppp-reference-guide

Bottom-up actions are those that begin at the most local level: the city or its particular neighborhoods and buildings.

Top-down support increases the capacity of cities to solve their own problems by providing them with policies, targets, financial mechanisms, etc.

Ecological Engineering is the design of ecosystems for the mutual benefit of humans and nature. Ecological engineers design, monitor and restore eco-systems, and design systems that reconnect or re-integrate human society with its natural environment. It's underlying principles are the conservation of nature and of non-renewable energy sources, the application of self-design, and a reliance on system approaches. To understand more, visit: https://www.eolss.net/Sample-Chapters/C15/E1-32-07-05.pdf

5. Monitoring and Evaluation

Performance indicators are a way of measuring the progress or success of a project. It is helpful for indicators to be 'SMART', Specific, Measurable, Achievable, Relevant, and Time-based. Whilst quantitative measures are often seen as the best way to measure your activities and outputs, qualitative measures such as the experiences of local communities can also provide information for project evaluation. To start thinking about how performance can be measured at the local government level, visit: https://icma.org/sites/default/files/Getting%20Started%20Performance%20Management%20for%20LG.pdf

Appendix D

Glossary

Adaptation in climate and resilience context is the term given to processes of adjustment in human or natural systems that respond to climate change and its effects.

Bioretention is a shallow area or basin with vegetation to retain and treat runoff, such as a rain garden.

Bioswale, a long, channeled depression or trench that receives rainwater runoff (as from a parking lot) and has vegetation (such as grasses, flowering herbs, and shrubs) and organic matter (such as mulch) to slow water infiltration and filter out pollutants. (Merriam-Webster Dictionary https://www.merriam-webster.com/dictionary/bioswale. Example: http://www.ppnenvironmental.com/build-bioswale/

Carbon sequestration is the long-term removal, capture or sequestration of carbon dioxide (CO_2) from the atmosphere to slow or reverse atmospheric CO2 pollution and to mitigate or reverse global warming. Source: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/carbon-sequestration and https://civilengineeringmagic.com/gabion-wall-types-and-applications/

Carbon tax is a fee imposed on the burning of carbon-based fuels, predominantly levied in the transportation and energy sectors to incentivize reductions in carbon dioxide emissions.

Compost is a product from controlled decomposition of organic waste, such as food waste, tree pruning, garden trimmings, etc. Can include other materials such as wood chips, manure and animal remains, depending on the location.

Consumerism is a social and economic order that encourages the acquisition of goods and services, driving increased resource consumption.

Consumption is the action of using up a resource, it is the use of goods and services for the satisfaction of individual or collective human needs and desires.

Efficiency describes a level of performance that uses minimal inputs to achieve maximum outputs. An efficient use of resources minimizes waste and makes good use of inputs such as time, money, labor or energy.

Environmental services are the qualitative functions given by natural assets of land, air and water, and their associated ecosystems. These include the provision of raw materials and energy, the absorption of waste from human activities, and wider support services for human needs.

Flow is the movement of energy or matter from one place to another. The material flows of food energy and water in cities are facilitated by physical infrastructure and governed by institutional and social arrangements.

Fragmentation occurs when a unified whole is split into distinctive parts. It refers to the disintegration or breakdown of collective thought or action.

Gabion wall - retaining wall made of stacked stone-filled gabions tied together with wire. Gabion walls are usually battered (angled back towards the slope), or stepped back with the slope, rather than stacked vertically. Definition and information available at en.wikipedia.org/wiki/Gabion

Geographic information system (GIS) is a computer system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data related to positions on the Earth's surface. It is thus a way of linking databases with maps, to display information, perform spatial analyses or develop and apply spatial models.

Governance is a term which encompasses the full range of means for deciding, managing, implementing and monitoring policies and measures. It recognizes the multi-scalar and multi-actor characteristics of decision making.

Green infrastructure is a network of natural and semi-natural areas which provide ecological functions and services.

