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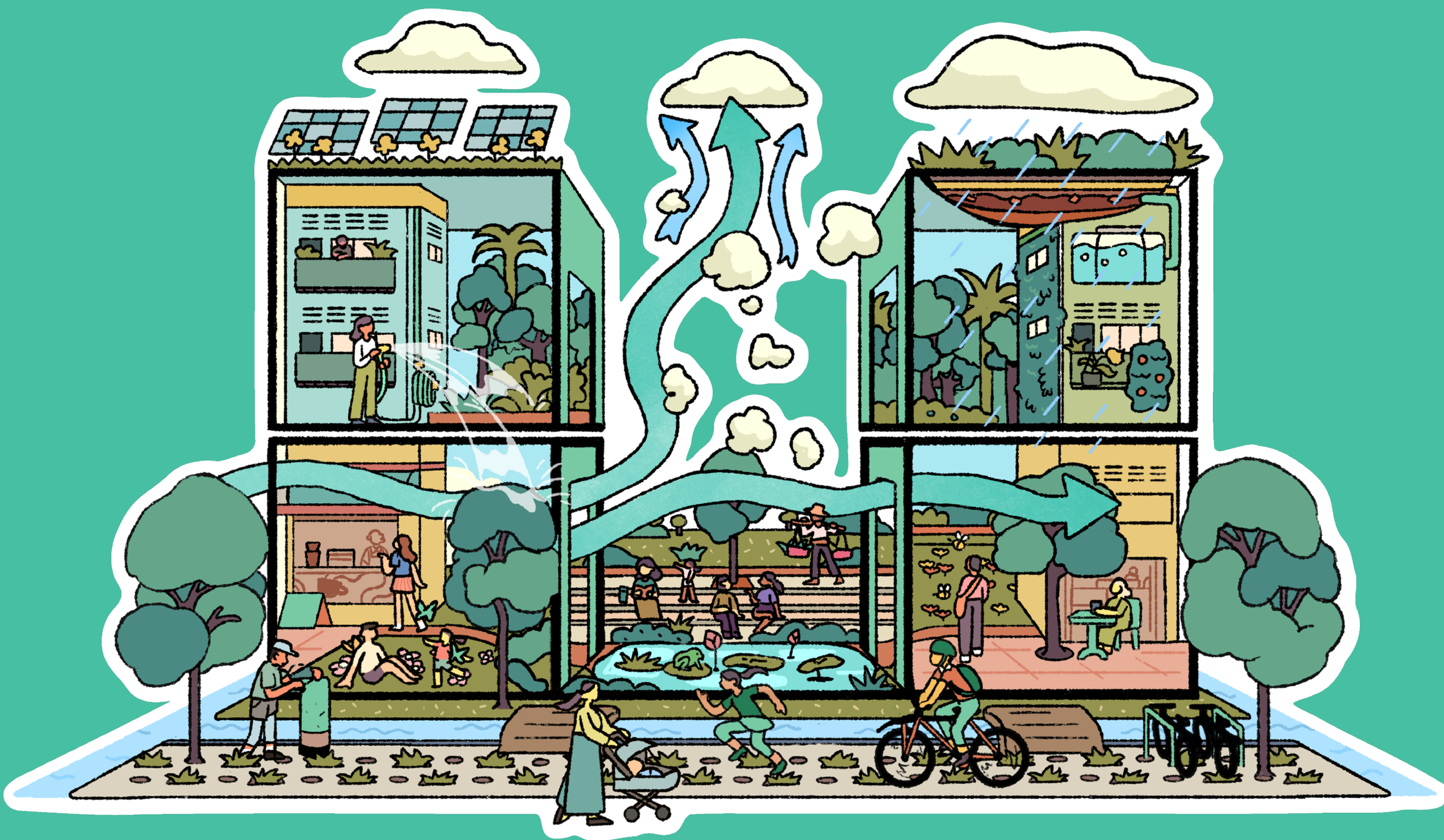

B4P TRANSFORMATION TOOLBOX

BLUE-GREEN INFRASTRUCTURE GUIDELINE

02.2

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Sustainable Development of Urban Regions

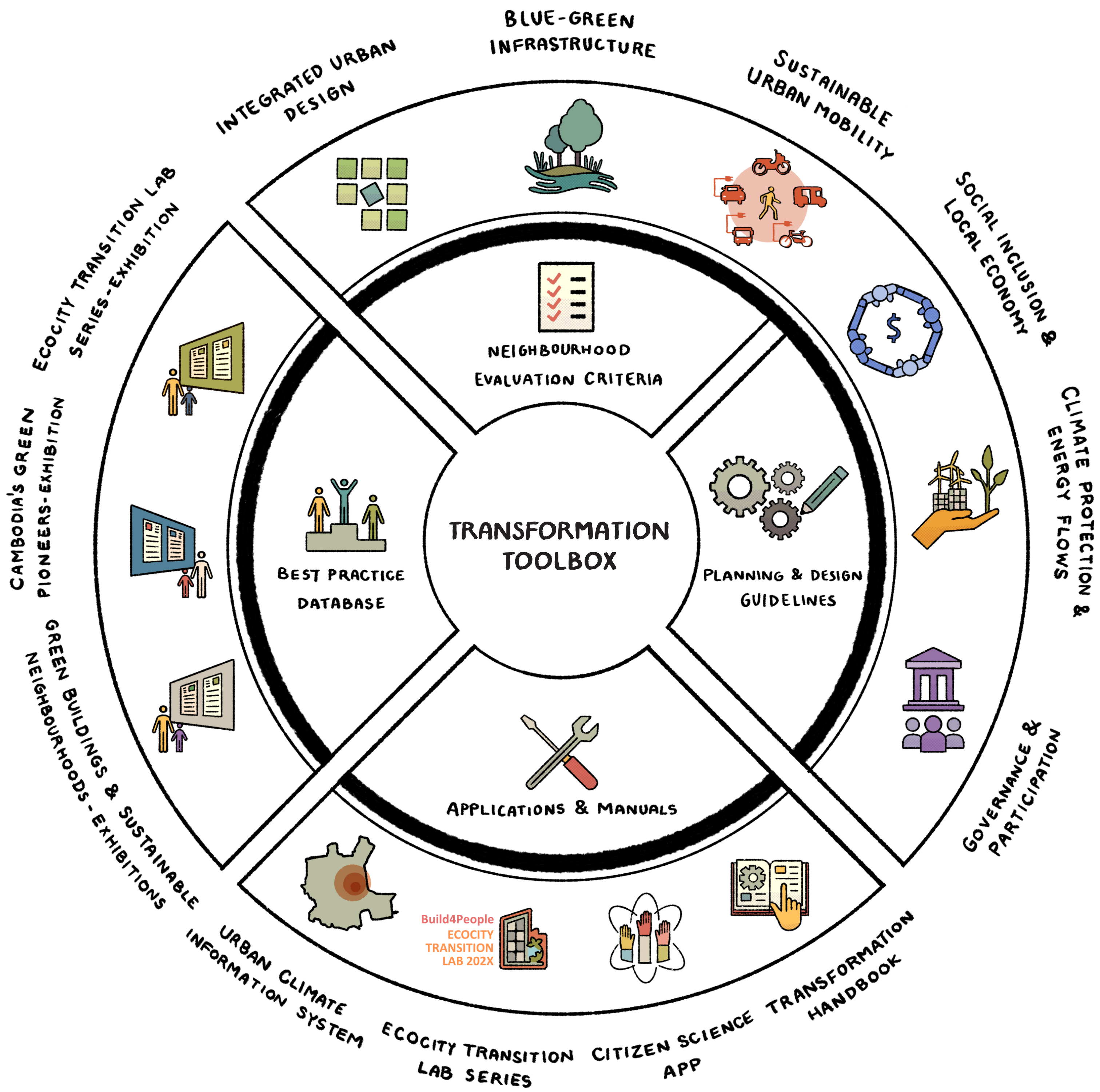

Figure 1. This guideline publication is part of the B4P Transformation Toolbox, a comprehensive learning platform developed by the Build4People project in cooperation with Phnom Penh City Hall to foster sustainable neighbourhood development in urban Cambodia.

02.2 BGI

BLUE-GREEN INFRASTRUCTURE

CONTENT

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Uddam Pen, Prosob Media, Phnom Penh.

02.2 BGI

BLUE-GREEN INFRASTRUCTURE

INTRODUCTION

Blue-Green Infrastructure (BGI) is an innovative approach to urban planning that integrates natural systems with built environments to create sustainable, resilient, and livable cities. BGI combines the principles of both green infrastructure and blue infrastructure, leveraging their synergies to address environmental challenges, enhance biodiversity, and improve urban living conditions. It aligns with the concept of Nature-based Solutions (NbS), which utilize natural processes to address societal challenges, including climate resilience and disaster risk reduction.

Green infrastructure refers to a network of natural and semi-natural areas, such as parks, gardens, green roofs, and street trees, which provide ecosystem services like air purification, temperature regulation, and recreational spaces. These elements are designed to mimic natural processes and contribute to a healthier, more sustainable urban environment.

Blue infrastructure, on the other hand, involves the management of water bodies and water-related systems, including rivers, lakes, wetlands, and stormwater management systems. It aims to manage water resources sustainably, reduce flood risks, and improve water quality. The synergy between green and blue infrastructures is crucial for creating resilient urban environments. When integrated, these systems enhance each other's benefits, leading to improved urban climate adaptation and mitigation strategies. As a Nature-based Solution, BGI optimizes these synergies by harnessing ecosystem functions to improve urban resilience.

Nature-based solutions play a critical role in addressing climate change by:

- Mitigating urban heat islands: Vegetation and water bodies cool urban areas through shade, evapotranspiration, and evaporative cooling, reducing the need for air conditioning and lowering energy consumption.
- Enhancing Carbon Sequestration: Green spaces capture and store carbon dioxide, helping to offset greenhouse gas emissions.
- Managing Stormwater: Blue infrastructure mitigates flooding by absorbing and slowly releasing stormwater, preventing overloads on drainage systems and reducing flood risks.
- Improving Air Quality: Vegetation filters pollutants and improves air quality, contributing to healthier urban environments.

Climate-sensitive design incorporates BGI principles to create adaptive and resilient urban spaces. This approach includes:

- Natural Ventilation: BGI supports the procurement of natural ventilation within cities. Strategically placed green spaces and water bodies enhance air circulation, reducing reliance on mechanical ventilation and improving indoor and outdoor air quality.
- Vegetation Cover: Extensive vegetation cover reduces thermal radiation and surface temperatures. Trees and plants provide shade, cool the air through evapotranspiration, and lower ambient temperatures, mitigating the urban heat island effect.
- Sustainable Materials: Incorporating natural materials that complement BGI can reduce heat accumulation and improve the overall thermal performance of urban areas.

This synergy between green and blue infrastructure aligns closely with Nature-based Solutions, as both approaches leverage ecosystem services to create climate-adaptive, healthier, and more sustainable urban environments.

Emerging countries like Cambodia can greatly benefit from adopting Blue-Green Infrastructure (BGI) to tackle immediate urban challenges like flooding and heat islands while enhancing long-term climate resilience. Drawing lessons from good-practice examples of integration of green spaces and advanced water management worldwide, Cambodia has the potential to improve urban livability, promote biodiversity, and manage stormwater more effectively. As an NbS-driven approach, BGI fosters sustainable growth, better public health, and greater adaptability to climate change impacts.

Figure 2. Proposal to integrate blue-green infrastructure on city-edge areas: Case study of the Chbar Ambov district, Phnom Penh, developed during the Build4People Ecocity Transition Lab 2020.

GUIDELINE 02.2

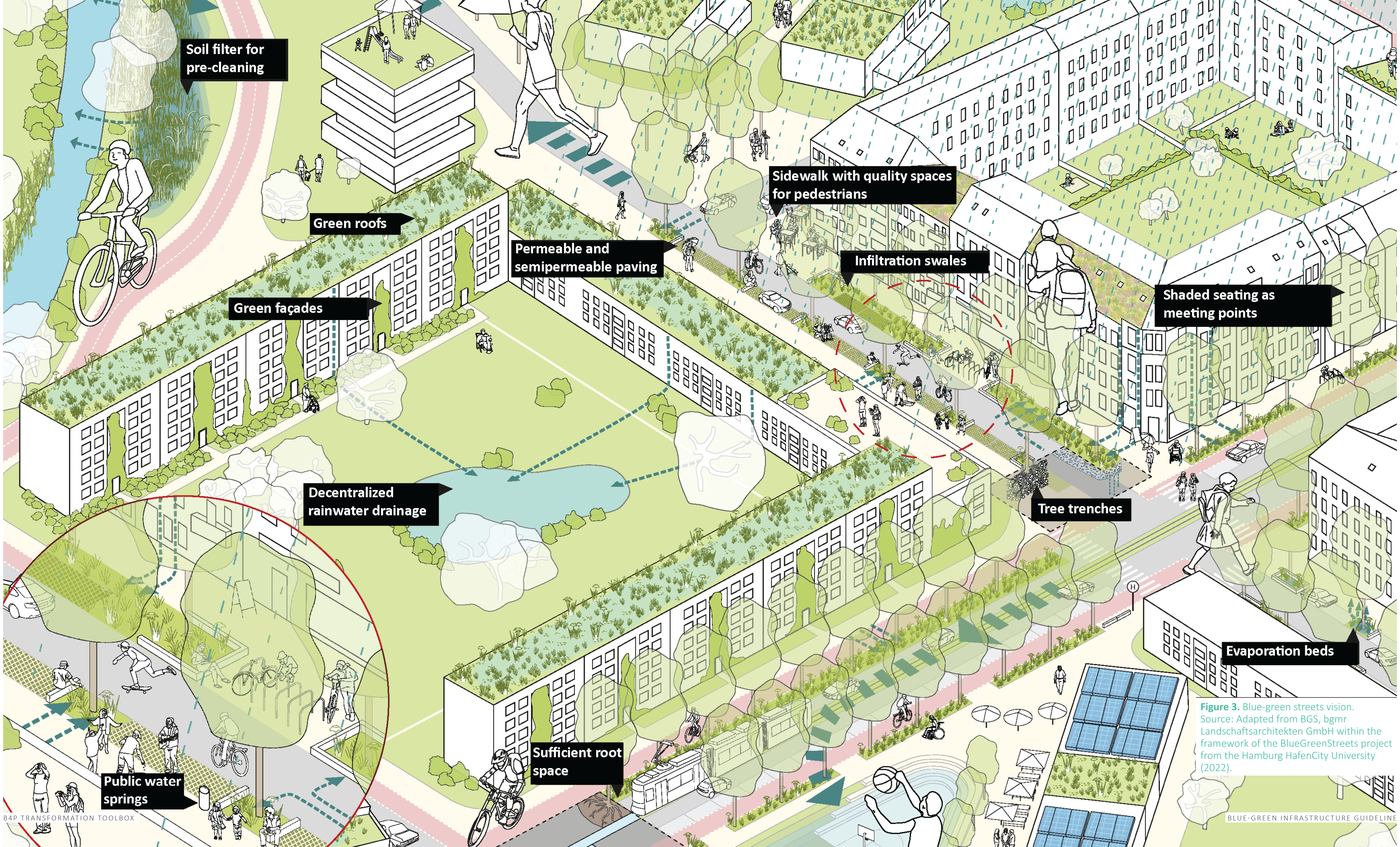


Figure 3. Blue-green streets vision. Source: Adapted from BGS, bgmr Landschaftsarchitekten GmbH within the framework of the BlueGreenStreets project from the Hamburg HafenCity University (2022).

NEIGHBOURHOOD BLUE-GREEN INFRASTRUCTURE

INTRODUCTION

Urban public green spaces are areas of land designated for communal use, predominantly featuring vegetation such as parks, gardens, and nature reserves. These spaces provide a range of benefits, including enhancing ecological balance, improving air quality, supporting biodiversity, and offering recreational opportunities for urban populations. Furthermore, they play a significant role in the social, economic, environmental, and aesthetic aspects of urban life, contributing to an improved quality of life for city residents.

Recognizing these benefits, the provision of urban green spaces is essential for fostering liveable cities and guiding urban development towards sustainability. Local authorities are encouraged to aim for a sufficient and reachable allocation of green spaces, exceeding minimum requirements wherever possible. This is imperative, as the most liveable cities in the world are often those that provide extensive green spaces for their populations. For example, Vienna, ranked as the most liveable city in Mercer's 2016 Quality of Living Survey, offers 120 square meters of urban green space per resident. Similarly, Singapore, the third densest city globally, provides 66 square meters per resident despite its high population density. Key is to pair the quantitative aspect of green space provision with qualitative aspects such as their accessibility and their capacity to offer leisure value.

The concept of urban green spaces evolves when integrated with water management systems to form blue-green infrastructure. This approach combines the ecological and social benefits of green spaces with sustainable water management strategies, such as storm water capture, flood mitigation, and groundwater recharge.

At the neighbourhood level, Nature-based Solutions as part of blue-green infrastructure emphasizes interconnected systems that blend vegetation with water features, creating multifunctional spaces capable of addressing urban environmental challenges while enhancing community resilience and well-being.

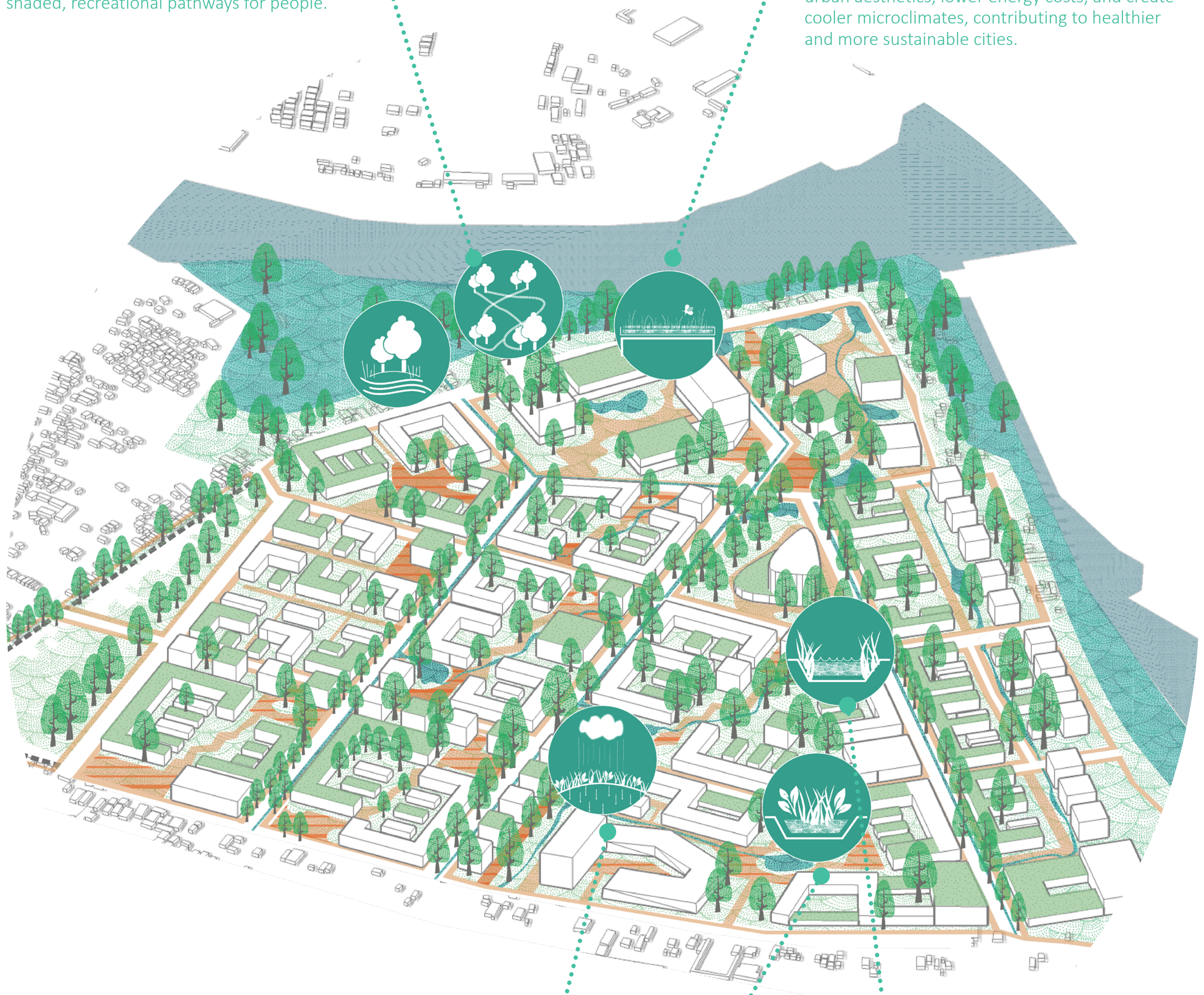


Figure 4. Proposal to integrate blue-green infrastructure solutions on neighbourhood level: Case study of the Chbar Ambov district, Phnom Penh, developed during the Build4People Ecocity Transition Lab 2023.