Grey infrastructure is manmade infrastructure/construction to address issues such as flooding, runoff, stormwater, as well as to provide water, wastewater treatment, transport, energy, etc., using manufactured materials, mostly concrete, hence the name.

Greenhouse gas emissions are released gaseous components of the atmosphere that absorb and emit radiation at specific wavelengths to create a heating effect. The primary greenhouse gases in the earth's atmosphere are water vapor, carbon dioxide, nitrous oxide, methane and ozone.

Hybrid infrastructure is infrastructure with both 'grey' components, which are usually human-engineered and constructed from hard materials, and 'blue-green' components, which are natural spaces that provide ecosystem services.

Inequality is the structural existence of uneven rights, opportunities and social positions within a group or society.

Infrastructure refers to the fundamental facilities and systems that support the functionality of human society. This includes the networks of roads, pipes, grids, and wires that make up the transport, water, energy, and telecommunications systems.

Innovation is the practical implementation of ideas that results in improvement in a process, product or service.

Integration occurs when separate components are mixed together or unified. Integration within or between organizations can increase the sharing of resources and knowledge and enhance capabilities.

Landfill is the oldest and most common form of waste disposal, in which waste is buried at a designated site.

Low Impact Development (LID): land development strategy for managing stormwater at the source with decentralized micro-scale control measures (Hansen et al., 2017).

Management is the planning, organizing, directing and controlling of resources or people for a given purpose. It is a problem-solving process of effectively achieving organizational objectives.

Mitigation is a human intervention to reduce emissions or enhance the sinks of greenhouse gases.

Municipalities are single administrative divisions that have powers of self-government as granted by national or regional laws.

Networks are collections of independent entities that share knowledge or communications to further their goals, and often share interdependencies with each other.

Permeable/porous / pavement is built with materials that allow water to be absorbed into the ground, such as porous asphalt, aggregate materials, such as sand, gravel and stones. Sometimes concrete rubble from demolition can be used as part of a permeable system for pavements.

Professional associations represent the interests of a particular industry and seek to further the interests of individuals engaged in those professions. They can assist individuals and organizations with networking, learning and research.

Public Administration is the planning, organizing, directing, and coordinating of government operations to implement government policies.

Rainwater harvesting is the collection and storage of rainwater.

Renewable refers to a natural resource or source of energy that is not depleted when used. Examples of renewable resources include solar energy, wind energy, and geothermal pressure.

Resilience is the capacity of environmental, social, and economic systems to cope with a disturbance; responding or reorganizing to retain its essential function, identity and structure.

Stormwater is the water resulting from rainfall or melting snow that does not infiltrate in the ground, running over paved or unpaved areas. Usually picks up and carries polluting materials such as sediments and waste, causing flooding, and degradation of water quality that impact public health and safety.

Subnational government is the sphere of public governing conducted by regional, municipal, or local authorities.

Sustainable Development Goals (SDGs) are the 17 goals for development adopted by all UN member states in 2015. They are a universal call to action to end poverty, protect the planet and achieve peace and prosperity by 2030.

Sustainable Urban Drainage Systems (SUDS) involve technologies for sustainable stormwater drainage, designed and implemented to be integrated in a specific environment.

Sustainability is a dynamic process that guarantees the persistence of natural and human systems in an equitable manner.

United Nations (UN) Organizations are specialized agencies with wide ranging international responsibilities, that are linked to the UN through cooperative agreements. Examples of organizations in the UN family include the World Health Organization (WHO) and the Food and Agricultural Organization (FAO).

Urban heat island (UHI) is the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island" in contrast with cooler areas in the surrounding landscape, usually in cities (EPA, 2008).

Waste (solid) is unwanted matter that has been disposed of by the public.

Wastewater is water that has been contaminated by human use, including domestic, agricultural, industrial and commercial activities. Wastewater also includes surface run-off and stormwater, and sewer inflows.

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