GUIDELINE 02.2

ECONOMIC, SOCIAL AND ENVIRONMENTAL BENEFITS

Phnom Penh's rapid urban spatial expansion went along with an enormous decrease of open and green spaces. With this area sealing, substantial water retention and infiltration surfaces got lost. This increased the city's vulnerability due to urban flooding, particularly in case of heavy rains that overload the existing inadequate drainage system. In this context the implementation of Nature-based Solutions offers an opportunity to combine urbanization needs with blue-green infrastructure.
The implementation of BGI in Phnom Penh represents a transformative opportunity for a rapidly growing city in a emerging country like Cambodia. As urbanization accelerates, the city faces increasing challenges such as flooding, rising temperatures, and limited access to green spaces. Integrating blue-green infrastructure would mark a significant shift towards sustainable urban development, offering a balanced approach that harmonizes growth with environmental preservation.

ECONOMIC BENEFITS FOR PRIVATE DEVELOPERS

- **Increased Property Value:** Increase attractiveness raises property demand and market value, resulting in higher returns on investment. Properties near well-maintained green infrastructure are more desirable, driving up prices.
- **Reduced Infrastructure Costs:** Green infrastructure naturally manages stormwater, reducing the need for costly traditional drainage systems like pipes, detention basins, and concrete channels. This can significantly lower construction and long-term operational costs.
- **Higher Market Appeal:** Eco-friendly developments stand out in competitive markets, appealing to environmentally conscious buyers, investors, and tenants. Projects that prioritize sustainability often attract premium buyers and increase occupancy rates.
- **Lower Maintenance Expenses:** Compared to traditional grey infrastructure, green infrastructure requires less long-term maintenance when designed with native plants and self-sustaining systems. This reduces ongoing maintenance and repair costs.

ECONOMIC BENEFITS FOR PUBLIC AUTORITIES

- **Cost-Effective Flood Management:** Water retention areas and green infrastructure reduce the frequency and severity of flooding by managing rainwater naturally. This minimizes costs related to flood damage, emergency response, and infrastructure repairs.
- **Public Health Savings:** Green spaces improve air quality, reduce urban heat, and provide recreational opportunities, which promote healthier lifestyles. This leads to lower healthcare costs and improved community well-being.
- **Economic Growth and Investment:** Functional, attractive green spaces enhance urban aesthetics, encouraging tourism, business investments, and increased local economic activity.
- **Climate Resilience:** By managing stormwater and reducing heat stress, green infrastructure lowers economic losses from extreme weather events, helping cities adapt to climate change cost-effectively.

ENVIRONMENTAL BENEFITS

- **Flood Risk Reduction:** Water retention areas slow rainwater flow, prevent flooding, and reduce downstream flood impacts. Trees and green infrastructure improve rainwater interception, lowering stormwater pressure on sewer systems.
- **Water Filtration:** Vegetation, gravel, and soil in retention areas filter contaminants from stormwater runoff, returning clean water to the environment.
- **Soil Protection:** Gradual water infiltration prevents soil desiccation, maintains moisture, and minimizes hard, impermeable soil formation.
- **Biodiversity Support:** Retention areas create habitats and ecological corridors with diverse plant species that sustain local ecosystems.
- **Carbon Sequestration:** Green infrastructure and retention areas capture and store carbon dioxide, improving air quality.
- **Heat Stress Reduction:** Water and vegetation cool urban areas through evapotranspiration, creating microclimates and mitigating the urban heat island effect.

SOCIAL BENEFITS

- **Enhancing Community Interaction:** These areas serve as spaces for social gatherings, strengthening community bonds. Green infrastructure improves urban aesthetics, creating attractive public spaces and enhancing urban identity.
- **Educational Opportunities:** Water retention areas promote community awareness of water management. When implemented in schools, they provide hands-on learning and play opportunities for children.
- **Improving Health and Recreation:** Green spaces, parks, playgrounds, and urban corridors integrated with water retention areas offer recreational opportunities, promoting physical and mental well-being. Multifunctional spaces support both wet and dry conditions while contributing to open-space development goals.

Source: Own compilation based on various sources.

SCIENTIFIC BACKGROUND AND KEY IDEAS

ECOSYSTEM SERVICES AND ITS RELATION TO BLUE-GREEN INFRASTRUCTURE

The integration of urban green spaces with blue-green infrastructure is particularly critical in regions like Southeast Asia, where wet seasons bring heavy rainfall and urban areas face rising temperatures. Blue-green infrastructure helps mitigate natural disasters, such as flooding, while delivering essential ecosystem services – the benefits that humans derive from natural systems.

A key benefit of green spaces is their cooling effect, which reduces urban heat through shading and evapotranspiration.

This creates more comfortable microclimates and counteracts the urban heat island effect (see also sub-chapter “Climate-Sensitive Urban Design” as part of this guideline). This is particularly important in densely populated cities, like Phnom Penh, where extreme temperatures can impact public health and overall liveability.

GREEN INFRASTRUCTURE: LANDSCAPE COMPOSITION AND CONFIGURATION

Blue-green infrastructure refers to a network of natural and semi-natural systems that combine water management (blue infrastructure) with green spaces with high ecological quality (green infrastructure) to enhance urban resilience. Green infrastructure in urban areas can be understood as a mosaic of spatial components (i.e. green spaces) that form specific structures or patterns described by two fundamental aspects: landscape composition and configuration (Gustafson, 1997; McGarigal and Marks, 1995). Landscape composition measure the presence and diversity element types within the urban landscape, without a reference to where in the landscape analysed classes are located (Turner and Gardner, 2015). Among land composition metrics are percentage of landscape occupied by a land cover class, i.e. tree covered, grass, shrubs; as well as the diversity and dominance of these classes. Landcape configuration is a complementary concept, measuring the spatial distribution of elements within the landscape considering the degree of connectivity and fragmentation as key landscape characteristic (Li J. et al., 2011).

BLUE INFRASTRUCTURE: FLOOD RISK MANAGEMENT

Stormwater management, a key component of blue-green infrastructure, involves using vegetation and permeable surfaces to absorb, filter, and redirect rainwater. This reduces the risk of urban flooding, replenishes groundwater, and minimizes strain on drainage systems during heavy rainfall. However, as climate change proceeds and weather events become more extreme, the need for diverting excess water increases. Essentially designed as shallow vegetated depressions, water retention areas are capable of filtering, diverting, intercepting, and altering runoff rate and volume, as well as cleansing the water of particulate pollutants. The effectiveness and treatment capacity of a water retention area are determined by soil quality, the type of vegetation used and the depth of the landform.

Multiple connected water retention applications, which form a hierarchical system throughout the city, can maximize the benefits and help to ameliorate urban inundation. These hybrid, blue-green elements enhance the urban landscape while reducing current climatic risks, particularly flooding. The Living with Water Principles illustrated in Figure 4 shows the delay-store-drain approach. This concept proceeds from the city’s water problems across the two precipitation seasons:

- Rainy season: Excess stormwater floods urban areas. Drainage is designed to get rid of water quickly.
- Dry season: Too little water. The over-extraction of potable water in the summer causes urban areas to subside- making them more flood-prone, and causing the groundwater level to drop, making it harder to obtain drinking water.

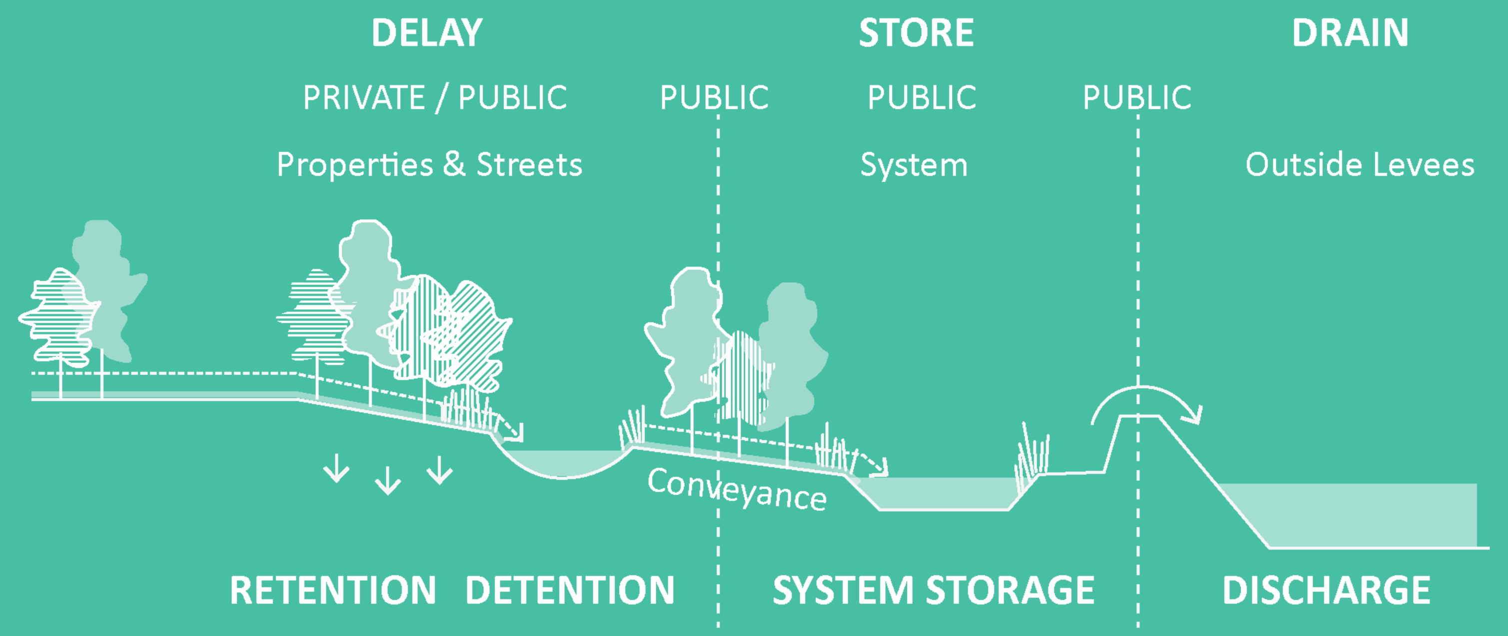


Figure 5. Living with water principles with delay-store-drain interventions. Source: OMGEVING cv and EMP, based on GIZ study

This delay-store-drain approach raises the sponge capacity of the city by replenishing its aquifers and preventing further subsidence. Water is held locally for greening, resulting in cooling through evapotranspiration. Therefore, it is an approach designed to deal with the complex challenges faced by urban areas.

Water retention systems can be in the form of permeable pavements, bioretention basins, bioswales and natural corridors. Each of these water retention areas can be seen as individual interventions, but they are complementary. They can be used for planning and implementation at multiple levels from neighbourhood to city and river basin scales.

SELECT TYPES OF WATER RETENTION AREAS

NATURAL CORRIDORS

According to Jack Ahern, one of the pioneers of the international green corridor movement, natural corridors are planned or unplanned linear landscape elements which enable numerous cultural, social, ecological, and other uses compatible with sustainable land use (Iberdrola, 2022).

These strips of trees, plants, or vegetation usually connect green spaces in a city, thereby establishing a green network of urban infrastructure.

A primary purpose of a green corridor is to link important natural areas in a city via a strip of rich vegetation. Thus, a kind of ‘skeleton’ is created, capable of shaping greener spaces in cities.

BIOSWALES

Bioswales are linear, shallow, vegetated drainage systems that retain and convey surface water. They collect stormwater from adjacent impervious surfaces, and simultaneously treat and infiltrate stormwater runoff following heavy downpours. Bioswales are the most effective green infrastructure at slowing down runoff rate and cleansing water while replenishing the underlying groundwater table (NACTO, 2013).

BIORETENTION BASINS / RAINGARDENS

Bioretention filters or rain gardens are rainwater control structures that absorb and filter water runoff. The stormwater is treated by running it through a shallow vegetated landscape, where pollutants are trapped. The refined runoff is subsequently harvested and delivered to the conveyance system, or exfiltrated into the surrounding soil if site circumstances allow.

- **Detention ponds** are regarded as a crucial flood control method whose purpose is to slow down water flow and hold it for a short amount of time, e.g., 24 hours. Then, they discharge the water into the sewer system. When it is not raining, they remain dry.
- **Retention ponds** are permanent bodies of water associated with vegetated edges. They differ from detention ponds in that they maintain a pool of water throughout the year, and they improve the water quality.

PERMEABLE SURFACES

With permeable pavements, rainwater can seep through the surface and into the underlying layers. Before infiltration into the earth, reuse or discharge to a drainage system, the water is temporarily stored. Permeable pavements can be divided into two types: porous pavements and permeable pavements, which are distinguished as follows:

- **Porous pavements** allow stormwater to flow full through them, e.g. gravel surfaces, pervious concrete, pervious asphalt, or reinforced grass.
- **Permeable pavements** are constructed with well-laid impervious blocks such as interlocking pavers, concrete grid pavers or plastic grid pavers which facilitate water flow between the voids.

Figure 6. Four types of water retention areas for urban application: permeable pavement, bioretention basin, bioswale and green corridor.
Source: OMGEVING cv, based on GIZ Implementation Guideline (2022).

FROM PUBLIC GREEN SPACES TO BLUE-GREEN INFRASTRUCTURE

EVALUATION CRITERIA

PUBLIC GREEN SPACE

PUBLIC GREEN SPACE

QUANTITATIVE CONSIDERATIONS

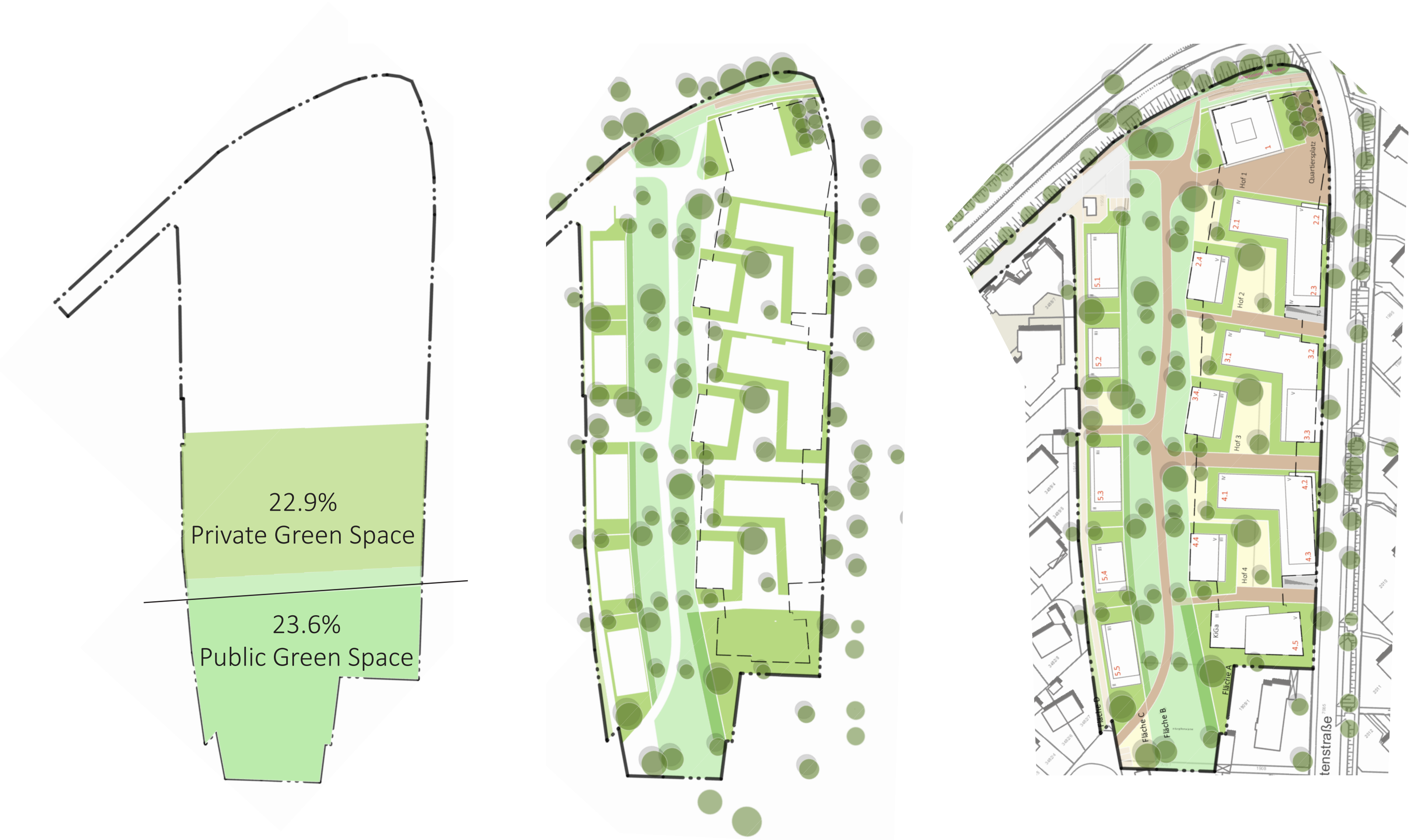
Planning green spaces is essential for urban well-being. They shall remain accessible and functional while supporting the city's green infrastructure. For the specific case of Phnom Penh, some initial considerations need to be taken:

- **Space Allocation Guidelines:**
  - » The definition of public green spaces integrates all those publicly accesible with trees and shrubs with a minimum area of 100m^2.
  - » ANUKRET 42 Sub-Decree (Art.45): Public green spaces shall cover at least 1ha per 1000 inhabitants or 15% GSA.
  - » ANUKRET 42 Sub-Decree (Art.33): In case of land use conversion, master plans must allocate 10% of the GSA for public and green spaces or 10m^2 per inhabitant.
  - » Practitioners Guidebook from UN-Habitat: Cities should provide at least 9 m² of accessible, safe, and functional green space per person (Butera, 2018).
- **Accessibility Standard:**
  - » Public spaces should be within a 750m radius to guarantee walkable access.

QUALITATIVE CONSIDERATIONS

Landscape composition and configuration influence green infrastructure's ability to deliver ecosystem services. When planning green spaces, consider these key recommendations:

- **Type of Green Cover (in order of preference):**
  1. Tree-covered areas
  2. Combination of tree and shrub-covered areas
  3. Grass-covered and permeable pavements for high-traffic zones
- **Coverage Targets:**
  - » Ensure at least 25% of green spaces are tree or shrub-covered.
  - » Cover 30% of the total GSA with grass and permeable pavements, consider public, semi-public and private green areas.
- **Balanced Distribution:**
  - » Prioritize multiple smaller green spaces (min.100 m²) evenly distributed rather than one large park (e.g., 1 ha).
- **Connectivity:**
  - » Plan green spaces close together or interconnect them through public, semi-public, or private green areas to create a continuous green network.



Total Development Area: 23,727 m²
Public Green Space: 5,610 m²
Private Green Space: 5,435 m²

Tree Covered Area: 3,334 m²
Permeable Pedestrian Area: 2,941 m²
Permeable Yards: 2,667m²

Tree Covered Area: 14.0% total area
30,1% total green spaces
Grass Covered Area: 32,5% total area

Permeable surfaces: 23.6% total area

Figure 7. Queck-Areal, Tuebingen, Germany, currently under construction. The neighbourhood planning proposal developed by Eble Messerschmidt Partner (EMP).

QUECK-AREAL

A GOOD PRACTICE EXAMPLE OF AN INTEGRATED NEIGHBOURHOOD PLANNING

Queck-areal is a neighborhood located at the Nordeast of Tuebingen, Germany, planned by Eble Messerschmidt Partner (EMP) (see Figure 6). The urban design was developed in collaboration with the Tübingen building authorities, Volksbau Tübingen, and the owners' association through planning workshops (2018–2019).

Public green space played a central role in the planning process. The open space design included a central public green zone with pathways, recreational and retention areas created along the old Neckar arm. The area is accessible for pedestrians and cyclists, with an extended green zone. Residential courtyards with 4- to 5-story buildings will open toward green space, while a kindergarten will anchor the Southwestern end. The city plans for 90% residential use, 10% commercial, and a daycare center. Furthermore, the district features underground parking, e-charging stations, and car sharing.

Further sustainability measures include KfW 40 energy-efficiency standards, photovoltaic systems, timber construction, and a connection to the local heating network.

BIOTOP AREA FACTOR TOOL

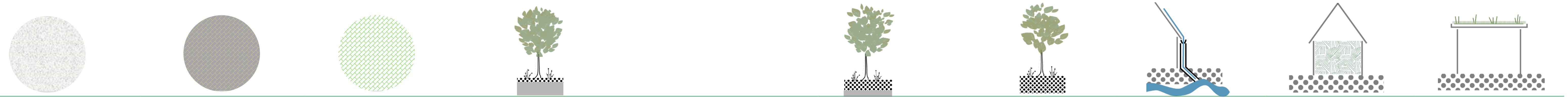
DESCRIPTION	Covering air- and water-impermeable, without plant growth	Surface permeable to air and water, generally no plant growth	Surface permeable to air and water, infiltration, vegetation	Vegetation areas without connection to existing soil	Vegetation areas without connection to existing soil	Vegetation connection to existing soil, available for the development of flora and fauna	Rainwater infiltration for the enrichment of groundwater, infiltration via vegetated areas	Greening of exterior walls and walls, the real height up to max. 10m is included	Extensive or intensive greening of roof surfaces
EXAMPLE	Concrete, asphalt, slabs with bonded substructure	Clinker bricks, mosaic paving, pavers with sand/ gravel substructure, water-bound surfaces, gravel surfaces, sand surfaces, grass paving, grass joint paving	Lawn gravel, wood paving	Surfaces on basement ceilings, underground garages	Surfaces on basement ceilings, underground garages				
									
AREA IN M²	**$100m^2$**	**$100m^2$**	**$100m^2$**	**$100m^2$**	**$100m^2$**	**$100m^2$**	**$100m^2$**	**$100m^2$**	**$100m^2$**
ECOLOGICAL QUALITY FACTOR	0.0	0.3	0.5	0.5	0.7	1.0	0.2	0.5	0.7
BIOTOP AREA FACTOR	**$0m^2$**	**$30m^2$**	**$50m^2$**	**$50m^2$**	**$70m^2$**	**$100m^2$**	**$20m^2$**	**$50m^2$**	**$70m^2$**

Table 1. Biotop Area Factor tool use by the German Sustainability Building Council (DGNB) to quantify the environmental qualities of vegetated and semivegetated surfaces. The table shows an example where there is $100m^2$ of each classified surface cover and the corresponding environmentally effective area for each case. To use this tool, calculate the area covered by each surface type and multiply it by the adequate biotop area factor.

EVALUATION CRITERIA

GREEN INFRASTRUCTURE

UNDERSTANDING
THE ECOLOGICAL QUALITY OF GREEN INFRASTRUCTURE

As mentioned in the previous section, lanscape cover types and the level of mixture included in a landscape design, i.e.landscape composition, play an important role on the effectivity of green spaces to provide ecosistem services. Bioswales, for example, bring more environmental benefits to the surrounding areas than porous pavements. A methodology used by the German Sustainable Building Council (DGNB) to evaluate the overall environmental quality of a vegetated area is the biotop area factor. In Table 3, the biotop area tool shows the different factors suggested by the DGNB, however these should be adapted to local conditions. For the evaluation, each vegetation sub-area is assigned a ecological quality factor between 0 and 1 according to its ecological quality (e.g. natural meadow = 1.0; park = 0.6; circulation area = 0). The corresponding surface are multiplied by its factor will give as a result the biotop area factor (BAF).
For example, if we consider:

Permeable Pavement with Vegetation: $100m^2$
Factor: 0.5
BAF= (sub-area) x factor
BAF_1: $100\ m^2 \times 0.5 = 50m^2$

Therefore, due to the 0.5 ecological quality factor, the permeable pavement surface correspond to $50m^2$ of environmentally effective area.
Now, if we consider:

Vegetated Area Connected with Existing Soil: $100m^2$
Factor: 1.0
BAF= (sub-area) x factor
BAF_2: $100m^2 \times 1.0 = 100m^2$

Thus, as the vegetated area that is connected with exiting soil has an ecological quality factor of 1.0, the total area would be considered as environmentally effective.
The total biotope area factor (tBAF) is calculated by dividing the individual BAFs in relation to the gross site area (GSA) of the district. For example; if the permeable pavement and vegetated area previously calculated where part of a new development, the biotop factor would be:

New development GSA: $1{,}000m^2$
BAF_1: $50m^2$
BAF_2: $100m^2$
tBAF: $(BAF_1+BAF_2+BAF_n)/\ GSA$
tBAF: $(50m^2+100m^2)/\ 1000m^2$
tBAF: $150m^2/1000m^2 = 0.15$

To bring a step further the green infrastructure network plan, the following recommendations should be considered:

- The total biotope area factor shall be $0.5 \leq tBAF \leq 0.1$
- Larger open green spaces ($500m^2$) adjacent to the district should be connected through the district (green infrastructure)
- All ecologically relevant open spaces within the district that are larger than $1{,}000\ m^2$ shall connected together through public, semi-public, or private green areas.
- Natural green corridors, bioswales and bioretention basins are excellent alternatives to combine blue and green infrastructure on a neighbourhood level.

GUIDELINE 02.2

EVALUATION CRITERIA

BLUE INFRASTRUCTURE

BLUE INFRASTRUCTURE
ON A NEIGHBOURHOOD LEVEL

Neighbourhoods are part of the natural water cycle and affect how water flows through river basins to the ocean. In cities like Phnom Penh, sealing surfaces (like roads and buildings) are a key factor that disrupts the water cycle and increases the risk of urban flooding, particularly in case of extreme weather events such as heavy rainfalls. Land use- such as surface sealing, altering natural topography, and building on floodplains - impacts how water is absorbed, how floods behave, and the quality of natural water resources.

At the neighbourhood scale, smaller implementation examples are:

1. Permeable pavements: Delay water runoff.
2. Bioswales: Guide and slow runoff along roads and pathways while allowing infiltration.
3. Natural corridors: Green streets and areas near infrastructure help slow stormwater and absorb it into the soil.
4. Small retention basins: Use bioretention filters, rain gardens, wetlands, and retention ponds to store excess water.
5. Resilient clusters: Combine multiple solutions to reduce pressure on city infrastructure while blending with urban design.

DESIGN RECOMMENDATIONS

Urban Function

- Suitable for residential, industrial, and commercial areas, as well as roads, parks, and parking lots.
- Integrate water retention facilities to manage stormwater effectively.

Urban density

- Use multifunctional water retention solutions, especially in dense urban areas.
- Combine various systems to manage runoff near the source and reduce the need for large storage sites:
  - » Bioretention filters / rain gardens
  - » Permeable pavements
  - » Bioretention tree pits

Scale

- On a neighbourhood scale, it is possible to create:
  - » Permeable pavements
  - » Bioretention filters in parks
  - » Bioswales and tree canopies along streets
- On a city level:
  - » Bioretention basins
  - » Natural corridors for large-scale water management

Incorporated into the urban landscape

- Combine water retention with infrastructure projects like sewer expansion, street renovation, and new stormwater drainage systems.
- Use natural corridors and green spaces to transform underutilized areas and enhance new urban developments.

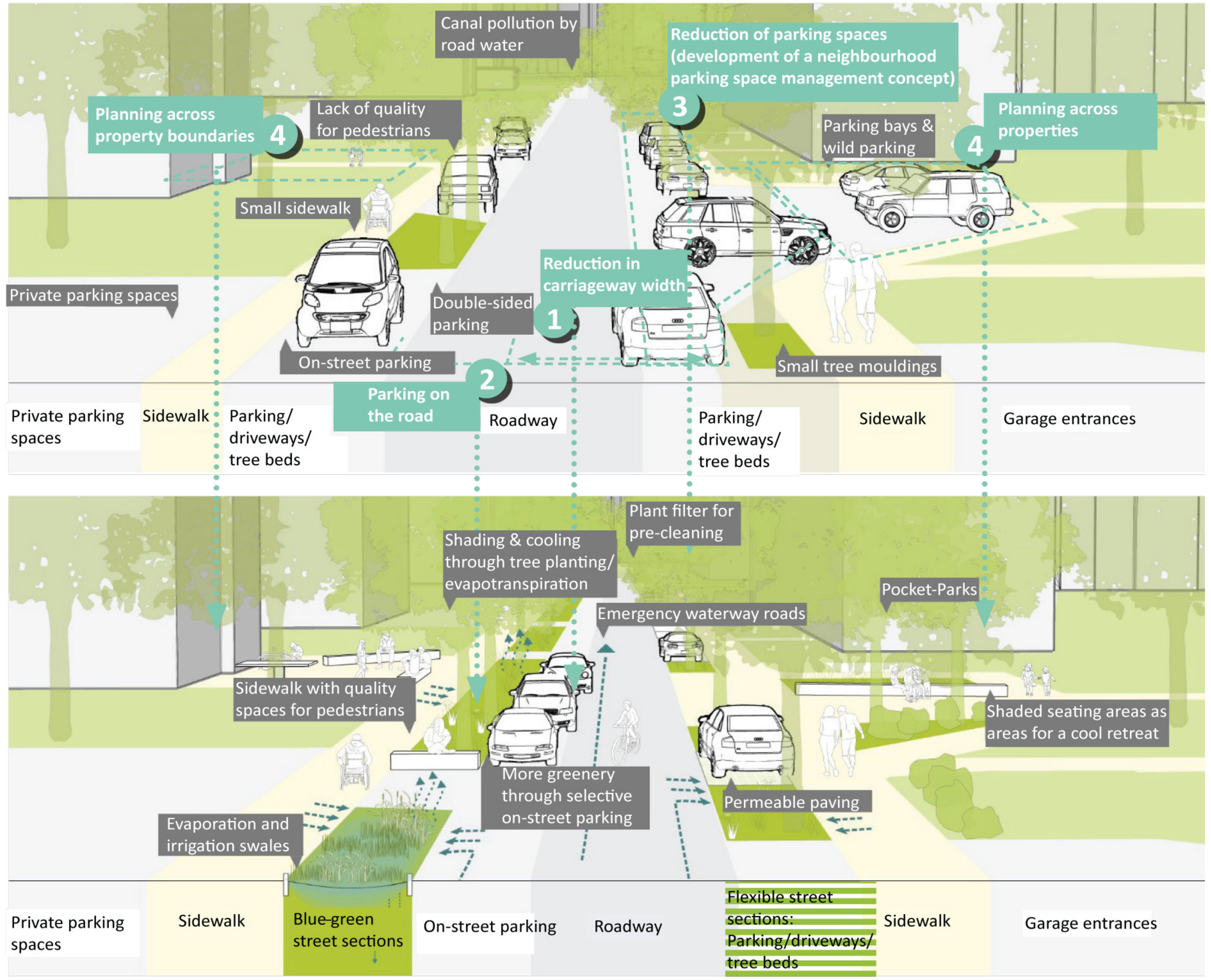


Figure 8. Combination of several strategies for land reallocation in the development of a new BGS cross-section in the pilot project Adolf-Reichwein-Straße, Bremen, above: Existing situation, below: BGS concept. Source: Adapted from BGS, bgmr Landschaftsarchitekten GmbH within the framework of the BlueGreenStreets project from the Hamburg HafenCity University (2022).

TECHNICAL RECOMMENDATIONS:

Slope And Stability

- Avoid unlined bioretention areas near landslide-prone zones, embankment slopes, or building foundations unless assessed by a geotechnical engineer.
- Ensure infiltrating water will not cause slope instability or damage foundations.
- Evaluate how ponding water affects soil strength and use slopes or collection systems to reduce risks.

Substrate

- Use loamy soil for infiltration and healthy plant growth. Add organic matter to improve soil quality.
- Apply a secondary filter layer (sand, gravel, or similar material) beneath the soil to enhance water absorption and purification.

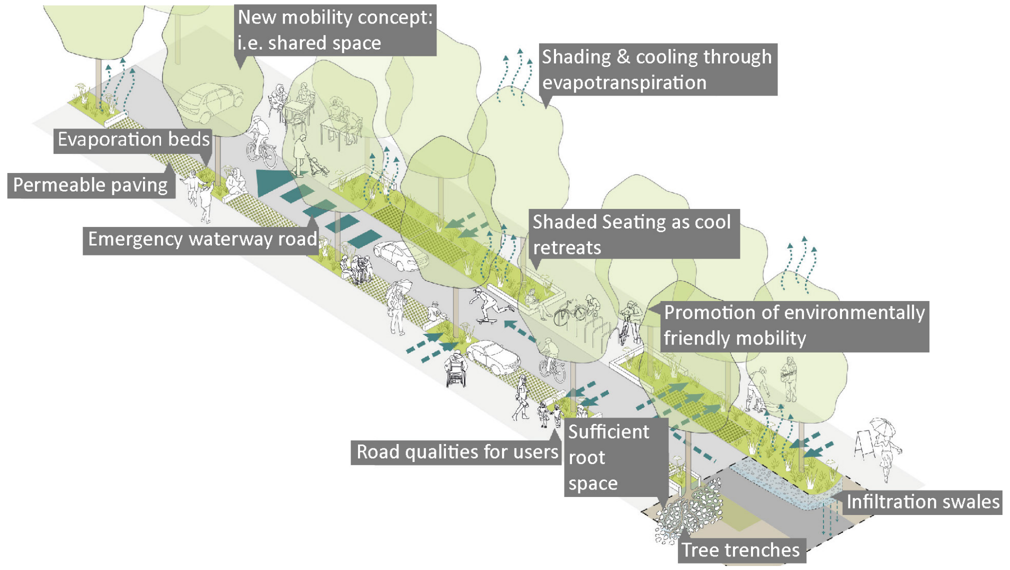


Figure 9. Blue-green, multi-coded street space.
Source: Adapted from BGS, bgmr Landschaftsarchitekten GmbH within the framework of the BlueGreenStreets project from the Hamburg HafenCity University (2022).

SPACE REQUIREMENT

- Permeable pavements: Replace impermeable surfaces without needing additional space. Ideal for roads and urban areas.
- Bioretention filters: Require 5–10% of the site area. Can be integrated into site landscaping for multi-functional use.
- Detention/retention ponds: Typically occupy 3–7% of the upstream catchment. Suitable for larger spaces.
- Bioswales: Need significant land due to shallow side-slopes, making them harder to fit into dense urban areas.
- Natural corridors: Ensure enough space for tree roots (minimum 1.5 m depth and width). Consider slope and vegetation density for proper design.

VEGETATION

- Choose native floodplain plants that tolerate varying soil saturation and flooding.
- Use trees and shrubs that can withstand urban stresses like pollution, ground vibration, and extreme conditions.
- Regularly prune trees to ensure safety near roads, buildings, and pedestrian areas.
- Prioritize plants that offer additional benefits:
  - » Environmental: Maximize carbon sequestration and heat reduction.
  - » Biodiversity: Provide habitat or food for wildlife.
  - » Aesthetic: Enhance the landscape's visual appeal.

CONNECTION TO EXISTING DRAINAGE SYSTEMS

- Overflow Systems: Connect water retention areas to sewer systems with overflow outlets or underdrains.
- Unstable Soil Areas: Use perforated pipes at the base to prevent water built-up and redirect excess rainwater to the drainage network.
- Low-Permeability or Sensitive Areas: Use non-infiltration systems to protect groundwater and collect water for reuse. Filtered water is directed through perforated pipes into the main drainage system, with an impervious membrane protecting the subgrade.

ASSESSING THE SITE

Planning a water retention project requires a thorough site assessment of the local climatic-geographical conditions to inform the optimum design and installation requirements.
A comprehensive site assessment examines the following elements:

Floodplain

- Carefully choose and design floodplain water retention facilities, considering the high groundwater table and potential erosion risks.
- Minimize grading and surface features that may be eroded during floods.
- Distribute surface water discharge evenly across the area. Ensure retention areas are designed to drain gradually within 48 hours after rainfall.
- Consider runoff from nearby properties and avoid obstructing natural runoff routes with buildings.
- Identify if the site is upstream or downstream of flood-prone areas early in the design process, as this affects water retention area criteria.

Groundwater

- The depth of the water table beneath the ground must be determined. High groundwater levels might cause flooding or damage to deep water retention structures. In this case, limiting infiltration is recommended by using liners.

Soils and Geology

- It is important to first understand the geology of the site, as a permeable layer may exist beneath shallow impermeable strata, allowing infiltration to occur at a greater depth.
- Where soil is poorly permeable, the water retention area should promote attenuation and water treatment above ground or adjacent to the surface.
- In particular regarding permeable pavements installed above
- impermeable soil, all water passed through the sub-base should be carried by an outlet pipe into the main drainage system to mitigate flooding on the pathway.

Run-Off Characteristic

- Designing water retention areas in industrial areas requires careful management to make sure that polluted water is well treated, isolated from the other clean water runoff, and does not infiltrate the underground water.
- A system with a liner and spill isolation is recommended. In addition, a series of different water retention types should be implemented to guarantee that water is subjected to a range of filtration systems and that flow is mitigated to allow pollutants to settle out.

Contaminated Soil

- Concerning contaminated soil areas, the water retention system should incorporate a liner to restrict water flow to the surface. This results in zero infiltration which help to avoid the transmission of impurities into the deeper soils and protects the vulnerable aquifers beneath.

Topography

- On flat land, managing surface runoff is harder than on sloped land, as gravity cannot help move the water.
- To manage runoff on flat land, keep water on the surface and manage it close to its source. For example:
  >> Use roadside kerbs or bioswales to channel water along the surface.
  >> Pumping should only be used as a last resort.
- On steep slopes, runoff moves faster, so extra care is needed when designing water retention areas.
- Avoid using infiltration methods on very steep slopes, as they may compromise slope stability.
- On steeper slopes:
  >> Use check dams or staged storage to slow down runoff.
  >> Design the site with platforms, like switchback roads, to manage runoff.
- Consider using terraced patterns for bioretention or wetland areas.

Existing Infrastructure

- Existing infrastructure should be evaluated when installing water retention areas on brownfield or pre-developed sites to provide the optimal solution.
- It is necessary to know the position and capacity of current the drainage system. Other subterranean infrastructure, such as utilities, have to be identified and taken into account when designing and implementing water retention facilities.

Protected Species and Habitat

- In developed places, water retention areas with their vegetation and water surface can help boost biodiversity and improve ecology.
- Nonetheless, their design should take current ecological circumstances into account.
- Preliminary site analysis should identify areas of interest, such as nature preserves, protected species habitats, and locally significant ecosystems.
- These areas should be protected or enhanced by water retention areas through smart integration and careful long-term planning to ensure that the habitat is not destroyed during maintenance.

SELECTION MATRIX FOR SITE CONDITIONS

		Permeable pavements	Bioretention basins	Bioswales	Natural corridor
Floodplains	Located in the flood plain?	•	x	•	•
Groundwater	Groundwater less than 3 mtrs below the ground surface?	• With liner and underdrain (no treatment)	• With liner	• With liner	•
Topography	Sited on a flat site (<5% gradient)?	• Source control	• Try to keep flows above ground	• Careful provide some gradient	•
	Sited on a steep slope (5-15% gradient)?	• If terraced	x	• If installed along contour	•
	Sited on a very steep slope (>15% gradiente)?	x	x	x	•
Soils and geology	Impermeable soil type (e.g. clay based type)?	• With underdrain (no treatment)	•	•	•
Contaminated land	Are there contaminated soils on site?	• With underdrain (no treatment)	• With liner	• With liner	•
Existing infrastructure	Are there underground utilities in the area?	• If possible relocate into a marked corridor for future maintenance	x	x	•
Run-off characteristics	Suitable for inclusion in high-risk contamination areas?	• With liner and spill isolation	x	• With liner and spill isolation	•
Protected species or habitat	Proximity to designated sites and priority habitats?	•	• If designed and maintained appropiately	•	•
Ownership and maintenance	Can the feature be designed for adoption?	Depending on design anf local adoption policies			

Legend:
x Unsuitable • Suitable

Table 2. Selection Matrix for Site Conditions.
Source: Aecom (2003).

OWNERSHIP AND MAINTENANCE

At the beginning of the project, detailed consultation should be carried out with the adopting stakeholders to guarantee that water retention areas are developed according to the criteria of the adopting authority. The adopter could be a municipal government, a roads authority, a property owner, or a water company, depending on the local requirements and circumstances.

When acceptance is unknown, it is best to build for flexibility with simple and minimal maintenance solutions. Table 3 provides a decision matrix to assist in choosing the most effective solution.

GUIDELINE 02.2

IMPLEMENTATION
OF WATER RETENTION AREAS

PRACTICAL RECOMMENDATIONS FOR NATURAL CORRIDORS

Natural corridors (trees and hedges) are planted to serve as a second line of flood defense to existing levees. The area between an existing levee on the riverbank and the new barriers creates recreational land during dry periods and serves to mitigate surface water flow during times of heavy rain. Regarding the implementation of tree corridors alongside urban roads, one should consider the integration of the existing underground technical infrastructure. The trees should be indigenous to the area and should also require minimal maintenance. Careful consideration of the invasiveness of the root systems of any trees (into existing subterranean infrastructure) should also be given.

1 *Digging the Hole*

Planting trees and shrubs too deeply is the most common cause of their death. Follow these steps to plant at the correct depth:

1. Locate the trunk flare, where the trunk meets the roots.
2. Gently remove any rope, burlap, or soil covering it.
3. Measure the distance from the bottom of the root mass to the trunk flare.
4. The root mass should rest on undisturbed soil — avoid digging too deep.
5. Position the trunk flare slightly above the surrounding soil level when finished.
6. Dig a hole 2-3 times wider than the root ball, sloping the sides outward to meet the soil grade.

4 *Backfilling and Watering The Planting Hole*

1. Backfill the hole halfway up the root ball, gently tamping the soil to remove air pockets.
2. Ensure the trunk is vertical and the trunk flare is slightly above the soil grade.
3. Finish backfilling to the top of the root ball without covering the trunk flare.
4. Build a 7–10 cm ridge around the hole to create a basin for water.
5. Fill the basin with water and let it soak in, or run a slow trickle for 15–30 minutes to evenly moisten the root zone and eliminate air pockets.
6. Ensure the trunk flare remains exposed.

2 *Backfill*

The approach to backfilling has changed in recent years.

1. Instead of adding compost or other amendments, it's now recommended to use the existing soil to encourage roots to grow into the surrounding area.
2. Adding mycorrhizal fungi is beneficial, as it helps roots absorb water and nutrients, improving stress tolerance and adaptation. Bone meal can also support root growth with its nutrient content.

3 *Planting*

1. When placing the plant in the planting hole, try not to disrupt the root ball.
2. Use the rope, burlap, or wire cage on the root ball to lift B&B trees and plants.
3. Lift potted plants by gripping thecontainer. Plants should not be lifted by their trunks, stems, or branches.
4. Allowing the root system to dry out before or during planting is not recommended.

5 *Mulching, Staking & Fertilizing*

1. Apply 5–8 cm of bark mulch over the planting hole, keeping it away from the trunk to prevent contact. Mulch helps conserve water and control weeds.
2. Staking isn't always needed; consider root-ball stability, trunk strength, wind, and canopy size. If unsure, consult a nursery expert.
3. Avoid fertilizing newly planted trees and shrubs during their first year.

6 *Watering*

1. Moisture is essential for the survival of a young tree or shrub.
2. The roots should never be allowed to dry out completely or to become saturated with water. To determine soil moisture, dig a 5–10 cm hole just outside the plant root mass and water if the soil is dry.
3. For the first two weeks, inspect and water newly planted shrubs and trees every other day. If less than 2.5cm of rain occurs throughout the week after the first two weeks, limit watering to once a week. Thorough drenching that moistens the soil to the full depth of the root mass is preferable to frequent light waterings.

Azadirachta indica (Neem Tree / Nim Tree)

Dalbergia cochinchinensis (Thailand Rosewood)

Delonix regia (Poinciana / phoenix flower)

Dipterocarpus alatus (Yang na / Sino-Tibetan)

Figure 10. Examples of indigenous Cambodian trees.
Source: Suto (2022), ERECON, Institute of Environmental Rehabilitation and Conservation.

PRACTICAL RECOMMENDATIONS FOR BIOSWALES

Bioswale systems are generally preferred in areas with permeable ground and relatively low groundwater levels. The only construction they require is the digging of a linear depression with slanted walls. Parabolic or trapezoidal shapes are recommended with side slopes no steeper than 3:1.

1 *Bioswale Location*

1. A bioswale should be at least 3m away from homes, offices or any other buildings.
2. The bioswale should be located on a low point with at least a 1% grade slope from the pavement, parking lot or roof leading from the green space or building.

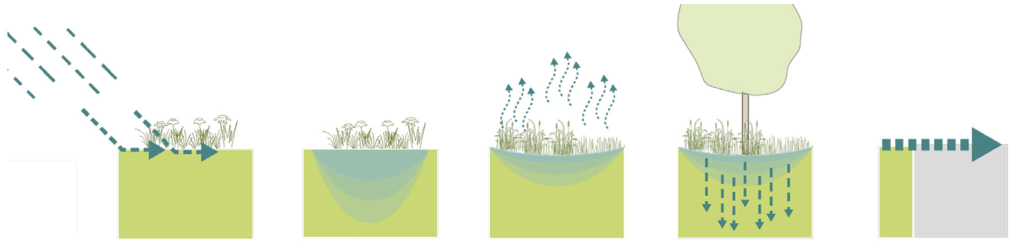
2 *Determine the Dimensions of the Bioswale*

1. Determining the size is one of the most important steps in creating a bioswale.
2. It is recommended to calculate the water ratio, volumes, etc., to properly determine the size of the bioswale.

3 *Dig and Prepare the Base Condition*

1. After determining the size and location, construction can start by removing some soil.
2. This will allow the bioswale to collect the rain, which will feed the plants and ultimately limit pollution, etc.
3. If there is a downspout nearby, it must drain into the bioswale. This might make it necessary to dig a small trench to direct its flow into the swale.
4. The bottom of each bioswale is filled with coarse gravel, which facilitates rapid infiltration. The gravel and gabion (a metal cage which serves as a conduit to the gravel layer below), are then wrapped in a permeable geotextile fabric. This fabric allows water to pass through but prevents dirt and sediment from clogging the pore space below.

Figure 11. The BGS Cascade: 1) Retention, 2) Utilization, 3) Evaporation, 4) Infiltration, 5) Drainage.
Source: Adapted from BGS, bgmr Landschaftsarchitekten GmbH within the framework of the BlueGreenStreets project from the Hamburg HafenCity University (2022).



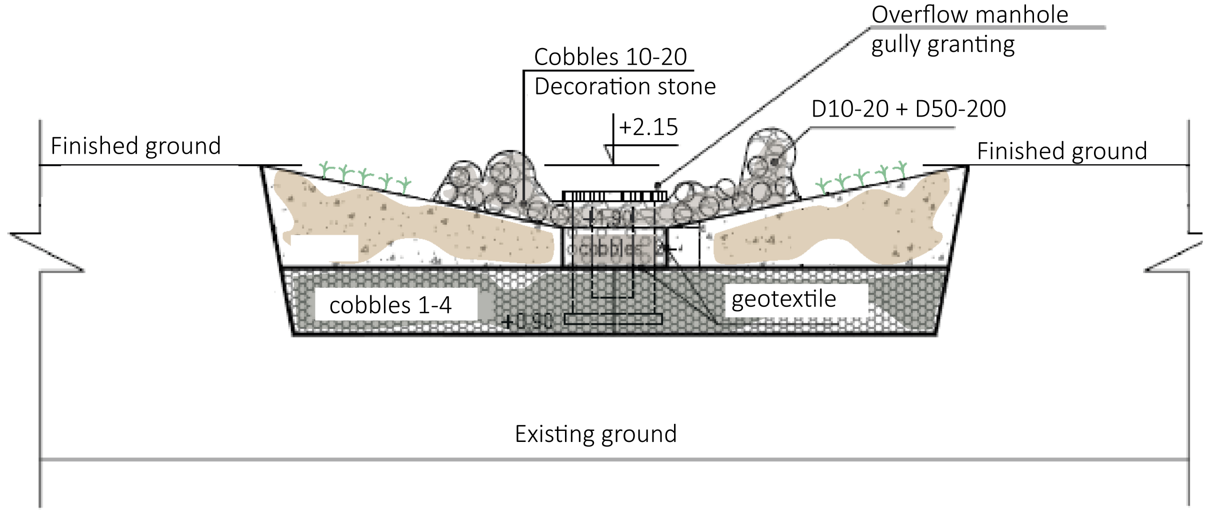
4 *Select Plant Materials*

1. The requirements of this stage will vary from one place to the next.
2. Promoting native plants over invasive species helps to regenerate the natural environment.
3. Before choosing plants, research is needed to ensure that the landscape is repopulated with indigenous plants.
4. To safeguard the area, a typical plant mix comprises sedges, grasses, and trees. Sedges and grasses should be employed along the margins of the bioswale to secure the banks, while "pollution eaters" can be planted in the center, where the water collects.

5 *Secure the Site*

1. Jute netting, native wildflowers, and grass seeds are needed to secure the site. After the planting is done, use jute netting around the bioswale edges to protect the area from erosion. The jute will mitigate erosion and preserve the site's natural slope. Using staples, secure the netting to create a solid foundation.
2. After the netting is in place, scatter indigenous wildflower and grass seeds over the area. This promotes native plant growth and helps to restrict the germination of invasive grasses and other weeds.

Figure 12. Bioswale cross-section. A bioswale is divided into four different layers:
1. The top layer of a bioswale is made up of densely packed vegetation that provides a large surface area for stormwater contact. The swale can filter pollutants better if the grasses are thicker and heavier. Plants with excellent nutrient-absorbing capabilities (ideally native plants) are selected and planted.
2. Underneath the vegetation, an absorbent layer of sand is laid down. It induces the colloids in murky water to aggregate into bigger clumps, making them easier to remove.
3. A layer of gravel, scoria, or baked clay pellets is encased in geotextile beneath that layer. Large voids in these materials allow rainfall to drain away. To keep the layer from becoming blocked by sludge or roots, it is wrapped in geotextile.
4. Below the second layer, there is a perforated drainage pipe. Overflows connected directly to this are added to prevent a bioswale from overflowing its banks during heavy downpours.
Source: Redrawn by OMGEVING cv based on Jusic et al. (2020).



PRACTICAL RECOMMENDATIONS FOR BIORETENTION BASINS

The installation of a bioretention basin is another solution. In Cambodia, there are various plants that can be used in a retention basin, which can green the landscape and filter the water at the same time.

1 *During Construction*

Avoid excessively compacting soil around the water retention area and accumulating silt around the drainage field. To minimize sediment loading in the treatment area, direct runoff to the water retention area only from areas that are stabilized; always divert construction runoff elsewhere.

2 *Backfilled*

Soil is typically backfilled in layers or 'lifts'. The type of lift will depend upon the nature of the backfill and the compaction equipment that is used. Place water retention soil media in 1-foot to 2-foot lifts and compact with minimal pressure until the desired elevation is reached. Some engineers suggest flooding the soil between each lift placement in lieu of compaction.

3 *Vegetated Soil Lifts*

A vegetated soil lift consists of wrapping 'lifts' of soil in geotextile fabric to form an edge for the stream. Willow stakes can be planted between the 'lifts' and through the top of them. Benefits of vegetated soil lifts include:

- Streambank stability
- Riparian habitat
- Aquatic habitat improvement

Figure 13. A good-practice example of blue-green infrastructure implementation is the recent construction of the Phu Xuan wetland park as soft adaptation measure in a suburban district of Ho Chi Minh City, Vietnam, characterized through many natural rivers and canals. The park was designed to preserve the existing 4.600-square-meter water coconut tree area and even to extend it by approximately 3,000 square meters of green fields and trees. Besides its function to store temporarily rainwater, Phu Xuan Park provides attractive spaces for leisure activities. In this way the park is following the sponge city concept. As a Nature-based Solution it further serves as a demonstration project for soft climate change adaption in Ho Chi Minh City, Vietnam, and the region.
Source: Waibel et al., (2024).

4 *Off-Line / On-Line*

In very permeable soils, water retention areas can be designed as "off-line" treatment structures (no overflow necessary). However, in most circumstances, they are designed as an "on-line" component of a stormwater management system. Ideally, overflow outlets should be located as far as possible from runoff inlets to maximize storage time and treatment within the water retention area. In general, water retention areas should be designed to drain within 72 hours.

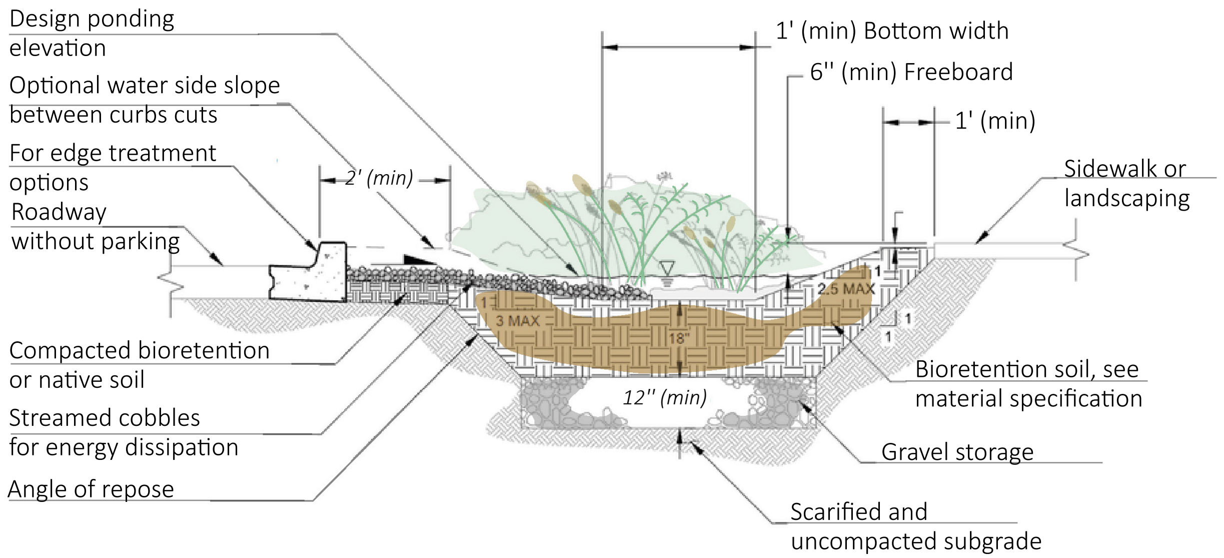
5 *Planting*

The technique of purifying water by growing grass on floating rafts is becoming increasingly popular. The roots of some species, such as water hyacinth, water spinach or other species of reed planted in floating tubs have the ability to decompose and absorb excess nutrients to prevent the growth of algae and the development of unpleasant odours. These roots can also trap and sequester black mud particles and heavy metals, which then sink to the bottom of the basin, thereby clarifying the water. Finally, they can replenish oxygen, restoring the natural balance of the system.

Figure 14. Bioretention basin cross-section (GSI city details and specifications). Water retention areas are typically designed in layers as follows (from the bottom of the excavation to the surface):

- Impermeable liner (optional)
- Gravel layer (approx.30 cm) with optional underdrain
- Pea stone layer (approx. 35 cm)
- Water retention soil media composed of 40% sand, 20- 30% topsoil, 30- 40% compost (between 60- 120 cm)
- Fine-shredded hardwood mulch (approx. 7 cm)
- Ponding depth (varies with site conditions; usually between 15-22cm)
- The planting plan typically includes herbaceous perennials and shrubs which can tolerate frequent ponding, saline conditions, and extended dry periods.

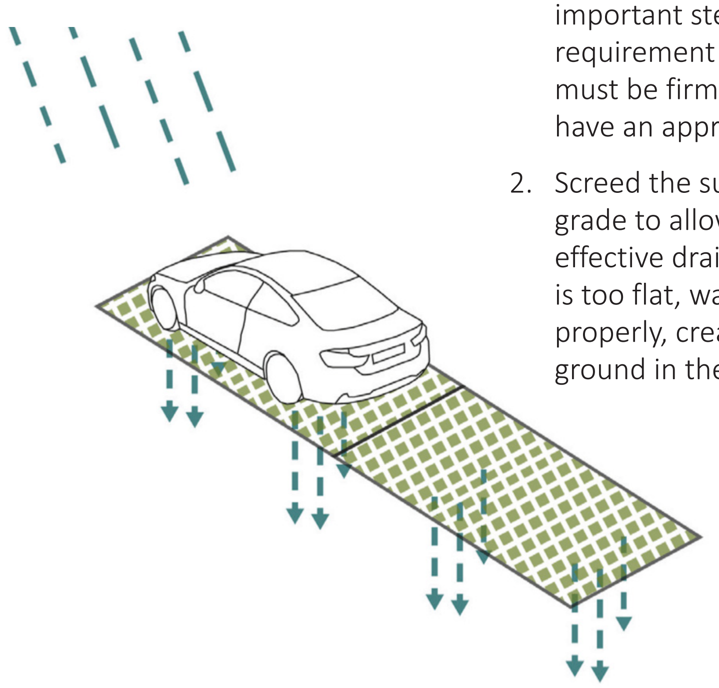
Source: Redrawn by OMGEVING cv based on Lotus Water (n.d.)



PRACTICAL RECOMMENDATIONS FOR PERMEABLE PAVEMENTS

In general, there are many types of porous materials suitable for pavement construction. In Cambodia, permeable asphalt and permeable concrete are quite new measures, still under experimentation and testing. The appropriate existing technology is the permeable interlocking block, which may allow for easier replication and maintenance in the local context. Thus, this section will focus on the implementation of this popular material-grass block pavers.

Figure 15. Water-permeable floor coverings / paving.
Source: Adapted from BGS, bgmr Landschaftsarchitekten GmbH within the framework of the BlueGreenStreets project from the Hamburg HafenCity University (2022).



1 *Prepare the Ground For Grass Block Pavers*

1. This is the first and most important step in paving. The requirement is that the ground must be firm, well compacted and have an appropriate slope.
2. Screed the substrate to a specific grade to allow for the most effective drainage. If the ground is too flat, water will not drain properly, creating soft, muddy ground in the area.

2 *Sketch the Outline of the Foundations for Bricklaying*

1. Geodetic survey, measuring poles, tensioning lines, or marking with lime from the outermost boundary of the paved area.
2. In the case of a pre-existing pavement, the existing boundary can be used.
3. If building a completely new pavement, define an outline for the pavement
4. Paint, spray on the ground can be used along the intended pavement.

5 *Laying the Grass Block Pavers*

1. Prepare the base of the pavement first, then start construction
2. Start laying the pavers in the middle and continue to pave up to the boundaries of the pavement
3. This will make the construction process simple, aesthetic and less labour-intensive.
4. However, it is necessary to use a brick cutter to cut the bricks to fit the required area.
5. Set aside the required uncut pavers for the boundaries.
6. They should only be cut when the main part of the pavement has been laid with intact pavers.

3 *Clean Up, Remove Weeds, and Install the Drainage*

When preparing the ground for a new pavement or for paving a parking lot, it is necessary to:

1. Remove weeds and install drainage pipes to drain underground water
2. These pipes should be installed at least 3-5 cm above the ground and run on a slope.

4 *Spread Crushed Stone to Avoid Future Subsidence*

1. Cover the base with a layer of crushed stone, spread it on the surface to a thickness of 5-10 cm
2. Use a compactor or roller to compact the crushed stone to create a solid pavement bed
3. During the process of planting the lawn, add 1-2 cm of sand and water evenly
4. Use a trowel or screed to create a flat surface, and place bricks near the area to be paved

6 *Spread Soil Into the Holes and Plant Grass*

1. Once pavers have been laid, spread a layer of soil on the surface of the pavement and gently rake the soil into the voids of the pavers
2. Add some additional soil and sand and sprinkle grass seeds on the surface
3. Water the seeds and continue to water regularly until they have germinated
4. Suitable grass species include:
   » Cynodon dactylon (Bermuda)
   » Zoysia japonica
   » Axonopus compressus
   » Bermuda Princess 77
5. Use of these species increases germination rates and save on monthly pruning and care costs.

Figure 16. Example of the application of permeable pavement in a parking area in urban Cambodia.
Source: Tep Makathy (2025).

GUIDELINE 02.2

APPLICATION EXAMPLE WITHIN AN URBAN CONTEXT

Blue-green infrastructure should integrate with streets, parking lots, sidewalks, and bike lanes. Careful planning ensures a balanced, sustainable urban environment that supports functionality, aesthetics, and community wellbeing while enhancing environmental quality at the neighborhood level.

A good practice example is the BlueGreenStreets project by HafenCity Universität Hamburg developped planning tools for green urban infrastructure, water management, and sustainable street design. The team tested various solutions in Berlin, Hamburg, and Neuenhagen. Based on the observations, the availability of space for blue-green street (BGS) elements in residential streets must be weighed up between three demands:

1. Water management objectives of stormwater retention
2. The objective/requirement to maintain car parking spaces
3. The requirements of flowing traffic (type, speed, frequency)

The cross-sections on the right show solutions with moderate proportions of BGS space covering a range of possible local conditions. The standard cross-sections with the defined strip widths contribute to the best possible consideration of both interests.

Spatial Requirements According To German „Guidelines for Contruction of Urban Roads“

- **Recommended carriageway:**
  - » Width: 4.5–5.5 m.
  - » Preferred width: 4.75 m (suitable for bicycle lanes).
  - » Minimum width: 4.5 m (4.1 m in very tight spaces).
  - » With public transport: 6.5-6.0m
- **Special Cases:**
  - » Narrow bidirectional lane with passing places carriageway width: 3.5 m.
    Includes parking lane to retain parking spaces while accommodating traffic.
  - » Mixed traffic area:
    Combined sidewalk and carriageway: 5.45 m.
    Suitable for urban areas with low building density and green zones.
- **Sidewalk Width:**
  - » Standard: 2.5 m.
  - » Minimum: 2.3 m (low traffic, no high barrier).
  - » Flex Strip Width:Minimum: 2.00 m (for longitudinal parking, trees, bicycle parking, seating, etc.).
- **Blue-Green Street Corridor:**
  - » Minimum: 2.30 m (for infiltration troughs, tree root space, and rainwater retention). Width adjustments depend on local spatial conditions.

BLUE-GREEN STREET SECTIONS

IDEAL CASE 1 A, B:
OPTIMAL LANE WIDTH

- High proportion of BGS & greenery (approx. 20-30 %)
- Low proportion of parking (approx. 20-30 %)
- General traffic conditions: 400-1,000 vehicles/h less 30 trucks/h Car-car / car-bike meeting case

CROSS-SECTIONS 2A, 2B:
REDUCED TRAFFIC WIDTHS

- Average proportion of parking spaces (approx. 40-60 %)
- Average proportion of BGS & green spaces (approx. 10-15 %)
- General traffic conditions 400-1,000 vehicles/h less 30 HGV/h car-car (cramped)/car-bike meeting case

CROSS-SECTIONS 3A, 3B

- Minimized traffic widths High proportion of parking spaces (approx. 75-100 %) High proportion of BGS & green spaces (approx. 20-30 %)
- 3a: Narrow two-way carriageway with parking on one side of the carriageway, passing places for car/ car and car/bike encounters, less than 70 vehicles/h
- 3b: Mixed traffic area with marked lane (3m), for car, bike and pedestrian traffic, less than 400 vehicles/h (peak hour traffic volume)

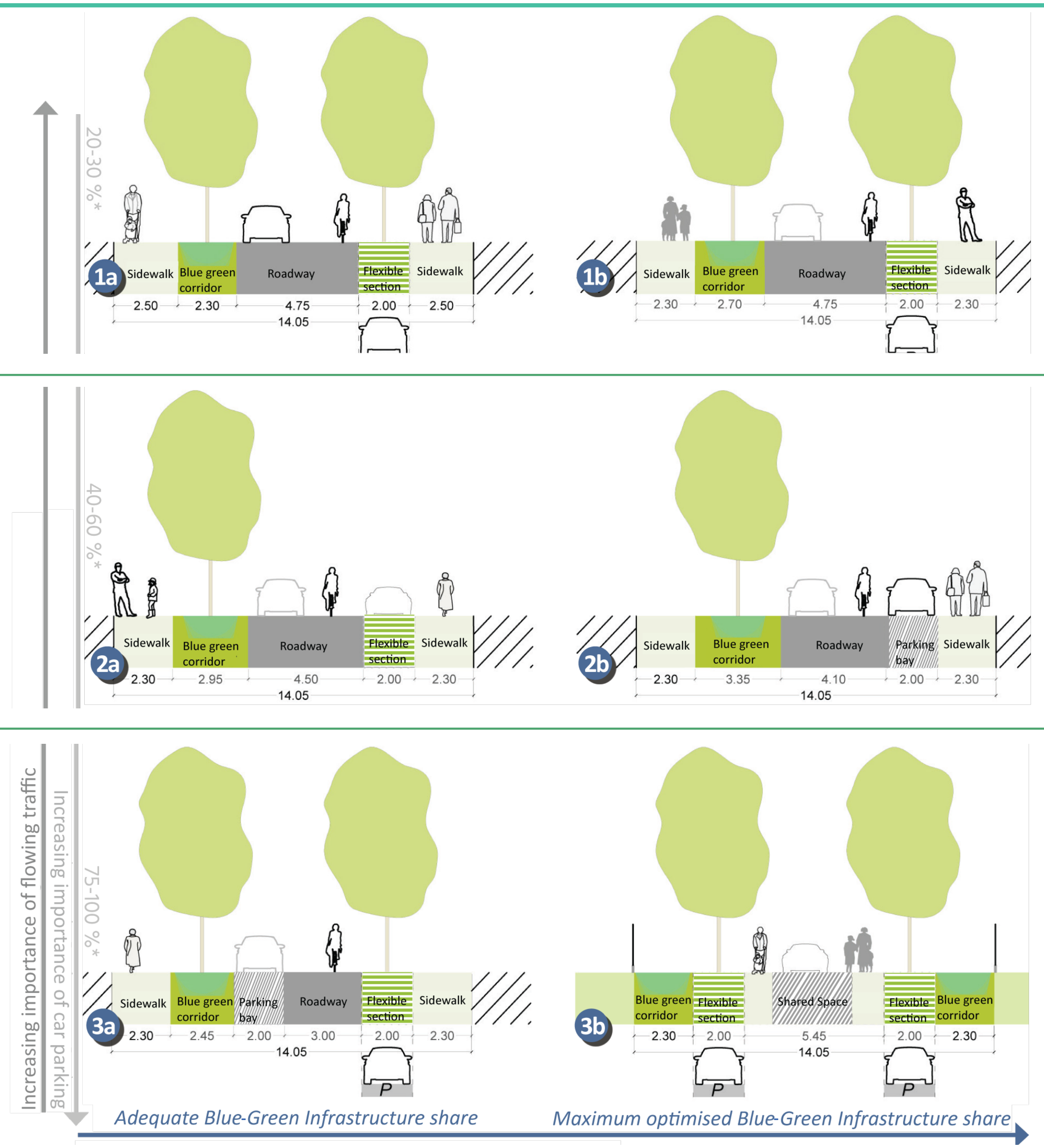


Table 3. Alternatives with optimized area shares of Blue-Green Streets. From top to bottom, the need for parking spaces in the cross-sections increases. Based on an assumed existing situation with parking lanes on both sides of the road, the area categories range from a high retention of parking spaces (80%) to a medium retention (50%) to a low retention (30%). Example cross-sections for residential streets, Berlin.
Source: Adapted from BGS, bgmr Landschaftsarchitekten GmbH within the framework of the BlueGreenStreets project from the Hamburg HafenCity University (2022).

II WAY FORWARD

TO BE FURTHER DISCUSSED WITH LOCAL STAKEHOLDERS DURING B4P IMPLEMENTATION PHASE 2025-2027

By prioritizing BGI, Phnom Penh has the potential to become a model for sustainable urban planning in Southeast Asia, setting a new standard for development that is both forward-looking and adaptable to local needs.

The incorporation of blue-green infrastructure is necessary to address the increasing impacts of climate change on cities. This type of adaptation needs to be implemented according to rigorous standards and technical guidance. Even more importantly, cities should primarily focus on conserving existing nature-based systems. As urban spatial expansion will continue in Cambodia in the future, urban growth needs to be more carefully managed because otherwise water and green spaces in urban areas are at significant risk of being destroyed (NCSD, MoE, MoI, 2021). Thus, it is a matter of great importance to maintain blue-green infrastructure in cities to remain resilient in the face of an increased frequency of extreme weather events and of urban heat islands. Consequently, all new urban infrastructure projects should seriously consider the integration of existing water retention areas.

CHALLENGES

The implementation of water retention areas in urban areas of emerging countries in Southeast Asia must take into account the following challenges:

- Limited governance structures (regulations, standards, etc.) and public policy incentives at both national and local levels
- Insufficiently tangible benefits as economic benefits are not immediately clear
- Lack of knowledge of water retention areas and their benefits
- Technical issues and maintenance
- Insufficient financial capacity and bankable funding schemes
- Insufficient public awareness of such projects and their benefits
- Lack of comprehensive database of technologies, products and manufacturers

RECOMMENDATIONS IN THE CASE OF PHNOM PENH

To foster transformative change in the field of blue-green infrastructure implementation in Cambodia, the following recommendations are being put forward:

- Promote public policies (i.e. legal obligations, taxation incentives, financing support, etc.) and appropriate strategies at national and local levels
- Stimulate knowledge sharing about the technical, environmental and social benefits
- Identify key components of the available financing mechanisms to design attractive incentive programmes
- Incorporate water retention areas in public projects to provide tangible examples and motivate private investors
- Develop a database of technologies, products and service providers for each geographical and climate region
- Promote enabling market conditions for green infrastructure industries
- Enhance collaboration between scientists, policymakers and practitioners to promote knowledge transfer and implementation
- Encourage the participation of urban residents to guarantee the successful implementation of water retention areas

These general recommendations must get further elaborated into more specific implementation measures as part of a continuous dialogue between government agencies, developer companies, the urban citizens and other relevant stakeholders. Only then, water retention areas and other blue-green solutions contribute to a resilient urban system as a basis for livable and sustainable cities of tomorrow.

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GUIDELINE 02.2

CLIMATE SENSITIVE URBAN DESIGN

INTRODUCTION

In Phnom Penh's high-density and tropical environment, comfort is an important factor in people's use of the outdoor space. The intense Urban Heat Island (UHI) effect in Phnom Penh's tropical wet and dry climate means high temperature in built-up areas and uncomfortable urban living. It leads to heat stress and other related health problems. The issues of health and comfort in the outdoor space become even more complicated in face of the challenges brought about by climate change.
The building industry plays an important role in the improvement of the urban microclimate, for example, by using lighter colors in façades, providing (constructive) shading, applying principles of bio-climatic architecture and incorporating greenery. The improved and more pleasant outdoor environment will in turn attract more visitors, reduce energy use in buildings and enhance the enjoyment of natural ventilation indoors.

The mesoscale Urban Climate Map (UCM) provides hints regarding the mentioned UHI. From here, it it possible to scale down to local climate conditions with microclimate analyses of Phnom Penh developed within the research project Build4People.
It is the goal of this guideline to give the industry's professionals and practitioners the inspiration and knowledge to consider projects' impacts on the urban microclimate. Strategies to optimise the microclimate conditions will be stipulated and reflected on with both, local and overseas case studies, and good practices. Recommendations for further studies and policy adjustments will also be made.
In this guideline sub-chapter, we take urban microclimate design as a set of practices aiming to optimise the climate variables of a small-scale area within the urban canopy layer to achieve better human physical wellbeing and comfort. The technical terms involved in this definition will be duly explained in the next section. The rest of the guideline takes readers through recommendations and examples that are particularly relevant to Phnom Penh. With better understanding of the dynamics between the built environment and the microclimate, and improved awareness in the building industry, Phnom Penh's urban living will become more comfortable and healthier.

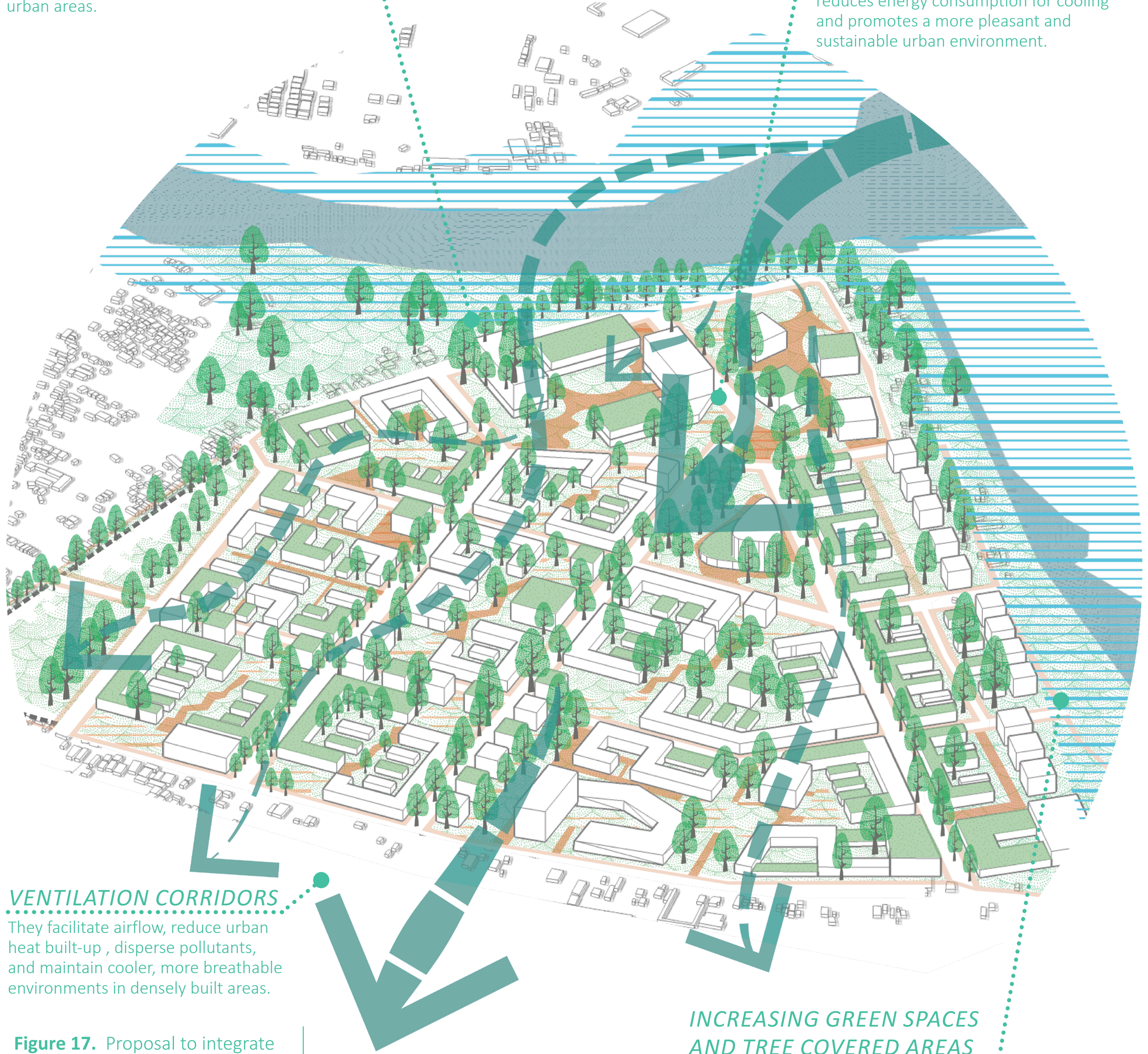


Figure 17. Proposal to integrate climate sensitive considerations on neighbourhood level: Case study of the Chbar Ambov district, Phnom Penh, developed during the Build4People Ecocity Transition Lab 2023.

ECONOMIC, SOCIAL AND ENVIRONMENTAL BENEFITS

Climate responsive design strategies offer a holistic approach to urban planning that aligns economic, environmental, and social benefits for both private developers and public authorities, particularly in the context of emerging countries. Drawing from the experiences of other Southeast Asian nations, these strategies provide valuable insights into sustainable urban growth.

ECONOMIC BENEFITS FOR PRIVATE DEVELOPERS

- **Operational Cost Savings:** Enhanced natural ventilation reduces the need for mechanical cooling systems, lowering electricity consumption and utility bills. Tree shading and efficient building orientation decrease heat gain, further reducing cooling requirements.
- **Market Appeal and Property Value:** Buildings that incorporate climate-responsive features are increasingly attractive to eco-conscious buyers and tenants. These properties often command higher rental and sale prices due to their sustainable attributes and reduced operating costs.
- **Maintenance and Durability:** Selecting materials that are resilient to local climatic conditions reduces wear, lowering maintenance costs and extending the lifespan of buildings. For example, materials that resist heat and humidity can prevent issues like mold and structural degradation.

ECONOMIC BENEFITS FOR PUBLIC AUTORITIES

- **Infrastructure Efficiency and Cost Reduction:** By promoting buildings that use less energy and water, the strain on public infrastructure is reduced, potentially delaying the need for expensive upgrades and expansions.
- **Economic Growth and Job Creation:** The promotion of green building practices can stimulate new markets and industries, such as renewable energy, green construction materials, and urban landscaping. This can lead to job creation and economic diversification.
- **Long-term Public Savings:** Investments in sustainable infrastructure can lead to significant long-term savings in public expenditure, particularly in areas like healthcare (due to improved public health) and disaster management (due to climate disasters).

ENVIRONMENTAL BENEFITS

- **Mitigation of Urban Heat Island Effect:** Tree shading and green spaces absorb and reflect less heat compared to concrete and asphalt, leading to cooler urban environments. This effect is enhanced by materials chosen for their low heat absorption.
- **Enhanced Biodiversity:** Urban greenery provides habitats for various species, contributing to urban biodiversity. This can help maintain ecological balance and promote environmental health.
- **Reduction in Carbon Footprint:** Energy-efficient buildings and increased vegetation contribute to lower overall energy consumption and carbon emissions. This aligns with global efforts to combat climate change.
- **Improved Air and Water Quality:** Vegetation acts as a natural filter, improving air quality by trapping pollutants and producing oxygen. Additionally, green infrastructure, like rain gardens and permeable pavements, enhances stormwater management and reduces runoff pollution.

SOCIAL BENEFITS

- **Improved Health and Comfort:** Enhanced ventilation and reduced heat accumulation create more comfortable indoor environments, reducing the risk of heat-related illnesses and improving overall wellbeing. Access to green spaces also promotes physical and mental health.
- **Community Engagement and Social Cohesion:** Green spaces and climate-responsive urban design foster community interactions and social cohesion. Public parks, community gardens, and green rooftops serve as gathering places, promoting a sense of community and belonging.
- **Resilience to Climate Change:** Urban areas designed with climate resilience in mind are better equipped to withstand extreme weather events, ensuring the safety and continuity of community life during adverse conditions.
- **Educational and Recreational Opportunities:** Urban green spaces provide educational opportunities about the environment. They also offer recreational spaces for exercise, relaxation, and social activities, contributing to a higher quality of urban life.

GUIDELINE 02.2

SCIENTIFIC BACKGROUND AND KEY IDEAS

Climate is a generic term covering a wide range of spatial scales—from macro to micro (see Figure 17). Therefore, a mesoscale urban climatic map is essential for any local actions. While climate at the macro scale is determined by a range of global factors, urban microclimate is more about the interactions between the local built environment, human activities, and climates at larger scales. Despite how complicated it may sound, the basic idea of urban microclimate can be summarised with the five elements below:

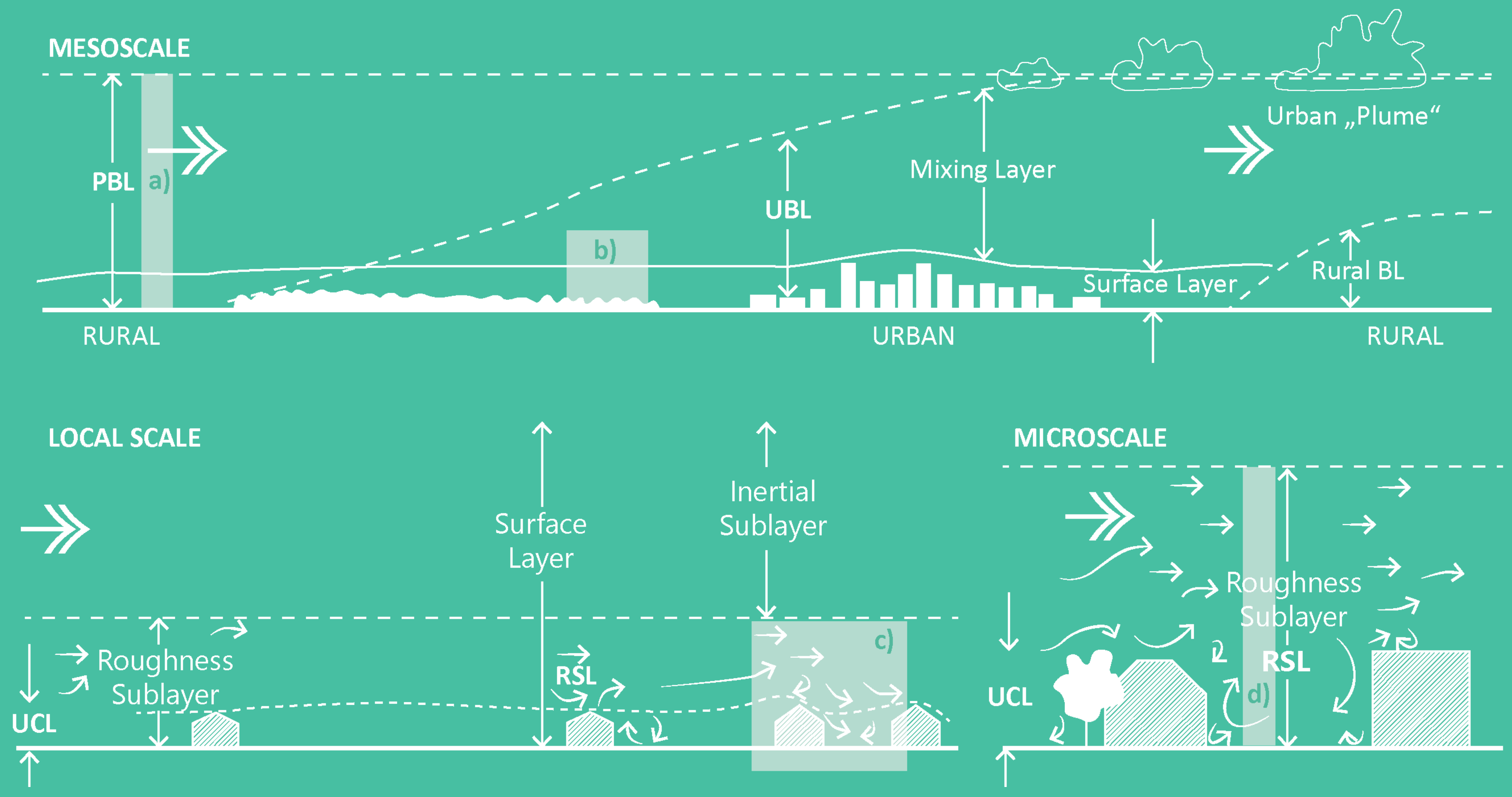


Figure 18. Urban climate scales (UCL = urban canopy layer; UBL = urban boundary layer). Source: Oke et al. (2017).

SCALE

The urban climate consists of the urban canopy layer (UCL) and the urban boundary layer (UBL) (see Figure 17). Urban microclimate happens within the UCL, where people live and work. Thus, urban microclimate affects people's quality of life significantly in terms of both, comfort and health. With regards to physical scales, the urban microclimate scale of 1m to 10m covers indoor climate and street canyon, while that of 10m to 1000m covers the neighborhood and the climatic variation.

COMPONENTS

Urban microclimate is determined by (a) local air velocity, temperature, and humidity; (b) solar radiation and reflection; (c) surface temperatures of buildings and ground, and (d) long-wave radiation exchange. The forms of urban development and human activities can change the energy balance, and thus climate, of an urban area.

FACTOR / INFLUENCES

A city's location, metabolism, urban setting, time and weather all affect its urban microclimate, as explained in Figure 18. For example, compact urban development reduces urban air flow and results in poor ventilation. Urban heat and air pollutants will be trapped, and residents' health will consequently be jeopardized.

WELL-KNOWN PHENOMENON

Urban Heat Island (UHI) is an extensively studied microclimate phenomenon in dense urban areas (see Figure 19). It refers to the relatively higher temperature in built-up areas compared to the surrounding rural parts. High UHI leads to higher energy consumption, thermal discomfort, and higher heat-related mortality in the summer.

BENEFITS

The cumulative effect of localized measures over time will eventually benefit the whole city and people from all walks of life. In general, the outdoor environment will become more pleasant. Thermal comfort, especially under hot and humid conditions in summer, will be improved, and energy consumption will be reduced.

WHY DOES CLIMATE CHANGE MATTER?

Climate change is mainly driven by the increased concentration of greenhouse gases in the atmosphere. It is extremely likely that greenhouse gas emissions by human activities are the main contributor of the warming trend. Climate change can bring serious threats to both the natural environment and human settlements. Key risks include heatwave and heat-related mortality, flooding, food and water security and urban poverty, as summarized in Table 5.
Cities are vulnerable to climate risks. In Phnom Penh, extreme weather events such as heatwaves could become more frequent, leading to rising electricity bills and health costs for both residents and businesses. Although climate change is often spoken of or projected at a broader scale, considerations at the local scale are equally important as that is where the impacts are most felt. Cities present great opportunities for both adaptation and mitigation, particularly as the majority of the world population now lives in urban areas. When it comes to urban climate strategies, the focus is on adaptation. Through land use planning, building design and the use of urban greenery, heatwaves and heat-related mortality can be duly managed. At the same time, if the urban climate is well taken care of, energy use and carbon emissions in cities can be reduced, and the adverse impact of climate change can be minimized.

KEY RISKS	URBAN CLIMATE STRATEGY
Heatwave and heat-related mortality	Urban land use Building design Urban vegetation
Flooding and related deaths, injuries, diseases	Urban infrastructure Seawall and drainage Water supply network
Food and water security	Urban planning Population control
Urbanization and urban poverty	Urban governance City planning and design
GLOBAL CLIMATE ⟶	**URBAN CLIMATE**

Table 4. Connection climate change and urban climate.

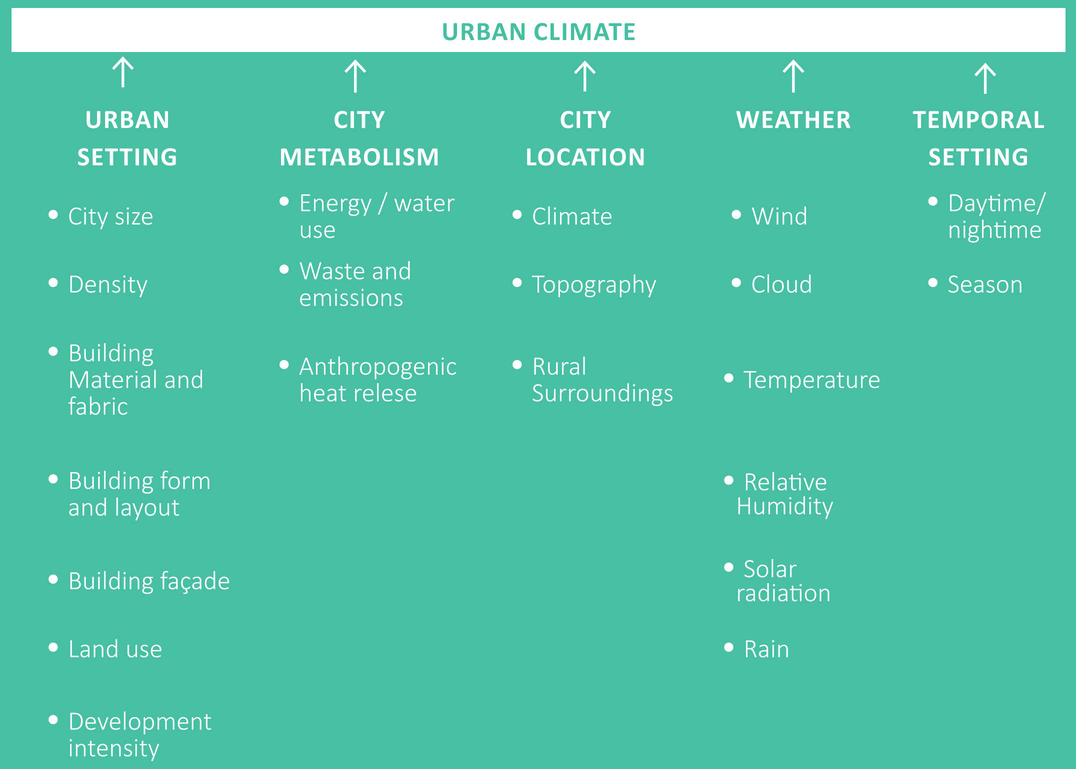


Figure 19. Factors influencing urban microclimate.
Source: Oke et al. (2017).

PHYSIOLOGICAL EQUIVALENT TEMPERATURE (PET)

PET is a widely used index for assessing the thermal environment. The analytical model is the thermal conditions of the human body in a physiologically relevant way. PET is applicable to any given place (both outdoor and indoor) and represents the equivalent air temperature at which, in a typical indoor setting, the heat balance of the human body is maintained with core and skin temperatures equal to those under the conditions being assessed.
PET thermal perceptions classifications are defined for both subtropical and temperate regions. In Phnom Penh, the classification for sub-tropical region is used, where a PET between 22°C and 34°C is considered comfortable (see Table 5).

WHAT IS OUTDOOR HUMAN THERMAL COMFORT?

A major objective of urban microclimate design is to enhance the outdoor environmental quality and to provide a thermally comfortable environment for pedestrians. To evaluate the urban microclimate of an outdoor space, human thermal comfort is commonly referred to.
It describes the perception of the surrounding thermal environment in relation to the subject's satisfaction. It is determined by personal preferences and external climatic factors that interact with the human body, such as wind, solar radiation, humidity, temperature, clothing, and metabolic rate. Several scientific methods have been developed to estimate the level of human thermal comfort at an outdoor space at any given time. With the assumption of similar personal preferences, the evaluation of human thermal comfort can be simplified to consider only the climatic factors.
A thermally comfortable outdoor space can be achieved through careful architectural and landscape considerations for the urban microclimate.
There are several widely accepted methodologies to measure outdoor human thermal comfort. Best for practical use in Phnom Penh can be the physiological equivalent temperature (PET), which is evaluated of outdoor thermal comfort.

THERMAL PERCEPTION	TPC FOR SUBTROPICAL REGIONS	RANGE OF THERMAL COMFORT
Very Cold	<14	*Too Cold*
Cold	≥ 14 to < 18	
Cool	≥ 18 to < 22	*Range of Thermal Comfort*
Slighly Cool	≥22 to < 26	
Neutral	≥ 26 to < 30	
Slightly Warm	≥ 30 to < 34	
Warm	≥ 34 to < 38	*Too Hot*
Hot	≥ 38 to < 42	
Very Hot	≥ 42	

Table 5. Thermal perception classification (TBC) and PET thermal comfort range. Source: Linn and Matzarakis (2008).

Figure 20. In urban areas, reduced wind velocity is closely linked to high building density and the absence of planned ventilation corridors. This limited airflow traps heat, intensifying the urban heat island effect and exacerbating temperature increases, especially during summer and heatwaves.

Direct and diffuse solar radiation, reflective radiation (short-wave)
Thermal radiation of the atmosphere and surfaces (horizontal and vertical (long-wave)
Human heat flow, respiration, evaporation, heat conduction and convection

Figure 21. Wind, thermal radiation, temperature, and precipitation are key parameters affecting the comfort level and usability of an outdoor space.

FROM URBAN CLIMATE CONDITIONS TO CLIMATE SENSITIVE RECOMMENDATIONS

EVALUATION CRITERIA

CLIMATE SENSITIVE DESIGN

Man's quest for a thermally comfortable environment through architecture dates back to ancient times. Over the years, valuable experience has been accumulated and the understanding of architecture and the environment has evolved. A set of factors has been found to have profound impact on urban microclimate and people's enjoyment of the outdoor environment. Considerations of these factors are becoming more important in the building industry not only because of its relation to the environment but also the added advantages of increased pedestrian activities and reduced energy use. This sub-chapter provides a comprehensive tool set for designers to adopt microclimate friendly designs with concrete strategies and easy-to-understand illustrations. It also reminds practitioners of the importance of considering these measures at an early stage of design.

High cooling potentials

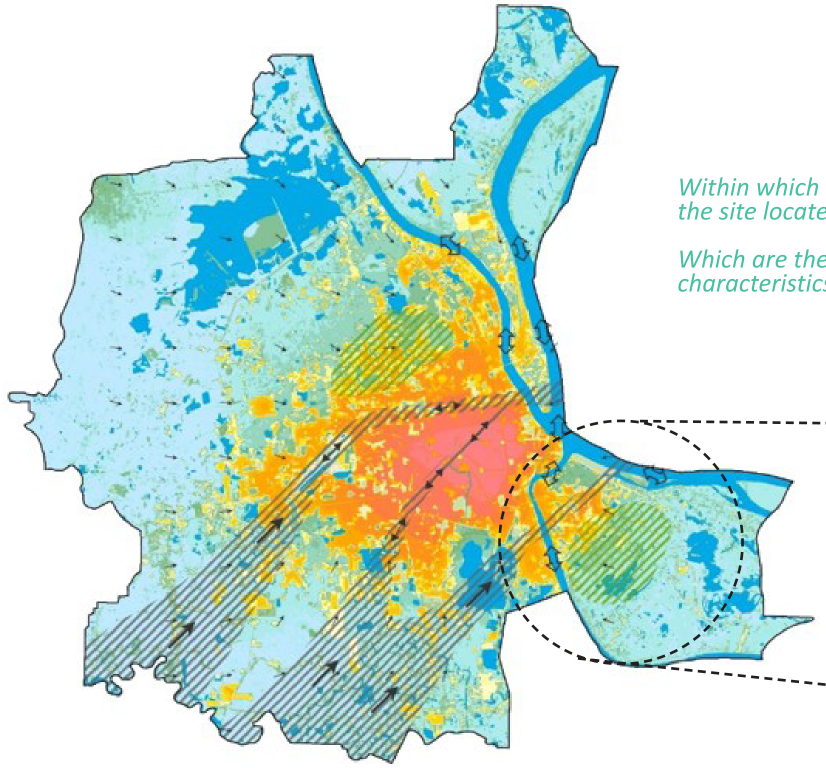
Medium cooling potentials

Cooling potentials

Minor heat loads

Moderate heat loads

Strong heat loads



Within which climatope is the site located?

Which are the climatic characteristics?

Figure 22. The Urban Climate Map allows planners to make informed decisions about urban plannung, architecture and landscape design, ultimately leading to interventions that harmonize with the natural environment and meet the specific needs of the area. Source: INKEK (2022).

ANALYSING
URBAN CLIMATE CONDITIONS ON A MESOSCALE

During the first planning stages it is crucial to understand the climatic characteristics of the area that will be intervened. Based on a mesoscale analysis, climate functions, climatope characteristics, ventilation and heat loads should be evaluated. The Urban Climate Map tool can serve as initial source of information to derive:

- Air paths
- Wind direction
- Outdoor thermal comfort

Ventilation corridors are planned routes in a city to enhance air circulation, alleviating heat and pollution. Those, together with main air paths and prevailing wind direction patterns need to be considered to define efficient ventilation strategies.

UNDERSTANDING
CLIMATE SENSITIVE RECOMMENDATIONS

Following a ventilation strategy and depending on the challenges defined by the site-specific climatope classification, a series of planning actions need to be integrated. On an urban planning level, design and planning elements such as street structure, building orientation and material selection can be adapted to integrate climate-responsive design principles.

In this guideline set, general planning recommendation are provided in order to support initial climate responsive urban planning proposals. These recommendations encompass:

- Wind
- Thermal Radiation
- Temperature
- Precipitation

DESIGNING
PROJECT-SPECIFIC PLANNING RECOMMENDATIONS

To achieve a detailed understanding of local climate conditions and project specific recommendations, climate simulations are essential. Utilizing environmental software enables precise modelling of how individual buildings and vegetation impact the microclimate based on site-specific characteristics. This approach allows for localized analyses, capturing the nuanced effects that built structures and natural elements have on temperature, airflow, and other climate factors at the neighbourhood level. By refining these models, planners can create more resilient and adaptable designs that respond to local environmental dynamics, ultimately enhancing the sustainability and comfort of urban areas.

GUIDELINE 02.2

EVALUATION CRITERIA

CLIMATE SENSITIVE DESIGN

WIND

INCREASE VENTILATION WITH SMART SITE PLANING

Heat accumulation within the urban canopy, and thus air temperature, can be reduced by improving ventilation. The increased air speed around a person will also accelerate sweat evaporation and therefore induce a cooler sensation. Breezeways are a crucial element of ventilation in dense urban areas. Major breezeways are typically formed by linear roadways and open spaces where the prevailing wind flows along. Minor breezeways are formed by building separation that allows wind to penetrate through the development. During site planning, careful consideration of the building layout is important to maintain major breezeways and leave sufficient gaps between buildings to facilitate wind penetration.

INCREASE VENTILATION WITH SMART BUILDING DESIGN

In addition to site planning and master layout, the building design stage also offers many opportunities to improve wind penetration through the development by increasing building blocks' permeability. In this section, strategies aiming to increase ventilation with podium and tower designs are discussed. This section is particularly relevant to compact sites, where size constraints make ventilation enhancement through site planning difficult. Nonetheless, they are also applicable to large sites in the improvement of ventilation.

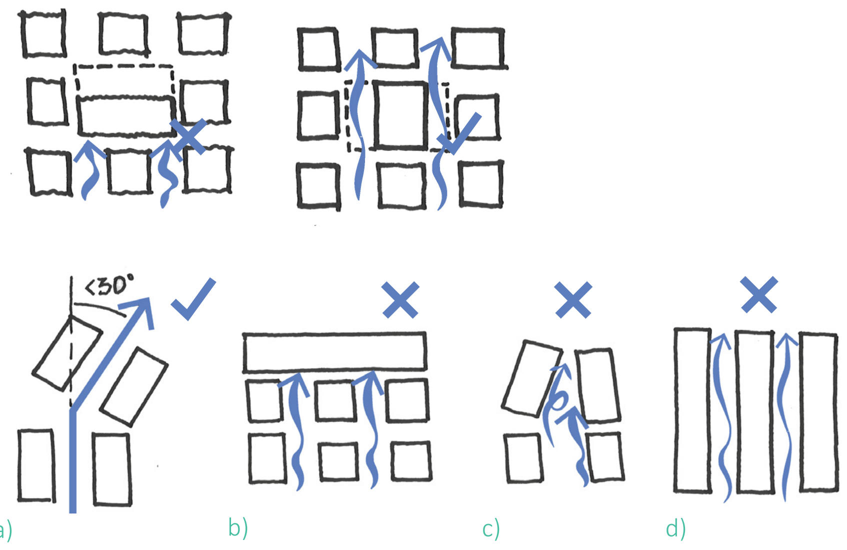


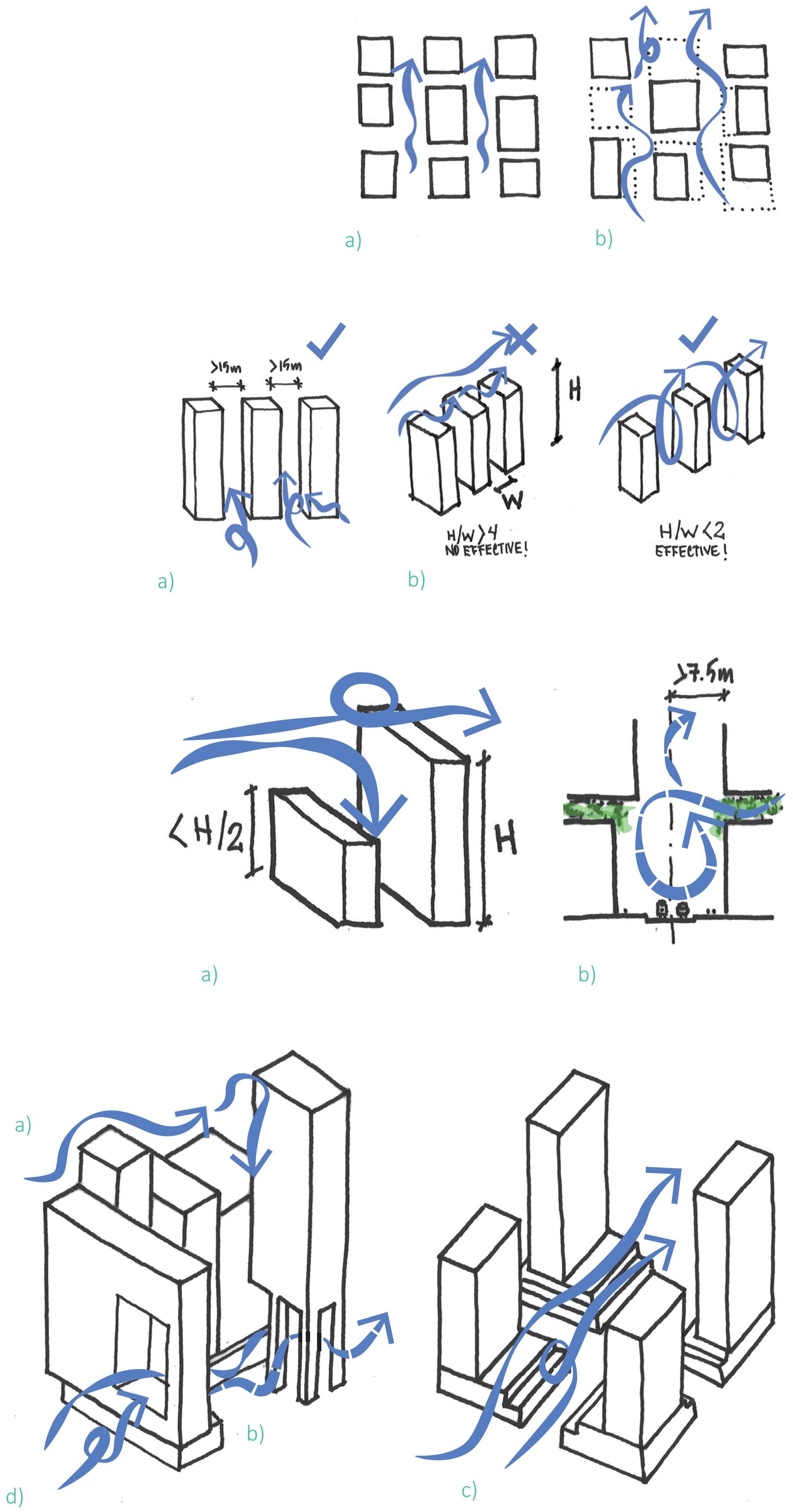
Figure 23. Ventilation flows in different site settings.
Source: Modified based on Hong Kong Green Building Council (2017).

1. Adapt layout to increase wind flow
2. a) Wind corridor should align with the prevailing wind

   b) Avoid large flank walls facing dominant wind

   c) Avoid funnel like gaps

   d) Avoid long parallel façade rows with smooth materials



3. a) Arrange buildings to channel wind

   b) Connect open spaces
4. a) Increase permeability of building blocks / no wall building

   b) When buildings cannot be arranged to channel wind flow, and a stepped profile cannot be adopted, a height-width ratio of less than 2 is recommended
5. a) Stepped building height profile

   b) Building setbacks
6. a) Downwash wind captured by building height difference

   b) Increase ground zone air volume with ventilation bay

   c) Permeable podium

   d) Urban window to increase building permeability

Figure 24. Ventilation flow at building level.

GUIDELINE 02.2

Figure 25. Illustration of an exemplary street in Phnom Penh, where strategies to reduce solar radiation are applied. Source: Own graphic

EVALUATION CRITERIA

CLIMATE SENSITIVE DESIGN

THERMAL RADIATION

REDUCE DIRECT SOLAR RADIATION

Direct solar radiation in the form of short-wave radiation plays an important role in outdoor thermal comfort. Pedestrians' direct exposure to solar radiation can be effectively reduced by making use of opaque shading devices. They can come in many forms, such as covers, tree canopies and building shade.

Provide Shading for Pedestrian Activities

Shade offers the most effective remedy to thermal discomfort caused by direct solar radiation.

- Install opaque shading devices at open areas with frequent pedestrian access. The reduction in solar radiation can be very high on a typical summer day. The reduction in solar radiation and impact on thermal comfort at different times of the year can be studied through computational analysis.

Shade Openness by Building Blocks

In a high-density high-rise urban environment, the shadows of building blocks often shade the surrounding ground space during different times of the day.

- Place outdoor open spaces at locations shaded by building blocks during certain periods at daytime. Sun shadow analysis can be performed to determine the appropriate location of an open space.

Provide Tree Canopies

Another way to reduce pedestrians' direct exposure to solar radiation is to shade them with tree canopies.

- Plant trees with large canopies in frequently used open spaces. Select plant species with high leaf density to maximise the shading effect. For large sites, provide tree coverage for over 25% of the total site area. For compact and single building sites, provide tree canopies in all frequently accessed outdoor spaces. The effectiveness depends on the crown size and leaf density.

Manipulate Building Façade Design to Provide Shading

Pedestrian walkways are often uncovered and exposed to direct solar radiation.

- Locate pedestrian walkways and open spaces adjacent to the building façade, which can act as a shading structure. Colonnade and cantilever structures are some examples of the design. The reduction in solar radiation and impact on thermal comfort at different times of the year can be studied through computational analysis.

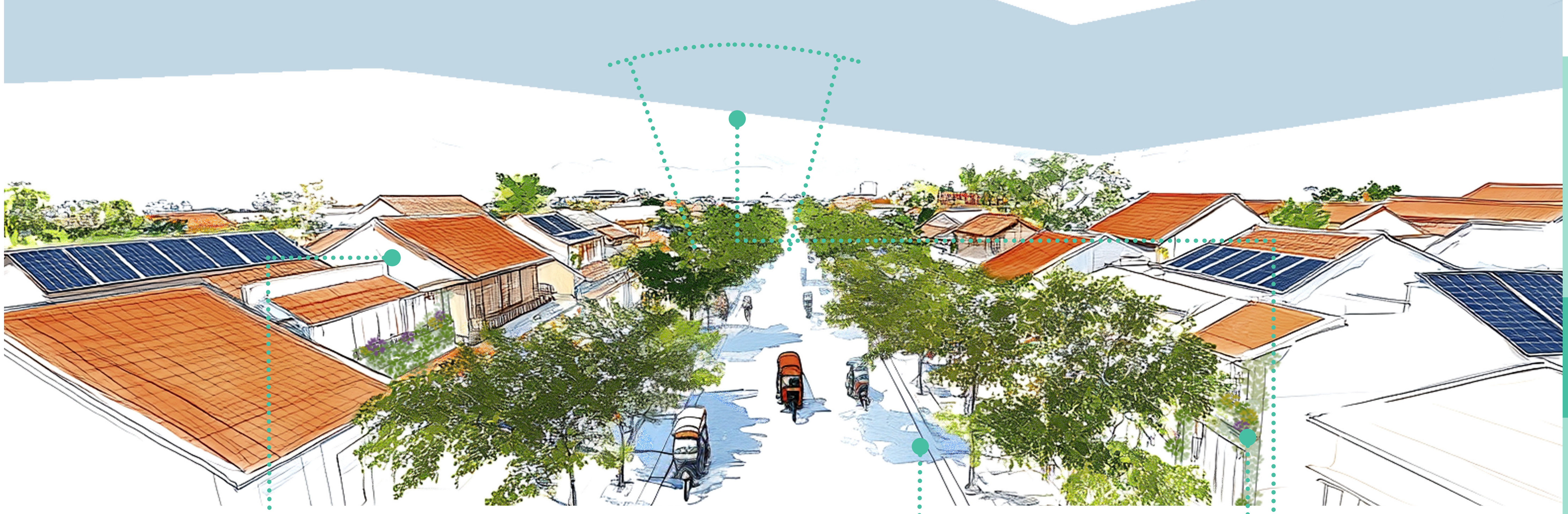
GUIDELINE 02.2

a) Natural roof materials: Clay Tiles

b) Photovoltaic Panels

c) Green Façades

d) High albedo ground materials: concrete/light coloured street materials.



REDUCE SURFACE TEMPERATURES

The rate of radiative heat transfer is proportional to the surface temperature of the heat source. Thus, strategies to reduce the surface temperature of the ground and surrounding building structures can help reduce heat stress on the pedestrians.

Figure 26. Illustration of an exemplary street in Phnom Penh, where strategies to reduce surface temperatures are applied. Source: Own graphic

Figure 27. a) clay tiles and b) photovoltaic panels as examples of low albedo materials. c) visualization of low-tech green façades and d) light coloured street material as examples of strategies to reduce surface temperatures.

Increase Albedo in Buildings

'Albedo', means whiteness in Latin. In modern use, the albedo of a surface is defined as the fraction of the incident sunlight reflected from it. A high-albedo material demonstrates high reflectivity in both light and heat. Using such material will reduce thermal absorption by the building material. A variety of measures, such as using light coloured surface paint or thermally treated surface material, can be adopted.

- Select high albedo building surface material of at least 0.4 to effectively lower the surface temperature and reduce radiative heat transfer to the surrounding environment. A light grey material with an albedo index of 0.5 will be cooler than a dark grey material of 0.2.

Use Cool Material for Ground Surface

Ground surface material absorbs solar heat and re-radiates it to the surrounding environment. Conventional pavements such as impervious concrete and asphalt can reach a surface temperature of 48-67°C. Cool materials with high solar reflectance (albedo) can help reduce the ground surface temperature.

- Use cool materials with an albedo index of at least 0.4, such as those of lighter colours, for outdoor ground surfaces. Researchers have estimated that a 10% increase in solar reflectance for ground surface pavement can reduce surface temperature. Albedo can be increased from 0.1 to 0.5 by replacing asphalt with concrete, and that can reduce the surface temperature.

Green Wall to Reduce Façade Surface Temperature

Green walls can help lower façade surface temperature as the leaves and substrates reduce solar heat transfer to the building surface.

- Install green walls on building façades near open spaces that are exposed to a substantial amount of solar radiation in summer. Solar radiation analysis can be conducted to identify or confirm the façade receiving the most solar radiation. The thermal performance of a green wall depends significantly on leaf coverage. With a high leaf coverage, a green wall can reduce the façade's surface temperature.

Increase Sky View Factor to Improve Night Cooling

Sky view factor (SVF) is the percentage of the sky visible from the ground up. An SVF of 1 means the entire sky is visible, whereas an SVF of 0 implies the sky is completely obstructed from the viewpoint. On a clear night, heat is radiated to the sky from the earth surface. The higher the SVF, the greater is the heat transfer rate, and the faster the earth surface is cooled down by the night cooling effect during the hot summer season.

- During site planning, arrange building blocks to increase the SVF at the open space, such as by varying building heights of the development or widening the gap between building locks. SVF can be obtained via analysis with simulation tools.

Figure 28. Illustration of an exemplary urban area with strategies to increase evaporate cooling.
Source: Own graphic

EVALUATION CRITERIA

CLIMATE SENSITIVE DESIGN

TEMPERATURE

INCREASE EVAPORATE COOLING

A direct way to improve thermal comfort is to reduce the ambient temperature. The large latent heat of evaporation (2,260kJ per liter of water) makes evaporation an effective way to extract and carry away heat from the environment. Carefully designed features can take full advantage of evaporation.

Water Features to Increase Evaporation

Blue infrastructure helps maintain a lower surrounding ambient temperature as water evaporation extracts heat from the surrounding environment.

- Provide water features in open spaces or landscape areas. Some effective examples are fountains, waterfalls and mist sprays. The water droplets they produce enhance the evaporation rate because of the increased surface area in contact with air. Static water features can reduce the ambient air temperature of the surrounding area within 3m by 0.2°C. For fountains and mist sprays, the ambient air temperature can be reduced.

Green Walls to Increase Evapotranspiration

Evapotranspiration refers to the process of moisture transferring from land and soil to the atmosphere by evaporation and transpiration. Green walls in general have a lower surface temperature, thus the ambient air temperature near the green wall can also be reduced.

- Install green walls on independant structures (e.g. trellis panels) at open spaces for communal use. There are broadly two types of plants commonly used in green walls: climbing and substrate based. Their cooling effect depends more on leaf coverage than plant types. With full leaf coverage, air temperature near the green wall can go down significantly.

Greening to Increase Evapotranspiration

Vegetation offers an effective way to reduce the ambient air temperature by evapotranspiration.

- Provide vegetation at all outdoor spaces, especially those for communal use. Large trees are more effective than grass and smaller planters as the total leaf surface area is larger. A tree coverage of 30% will reduce air temperature.

Use Permeable Paving

Permeable paving is a key strategy for stormwater control. It allows air and water to enter the void of the material. The moisture content in the void reduces the ground surface temperature through evaporation and helps create a cooler near-ground environment.

- Use permeable or semi-permeable paving in walkways and open spaces for communal use. Attention should be paid to the structural needs for the expected traffic loads. A permeable pavement saturated with water will reduce the air temperature 1m above.

Figure 29. Suzhou Ecotown district project designed by John Thompson & Partners and Eble Messerschmidt Partner as consultants and Prof. Yen-Yi Li, Shu-Te University Kaohsiung. Bioclimatic ventilation geometry of public space and built structure for daily and seasonal wind corridors. Blue vertical arrows represent the cooling effect of summer breeze daytime. Yellow horizontal arrows represent the cooling effect of summer breeze evening.

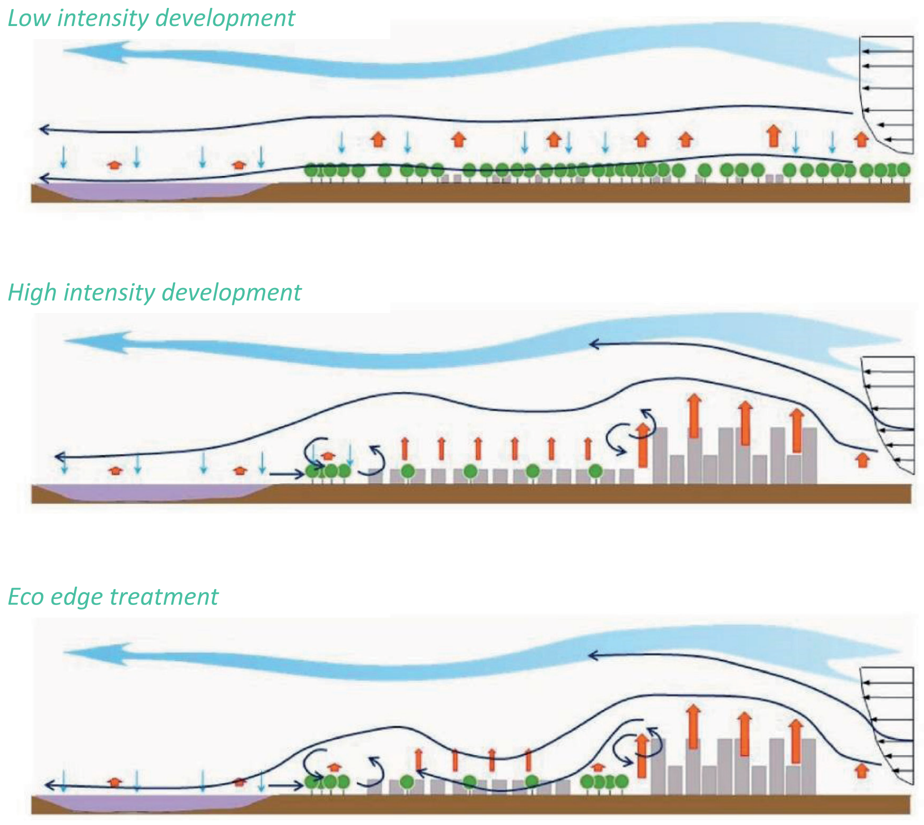
REDUCE HEAT ACCUMULATION

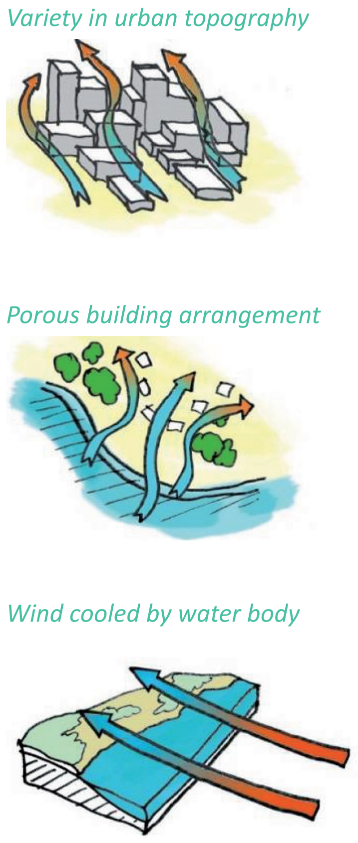
Poorly designed outdoor spaces can trap heat from nearby air conditioners and traffic, whilst improved ventilation can help increase the rate of heat dissipation. The introduction of cooler air from nearby mountains and water bodies is also helpful in the reduction of the ambient temperature.

Increase ventilation to carry away heat energy

Solar heat in the outdoor environment tends to be trapped in built-up areas, especially at open spaces surrounded by building blocks with weak ventilation. Localized ventilation can carry away the heated air and introduce cooler fresh air from the surroundings.

- Increase ventilation at open spaces frequently accessed by pedestrians. Locate them at wind paths.
- Avoid air stagnation under prevailing wind condition and ideally also under windless condition, by using mechanical ventilation. A minimum wind speed of 1m/s is recommended for a comfortable environment under shade during summer.





Reduce thermal mass heat storage of building materials

Thermal mass is the material property of absorbing and storing heat energy. Building materials such as concrete and bricks typically have high thermal mass. These materials store heat energy under sun exposure during the day and release it to the surrounding area at night. By reducing the thermal storage of the building materials, heat dissipation to the outdoor environment and ambient temperature can be reduced.

- Reduce solar exposure of building materials with a heavy thermal weight.
- Shade the building mass from the sun with light-weight external shades, such as aluminium louvres or green walls. Materials with low thermal mass are those with low specific heat capacity and density.

Allow thermal induced ventilation

During calm wind conditions, the temperature difference between the city fabric and vegetated slopes will induce a local air flow, known as katabatic wind. This air flow under tree canopies is significantly lower than the ambient air temperature. The slightly cooler and denser air on the vegetated slopes flows down the slope towards the urban area, permeating and cooling the streets. This strategy is not commonly adopted at the moment. However, as the government of Phnom Penh plans to build at the urban fringes, considerations about the downhill wind flow will become more important in the future.

- For developments facing vegetated slopes, make sure the building does not obstruct the katabatic wind flow from uphill.

- Maintain adequate gaps between buildings and increase permeability in podium design to enhance the flow through the site.
- The wind path through the development must be shaded or vegetated to avoid heating up the air.

Figure 30. In the Suzhou Ecotown district project proposal, a network of wind corridors were formed by the roads, canals and linked green spaces, while existing water system was enhanced and expanded to play a central role in the town. The existing lake, together with the planned canals and ponds were intended to create a complex network of green and blue infrastructure, greatly influencing the local microclimate.

PRECIPITATION

PROVIDE RAIN PROTECTION

Phnom Penh with its subtropical climate sees heavy and frequent rainfall and thunderstorms during the rainy season. Protecting pedestrians from precipitation will improve the microclimate and usability of open spaces.

Provide cover for rain protection

Relative humidity is close to 100% on rainy days. Covered structures keep pedestrians dry and speed up the heat dissipation process for better thermal comfort.

- Provide rain cover along major pedestrian walkways. The angle of deflection from the driving rain effect should be taken into consideration. The estimated angle of deflection of driving rain under the typical heavy rain condition in Phnom Penh is approximately 10. This should be taken into account in the design of covered walkways for effective rain protection.

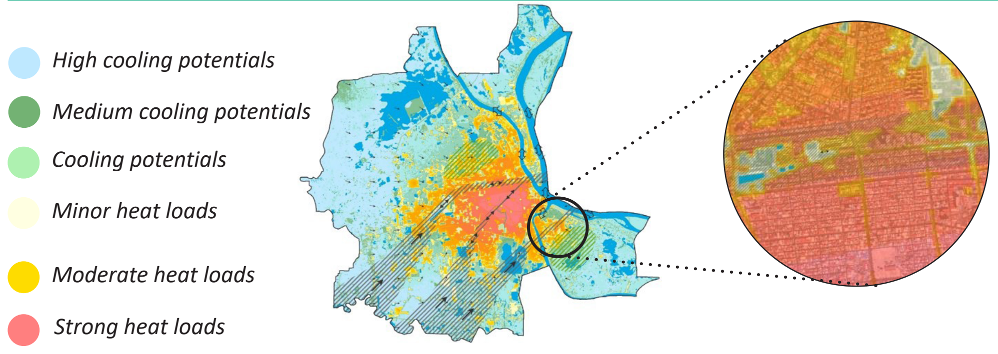
EVALUATION CRITERIA

CLIMATE SENSITIVE DESIGN

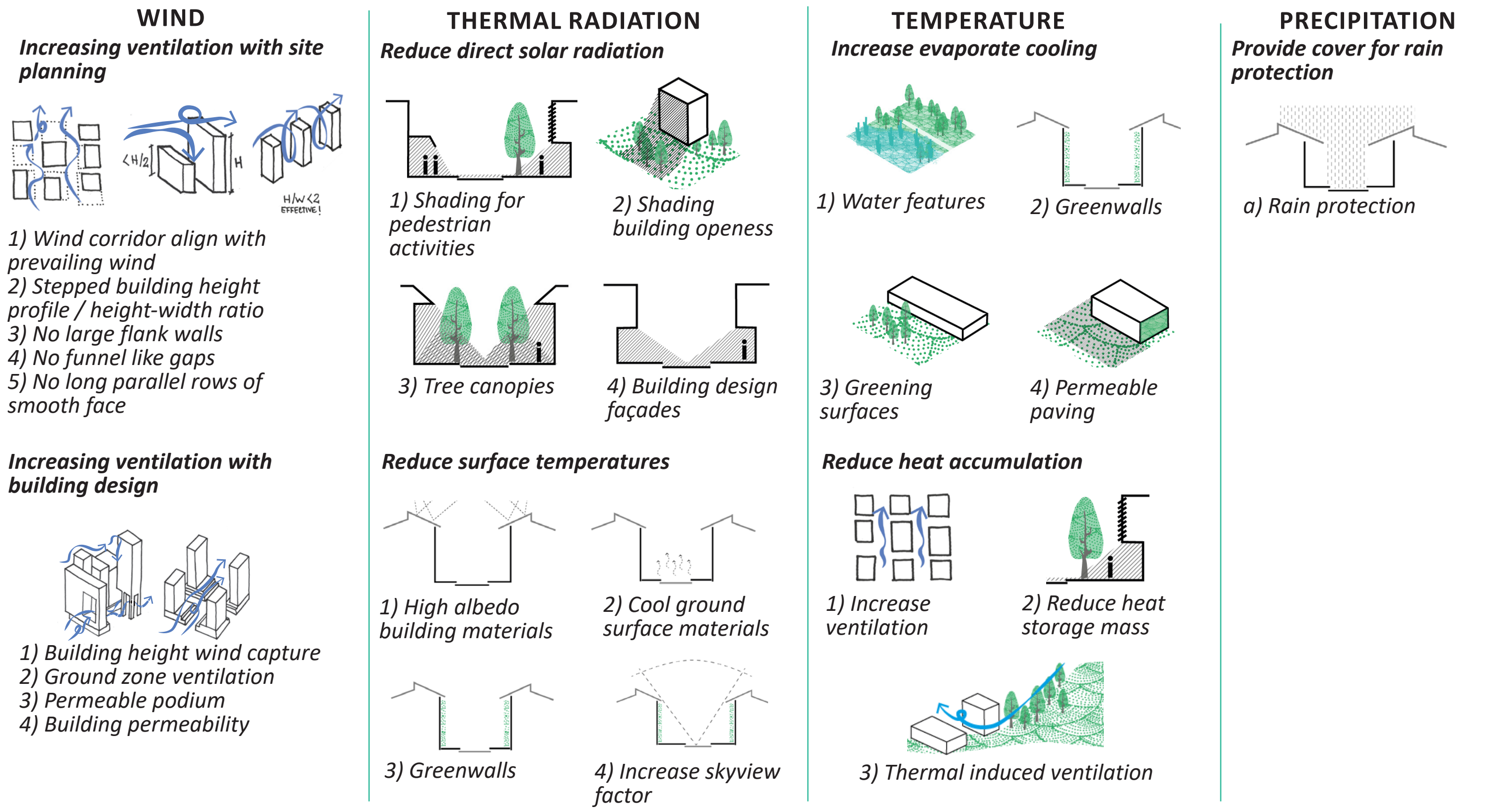
Figure 31. An AI generated example of a street, where strategies to provide rain protection are applied.
Note: Image generated using Midjourney from variations of the prompt a commercial area that provides rain protection to visitors in Phnom Penh. Further edition with Photoshop.

PROCESS OVERVIEW FOR CLIMATE SENSITIVE URBAN DESIGN

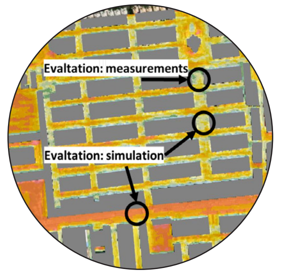
ANALYSING *URBAN CLIMATE CONDITIONS ON A MESOSCALE*



UNDERSTANDING *CLIMATE SENSITIVE RECOMMENDATIONS*



DESIGNING *PROJECT-SPECIFIC PLANNING RECOMMENDATIONS ON A MICROSCALE*



Numerical microclimate modelling enables precise modeling of how individual buildings and vegetation impact the microclimate based on site-specific characteristics. This localized analysis, captures the effects that built structures and natural elements have on temperature, airflow, and other climate factors at the neighbourhood level.

DESIGNING
PROJECT-SPECIFIC PLANNING RECOMMENDATIONS ON A MICROSCALE

Urban climate analyses are essential for understanding local and microclimatic conditions and their interaction with urban planning. They provide a foundation for climate-responsive design by identifying areas prone to heat accumulation, poor air circulation, or excessive solar exposure. By analysing these maps, planners can:

- Identify microclimatic challenges such as ventilation corridors.
- Optimise building orientation and material choices to improve thermal efficiency.
- Integrate green infrastructure, including trees and water bodies, to mitigate excessive heat.
- Enhance air quality and pedestrian comfort through the strategic placement of open spaces.

Urban Climate Maps highlight large-scale patterns such as heat distribution, wind flow, and solar exposure. Urban Climate Maps provide a valuable overview and a good starting point for planners.
By combining this information with the guideline outlined in this booklet, a transdisciplinary team—comprising experts in architecture, urban design, climate studies, and engineering—can steer the planning process in the right direction, ensuring that initial concepts are aligned with climate-responsive goals.
However, to ensure project proposals are both precise and effective, project-specific recommendations must be developed. These recommendations should aim to optimise thermal comfort, reduce energy consumption, and enhance urban resilience to climate change, tailored to the unique characteristics of each project.

The Role of Microclimate Simulations in Planning

Microclimate simulations using numerical 3D modelling tools are critical for translating general insights into actionable recommendations. These tools quantify the effects of various planning strategies on the local climate, enabling evidence-based decision-making.
Key applications of microclimate simulations in urban planning include:

- Simulating airflow around and between buildings to improve understanding of ventilation dynamics.
- Analysing heat exchange processes at ground level and building facades to assess heat retention and dispersion.
- Evaluating the role of vegetation in cooling, shading, and air purification.

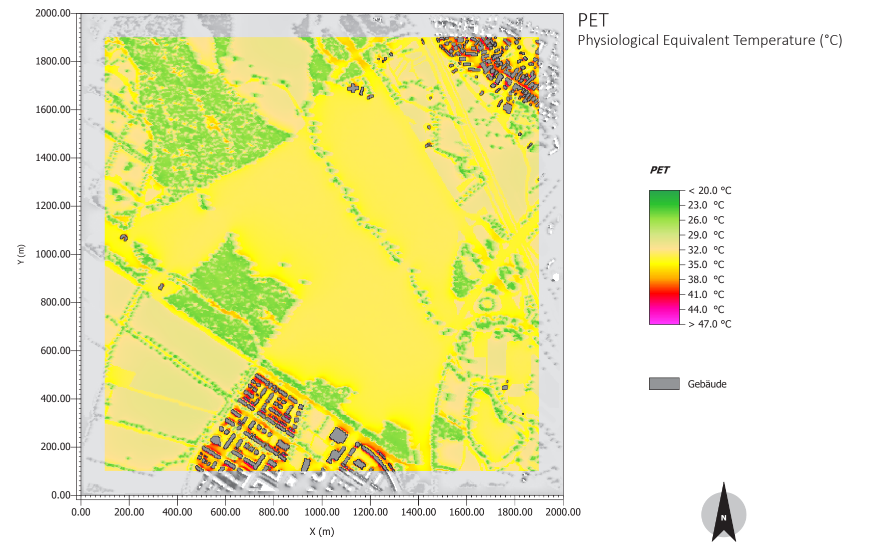
Studying Microclimatic Effects to Develop Project-Specific Recommendations

When designing new urban areas, it is essential to consider their impact on local microclimates. Numerical 3D modelling allows for detailed assessment and testing of different design strategies, enabling planners to:

- Predict temperature variations resulting from different urban layouts.
- Assess the effectiveness of green roofs and walls in reducing heat stress.
- Optimise street orientations to enhance natural ventilation.
- Minimise the risk of extreme heat events through the strategic placement of shading elements and vegetation.

By using climate analyses and microclimate simulations, planners, in collaboration with climate experts and other specialists, can create well-informed, climate-responsive designs. This integrated approach ensures that new developments contribute positively to environmental sustainability, urban comfort, and public health. Crucially, the success of these projects depends on transdisciplinary collaboration — bringing together expertise from architecture, urban design, engineering, climate studies, and urban planning to develop holistic and sustainable solutions.

a)



b)

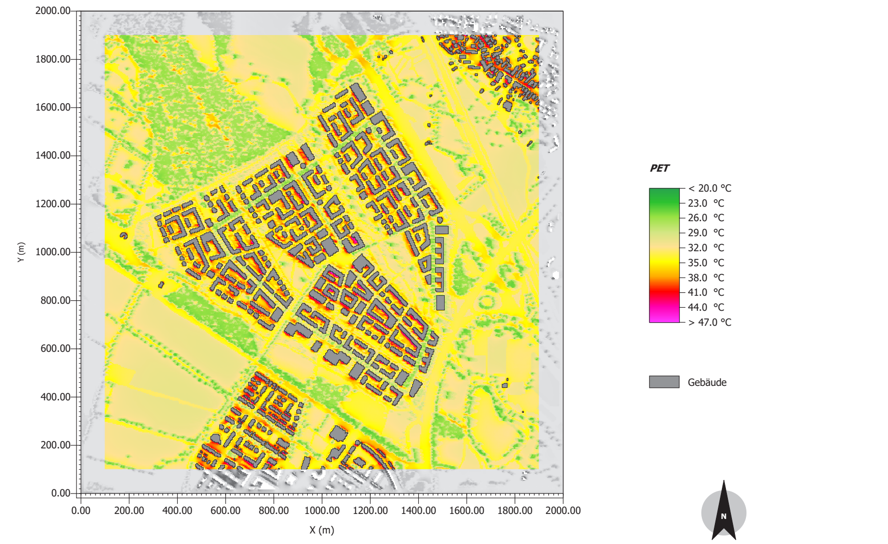


Figure 32. Example of numerical 3D modeling simulations to evaluate the influence of building layouts on the local microclimate.
a) This figure shows the current PET (daily average PET btween 10am-6pm MET, Germany) in the same open space like a). Trees appear cooler (green) than buildings or sealed areas (orange to red). PET is high in the middle because of the highly sealed area with direct solar radiation nearly all day long.
b) In the middle of the figure new buildings are simulated with vegetation between them (trees, lawn, hedges). The effect is a lower PET due to evaporation, less warming of materials (roads, pavement), mutual shading of the buildings, culverts between the buildings which allow for better ventilation (also towards other areas).
Source: Own Graphic

II

WAY FORWARD

TO BE FURTHER DISCUSSED WITH LOCAL STAKEHOLDERS DURING B4P IMPLEMENTATION PHASE 2025-2027

This guideline is a beginning for climatic oriented design, which helps to improve the urban climate and microclimate designs. Phnom Penh has the aim to walk a long way down the path towards a healthier and more comfortable city. There are three areas where advancement must be made to improve the city's microclimate:

- science and technology development,
- policy, practice and design, and
- public awareness and education.

The potentials in each area are identified, and the suggestions made here are not only attainable but also crucial to the improvement of the city's environment.

SCIENCE AND TECHNOLOGY DEVELOPMENT

The Royal University of Phnom Penh has record of research on urban climate and the researchers contributed to the development of new methodologies to obtain urban data, implementation of scientific findings in research on urban climate, planning and outdoor thermal comfort.
These efforts to advance knowledge and technology must be encouraged and further deepened for the development of strategies and measurements that take the city's unique context into consideration. Adequate funding is essential. Only in this way can the next step forward be solid and grounded.

PUBLIC AWARENESS AND EDUCATION

The local good practices highlighted in the Guideline is a testimony to effective promotion and education. However, public and professional awareness can still be further enhanced and the gap in professional education and knowledge transfer must be filled.
The guideline attempts to be simple and easy to understand: It speaks to practitioners as well as interested laymen in a language stripped of professional jargon. Future efforts similar to this are essential to the spread of knowledge and increase in awareness. The architectural profession as a whole—not just those focusing on green buildings—and the wider population must be engaged in building a better city.
At the same time, there is a gap in the professional education of urban climatology between brief courses and extremely in-depth knowledge pursuit, such as in the form of a PhD. A better ladder of professional training must be provided to engage a bigger number of practitioners and encourage wider application.
Academic institutions are in a good position to take the lead.

POLICY, PRACTICE AND DESIGN

For the future, governments should introduce a range of measures and proposals for a variety of studies to improve the urban climate.
The urban climatic map is very much appreciated, but these efforts must be continuous and concerted. Departments must work together to create a synergy. Particularly, microclimate related data and information should be readily shared among different governmental parties. Further, policy encouragement may be needed to motivate developers to employ urban microclimate strategies.
Three particular areas have been identified in the development of the guideline: the installation of covered walkway and canopies, adoption of non-building areas, and setting up of green walls. Developers often find it difficult to adopt strategies in these areas because of commercial or statutory constraints. The Government and developers must come together to look for a way out. It will take some negotiations and the result may be of a carrot-and-stick approach, but the main message here is that communication with the industry is just as important as between different governmental bureaus and departments. Industry practitioners should take the initiative to learn about urban microclimate and implement the strategies introduced in this guideline in their projects. A better outdoor environment is for the benefit of both, the general public and the development itself.

GUIDELINE 02.2

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Recommendations for further information:

Cool Coalition:
https://coolcoalition.org

Heat Island Group- Lawrence Berkeley National Laboratory:
https://heatisland.lbl.gov

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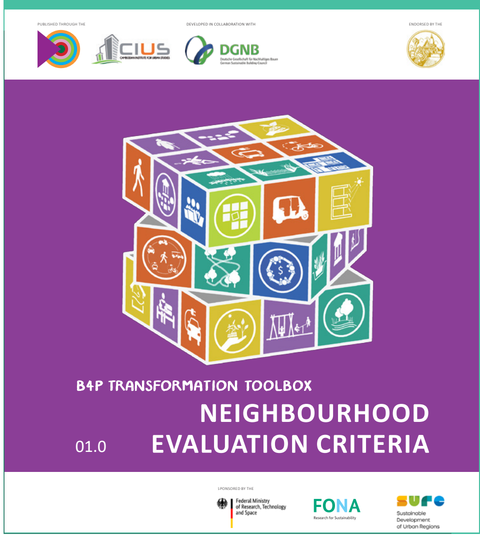

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